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Geospatial Tools for Assessing Changes in Land Use / Land Cover of Vadodara City

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Abstract

Changes in land use/land cover (LULC) are increasingly highly emphasized in current systems for managing water resources and monitoring changes. This article presents the changes in land use for Vadodara City using approaches from remote sensing and geographic information systems. These two Landsat satellite images of the years 1995 and 2015 were used for assessing methods. Combined classification was utilized in the pre-processing of the images from these two years. Using image categorization based on satellite images and Google Maps, five distinct land use classes—waterbody, urban settlement, natural vegetation, agricultural land and barren land —have been identified. The findings in 1995 and 2015 indicated an important shift in land use classes. In terms of percentage, built-up space increased from 35.95% in 1995 to 48.89% in 2015. Waterbodies now account for 0.52% of the overall contribution, compared to 1.62% previously. Also declining, from 11.97% to 4.81%, is the percentage share of vegetated regions. Additionally, the percentage share of barren land has declined from 17.80% to 9.88%. The agricultural land has a slight rise of its percentage share from 32.65% to 35.90%. These results indicate that the built environment and agricultural land, with the built environment having the greatest proportion of all, fully compensate for the loss of waterbody, natural vegetation and barren land. According to the present research, the population increase and associated development activities have had a major impact on the shift in land use classifications. The public, legislators, and ecological management organizations can better comprehend the region as to the quantification of land use variation in the Vadodara city region. When planning for future land uses, the Vadodara municipal authority may find the increased land use developments beneficial.

***Key words*:** Accuracy assessment, Change detection, Geographical information system, Image processing, Land use/Land cover, Remote sensing

The rapidly changing human activities, such as population growth, industrialization, and urbanization, are causing significant changes in LULC patterns [1]. Rapid modifications in LULC patterns are especially detrimental to developing countries and are depleting vital resources like vegetative cover, body of water, and types of soil [2]. By boosting water flow and heightening gradients towards flooding, these artificial interruptions also have a substantial impact on changing the climate and triggering disasters [3]. Water's ability to erode surfaces also gets stronger as runoff up slopes rises. The bare slopes thus serve as triggers for natural disasters like flooding and widespread migration [4]. An increasing number of people are using up the limited availability of water, as well as agricultural land, forest, land for urban uses, and industry. More land needs to be cultivated in order to support the needs of a growing population. Changes in land use and land cover are measurable fluctuations in the spatial extent (an increase or decrease) of some kinds of LULC. Changes in land use and vegetation cover (LULC) have an impact on both the local and regional climate of a region, and they are a major factor in the reduction of biodiversity. The shifting landscape may have a profound impact on both the local and global ecosystem [5]. Changes in land use and land cover, or LULC, are measurable variations in the spatial extent (increases or decreases) of a certain form of LULC. Changes in land use and cover (LULC) have an impact on both the local and regional climate of a region, and they are a major factor in the decreasing amount of biodiversity.

For instance, modifications to land usage may result in climate change, which may raise temperatures and cause water bodies to dry up. The stability of the ecosystem may be threatened as a result of a decline in vegetation or an uneven pattern of it [6]. Quick population growth and economic development are two factors that contribute to the quick change in LULC that is happening in most of the world [7-8]. The selection, planning, and management of natural resources can be used by public or private organisations to meet the growing demands for basic human needs and welfare while also achieving sustainable development goals with a more thorough analysis of LULC change [9-10]. For the monitoring and study of LULC changes since the 1970s, satellite Remote Sensing (RS) data has been the main and most reliable source of data. It

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makes it possible for researchers to more quickly, efficiently, and thoroughly examine changes in land cover. Geographic information system (GIS) methods are frequently utilised with RS to enhance the effectiveness of land cover change detection [11].

