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Assessment of spatial changes of land use/land cover dynamics, using multi-temporal Landsat data in Dadri Block, Gautam Buddh Nagar, India

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Abstract

The present work aims at presenting certain important observations on food and water security of the peri-urban environment, by considering field data and satellite image classification to understand the spatial change pattern of natural resources and its impact on agriculture and water resources. Gautam Buddh Nagar is considered one of the important urban areas of the National Capital Region (NCR), being associated with multi-functional activity; it continues to grow in terms of infrastructure and other urban activities and the numerous infrastructural projects and other anthropogenic actions in the area cause a rising pressure on water, agriculture, and human health. The Landsat satellite images from 2000, 2005, 2010, and 2016 were classified and used to obtain the Land use / Land cover maps of the area, in order to estimate and to understand the rate of change during the last 16 years. There are mapped the important land use classes, such as the agricultural land, the vegetation surfaces, the built-up areas, the open land, and the water bodies. The results indicate the fact that during the 16 years taken into study, vegetation (2.26%), water bodies (1.65%), and agriculture (3.5%) undergone a major decline, while the built-up land displayed values increased around four times (from 3.39% to 12.26%). The results of the present work clearly showed that the large-scale changes in natural land cover affected the agriculture, as well as the surface and groundwater resources of the area.

Keywords: *Land use, Satellite image classification, Dadri, India*

Rezumat. Evaluarea modificărilor spațiale asociate dinamicii utilizării/acoperirii terenurilor, folosind date Landsat multi-temporale, în unitatea administrativă Dadri, Gautam Buddh Nagar, India

Lucrarea prezintă observații importante referitoare la securitatea alimentară și a apei din mediul periurban, luând în considerare datele din teren și clasificarea imaginilor satelitare pentru a înțelege tiparele modificărilor spațiale ale resurselor naturale și impactul lor asupra agriculturii și resurselor de apă. Gautam Buddh Nagar este una dintre zonele urbane importante ale Regiunii Capitalei Naționale, fiind asociată activității multifuncționale; numărul mare de proiecte de infrastructură în continuă dezvoltare, precum și alte activități antropice în zonă determină o presiune crescândă asupra apei, agriculturii și sănătății umane. Imaginile satelitare Landsat din 2000, 2005, 2010 și 2016 au fost clasificate și utilizate pentru a obține reprezentarea utilizării/acoperirii terenului din zonă, pentru a estima și a înțelege rata modificărilor din ultimii 16 ani. Sunt cartografiate clasele importante de utilizare a terenului, precum terenurile agricole, vegetația, terenurile construite, terenurile deschise și corpurile de apă. Rezultatele indică faptul că în cei 16 ani vegetația (2,26%), corpurile de apă (1,65%) și terenurile agricole (3,5%) au înregistrat un declin major, în timp ce suprafețele construite au câștigat aproximativ de patru ori mai mult teren (de la 3,39% la 12,26%). Rezultatele lucrării arată clar că extinsele modificări ale acoperirii naturale a terenurilor afectează agricultura, precum și resursele hidrografice locale de suprafață și subterane.

Cuvinte-cheie: *Utilizarea terenurilor, clasificarea imaginilor satelitare, Dadri, India*

Introduction

Urbanization is a continuous process and unplanned urbanization leads to many natural, environmental, and social issues. Land use / Land cover changes in the peri-urban areas create many problems such as a change in water quantity and quality, agricultural land loss, and urban environmental issues. The society today is already in the mainstream of another revolution, the information revolution, due to those massive changes to life and living, providing new approaches to resource mapping and monitoring. Land-use change is a combined activity of natural and anthropogenic activity, mainly affecting the natural resources and the environment (Singh et al. 2012). The assessment of land use patterns of any terrain is an important aspect for natural resources evaluation and their management. Climate changes are the significant driver for the modification of the land resources, and they are the main component of spatially and temporally changes in land use patterns. Apart from climate changes, anthropogenic activities such as deforestation, overexploitation of natural resources, rapid urbanization, the impact of pesticides, and other human influences have significant changes in land-use categories. Satellite-based earth observation and monitoring is a very scientific and useful tool for the proper management of the natural resources (Vishwakarma et al., 2016; Verma et al., 2019).

