FORUM GEOGRAFIC

Forum geografic. Studii și cercetări de geografie și protecția mediului
Volume **XVIII**, Issue 1 (**June** 2018), pp. **90-98**
http://dx.doi.org/**10.5775/fg.2018.144.i**

Mapping spatial urban growth and land use change using geoinformatics technique in Varanasi District, Uttar Pradesh, India

Sunita SINGH[1*]

[1] Department of Geography, Banaras Hindu University, Varanasi, India
* *Corresponding author*: sunbhu11@gmail.com

Received on 07-04-2018, reviewed on 15-05-2018, accepted on 25-05-2018

Abstract

Urban growth is a worldwide phenomenon, but the rate of urbanization is very fast in developing countries like India. It is mainly driven by unorganized expansion, increased immigration, rapidly increasing population. In this context, land use and land cover change are considered central components in current strategies for managing natural resources and monitoring environmental changes. Uncontrolled momentum of urban sprawl and land use change raises many issues which might have both positive and negative effects. This sprawl can be effectively monitored using remotely sensed data from different dates by digital analysis of the imagery using change detection techniques.
The present study aims to examine the change in urban sprawl, land use/land cover (LU/LC) over a time point and assesses the pattern of sprawl through GIS technique. The geographical area of Varanasi district is 1535 sq.km including 1,371.22 km² rural area and 163.78 km² urban area, its population is 3,676,841 persons in 2011. It consists of eight blocks namely Baragaon, Pindra, Cholapur, Chiraigaon, Harahua, Sevapuri, Arajiline and Kashi Vidyapeeth. The spatio-temporal study of LU/LC as well as settlement is carried out for two time points 1990 and 2016. The data source used for analysis is Landsat MSS and Landsat OLI. The analysis mainly focused the urban growth along with landuse/landcover changes using digital image processing techniques like Maximum Likelihood Classifier algorithm for Supervised Classification and NDVI vegetation index. The trend of sprawl is notably higher in the urban centers than in the revenue villages.

Keywords: *urban growth, land use, NDVI, remote sensing.*

Rezumat. Cartarea expansiunii spaţiale urbane şi a schimbărilor în utilizarea terenurilor folosind tehnica geoinformatică în Districtul Varanasi, Uttar Pradesh, India

Expansiunea urbană este un fenomen mondial, iar rata de urbanizare este foarte rapidă în ţările în curs de dezvoltare, cum este cazul Indiei. Aceasta se datorează în principal expansiunii neorganizate, imigrației sporite, populației în creştere rapidă. În acest context, utilizarea terenurilor și acoperirea terenului sunt considerate componentele centrale ale strategiilor actuale de gestionare a resurselor naturale și de monitorizare a schimbărilor de mediu. Avântul necontrolat al dezvoltării urbane și al schimbărilor în utilizarea terenurilor ridică numeroase probleme care ar putea avea efecte pozitive, dar și negative. Această extindere urbană necontrolată poate fi monitorizată eficient utilizând date aparţinând teledetecţiei, de la momente diferite, prin analiza digitală a imaginilor, utilizând tehnici avansate de detectare a modificărilor.
Prezentul studiu își propune să examineze modificările referitoare la expansiune urbană, la utilizarea terenurilor/acoperirea terenului (LU/LC) pe o perioadă de timp și să evalueze modelul de extindere prin tehnici SIG. Aria geografică a districtului Varanasi este de 1535 kmp, incluzând o arie rurală de 1371,22 kmp și o arie urbană de 163,78 kmp, iar populația era de 3676841 persoane în 2011. Se compune din opt unităţi administrative: Baragaon, Pindra, Cholapur, Chiraigaon, Harahua, Arajiline și Kashi Vidyapeeth. Studiul dinamicii spațio-temporale a utilizării/acoperirii terenurilor s-a efectuat pentru două repere temporale: 1990 și 2016. Sursele de date utilizate pentru analiză sunt Landsat MSS și Landsat OLI. Analiza s-a concentrat în principal asupra creșterii urbane, împreună cu schimbările în utilizarea/acoperirea terenurilor utilizând tehnici de procesare a imaginilor digitale, cum ar fi algoritmul de clasificare a riscurilor maxime pentru clasificarea supravegheată și indicele de vegetație NDVI. Tendința de extindere necontrolată este semnificativ mai mare în centrele urbane decât în unităţile administrative rurale.

Cuvinte-cheie: *expansiune urbană, utilizarea terenurilor, NDVI, teledetecţie*

Introduction

Land-use is inclined by economic, cultural, political, historical and land-tenure factors at multiple scales. Land-use referred to as man's activities and various uses which are undertaken upon land. Urbanization is inevitable, when pressure on land is high, agriculture incomes are low and increasing demographic pressures become excessive as is the case in most developing countries of the world.

