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Land Change Detection of Delhi Area, India: A GIS Approach

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ABSTRACT

In this study, the metropolitan area of Delhi considered utilizing Landsat images from 1991 and 2011 in order to recognize changes to land cover. The changes in temporal land cover have an effect on the climate and its urban landscape. A change detection analyses the nature, extent of urban sprawl due to changes in land cover, land use/land cover (LULC) and twenty years of overtime change detection. This work explores the significant growth of the city at the expense of unbuilt land in its region. In the study area, there was a substantial land exchange between numerous LULC groups, not just because of the development of the city area. The accuracy assessment of the supervised classification showed good accuracy for 1991 and 2011 respectively, which was 96.31 and 97.35 percent. The twenty-year growth rate in the Delhi area was 11%. The study showed a dramatic shift in urban areas and agricultural land in Delhi and it contributed to 54116.2 hectares declining to 37243.17 hectares in 1991 and 2011 respectively.

1. Introduction

The development of urbanization and population increase rapidly change the land cover for a certain metropolitan city. A metropolitan city's suburban or peripheral area was rising more rapidly. The wetland, sparse vegetation, water body, and forests changed into a built-up area to meet the need for infrastructure and industry for the densest population in the world. The utilization of remote sensing techniques for land cover and land use has been using for several decades. For instance, utilizing various layers, including classified images, maps of agriculture, maps of soils, maps of topographical, hydrological maps and geological maps provides a greater ability to collect valuable data regarding improvements across a specific region. In addition, by modelling the available information and using statistical and analytical features, GIS can assess the patterns in such modifications. The value of GIS is to provide multiple outputs in various formats such as tables or maps, enabling people to select the correct output to retrieve the required data [1]. Remote sensed information and GIS are frequently utilised to assess changes in land cover and land use. Several studies have tried to utilize remote sensed information and GIS to investigate the identification of land-use transition [2], [3].

In addition, many researchers have utilized Remote Sensing techniques; others have combined GIS information with remote sensing [4], [5]. Satellite imaging offers the ability to quickly acquired and timed land cover data to determine changes in spatial and temporal land cover as well as to comprehend its exorbitant environmental effects. Rapid changes in urban systems, particularly global urban extension, have significant effect at all geographical levels on human and natural systems [6]. The increasing population worldwide represents an effect on the human aspect such as the primary driving force in land-use change. Asia is home to about 4.6 billion people, with a global population of over 7 billion, including two of the most populated countries in the world (China and India), each with over 1 billion inhabitants, making earth's transformation features and environmental impacts a crucial problem with this huge population, and a major concern [7]. The unfavourable effect of crowding, inadequate infrastructure, housing and urban landscape and urban ecological issues requires surveillance and vice versa.

Due to the wide spatial and spectral diversity of surfaces, an urban area is among the major areas for remote sensing research [8], [9]. Several researchers had also analysed changes in land cover, especially in urban regions. Unplanned changes in the land use of the population of the city, and induced by urban sprawls, combined with industrial growth, and land mistreatment, which transforms productive agricultural land into unplanned land, is taking place [1]. Zhang et al [10] and Wang et al [11] used multi-temporal remote sensing images for land cover assessment in the Beijing Metropolitan region. Liu and Zhou [12] and Bihamta et al [13] studied the urban spatial model and the future urban growth predicted. Coppin et al [14] and Lakshmi & Karthikeyan [15] studied by analysing problems with the detection of land cover change geospatial information systems. This study focuses on the identification with temporary data of Landsat TM 5 of the change in urban areas around Delhi (Thematic Mapper 5). In the 1991 and 2011 images, developments in that region were studied. It is very effective to identify difference-using images from two decades since they predict variation in the landscape. The environment change assessment between 1991 and 2011 could provide crucial information on decision-making methods since it could signify a raise in urban areas or a decrease in agricultural land, which would have a significant environmental impact. This study analyzed and mapped modifications into a certain land cover. The objectives of this research work are to analyse land use and land cover changes for the years 1991 and 2011 of the Delhi region, using remote sensing and GIS and to estimate change detection.