In developing countries like India, efforts are being made for sustainable land resource planning and management, with reliable and updated geoinformation, which is the pre-requisite for land use planning. Such information could only be obtained

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through modern techniques and equipment for research and mapping. Since land use and land cover changes are powerful features over space and time, it is challenging to obtain real-time information through conventional resources, and these methods are time-consuming, laborious, high cost, and workforce oriented. In modern times, satellite-based remote sensing technology has been developed, which are of immense value for preparing LULC map and their monitoring at regular periodic intervals of time (Kumar et al., 2004; Rao et al., 2006; Chaudhary et al., 2008; Singh et al., 2012). Remote sensing offers unique perspectives to study the land use/land cover and their changes, because it provides spatially explicit and synoptic views of the landscape that are available over time. It is, therefore, able to provide detailed information from individual resources to regional and local change. Earth observation technology plays an important role in providing information on landscape mapping and monitoring to help the management of natural resources. Remote sensing provides the basic data to undertake an inventory of land, as well as the temporal information required to monitor sustainable land management.

Remote sensing data, along with an increased resolution from satellite platforms, makes these technologies appear poised to induce a better impact on land resource management. Initiatives involved in monitoring LULC mapping and change detection at varying spatial ranges in semi-arid regions are undergoing severe stresses due to the combined effects of the growing population and climate change. Recent advances in remote sensing and geographic information system (GIS) techniques allow researchers for mapping, analysis of land cover/use, and model the growth rate of urban areas. Images of remotely sensed satellite give excellent data that contain efficient information about land cover/ use. It can be easily extracted, simulated, analyzed by GIS techniques with better accuracy in less time, and low cost (Alberti et al., 2004; Rai et al., 2011; Mishra et al., 2014 & 2016; Kikon et al., 2016; Mishra & Rai, 2016; Chaudhuri et al., 2017 & 2018; Singh & Rai, 2017). Dadri block of Gautam Budh Nagar is one of the important agricultural and fast-growing suburban areas, where numerous urban and industrial projects take place and the development continues. In the present work, recent satellite data covering 16 years were classified, and changes were analyzed in order to understand the spatial changes in the land-use practices, particularly in agriculture and built-up land and their possible short term and long-term impact on food and water security.

Study Area

Dadri is a Nagar Block of Gautam Buddha Nagar, Uttar Pradesh, India and it represents an important sub-urban area of National Capital Region (NCR), Delhi. The Dadri block extends between the 28°25′–28°40′N latitude and 77°30′–77°40′E longitude. It covers an area about 203 km2 (Fig. 1).