In India, a vast majority of the population lives in urban areas or regularly commutes in and out of urban areas. Urban sprawl poise to handicap effective allocation of limited resources and infrastructure facilitation becomes challenging to the authorities. Sprawl seems to threaten every chance of sustainable development of a country as it encroaches in to other important land-uses such as agriculture, wetland, forest, open spaces and recreational parks. In order to prevent this type of growth, monitoring urban development through measures such as legislation, zonation, preparing master plan etc. has become imperative. Across developing countries there is not growing awareness and concern about urban growth, which has different background in the cities of China, Europe and North America. Land development has been out of control and the construction land has kept expanding blindly, especially in the marginal areas of some metropolises. Nowadays urban areas experience fast growth due to enormous population growth, rapid industrialization, economic development and specific economic policies adopted by governments and immigration of people from villages to cities. Accelerated urban growth is usually associated with and driven by the population concentration in an area. The extent of urbanization or its growth drives the change in land use/cover pattern. The rapid changes of land use and cover are often characterized by uncontrolled urban sprawling, land degradation or the transformation of agricultural land to farming resulting enormous cost to the environment (Sankhala&Singh, 2014). Uncontrolled urbanization has been responsible for many of the problems our cities experience today, resulting in substandard living environment, acute problems of drinking water, noise and airpollution, disposal of waste, traffic congestion etc.

Remote sensing imageries and techniques showed considerable potentials for urban growth and land-use analysis. Land-use and land-cover classes (LU/LC) are important indicators for understanding the connections between surroundings and human activities which can be efficiently obtained from satellite imageries through image classification. The availability of remotely sensed data from multiple dates enables to carry out studies on multitemporal urban modeling. The extent of urban areas can be automatically identified from satellite imagery using machine learning algorithms. Change detection analysis can be carried out to measure the changes between two LU/LC maps from different periods of time.

Recently, remote sensing has been used in combination with GIS and Global Positioning Systems (GPS) to assess land-cover change more effectively than by remote sensing data only (Dewan et al., 2012; Boori et al., 2015a). It has already proved useful in mapping urban areas and as data source for the analysis and modeling of urban growth and land use/land cover change (e.g., Rodriguez-Galiano&Chica-Olmo, 2012; Grey et al., 2003; Herold et al., 2003; Wilson et al., 2003).

Remote sensing data is very useful because of its synoptic view, repetitive coverage and real time data acquisition. The satellite data in digital form therefore, enable to accurately compute various land cover/land use categories and help in maintaining the spatial data infrastructure which is essential for monitoring urban expansion and land-use studies (Mukherjee, 1987). The purpose of using GIS is that maps provide an added dimension to data analysis, which brings us one step closer to visualizing the complex patterns and relationships that characterize real-world planning and policy problems. Visualization of spatial patterns also supports change analysis, which is important in monitoring social indicators. This in turn should result in improving need assessment. The objectives of this paper is to explain remote sensing and GIS applications in various stages of planning, implementation and monitoring of the urban area.

Overview of Change Detection Techniques in Urban Areas

A variety of change detection techniques are available for monitoring land use/land cover changes. These techniques can be grouped into two main categories: post-classification comparison techniques and enhancement change detection techniques (Nelson, 1998).

The post-classification technique involves the independent production and subsequent comparison of spectral classifications for the same area at two different time periods (Mas, 1999). Post classification techniques have the advantage of providing direct information on the nature of land-cover changes. The classification process used with these techniques can be either supervised or unsupervised. Sohl (1999) reported accuracies of 96 per cent for the identification of new forest land and 62 per cent for new agricultural land using a post-classification technique in a semi-arid environment. Furthermore, Sohl (1999) noted the accuracy of the method for providing users with a complete descriptive comparison between images. Pilon et al. (1988) employed post-classification in combination with a simple enhancement technique to differentiate areas of human induced change from areas of natural change. Mas (1999) also obtained the highest accuracy with this technique in a study comparing six different techniques.

Enhancement Change Detection Techniques involve the mathematical combination of images from different dates which, when displayed as a composite image, show changes in distinctive colors (Pilon et al., 1988). The enhancement change detection techniques have the advantage of generally being more accurate in identifying areas of spectral change (Singh, 1989).

Image Differencing Technique

Image differencing is a technique by which registered images acquired at different times have

DN values for one band subtracted from the corresponding DN values from the same band in the second image to produce a residue image, which represents the change between the two dates (mass1990). Ridd&Liu (1998) reported image differencing was fairly effective in its ability to detect change in an urban environment, with TM band 3 producing the highest accuracies. Sunar (1998) and Sohl (1999) reported that the image differencing technique was extremely straightforward, but with the qualification that image differencing technique becomes slightly more complicated when using multiple bands, instead of single bands, due to the difficulty of interpreting the colors of multiband false color composites.