2. Material and Methods

Study Area

Delhi is located between from 77°14´E to 77°22´E longitude and 28°40´N to 28°67´N latitude (Fig. 1). According to the census of 2011, the area of the city is the extent of about 1483 km2 and approximately 16.78 million total population of Delhi. Delhi lies on the banks of the Yamuna River and is surrounded by the eastern part of Uttar Pradesh and other parts located around Haryana namely as Jhajjar in the western part, Gurugram in southern and Sonipat districts on the northern side.

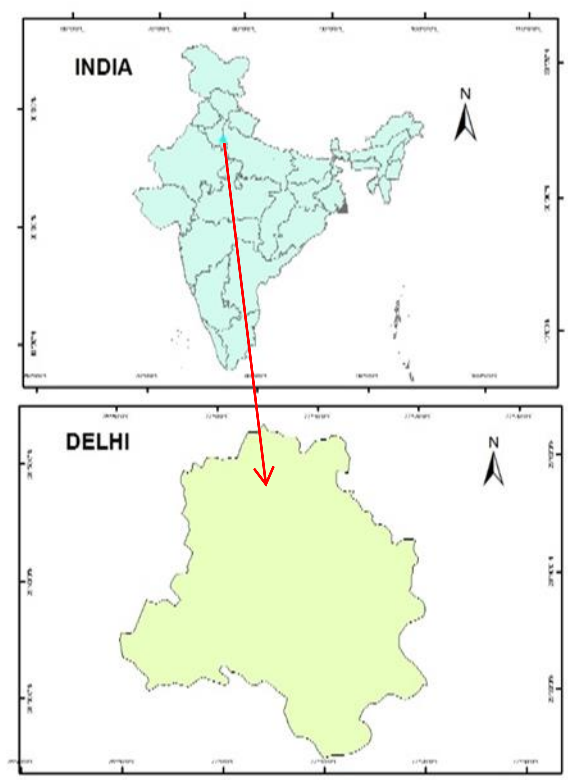


Fig. 1 Location Map of Delhi

In the larger geographic context, Delhi situated between the Himalayas in the north and Aravalli mountainous ranges. The temperature in the summer varies from 45 ° to about 4 ° C in the winter and has yearly average precipitation between 750 and 1500 mm. The elevation of the city ranges between 213m and 290m. In modern times, Delhi is a cluster of a number of cities spread across the metropolitan region. The National Capital Region of the Delhi Region (NCR), which was developed by the National Capital Region Planning Board Act (1985), is a unique "interstate regional planning" area.

Data Source

The Landsat 5 TM images of 14th March 1991 and 28th March 2011 were downloads from the USGS website. In the month of March, imageries are clear for information. The radiometric correction of Landsat images employed for detecting changes of surface reflectance, using a relative radiometric correction method. The images of two dates were rectified by taken ground control points and projected to a common coordinate system for the World Geodetic System (WGS 84) that had used in Universal Transverse Mercator (UTM) with the spatial resolution is 30 m x 30 m, although with three bands 2, 3 the visible-near infrared band 4 was chosen. By using 9.3 imagine software of ERDAS, the two images were initially geo-referenced and geo-corrected. In order to create a false-colour composite, the satellite imaging was stacked in various bands sub-setting an image obtained the region of interest. By sub-setting the city planning map, the zone of interest (Administrative Boundaries of the Delhi Region) has collected. The images have described in the shape of polygon covering different land-use coverage classifications in a GIS environment utilizing ArcGIS 10 software. With the help of a global positioning system (GPS), it can observe the readings of ground control points of any area. The Level 1 classification system was adopted and data were categorized into the five land-use classes covering a total area of 150540.02 hectares (also district limits) in the area of Delhi. The tendency and variation of urban sprawl were estimated and the various regional maps indicated and analysed each polygon comprising the specific class. The research moreover analyses the land change by overlaying the LU/LC maps in a GIS environment for such two time periods. The aim was to complete a matrix with changes between the classified categories of LU/LC. Image enhancement techniques such as contrast stretching and ratio images visual interpretability of the image has developed. A ratio image effectively compensates for the brightness variation caused by varying topography and emphasized the colour content of the data. As per the aim of the study, the method was used for supervised classification for making land use and land cover (LULC) maps.

