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Land-Use/Land-Cover Change Detection Analysis using Machine Learning Algorithms: Pune as a use Case

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Abstract:- Urbanization leads to the dynamic use of land and it has significant impact on the urban ecosystem. In the present scenario, remote sensing plays a significant role in monitoring, planning and controlling the natural resources. Improvements in the remote sensing satellite technology coupled with better remote sensors providing high resolution data, have given scientists an opportunity to perform extensive space time data analysis. This paper primarily deals with changes in the urban sprawl of Pune city. Landsat images of 1991 and 2011 covered by path 147 and rows 47 were acquired, LULC classification was used to stratify the images, while the LULC map was analyzed using SAGA version 7.3.0 software. The result indicates that severe land changes have occurred in urban (79%), Green Zone (forest + shrubland + grassland) (-9%), openland (-15%) and water bodies (5%) areas over the period of two decades. The result highlights an immense increase in the urbanization. This type of an outcome can be used for making better policies and regulations to sustain rapid urbanization.

Keywords:- *Geographic Information System (GIS), Urbanization, Classification, Land Cover Land Use (LULC), Change Analysis.*

I. INTRODUCTION

Urbanization leads to significant impact on the condition of our urban ecosystem [1]. At a broad level, urban areas act as epicenter for growth and drive the development of rural and semi-urban areas. In due course of time, semi-urban areas are converted into urban areas which has increased the reach of benefits and development to larger section of communities [2]. However, on the socio economic front, potential of the urban areas is harnessed when these growth centers are in vicinity of rural and semi-urban areas because the increase in urbanization leads to pressure on the natural resources [3, 4]. If urbanization happens in an uncontrolled manner, it will create an excessive pressure on the natural resources that are necessary to sustain the human settlement [5]. Therefore, it is necessary to monitor these developments using appropriate technologies. Remote sensing technology comes handy for this purpose as the remotely sensed data from the advance sensors give a synoptic view with high spatial resolution of multi spectral data [6, 10]. It gives us an in-depth insight into the growth pattern along a suggestive reason for such a change in land use/land cover. In this paper, machine learning based classification technique is used based on the parameter like indices values such as Normalized Built-Up Index to segregate urban and non-urban areas [7, 8].

This has been implemented using the images from the Landsat satellite which are then processed by the open source software called SAGA version 7.3.0 (System for Automated Geoscientific Analyses) [9].

II. METHODOLOGY & PROCESS

➢ *Study Area*

Pune is the second largest city in Maharashtra, India, situated at a height of 560 meters (1,837 ft.) and located 18º33′04″ N latitude and 73º52′04″ E longitude. Pune now comes under the jurisdiction of Pune Metropolitan Region (PMR) which covers an area of 7,256.46 km^2 [11]. There are two municipal corporations, three cantonment boards and seven municipal councils which locally administer 13 census towns and 842 villages. PMR is estimated to have a population of 7.27 million and it is the 9th most populous city in India. According to the 2011 census, Pune urban agglomeration has a population of 5,057,709. Being an IT and automobile hub of the country, there is a rapid growth in urbanization. Pune is also included in the *Smart Cities Flagship Programme* of the Government of India and a lot of development activities are in progress [12]. This rapid urbanization is creating a pressure on the natural resources necessary for human settlement. The focus of this study is to carry out change detection over a period of time by using geo spatial analysis.

➢ *Data Acquisition*

In this section, we present an overview of the datasets and the software used. In the present study, remote-sensing data collected from United State of Geological Survey (USGS) website Landsat 5 TM earth sat for the years 1991 and 2011 have been used for change detection. Satellite images are composed of different spectral bands [13]. The main advantage of these spectral bands is that they can measure the reflected radiation level beyond the visible range. By a suitable selection of band combination, we can compose various sets of images depending upon the aim of the studies. When these spectrum bands are stacked together, they create a True Color Composite (TCC) image which resembles very close to observations based on

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human eyes [14]. However, the composite images in some scenarios cannot differentiate the features which have a very minute difference in the reflectance value for a specific band. In such scenarios, we use False Color Composite (FCC) images by selecting the bands which are beyond the visual range. This FCC can be used to uncover the hidden information that cannot be revealed by the naked human eye. Spectrum range of Landsat TM bands is shown in Table 1. Figure 1(a), Figure 1(b) and Figure 1(c) depict the scatterplot of the band-1, band-2 and band-3 respectively.