Using an unsupervised classification method, [12] mapped changes in land use and land cover. ERDAS imagine software was used to categorize the data and create the final maps. The ERDAS Imagine programme has been used by scientists and researchers in a variety of projects for classification purposes. The Indian Municipal Corporation of Hyderabad provided integrated Indian Remote Sensing - ID PAN and Linear Imaging Self Scanning Sensor - III satellite data, which was used by [13] to create a spatial digital database of land use/ land cover (LULC). ERDAS, an image processing programme, was utilized for data conversion and input. Database creation and analysis were carried out using Arc/Info and ArcView GIS software. Using imagery from the Landsat MSS Image from 1976, the Landsat TM Image from 1990, and the IRS ID LISS III from 2005 [14], carried out additional analysis in ERDAS IMAGINE in the Birahi Ganga Sub-Watershed of the Garhwal Himalaya, India. Several researchers, including [12], [15], have used supervised classification in their investigations as opposed to unsupervised classification. The highest level of classification accuracy was achieved, they claimed, using the Maximum Likelihood Classification (MLC) decision rule to identify land use and land cover. Studies have been on watershed management have been carried out where resources can be most effectively applied to improving the welfare of the inhabitants and the regional economy. Studies were conducted to decide on different land use alternatives in a watershed by visual interpretation techniques utilizing GIS in order to obtain the best possible resource utilization. Mohan [16] conducted urban LULC change detection as part of planning for rural and urban populations in the National Capital Region (NCR) in Delhi, where a related study was conducted.

Additionally, RS and GIS technology make detection of LULC changes easier and quicker than it is with traditional surveying and mapping methods [17]. Furthermore, remote sensing data is the only reliable technique to observe the variations of LULC swiftly, affordably, and correctly. To detect the change using remotely sensed data, various techniques have been developed recently, such as supervised classification, or unsupervised classification.

MATERIALS AND METHODS

Study area

The city of Vadodara in the Indian state of Gujarat was chosen as the study region. At an elevation of 34 metres, Vadodara is situated in western India at 22.30°N 73.19°E. The town is located in the heart of Gujarat along the Vishwamitri River. The study area Vadodara city is shown in (Fig 1). In the summer, the Vishwamitri regularly dries out, leaving only a tiny stream of water. The city is situated between the Mahi and Narmada rivers in a lush plain. The metropolis is classified as being in seismic zone III by the Bureau of Indian Standards, on a scale of I to V (in order of increasing earthquake susceptibility).

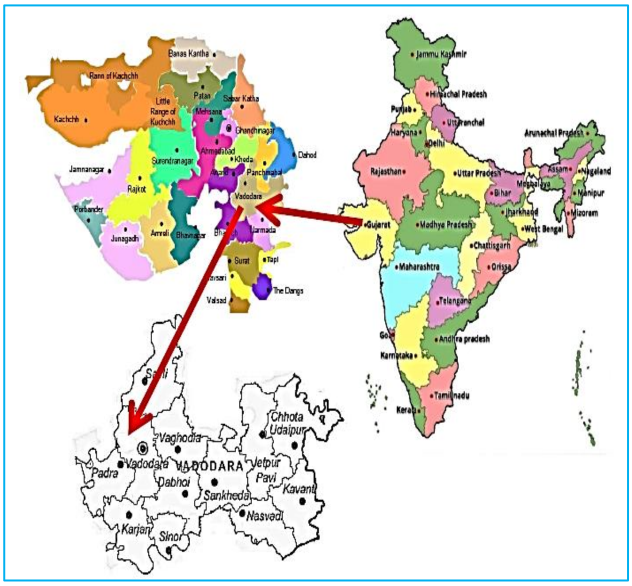

Fig 1 Location map of Vadodara City

In the last twenty years, Vadodara has experienced a rapid urbanization process that has intensified land use change in tandem with population growth and economic expansion. The metropolis has grown horizontally in all directions, changing the land usage on a significant scale. One of the main issues is the rise in slums, particularly along the banks of the river Vishwamitri and its surrounding low-lying neighborhoods, which are frequently inundated during monsoon season, causing significant economic loss as well as effects on health and the environment.

Rapid population expansion would undoubtedly put more strain on land use, but its effects may be lessened with the right planning. Accurate land use maps may be created with the help of RS and GIS, and changes can be tracked over time. Remote sensing has previously demonstrated its ability to track the expansion of urban land use changes and establish statistics. As Vadodara city struggles with the serious issue of both urbanization and industry, this has become a need.

Table 1 Characteristics of the Landsat images used for the study

Satellite imagery used						
Satellite / Sensor	Path/row	Acquisition date	No. of bands	Spatial resolution (m)	Cloud cover	Source
L5 / TM	148/45	March 23, 1995	7	30	0.00	USGS
L8 / OLI	148/45	March 30, 2015	11	30	0.00	USGS

Data acquisition and image processing

Data in (Table 1) shows the data and its characteristics, that were acquired for the study and also its source. Using ArcGIS 10.5, Erdas Imagine 2015, and standard techniques, the two satellite images were processed. These methods included layer stacking (band selection and combination), image enhancement, sub-setting (clipping), extraction, geometric correction or georeferencing, atmospheric correction, topography correction, and layer correction. Using WGS 84 projection parameters, the two images were aligned to a single UTM Zone 43 N.