Supervised classification

For supervised classification, the software Erdas Imagine 9.3 are used. The pixels of different categories of LULC based on spectral signature was identified. For each category of LULC, ten training areas (belongs to homogeneous pixels) were selected. Similar signatures of a particular category of LULC are merge which results in the new spectral signature of that category. For the supervised classification of LULC, the maximum likelihood method was select and performed in Erdas Imagine. Similarly, this classification technique was applied on two years Landsat data to obtained changes in LULC categories and LULC maps of the year 1991, 2011 were obtained (Fig. 2).

Accuracy Assessment

The accuracy assessment of land use and land cover changes was done by the relative deviation method in which variations between the actual area and a changing area of the detection analysis were calculated. The relative deviation method formula is given by:

$$\frac{x_i - X}{x_i} \times 100 \qquad (1)$$

Where Xi is the actual area and X is the changing area.

Accuracy evaluation and verification were used to show the level of accuracy of the classified image obtained through the classification methods [16] [17]. Accuracy evaluation is one of the key steps of LULC detection of change analysis.

3. Results and Discussion

Built-up land and water bodies

In the year 1991 percent built-up land was 32.2 and in 2011 47.5 with an increment of approximately 15 percent (Table 1). Agricultural land was converted into built-up land as the urban population is increasing continuously in the Delhi NCR. People migrated from rural areas to an urban area in the search of employment, study purpose, business, and medical facilities for better living conditions. Highways and roads are built in both urban and rural areas. Whereas water bodies in 1991 were 0.84 and in 2011 it was 1.5 percent (Table 1) and approximately remained the same. It was slightly increased due to the increase in the Yamuna river catchment area.

Open Land

In the year 1991 open land was 15.4 and in 2011 12.6 percent and decreased by nearly 3% (Table 1) because barren land converted in a built-up land and due to some unauthorized activities (constructions) open land was converted into built-up land. The bare identified rocks together with some quarrying areas involve barren lands. These are fewer vegetable fields and have partial livelihoods. This class was mapped throughout the rocky areas of the study area i.e. the ranges of Aravalli's bare rock surfaces.

Natural vegetation

The natural vegetation was 15.7 and 13.4 percent in 1991 and 2011 with a decrement of 2.3 percent (Table 1) and because the Delhi government preserves the natural vegetation with the fancy boundaries e.g. in the campus

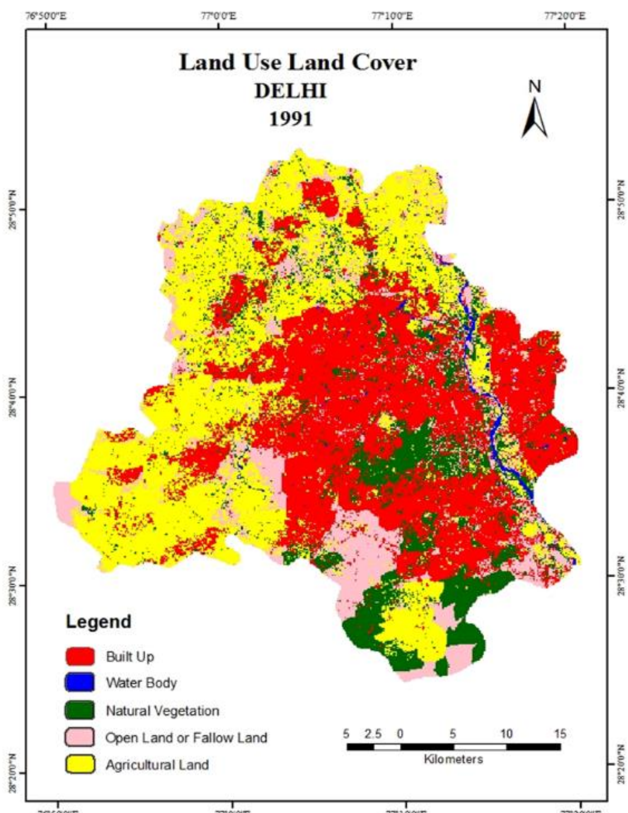
Jawahar Lal Nehru University (JNU), Jamia Hamdard University, etc. Due to higher anthropogenic pressure, the extent of natural vegetation reduced.