Band	Resolution	Wavelength Range	Description
1	30 m	0.45 - 0.52	Blue
2	30 m	0.53 - 0.61	Green
3	30 m	0.63 - 0.69	Red
4	30 m	0.78 -0.98	Near Infrared
5	30 m	1.55 -1.75	Short Wave infrared
6	120 m	10.4 - 12.5	Thermal Infrared
7	30 m	2.09 -2.35	Short Wave Infrared

Table 1:- Landsat TM band details

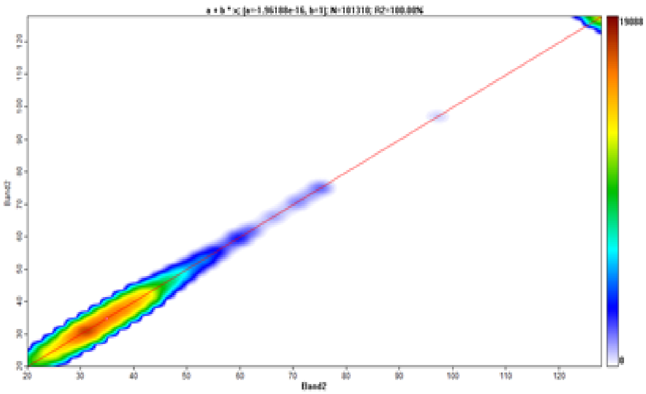

Fig 1(a):- Scatterplot of band-1

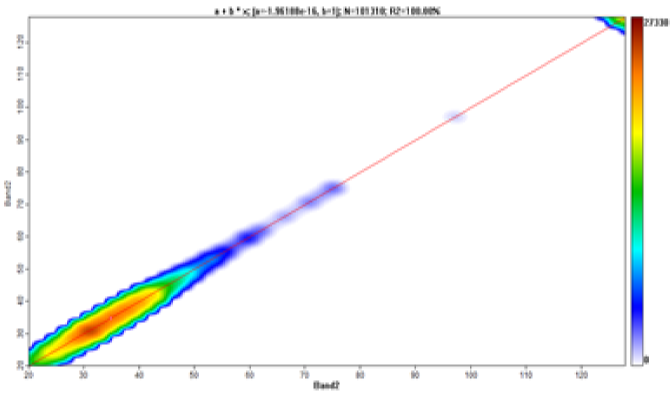

Fig 1 (b):- Scatterplot of band-2

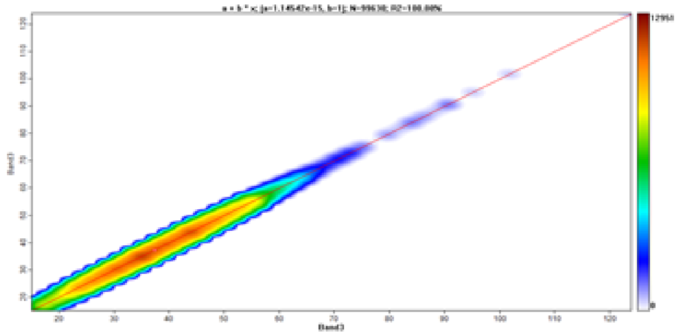

Fig 1 (c):- Scatterplot of band-3

Selecting the appropriate bands will have a huge impact in geo spatial analysis [10]. The band combination 3,2,1 is used for generating the TCC image. The band combination required to generate the FCC image is 4,3,2 (NIR false composite) in the Landsat image. Band 4 i.e. Infrared based bands makes the land and water boundaries clearly distinct. It also helps to differentiate different types of vegetation.

Once the appropriate bands are selected, layer stacking process can be initiated to create composite images which will be further used for classification analysis.