Normalized Difference Vegetation Index

The Normalized Difference Vegetation Index (NDVI) estimates the vitality of vegetation by exploiting the known gap in vegetation reflectance between the visible and near infrared channels. Common change detection methods include the comparison of land-cover classifications, multi-date classification, band arithmetic, simple rationing, vegetation index differencing and change vector analysis (Jomaa, 2003). The NDVI is calculated as a normalized ratio (ranging from -1 to1 from the NIR and the red band and emphases apparent vegetation (Sabins, 1996).

Study area

Varanasi district comes between 25°10′ to 25°37′ N latitude and 82°39′ to 83°10′ E, lies in eastern Uttar Pradesh, India (Fig. 1). Physiographically, it lies in the Middle Ganga Plain. The district is bounded by river Gomati and Jaunpur district in the north, Mirzapur in south, Sant Ravidas Nagar Bhadohi in the west and Chandauli district in the east. This district is divided in to eight blocks, namely: Araziline, Baragaon, Chiraigaon, Cholapur, Haruha, Kashi Vidya Peeth, Pindra and Sewapuri. Morphologically, the study area is covered by the alluvial deposits of Quaternary age. Ganga is the main river of the District. Geologically the district is made of Gangetic alluvium formed by the deposition of the sediments brought by the Ganga river and its tributaries. The tributaries are Gomti, Varuna, Asi, Banganga, Chandra Prabha and Karmanasa, that drain the area. It consists mainly of sand, silt and clay mixed by kankar at a few places. The area comes under subtropical monsoonal climate characterized by seasonal extremities. January is the coldest month with mean maximum temperature of 23°C. Sometimes, the minimum temperature may go around 5°C during December and January, coupled with occurrence of dense fog. June is the hottest month with mean maximum temperature around 35°C. However temperatures' soaring above 40°C is not uncommon, with occasional rise above 45°C under the impact of heat wave and hot air blowing in May and June, locally named *loo*. The average annual rainfall of the district is around 110 cms bulk of which is received from the south west monsoons during June to September, August the rainiest month.

Data used and methodology

Survey of India toposheet (1:50,000) and satellite data Landsat (TM) of 1990 and Landsat 8 (OLI&TIRS having 30 m resolution) of 2016 has been used. The Survey of India toposheet and satellite images have been geometrically corrected and rectified using ERDAS Imagine 14.

The study area map was prepared from SOI topographical sheets on 1:50,000 scale. The settlement in the study area, during 1990 and 2016 were derived from the Satellite images and werecompared with one another to carry out change detection studies for the period 1990 and 2016.The same classes were then visually interpreted from the 1990 satellite data by using the common image interpretation elements. Necessary field checks were carried out and corrections were made at required places. Then, the software such as Arc GIS 10.3 and Erdas imagine14 were used to prepare the urban settlement cover changes during 1990-2016.

Change Detection Methods adopted

The change detection techniques will be discussed, using the two main categories, post classification comparison techniques and enhancement change detection techniques described in the literature section.

Forum geografic. Studii și cercetări de geografie și protecția mediului
Volume **XVII**, Issue **1** (**June 2018**), pp. **90-98**
http://dx.doi.org/**10.5775/fg.2018.144.i**