Image classification

The technique of classifying a picture into fewer distinct types based on reflectance values is known as image classification. The photographs were categorized using the history function of Google Earth, visual interpretation of each LULC class, supplemental information, the local expertise, and physiographic understanding of the study area. (Table 2) displays the five classifications and the descriptions that go with them. In this study, a combined classification is used firstly the unsupervised and then after the supervised algorithm was used. Each image was first subjected to an unsupervised classification method because supervised classification was unable to distinguish between river body and built-up areas due to conflict in spectral reflectance. Then, the supervised categorization process was completed. Ten to twelve training samples were used in a supervised classification approach. To create these samples, a polygon or area of interest was drawn around each of the four, land use/land cover classifications. The average signature was then created for each class. The land cover types were identified in ERDAS Imagine 2015 using the maximum likelihood algorithm.

Table 2 LULC classification scheme used in the study area

LULC class	Description
Waterbody	Rivers, streams, ponds and lakes
Urban settlement	Residential areas, commercial areas, industrial areas, urban areas, roads and airport
Natural vegetation	Trees which have grown naturally without human aid and has been left undisturbed by humans for a long time
Agricultural land	All the cultivated and uncultivated land used for agriculture, crops, and horticulture
Barren land	Locations outside of and inside of cities that are completely devoid of vegetation, including waste grounds and exposed earth

Change Detection in Land use/ Land cover

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Change Detection in Land use/ Land cover

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Initial land use/land cover classification

↓

Ground Truthing

↓

Editing of Initial land use/land cover maps

↓

Final production of land use/land cover maps

↓

Change detection analysis based on land use/land

↓

Display the change detection result

Fig 2 Methodology flowchart

The (Fig 2) displays the stepwise methodology in the form of flowchart, that is carried out for the study area.

Accuracy assessment of the images

A crucial stage in LULC change analysis is accuracy assessment of a categorized image. To ensure that each of the five LULC classes was appropriately represented, 50 reference data were gathered using a stratified random sample technique, considering the relative area of each class. Images from Google Earth were utilized to collect reference information. Only that satellite image from 2015 was used to evaluate the accuracy. The accuracy evaluation of the 1995 image was not done since there was a shortage of ground validation data in the form of aerial photographs and older Google Earth images. The confusion (error) matrix's producer and user accuracies, overall accuracy, and Kappa coefficient were used to determine the accuracy evaluation [18-19]. The link between the categorized map and reference data is indicated by the Kappa coefficient (Lillesand and Keifer 2000). The accuracy of the five land use classes, both individually and collectively, was calculated using the error matrix. The Jensen and Cowen [20] equation was used to calculate the Kappa coefficient.

RESULTS AND DISCUSSION

After carrying out the image classification, the results obtained are shown in (Fig 3).