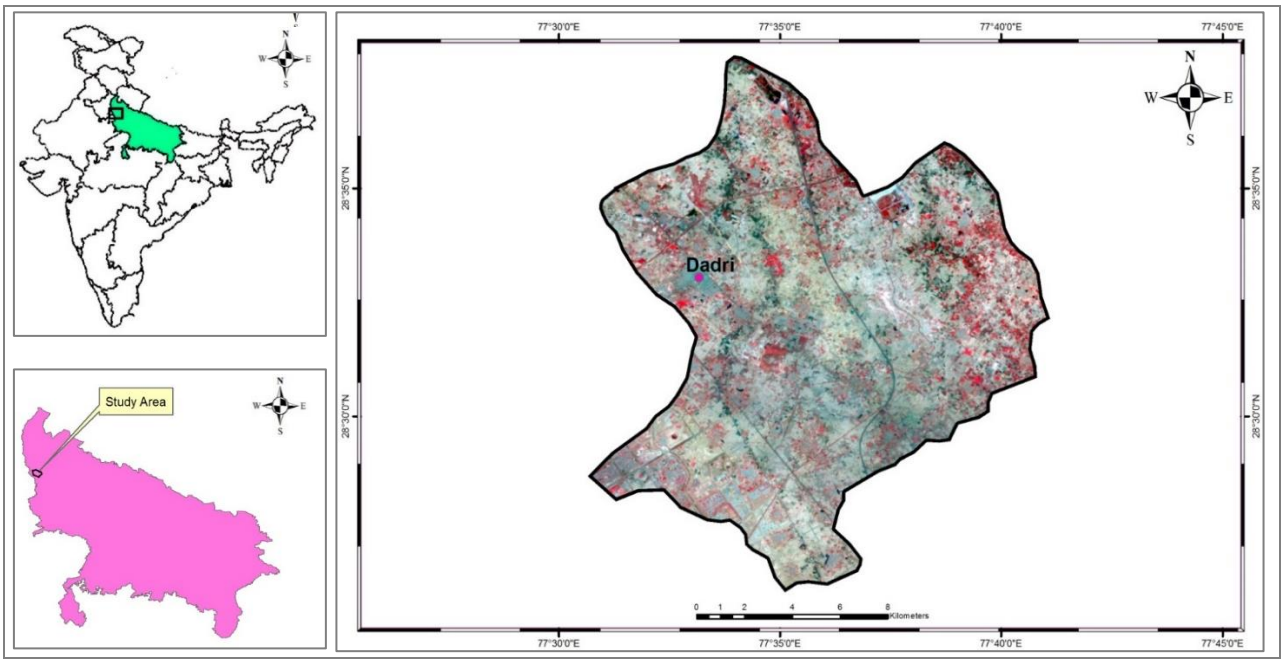

Fig. 1: Location of Dadri Block, Gautam Budh Nagar, India, as viewed on Landsat data (OLI TIRS) of 2016

It is located 25 km towards north from the District headquarter of Noida and 445 km towards East from State capital of Lucknow. Topographically, the area comes under the Indo-Gangetic plain and two important rivers flowing in the area, namely the Hindon and the Yamuna rivers, represent the major sources

of water for irrigation purposes. The elevation of the area is 210 m above mean sea level (MSL). As per the Indian Meteorological Department, Pune (India), the temperature of the area variates from 23°C to 44°C in the summer, while the lowest temperature in the winter season reached up to 4°C. The region comes under the semi-arid climatic zone and the average rainfall in the area is around 790 mm. The area is characterized by the fertile soil of Ganga alluvial plain, with major crops such as rice, wheat, sugarcane, barley, mustard etc. The block has a very high growth rate in terms of population, due to the large number of industrial activities in the area and it continues to increase. At the 2011 Census, the block had a total population of 91,189 persons, out of which 48,856 are males and 42,333 are females. The literacy rate of the Dadri is 74.37%, which is higher than the state average (i.e. 67.68%).

Data and Methodology

During this study, multi-temporal Landsat data sets for the years 2000, 2005, 2010, and 2016 were used for the development of land use / land cover maps and for the assessment of spatial changes in the area (Table 1).

The standard image processing techniques were used to develop the signature file for each land-use class and the classification of the images was conducted by using the ERDAS Imagine and Geomatica software. The analysis of land use/ cover hybrid classification process has been used along with the field verification.

Field visit has been carried for ground truth verification of the classified data, using the GARMIN Oregon 550 GPS receiver. The ground truth data were used as the reference data point collected by using Geographical Positioning System (GPS) for image analysis, these data used for image classification and overall accuracy assessment of the classified data.

The study aims to assess the urban growth and its impact on the natural resources of Dadri town. Land use/land cover is prepared by hybrid classification (visual interpretation and unsupervised classification), and spatial statistics have been calculated using ERDAS Imagine software. After the classification and mapping of all the data sets, the spatial change assessment has been performed. An accuracy assessment has been performed for all the classified maps using the kappa coefficient to assess the mapping accuracy. Five major land use/cover classes are identified in the study area (i.e. vegetation, agricultural land, built-up land, water bodies, and open land/construction sites).