Agricultural Land

Mostly paddy land, wheat crops, and vegetable fields are part of the agricultural class. In the year, 1991 crop area was 35.9 and in 2011 was 24.7 percent and crops decreased by 11.2% (Table 1). Wheat is the main crop used in agriculture. The reduction in their area is due to the growth of the built-up area on fertile farmlands and the employment shift of people from primary to secondary and tertiary. Agriculture land would decreased because the land area from agricultural land were converted into built-up land due to a rapid increase in the population, residential areas, contractions of highways and roads, etc.

Accuracy Assessment

The overall accuracy of the year 1991 image is 96.31% and in 2011 was 97.35% and this indicates that the accuracy level was very fine and reliable. As for the individual classes like agricultural land, water bodies, natural vegetation and open bodies ranged between 91.94 and 100.0 but form natural vegetation was low (86.09 %) in 1991 (Table 2 and 3).



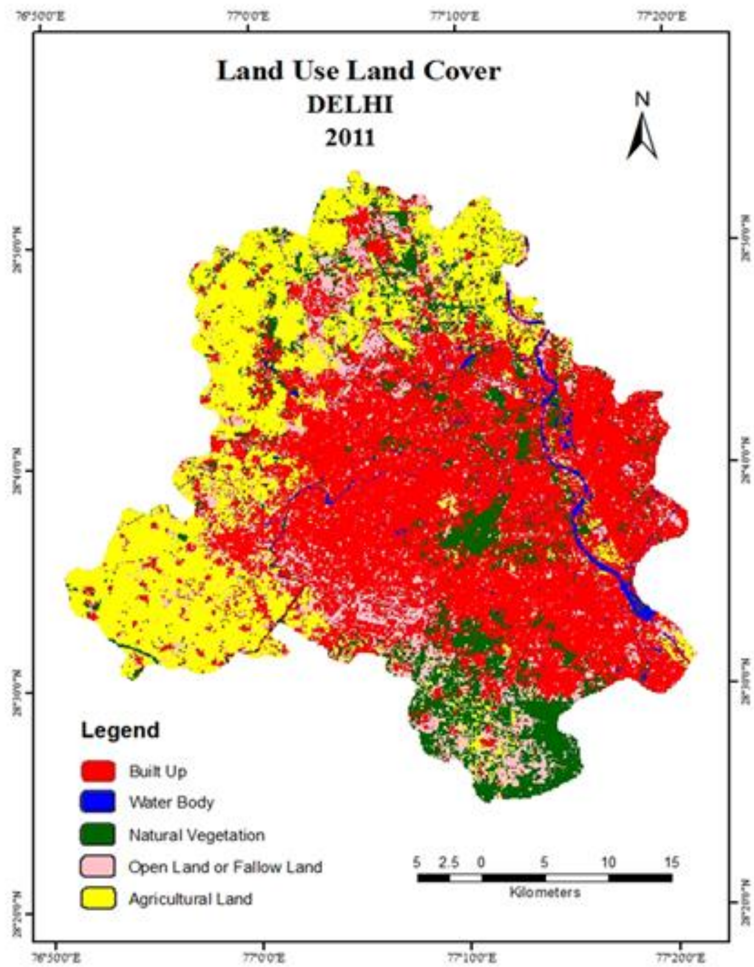


Fig. 2 LULC Map 1991 and 2011

TABLE 1. Land use pattern

Land use/ Land cover classes	**1991**		**2011**		
	Area(ha)	*Area Percentage*	*Area(ha)*	*Area Percentage*	*Percentage Change*
Built Up	48524.35	32.2	71616.92	47.5	15.3
Open Land	23207.55	15.4	19087.57	12.6	-2.8
Natural Vegetation	23588.34	15.7	20195.64	13.4	-2.3
Agricultural Land	53966.37	35.9	37243.17	24.7	-11.2
Water Bodies	1253.43	0.84	2397.24	1.5	0.66
Total	150540.04	100	150540.04	100	