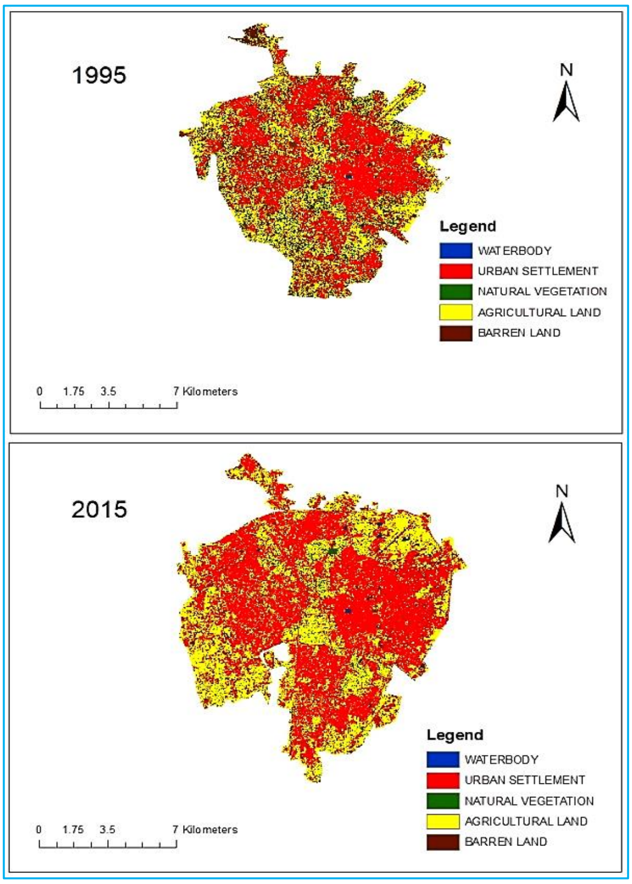

Fig 3 LU/LC changes of Vadodara city in 1995 and 2015

As per (Fig 3), a rising tendency in urban settlement and agricultural land appeared to be countering a decline in waterbody, natural vegetation and barren land. However, the built-up region has experienced the greatest proportion of its area's growth. The total area for the year 1995 is 110.30 square kilometres (Km^2), and (Table 3) lists the values of the areas of the five land use classes of land: waterbody, urban settlement, natural vegetation, agricultural land, and barren land. The values of the areas of these land use classes, namely waterbody, urban settlement, natural vegetation, agricultural land, and barren land, are shown in (Table 4) for the year 2015, where the total area is 149.184 Km^2. The city has grown from 110.30 square kilometres to 149.18 square kilometres, which appears to be an expansion of 35% of the entire area. Between 1995 and 2015, water bodies appear to have decreased by 1.02 square kilometres, natural vegetation by 6.03 square kilometres and barren land by 4.89 square kilometres whereas on the other hand urban settlement has increased by an area of 33.28 square kilometres agricultural land by 17.53 square kilometres.

Table 3 Values of the areas of the five land use classes of the year 1995

Year	1995 (Area Km^2)
Waterbody	1.80
Urban settlement	39.66
Natural vegetation	13.20
Agriculture land	36.02
Barren land	19.63
Total area	110.30

Table 4 Values of the areas of the five land use classes of the year 2015

Year	2015 (Area Km^2)
Waterbody	0.78
Urban settlement	72.94
Natural vegetation	7.17
Agriculture land	53.55
Barren land	14.74
Total area	149.18