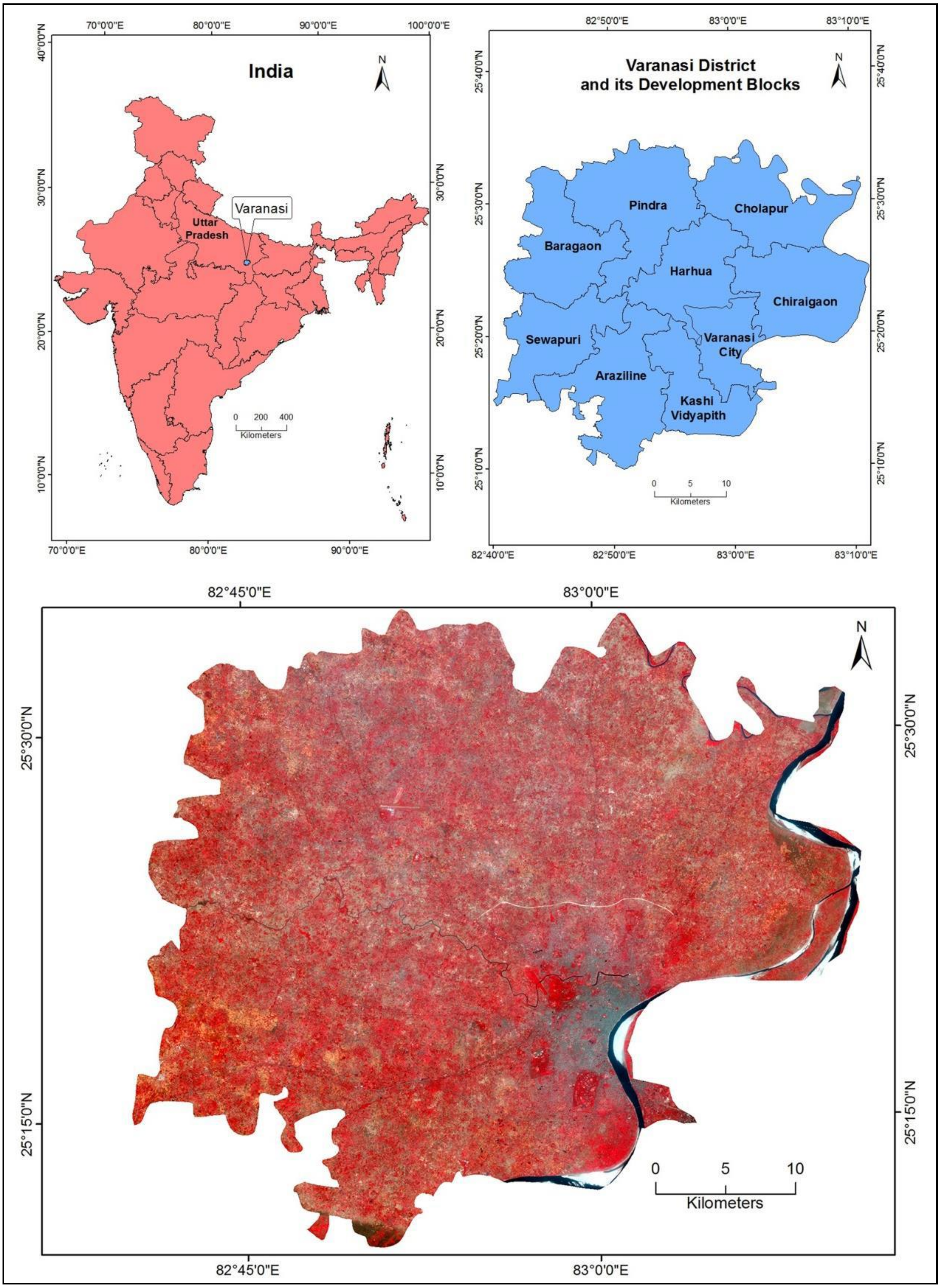

Figure 1: Location of the study area

Table 1: Details of Landsat images used in the study

Satellite sensor	Path/Row	Date of aquisition	Cloud coverage
Landsat-5 TM	142/42 142/43	February,18th, 1990	no
Landsat 8-OLI TIRS	142/42 142/43	February, 3rd, 2016	no

Geometric and Radiometric Correction

The images were co-registered to each other using ground control points (GCPs). Hundred GCPs were collected and the number of GCPs was reduced to ten in order to achieve an acceptable RMS error. The RMS error was 0.44. The X RMS error was 0.36 and the Y RMS error was 0.25. The images were resampled with cubic convolution (3). Both of the images' pixel spacing was set to 30 m. The images were then atmospherically corrected using calibration files in the software (ENVI-5.3).

Radiometric correction was performed on the images using pseudo-invariant features (PIFs). Google map was used as reference to verify the nature of the features.

Image analysis

Image Classification Techniques

In this study, Anderson classification system (Level 1) was adopted for the selection of LU/LC classes. This approach is most appropriate to prepare land use/cover maps from remote sensing data, specifically Landsat data (Alrababah&Alhamad 2006, Rozenstein&Karnieli 2011, Zhu&Woodcock 2014). A total of 100 training areas were selected on the image, checked with field survey and seven LU/LC classes were made. These signatures were used for supervised classification incorporating maximum likelihood classification (MLC) algorithm that was run with a feature-space non-parametric decision rule. Afterwards, all classes are merged into suitable seven classes using recode function.

Post-Classification processing

Supervised classification provides unsatisfactory classification results because of Spectral confusion. Spectral similarity of various objects causes such confusion. For example, barren land and agricultural fallow land; settlement and open forest each are often erroneously classified into other class. To avoid such problems, post-classification processing of the classified maps was employed in the study. The post classification processing included in this study is recoding of classified erroneous classes to appropriate classes based on digitized polygons of LU/LC classes obtained from Google earth image and satellite images. For this operation, hundreds of polygon that cover the patch of built-up area, agricultural land, barren land, river channels, open and dense forests were digitized on Google earth image. Most of the built-up area, barren lands and river channels were digitized; while some selected part of agricultural land and forested area were digitized. For the fine tuning, small patches of built-up, barren and agricultural land in the most confusing part were also digitized. The digitized polygons were converted into AOI and within AOI LU/LC image were changed by recoding. Finally, to remove 'salt&paper' noise that quite appears in digital image processing, a majority filter (3X3 filter) was employed for three classified images.

Results and discussion

Change detection

The analysis reveals the following information and changes also shown in clearly in Table no. 2. This will help the planners and other researchers for further research at both micro level and macro level. The changes are mostly cause of human inference which affects the natural ecosystem one or other way. The normal temperature raised significantly compares with last 3 decades this result of urbanization and settlement expansion.