TABLE 2. Land use accuracy assessment for 1991

Land Use Class	Agricultural Land	Water Bodies	Built-Up	Natural Vegetation	Open Land	Total	User Accuracy (%)
Agricultural Land	1554	0	0	16	0	1570	98.98
Water Bodies	0	313	3	0	0	316	98.11
Built Up	0	0	1620	6	5	1631	99.32
Natural Vegetation	7	4	5	1375	206	1597	86.09
Open Land	1	2	22	1	2409	2435	98.93
Total	1562	319	1650	1398	2620	7549	
Producer Accuracy (%)	99.48	98.11	98.18	98.35	91.94		
Overall Accuracy %)	96.31						

TABLE 3. Land use accuracy assessment for 2011

Land Use Class	Agricultural Land	Water Bodies	Built-Up	Natural Vegetation	Open Land	Total	User accuracy (%)
Agricultural Land	1587	0	2	0	0	1589	99.87
Water Bodies	0	361	0	4	0	365	98.9
Built Up	0	11	1872	28	0	1911	97.95
Natural Vegetation	7	1	91	1920	0	2012	95.42
Open Land	0	0	22	10	489	521	93.85
Total	1587	373	1987	1962	489	6398	
Producer Accuracy (%)	100	96.78	94.21	97.85	100		
Overall Accuracy (%)	97.35						

4. Change detection in Delhi region

Due to the various natural and man-made processes, the land is in a continuous state of change detection [18]. The key element of the identification of changes is deciding which type of land use is really changing to the other one. These data reveal both favourable and unwanted changes and over time the relatively stable classifications. Data is also a crucial method for decision-making in management. The Delhi area had not only expanded from its original size during the study period, but there was a significant land exchange between different land use/cover classes. These improvements lead to increased land demand for residential, commercial, industrial uses, etc. because of the growth of the city. The attractiveness, functional commodity, functional magnetism and land value of these land standards finally impact the pace and path of the identification of urban land change. Table 4 and Map 3, shows this change detection (transformation) between 1991 and 2011. The development was noted far from the centre of the city according to Christaller's (1933) concept of urban growth. The identification of changes is apparent in the outer region of the city. Among built-up areas, open land, agricultural land and water bodies, the significant detection in land change were witnessed. Mostly the area of Delhi remain same as shown by grey colour (no change), few areas had changed as discussed above. The area of Delhi also performed an unstructured role in the plan and political uncertainty in turning the city into an unscheduled one. Unplanned consumption of most of the vacant land particularly suited for commercial. Unemployed young people attempt to do their own business without suitable registration of the government organization leading to a selection of places by themselves. More growth in the town would contribute to further land change. Though the state master plan was already ready, there was still a lack of applications. Evaluating the nature of the stability changes, i.e. regions without change and reduction or gain from uncertainty by each class, as shown in table 4 between 1991 and 2011, stability is an appropriate term since no category is actually stable throughout this time span.