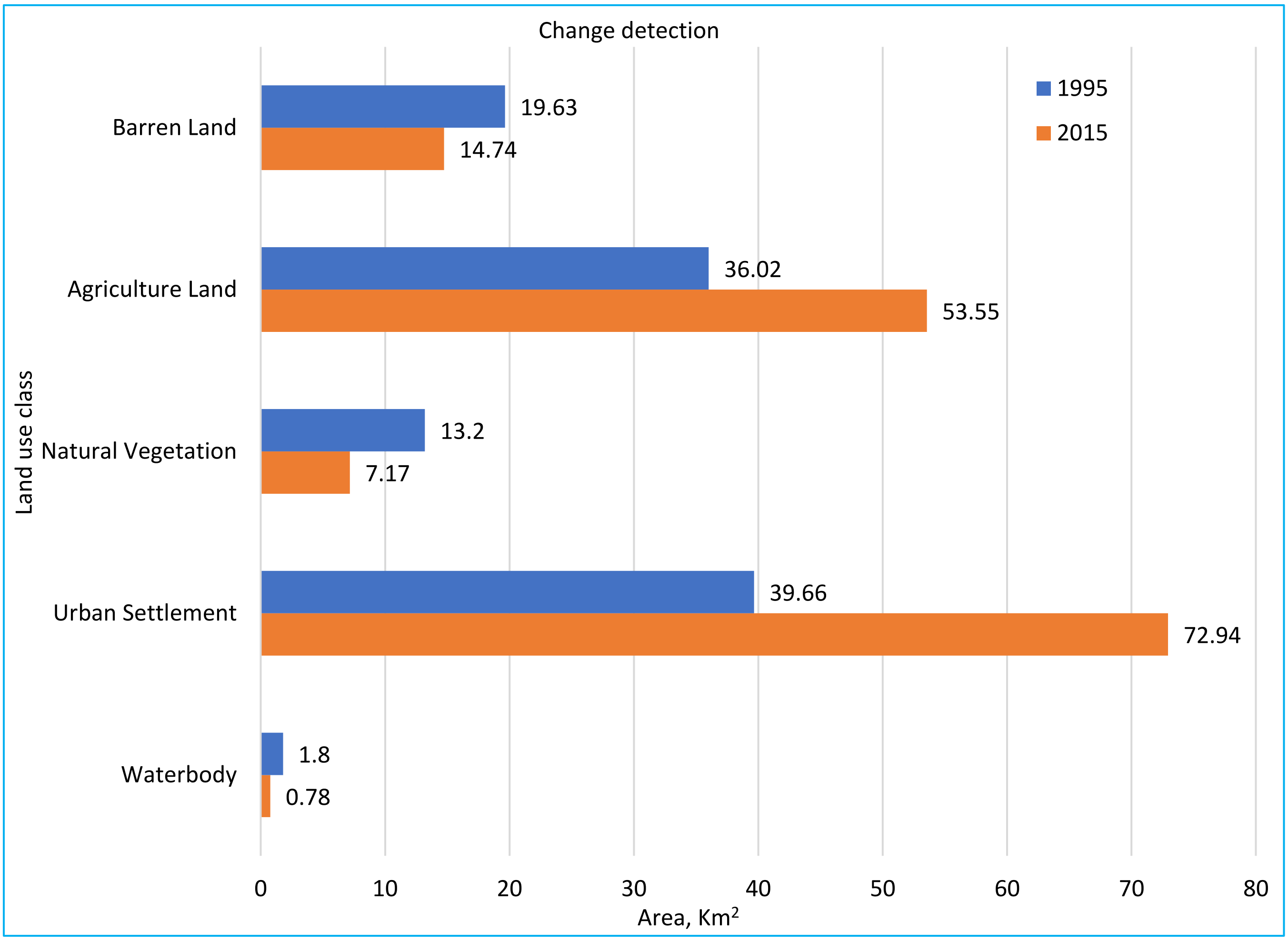

Fig 4 LU/LC change detection of Vadodara city in 1995 and 2015 for different land use classes

The (Fig 4) shows the comparison of various classes namely waterbody, urban settlement, natural vegetation, agricultural land, and barren land for the year 1995 and 2015. Accuracy assessment has also been done to determine the accuracy of image classification where the overall accuracy of the year 2015 decades was 92% the Kappa coefficient of 0.89.

CONCLUSION

Using remote sensing data and GIS technologies, this article focuses on LU/LC variations in an urban area, Vadodara, India. The findings unmistakably demonstrate that LU/LC variations were significant between 1995 and 2015. There has been a noticeable increase in the built-up area. There has been a noticeable rise in urban settlement. The percentage wise proportion of urban settlement was 35.95% in 1995, and it rose to 48.89% in 2015. The percentage share for waterbodies decreased from 1.63% to 0.52%. The percentage of natural vegetation has also reduced, going from 11.97 to 4.81%. The percentage of agricultural land has been slightly increased, going from 32.65% to 35.90%. Additionally, the proportion of barren land has dropped from 17.80% to 9.88%. These findings show that the built environment and agricultural totally make up for the loss of waterbody, natural vegetation and barren land, with the built environment having the largest proportion of all. According to this study, the LU/LC change in the study area has been significantly impacted by population growth and related development activities. This study establishes that remote sensing and GIS integration are powerful tools for managing and planning metropolitan areas. The quantification of LU/LC variations in the Vadodara city region helps the public, policymakers, and environmental management organizations better understand the area. The Vadodara municipal corporation may find the increased land use patterns helpful when planning for future land uses.

Conflict of interest

Dr. T. M. V. Suryanarayana is Director at Water Resources Engineering and Management Institute, Faculty of Technology and Engineering, The Maharaja Sayajirao University of Baroda.

Ms. Sumitra Sonaliya is a research scholar at Water Resources Engineering and Management Institute, Faculty of Technology and Engineering, The Maharaja Sayajirao University of Baroda.

All other authors have no conflicts of interest.

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Author's contribution

Dr. T. M. V. Suryanarayana: Conceived and designed the analysis; collected the data.

Ms. Sumitra Sonaliya: Collected the data, contributed data or analysis tools; performed the analysis; wrote the paper.

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Declarations

I/We Sumitra Sonaliya and Tallavajhala Maruti Venkata Suryanarayana, declare that the Submitted Research Paper is my original work and no part of it has been published anywhere else in the past. We also declare that we have no competing interests. Also, no funding is applicable.

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