Table 1 Data used in the study

Satellite data	Path & Row	Spatial resolution (m)	Date acquired	Cloud coverage	Source
Landsat 7 (ETM+)	146, 40	30 m (Visible, NIR, SWIR), 15 m (Panchromatic)	08-10-2000	0%	https://earthexplorer.usgs.gov
Landsat 7 (ETM+)	146, 40	30 m (Visible, NIR, SWIR), 15 m (Panchromatic)	22-10-2005		
Landsat 7 (ETM+)	146, 40	30 m (Visible, NIR, SWIR), 15 m (Panchromatic)	20-10-2010		
Landsat 8 (OLI TIRS)	146, 40	30 m (Visible, NIR, SWIR), 15 m (Panchromatic), 100 m (Thermal)	09-10-2016		

Results and Discussion

Temporal Land use / Land cover change monitoring

Assessment, identification, and mapping of land cover/land use and its temporal changes over time represent important steps towards land management. Land cover/land use has been used extensively to derive several variables, such as built up, vegetation, biomass, water bodies, and other landscape features. Land use/ land cover pattern and its changes produce the underlying natural and social processes, thus providing essential information for understanding many different phenomena within the area. Periodic land use mapping and its temporal change assessment represent a necessary requirement for the sustainable land, water, and environmental management of any area (Singh et al. 2012; Somvanshi et al. 2020).

Land use/land cover mapping using temporal Landsat satellite data for the study area has been carried out to understand the major land-use practices in the area and its spatial-temporal change pattern from 2000 to 2016. The land use pattern under study is that of Dadri block, which covers urban and suburban parts of the Gautam Budh Nagar district, being an important city in the National Capital Region (NCR), Delhi.

The demographic size of the study area increased very fast; as revealed by the 2001 to 2011 Census data, the area has witnessed around 186.64% growth in population. Due to the speedy growth in population in the study area, many changes took place in terms of built-up land, industrial growth, and many other land conversion practices, which have a negative impact on natural resources. A standard hybrid image classification technique has been applied for the generation of LULC maps of the different years of the Dadri block for the year 2000, 2005, 2010 and 2016. Based on classi-

fied images, it has been observed that the major classes are agricultural land, vegetation areas, built-up areas, open land, including under-construction sites and water bodies. The final classified images were crossed, checked and verified in the field before the final calculation of the spatial distribution of the land use classes. The observed results from the classified data indicate that the large-scale changes in land-use practices were taken place in the area in the last 16 years.

It is observed that the vegetation cover undergone a change from 8.08 % in 2000, its decreased value reaching up to 6.80 due to the construction activity in the area. Important surfaces occupied by water bodies, in the form of small streams and wetlands, get degraded (from 3.71 % in 2000 to 2.06%) due to large scale changes in the landscape and overutilization of water bodies for agriculture and other development projects in the study area. The next important land use practice in the area and around was agriculture (78.71% in 2000) and it decreased up to 75.19 %, including many other non-agricultural areas.

Dadri is considered a rural area, having a large number of villages and being mainly associated with agricultural activities in the region, due to the fertile soil and to the availability of water resources for irrigation purposes. During the last two decades, it is observed that many changes took place in the Dadri block, such as those concerning the built-up region, with many industries occupying the area, as well as numerous big projects that are approved for development in the near future. The built-up area has extended at a very fast rate as compared to other land uses; the total built-up surface was 3.39 % in 2000 and increased up to 12.26 % in 2016. It is also observed that the open land, including wasteland and extended wetlands in the area, also undergone a decrease from 6.12% to 3.69%.

The overall changes marked the natural landscape and they severely affected groundwater quality/quantity, the urban temperature, also giving raise to pollution problems in the area. The total spatial changes and land use maps are presented (Table 2 & Fig. 2).