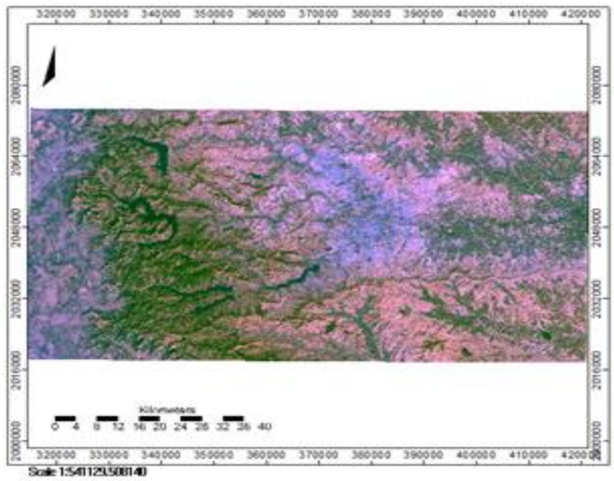

Fig 2 (a):- TCC Image

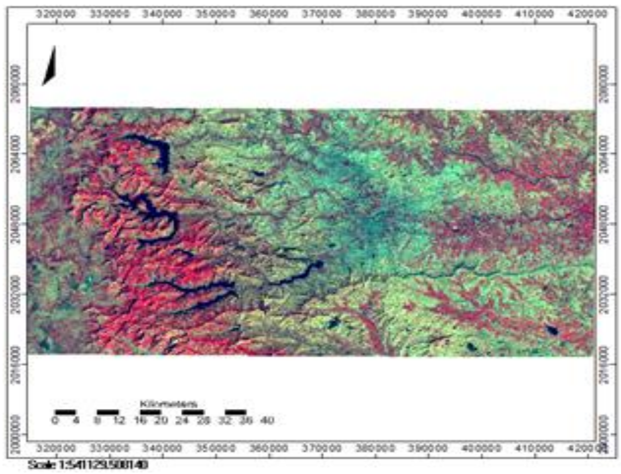

Fig 2 (b):- FCC Image

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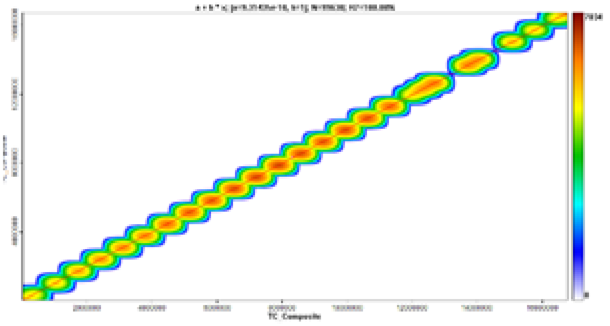

Fig 2 (c):- Scatterplot of TCC Image

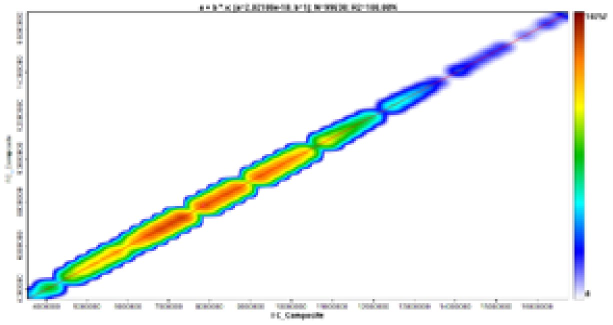

Fig 2 (d):- Scatterplot of FCC Image

➢ *Data Preprocessing*

Geo referencing means the internal coordinate system of the satellite image, which is related to the ground system of geographic coordinates. The relevant co-ordinates are stored in the image file and can be easily viewed in any geo analysis tools [15]. In this study, we have used the graticule intersections of the latitude and longitude, because the geographical coordinates of the area are known. This is the essential process in geo spatial image analysis. Once this process is accomplished, the satellite image can be tagged as a mapped satellite image which can be better understood because the image can be referenced to a map, based on real world co-ordinate system. After Geo referencing has been done, we now carry out digital classification on this image. The indices which are used in this study are Normalized Difference Built up Index (NDBI). This is used as a general parameter:

$$NDBI = \frac{\lambda_{SWIR} - \lambda_{NIR}}{\lambda_{SWIR} + \lambda_{NIR}}$$

➢ *Image Classification*

In this study, the classification of LULC was categorized into 6 major classes such as urban, forest, shrubland, grassland, openland and water bodies, whereas the forest, shrubland and grassland together form the Green Zone. Figure 3 (a) and Figure 3 (b) show the classified images of the Pune region. An attempt has been made to use the three bands for the delineation of the urban area and to showcase the changes, which have taken place over the period of time.