It is apparent that urban expansion is maximum than all the other land classifications. In short, the results have shown that there is a significant increase in urban expansion leading to a significant drop in fallow land, marshy land and barren land during the study period. It is thought that the main explanation for the rapid increase in urban area is population growth, migration from rural areas to Varanasi city and more general economic development. The marsh area has decreased from 0.69 per cent in year 1990 to 0.07 per cent in the year 2016. It is noticed that a heavy flood in Varanasi in 1978 which increased marsh land during early time periods. During the study, it is shown that the area under the vegetation or orchards has increased from 1990 (6.13 per cent) to 2016 (9.65 per cent). It shows gradual increase from 1990 to 2016, due to people's increased awareness and to the governmental plan.

Forum geografic. Studii și cercetări de geografie și protecția mediului
Volume **XVII**, Issue **1** (**June 2018**), pp. **90-98**
http://dx.doi.org/**10.5775/fg.2018.144.i**

Table 2: Area Distribution of Land Use Land Cover (%) and change in area (%)

LU/LC Classes	Area (%) 1990	Area (%) 2016	Change in area (%) 1990-2016
Water body	2.75	1.99	-0.76
Fallow Land	40.12	10.07	-30.05
Crop Land	41.91	53.07	+11.16
Sand Bar	0.95	1.28	+0.33
Barren Land	0.96	0.03	-0.93
Built Up Area	**6.94**	**23.82**	**+16.88**
Vegetation	6.13	9.65	+3.52
Marsh Land	0.69	0.07	-0.62
Total Area	100	100	--

Note: Positive (+) values indicate gain in the area whereas negative (-) values indicate loss in area

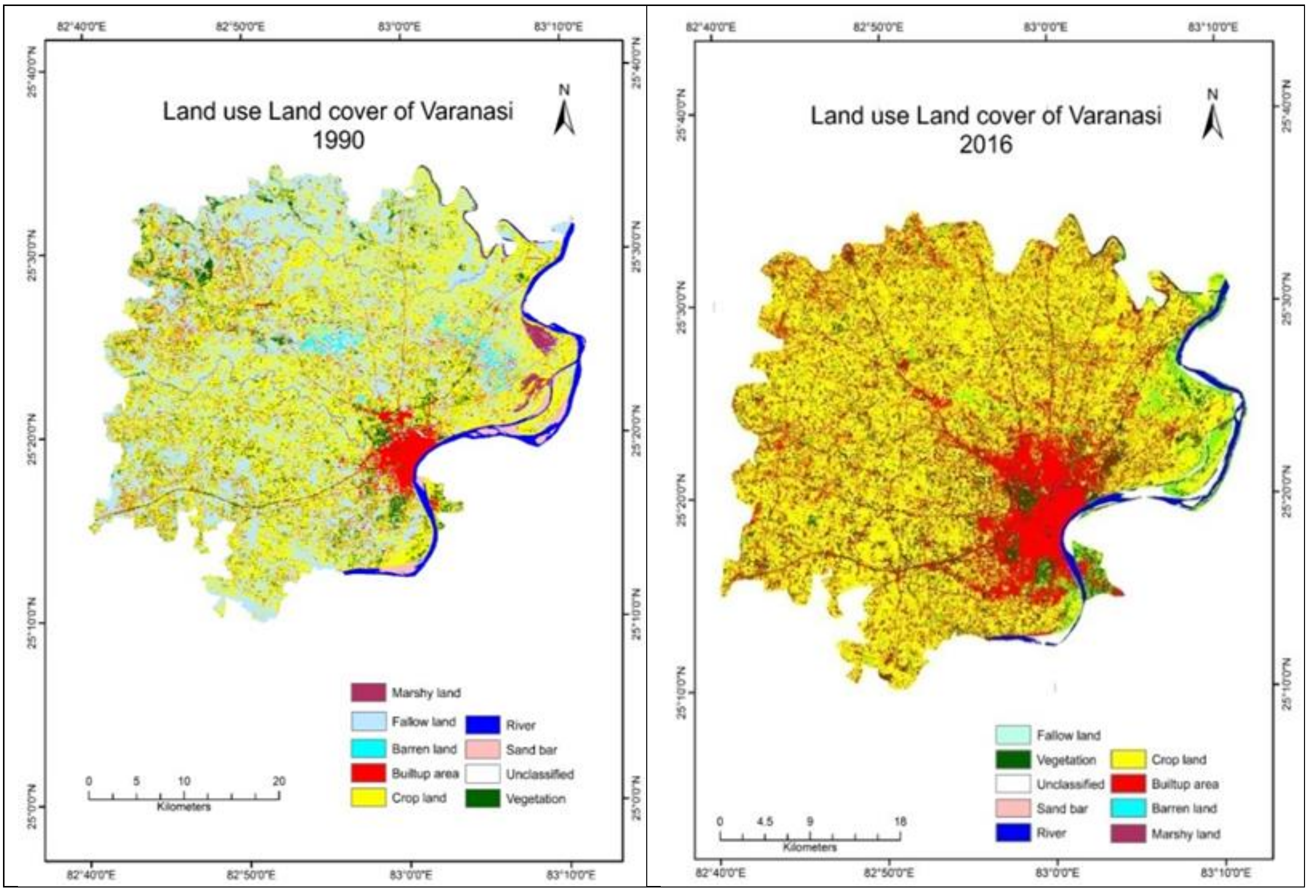

Figure 2: LULC Map of 1990 &2016

Normalized difference vegetation index (NDVI)