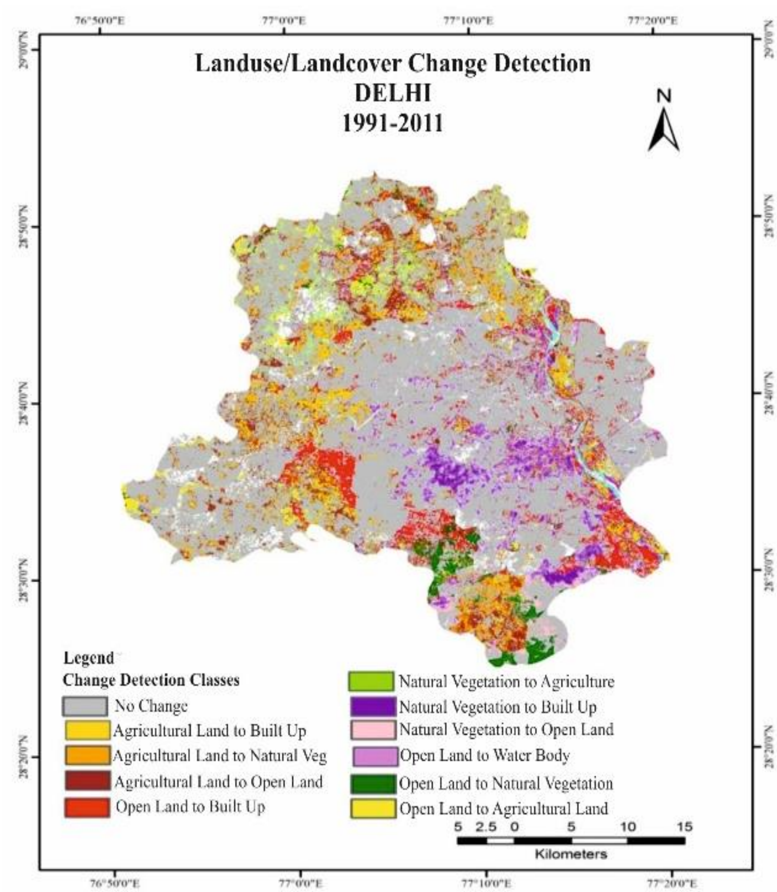


Fig. 3 LULC Change Detection

TABLE 4. Change Detection matrix of Delhi (1991-2011)

Year	**2011**					
1991	*Built-Up*	*Open Land*	*Water Bodies*	*Agricultural Land*	*Natural Vegetation*	*Total*
Built Up	47594.92	0	929.43	0	0	48524.35
Open Land	7534.71	9536.1	205.65	2826.99	3104.1	23207.55
Water Bodies	390.42	87.57	635.04	27.09	113.31	1253.43
Agricultural Land	9042.03	7384.8	364.59	32444.64	4730.31	53966.37
Natural Vegetation	7053.84	2078.7	262.53	1944.45	12247.92	23588.34
Total	71616.91	19087.57	2397.23	37243.17	20195.64	150540.04

5. Conclusion

The accuracy assessment of supervised classification was showing good accuracy, which was 96.31% and 97.35% for the years 1991 and 2011 respectively. The built-up area has risen in all directions but to the west and north of the city, this is more prominent than to the east, where density is high. The study showed that in residential areas, the population in the city grew rapidly, but in unexpected residential zones, they are more pronounced. Several planned regions had also evolved over this period, for example, Dwarka, Rohini, etc. Delhi's residential area was 48,524.35 hectares in 1991 up to 71,616.91 hectares in 2011. The total area increased by 23092.5 hectares. In twenty years (1991-2011) and during the study period, the growth rate is 15.3%. Agricultural areas had rapidly converted into non-agricultural implementations. The total land area of agriculture was 53966.37 hectares, which reduces in 1991 to 37243.17 hectares, in 2011. The share of agriculture land was 35.9% of land in 1991, which decreases to 24.7% of the total land in 2011. The identification of change in main corridors is the distinctive characteristic of urban development, which has grown through various national roads at this time. Ridge and forest remained unchanged during this time, whereas the greenery improved in Delhi.

The research using GIS and remote sensing techniques is an excellent tool for identifying urban land changes. In future planning at the locally and globally levels, the evaluation of the LU/LC transition is very valuable. The latest survey on land cover in Delhi between 1991 and 2011 indicates that the landscape had changed very rapidly since the area developed only increased by 20 years. Built-up areas occupy the sparsely and densely vegetated land, while the fallow land has decreased slightly, and over time, the water body has been virtually stagnant. The area of the urban sprawl expanded from central east to the rest of the region and occupied most of the regions in the north, west, and south. Since it defines the boundary or limit of Delhi, the eastern part is pretty saturated from the start, so if this development pattern continues the majority of the vegetable regions will soon be built up, which could pose a threat to the environment.

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