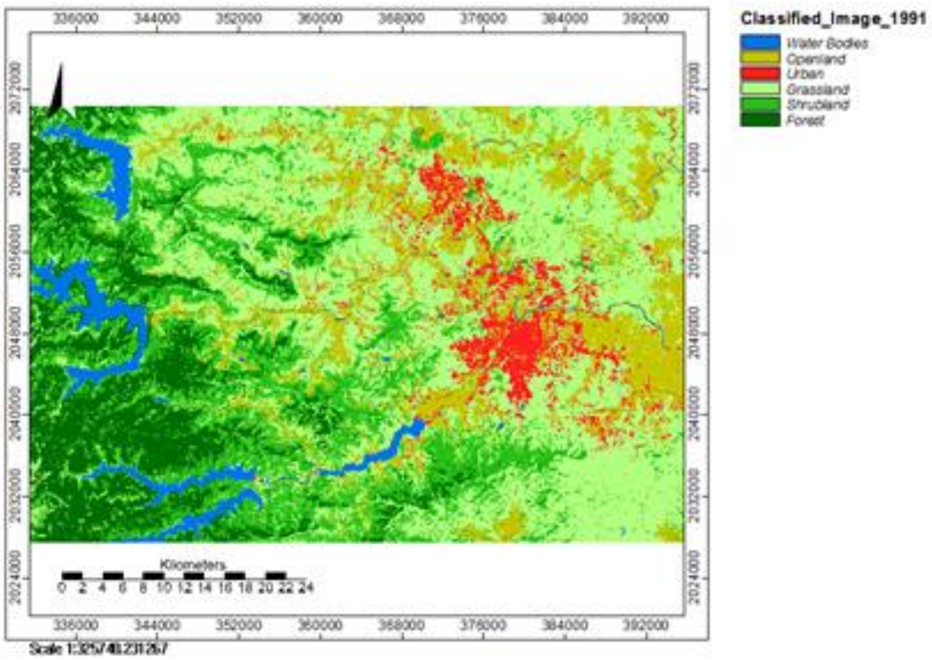

Fig 3 (a):- 1991: Land use/Land cover distribution

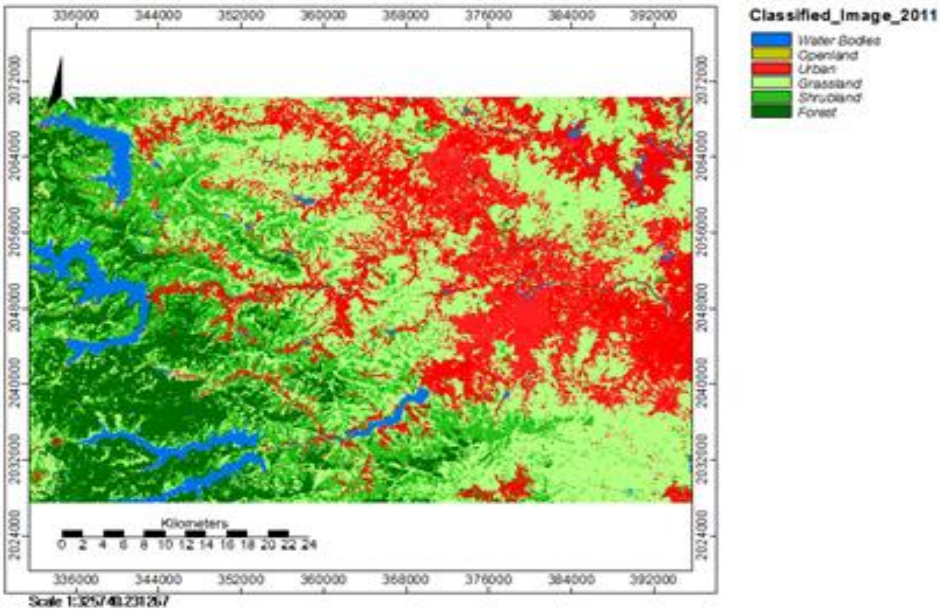

Fig 3 (b):- 2011 Land use/Land cover distribution

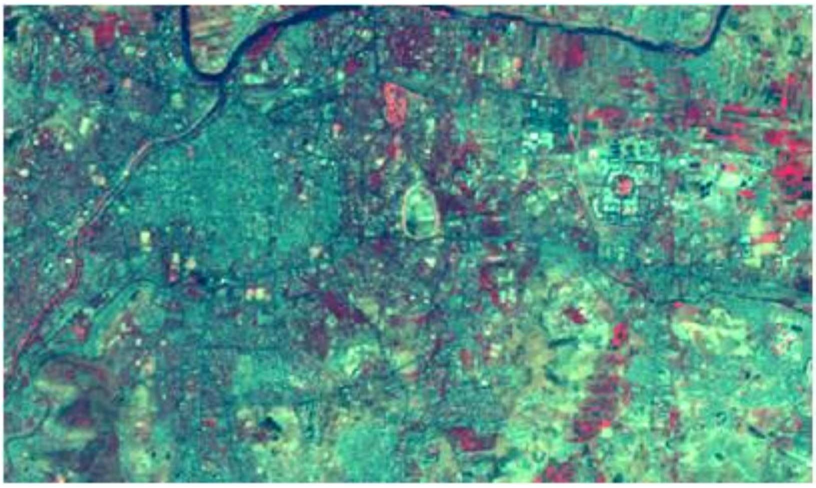

Fig 3 (c):- 1991: Major urban sprawl highlighted

Fig 3 (d):- 2011: Major urban sprawl highlighted

III. RESULTS AND DISCUSSION

➢ *Change Detection and Explanation*

Comparative analysis of two classified images of the Pune region was done. The total area of interest in this study is 2752.24 sq. km. The present work has clearly showcased that we can easily distinguish urban area and non-urban area from the classified Landsat images. The statistics of LULC are showcased in the table 2. As shown in the table 2, there is a significant change in the urban area from 146.55 sq. km. in 1991 to 262.87 sq. km. 2011, which is 79%. During the period of 1991 to 2011, the Green Zone is marginally decreased from 2100.49 sq. km. to 1918.53 sq. km. (-9%). The Green Zone is not decreased significantly only due to the heavy rainfall in Pune and its adjoining areas during monsoon. The result also shows a slight increase in the openland and water bodies areas.

S. No.	Name of the Class	1991		2011	
		No. of Pixels	Area in sq. km.	No. of Pixels	Area in sq. km.
1	Forest	432142	388.93	447090	402.38
2	Shrubland	681826	613.64	531015	477.91
3	Grassland	1219915	1097.92	1153598	1038.24
4	**Urban**	**162832**	**146.55**	**292074**	**262.87**
5	Openland	436891	393.20	503061	452.75
6	Water Bodies	124441	112.00	131208	118.09

Table 2:- LULC distribution pattern of 1991 and 2011

S. No.	Name of the Class	Year 1991	Year 2011	Comparative Analysis	