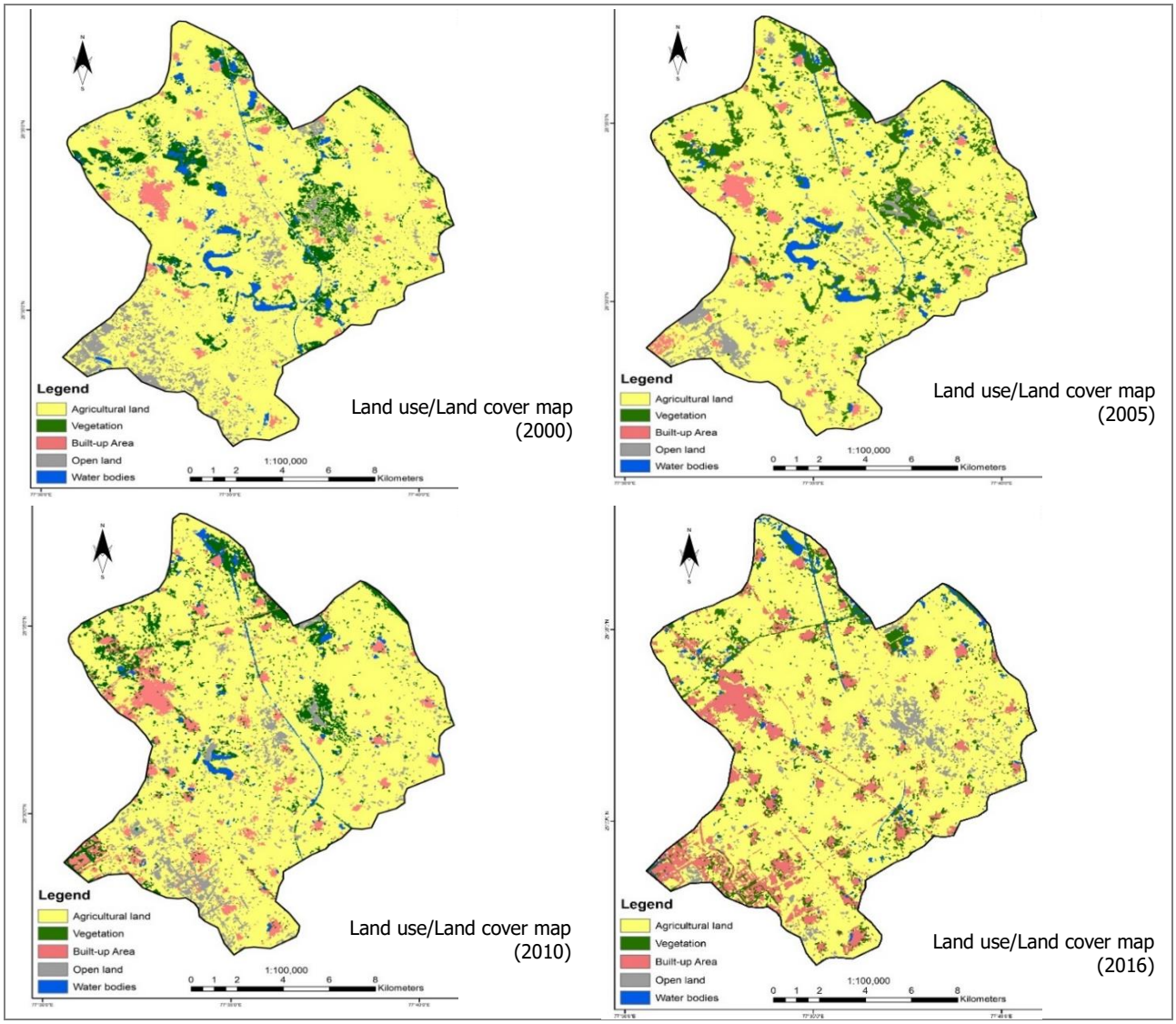

Fig. 2: Land use/Land cover changes within Dadri Block in 2000, 2005, 2010, and 2016