NDVI is calculated from the visible and near-infrared light reflected by vegetation. NDVI has proved to have an extremely wide (and growing) range of applications. It is used to monitor vegetation conditions and therefore provide early warning on droughts and famines. Calculations of NDVI for a given pixel always result in a number that ranges from minus one (-1) to plus one (+1); 0 means no vegetation, (0.8-0.9) indicates the highest possible density of green leaves. 0 to -1 indicated higher red reflectance than NIR. Water typically has an NDVI value lower than 0, bare soils between 0 and 0.1 and vegetation over 0.1.

The NDVI analysis reveals that: (1) decrease in NDVI between two scenes will be the result of new development and (2) increase in NDVI between two scenes will be the result of forest re-growth; (3) urban changes in red signal may be unrelated to vegetation (Source: NSAS Earth Observatory).

The NDVI of multi-temporal data result (Fig. 3) shows that there is increase in built-up area. The urban extent of Varanasi city has increased tremendously: the built-up area has changed from 6.94% in 1990 to 23.82% in 2016.

Accuracy assessment

The ground truth data collected with GPS were used as the reference for assessing the accuracy of classification. The accuracy and KAPPA statistic of the classified image checked with the help of accuracy assessment. The overall accuracy of the image is given in the Table no. 3.

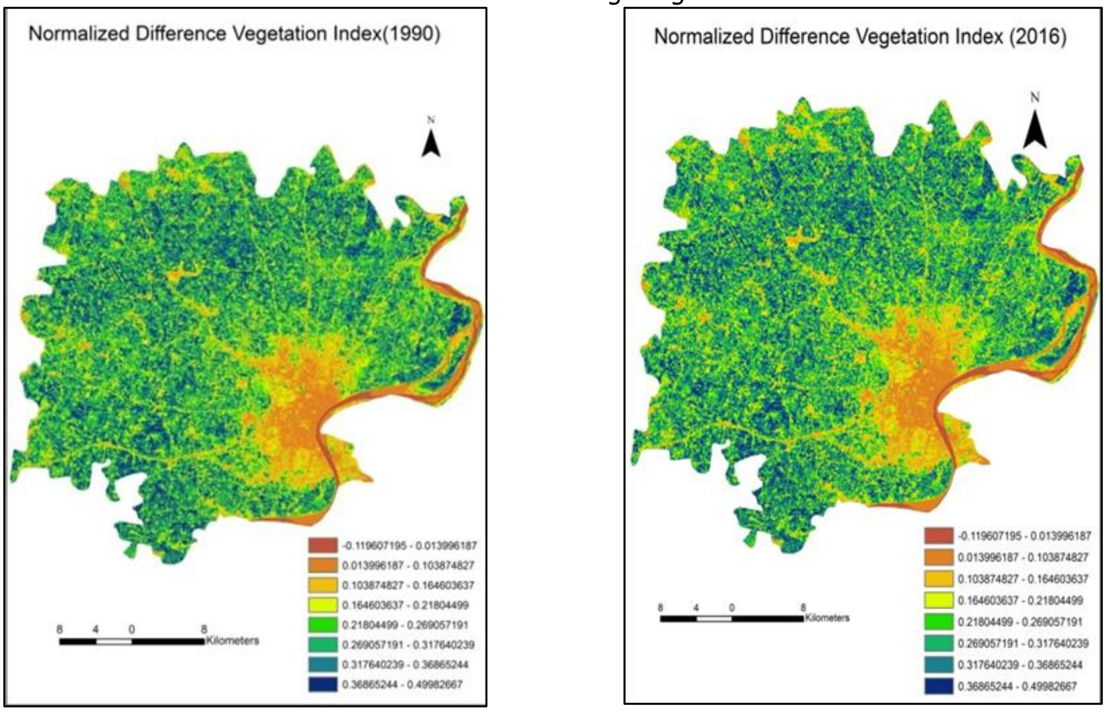

Figure 3: NDVI Map of 1990 &2016

Table 3: Overall accuracy of classified images

Year	Overall accuracy
1990	84%
2016	90%

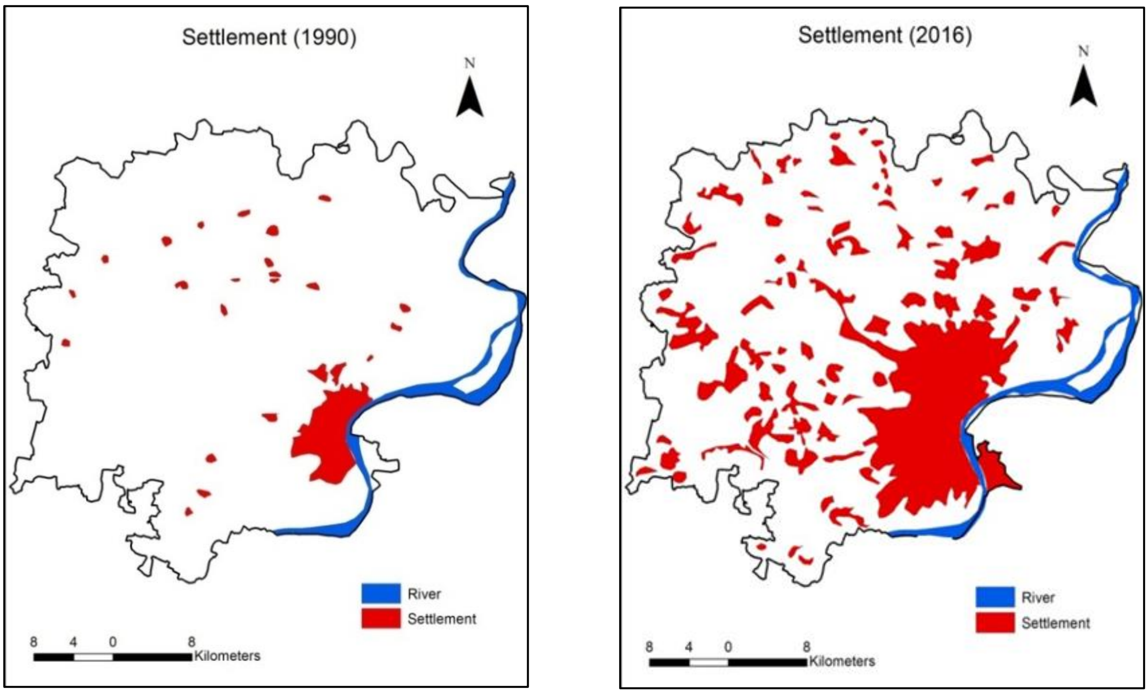

Figure 4: Settlement Map of 1990 &2016

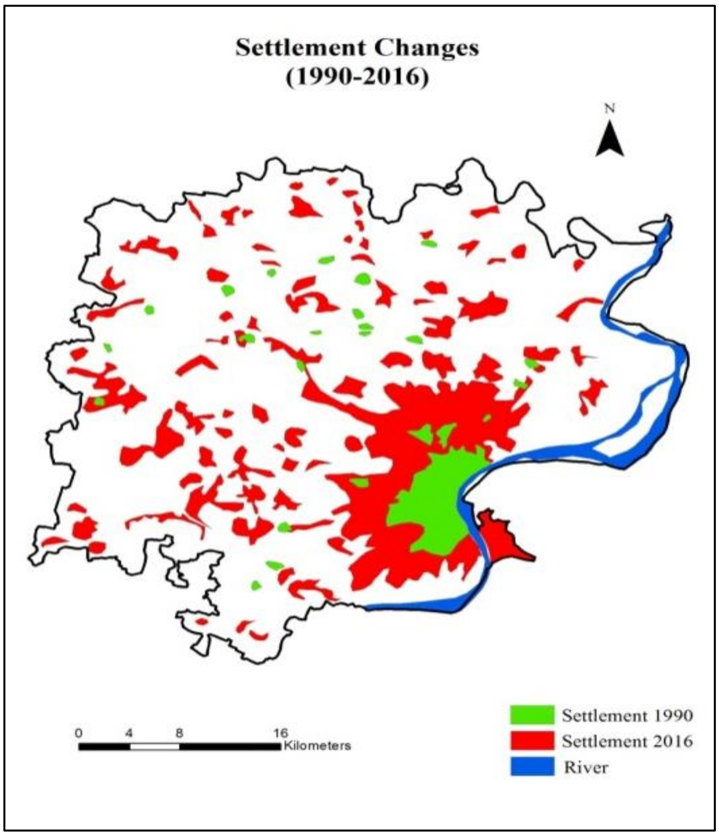

Figure 5: Settlement changes from 1990 to 2016

Conclusion

Urban dynamics research provides vital clues for evolving appropriate land use policy for sustainable management of natural resources. The results clearly reveal the significance of the use of multi-temporal Landsat data which offers an accurate and economical way of mapping and conducting analysis on the changes in LU/LC during the study period 1990-2016. Geographical information system (GIS) have been used in this study to provide spatial inputs and preparing maps for comparing changes.