		Area in sq. km.	Area in sq. km.	Change in Area in sq. km.	% Change (Area)
1	Forest	388.93	402.38	13.45	3%
2	Shrubland	613.64	477.91	-135.73	-22%
3	Grassland	1097.92	1038.24	-59.69	-5%
4	**Urban**	**146.55**	**262.87**	**116.32**	**79%**
5	Openland	393.20	452.75	59.55	15%
6	Water Bodies	112.00	118.09	6.09	5%

Table 3:- Change detection in LULC over two decades

S. No.	Green Zone	Year 1990	Year 2011	Change	% Change (Area)
		Area in sq. km.	Area in sq. km.		
1	Forest + Shrubland + Grassland	2100.49	1918.53	-181.96	-9%

Table 4:- Statistics of Green Zone

IV. CONCLUSION

Over the past few decades, Pune has undergone substantial unplanned development. The present study has demonstrated that there is 79% increase in urbanization in two decades. Even though there is a slight increase in the forest area (3%), the overall Green Zone area is decreased (-9%). There is no significant increase in most critical of all i.e. water bodies, as compared to percentage of expansion of urbanization. The result shows that the change in area of urban sprawl is creating pressure on the natural recourses which are vital for human habitation. The prime concern according to this study is that as the rate of growth of urbanization is not in sync with the rate of growth of water bodies. This research has shown that the urban sprawl is growing with an exponential speed. It is indicated that sustainable use of natural resources for future development can be based on predictive model, which can be achieved by using widely available remote sensed data and latest analyses techniques.

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