Table 2 Spatial changes in different Land use/Land cover classes in the area between 2000 and 2016

LULC Classes	2000 area		2005 area		2010 area		2016 area	
	sq.km	%	sq.km	%	sq.km	%	sq.km	%
Vegetation	16.41	8.08	22.03	10.81	16.82	8.25	13.85	6.80
Water bodies	7.53	3.71	6.08	2.98	3.90	1.92	4.20	2.06
Agricultural land	159.99	78.71	159.71	78.38	156.20	76.62	153.29	75.19
Built-up area	6.88	3.39	8.02	3.94	14.41	7.07	24.99	12.26
Open land	12.45	6.12	7.91	3.88	12.54	6.15	7.52	3.69
	203.27	100.00	203.76	100.00	203.86	100.00	203.86	100.00

The Accuracy Assessment

The accuracy assessment of classified land use/land cover maps is one of the important steps in the classification process for validation and verification, before the finalization of the maps. The purpose of accuracy assessment is to quantitatively check the land use classes with the reference sampled land-use classes. Assessment of accuracy includes the comparison of the different class of classified data to the reference data of the same location (Lachowski, 1996). The overall accuracy of the classified maps of 2000, 2005, 2010, and 2016 was obtained as 99 %, 98%, 91.25 % and 93.33 % (Tables 3 & 4). The kappa coefficient of the years 2000, 2005, 2010, and 2016 classified LULC were recorded as 0.97, 0.96, 0.89, and 0.83, respectively (Table 4). All values of Kappa coefficient are above the 0.80, which indicates that the hybrid classification method has extracted very well the time-series for the analysis of land use/cover of the study area (Alexakis et al., 2012).

Table 3 Producer and user accuracy of classified images

Class Name	2000 accuracy (%)		2005 accuracy (%)		2010 accuracy (%)		2016 accuracy (%)	
	Producers	Users	Producers	Users	Producers	Users	Producers	Users
Water bodies	100	100	75	100	100	100	---	---
Vegetation	85.71	100	87.50	100	75.00	100	100	100
Agricultural land	100	98.68	100	97.47	98.25	90.32	100	91.67
Built-up area	100	100	100	100	72.73	88.89	66.67	100
Open land	100	100	100	100	66.67	100	66.67	100

Table 4 Overall accuracy assessment results of classified images

Year	Classification accuracy (%)	Kappa statistics
2000	99	0.9759
2005	98	0.9672
2010	91.25	0.8946
2016	93.33	0.8315

Conclusions

The long-term land use/land cover mapping through remote sensing data provides essential information about the area, on the temporal aspect.

There are mapped the important land use classes, such as the agricultural land, the vegetation surfaces, the built-up areas, the open land, and the water bodies. The results indicate the fact that during the 16 years taken into study, vegetation (2.26%), water bodies (1.65%), and agriculture (3.5%) undergone a major decline, while the built-up land displayed values increased around four times (from 3.39% to 12.26%). The results of the present work clearly showed that the large-scale changes in natural land cover affected the agriculture, as well as the surface and ground-water resources of the area.

Based on the above summary, it can be concluded that the rapid increase and expansion of the urban area, especially of the built-up land, can be a major factor for loss of agriculture, surface and groundwater resources, increase surface runoff, reducing natural groundwater recharge and many other environmental issues such increasing the LST. Based on the observations from the present work, it is clearly indicated that the use of satellite data for land use mapping and change assessment is an important aspect of sustainable land, water, and environmental management. It is also suggested that appropriate measures are required in the area for the conservation of local natural resources, because more constructions will be made soon in order to accommodate the increasing population. The observations of the present work prove that satellite-based image classification and mapping of land use lead to important data for urban planning and management. The quantification of LULC changes of Dadri town and its impact is very useful for environmental management and resource planning.

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