The study has identified several patterns and trends of the changes in LU/LC in the area. It is apparent that the built-up areas resulting from urban expansion hold primary position as compared to all the other land classifications. In short, the results have shown that there is a significant increase in urban expansion leading to a significant drop in agricultural land-use and vegetation during the study period. Urban sprawl is taking place continuously at a faster rate in outskirts and buffer regions. It is thought that the main explanation for the rapid increase in urban area is population growth, migration from rural areas to the Varanasi city and more general economic development. Identification and analysis of the sprawl patterns would help in effective land use planning and environmental management in urban area.

Acknowledgements

The author is thankful to the Department of Geography, Banaras Hindu University, India, to carry out this research work.

References

Alrababah, M. A., Alhamad, M. N. (2006). Land use/cover classification of arid and semi-arid Mediterranean landscapes using Landsat ETM. International Journal of Remote Sensing, 27, 2703.

Boori, M.S., Vozenilek V., Choudhary, K. (2015a) Exposer intensity, vulnerability index and landscape change assessment in Olomuc, Czech Republic, Int Arch Photogramm Remote SensSpatial Inf Sci XL-7/W3:771–776. doi:10.5194/isprsarchives-XL-7-W3-771-2015

Dewan, A.M., Yamaguchi, Y., Rahman, M.Z. (2012) Dynamics of land use/cover changes and the analysis of landscape fragmentation in Dhaka Metropolitan, Bangladesh, Geo J 77(3):315–330.

Fung, T., Le Drew E. (1987). Application of Principle Component Analysis to Change Detection.

Photogrammetric Engineering Remote Sensing: 53: 1649-1658.
Herold, M., Goldstein, N., Clarke, K.C. (2003). The spatio-temporal form of urban growth: measurement, analysis and modeling. Remote Sensing of Environment, 86(3), 286–302.
Jomaa, I. , Kheir Bou, R. (2003). "Multitemporal unsupervised classification and NDVI to monitor Land cover change in Lebanon (1987-1997)" National Council for Scientific Research/National Center for Remote Sensing, Beirut, Lebanon.
Kumar Jat, M., Garg, P.K., Khare, D. (2008). Monitoring and modeling of urban sprawl using remote sensing and GIS techniques, International Journal of Applied Earth Observation and Geoinformation, 10, 26-43.
Li, X., Yeh, A. (1998). Principle Component Analysis of Stacked Multi-Temporal Images for the Monitoring of Rapid Urban Expansion in the Pearl River Delta, International Journal of Remote Sensing, 19 (8), 1501-1518.
Mas, J. F. (1999). Monitoring land-cover change: a comparison of change detection techniques., International Journal of Remote Sensing, 20, 139–152.
Mishra, V.N., Rai, P.K., Kumar, P. Prashad, R., (2016). Evaluation of Land Use/Land Covers Classification Accuracy Using Multi-Temporal Remote Sensing Images, Forum Geografic. Studii de geografie şi protecţia mediului (Romania), 15 (1), 45-53.
Mukherjee, S. (1987). Land use maps for conservation of ecosystems, Geog. Rev. India, 3, 23–28.
Nielson , A., Conradsen, K., , Simpson, J. (1998), Multivariate alteration detection (MAD) and MAF post processing in multi-spectral bi-temporal image data: new approaches to change detection studies, Remote Sensing of Environment, 64, 1–19.
Rai, P.K., Singh, S., Mohan, K. (2015). Land Use Change Detection Using Multi-Temporal Satellite Data: A Case Study of Haridwar District, Uttrakhand, Journal of Scientific Research,Institute of Science, Banaras Hindu University, 59 (1&2), 1-16.
Rozenstein, O., Karnieli, A. (2011). Comparison of methods for land-use classification incorporating remote sensing and GIS inputs, Applied Geography, 31, 533–544.
Rodriguez-Galiano V., Chica-Olmo, M. (2012). Land cover change analysis of a Mediterranean area in Spain using different sources of data: multi-seasonal Landsat images, land surface temperature, digital terrain models and texture. Applied Geography, 35(1), 208–218.
Sankhala, S., Singh, B. (2014). Evaluation of urban sprawl and land use land cover change using remote sensing and GIS techniques: a case study of Jaipur City, India, International Journal of Emerging Technology and Advanced Engineering. 4 (1), 66–72.
Singh, A. (1989). Digital Change Detection Techniques Using Remotely Sensed Data, International Journal of Remote Sensing, 10, (6), 989-1003.
Sohl, T.L. (1999). Change Analysis in the United Arab Emirates: An Investigation of Techniques. Photogrammetric Engineering and Remote Sensing, 65(4), 475 – 484.
Sunar, F. (1998). An Analysis of Change in a Multi-date Data Set: A Case study in The Ikitelli Area, Istanbul, Turkey, International Journal of Remote Sensing, 19, 225-235.