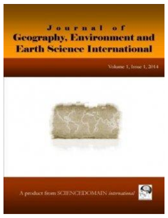

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Monitoring Urban Growth and Land Use Change with Geospatial Techniques in Varanasi District, Uttar Pradesh, India

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Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

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ABSTRACT

The cities are growing in all directions resulting in urban sprawl, and it is governed by geographic and socio-economic factors such as population growth, policy and economic development. The uncontrolled momentum of urban sprawl and land use change raises many issues which might have both positive and negative impacts. This sprawl can be adequately 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 demography, land use /land cover (LU/LC) over a time point and assesses the pattern of sprawl through GIS technique of Varanasi city. The geographical area is 1535 sq.km including 1,371.22 km² rural area and 163.78 km² urban area. Varanasi has a population of 36, 76,841 persons in 2011. There are 5, 60,162 houses in the district. It consists of 8 blocks. The spatio-temporal study of LU/LC is carried out for two-time points 1990and 2016. The data source used for analysis is Landsat MSS and Landsat OLI. The analysis mainly focused the urban growth along with land use/ 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 high in the urban centers than in the revenue villages.

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Keywords: Urban growth; land use; NDVI.

1. INTRODUCTION

Land use is inclined by economic, cultural, political, and historical and land – tenure factors at multiple scales. Land use referred to as man's activities and the various uses which are carried on land. Urbanization is inevitable when pressure on land is high, agriculture incomes are low, and population increases are excessive, as is the case in most of the developing countries of the world. The rapid changes of land use and cover are often characterized by rampant urban sprawling, land degradation, or the transformation of agricultural land to shrimp farming ensuing enormous cost to the environment [1]. This in way urbanisation is desirable for human development. However, uncontrolled urbanisation has been responsible for many of the problems, our cities experience today, resulting in substandard living environment, acute problems of drinking water, noise and air pollution, disposal of waste, traffic congestion etc.

Recent technological advances made in the domain of spatial technology, cause considerable impact on planning activities. This domain of planning is of prime importance for a country like India with varied geographic patterns, cultural activities etc. Satellite remote sensing is a potentially powerful means of monitoring land-use change at a high temporal resolution and lower costs than those associated with the use of traditional methods [2]. 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 compute various land cover/land use categories accurately and help in maintaining the spatial data infrastructure which is very essential for monitoring urban expansion and land use studies [3]. The purpose of using GIS is that maps provide an added dimension to data analysis, which brings us one step closer to visualising the complex patterns and relationships that characterise real-world planning and policy problems. Visualization of spatial patterns also supports change analysis, which is important in the monitoring of social indicators. This, in turn, should result in improving the need assessment. According to Macleod and Congalton [4], in general, remote sensing considers following four aspects of change detection (a) detect the changes, (b) identify the nature of change, (c) measure the aerial extent of change and (d) assess the spatial pattern of change.

The objectives of this paper are to explain remote sensing and GIS applications in various stages of planning, implementation and monitoring of the urban area.

2. OVERVIEW OF DETECT CHANGES IN URBAN

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).

2.1 Post Classification Techniques

The post-classification technique involves the independent production and subsequent comparison of spectral classifications for the same area at two different time periods [5]. 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 [6] reported accuracies of 96 per cent for the identification of new forest land and 62 percent for new agricultural land using a post-classification technique in a semi-arid environment. Furthermore, Sohl [6] noted the strength 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 [5] also obtained the highest accuracy with this technique in a study comparing six different techniques.

2.2 Enhancement Change Detection Techniques

Enhancement 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 [7].

2.2.1 Image differencing technique

Image differencing is a technique by which registered images acquired at different times have pixel DN values for one band subtracted from the corresponding pixel DN values from the same band in the second image to produce a residual image, which represents the change between the two dates (Mass 1990) Ridd and 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 [8] and Sohl [6] 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.

2.2.2 Principle component analysis

Principal component analysis (PCA) is a commonly used statistical method for many aspects of remote sensing image analysis, including estimation of the underlying dimensions of remotely sensed data, data enhancements for geological studies, and land cover change detection [9]. The PCA technique for change detection requires the separate images first be stacked in a multi-temporal composite image [8]. The major strength of this technique is its ability to reduce the dimensionality of the data with relatively minor loss of overall information content. The major weakness of this technique is that it can be difficult to interpret. Li and Yeh [10] compared principal component analysis to post classification techniques and concluded that principal component analysis was much more accurate than post classification techniques and therefore suggested it as an accurate alternative for detecting land use change.

2.2.3 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 [11]. The NDVI is calculated as a normalized ratio (ranging from -1 through 1) from the NIR and the red band and emphases apparent vegetation (Sabins, 1996).

2.3 Study Area

Varanasi district, falls between 25°10’ to 25°37’ N latitude and 82°39’ to 83°10’ E, lies in eastern Uttar Pradesh, India (Fig. 1). The district has an area of 1535 sq.km; 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. Topographically the study area is covered by the alluvial deposits of Quaternary age. River 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 River Ganga and its tributaries. It consists mainly of sand, silt and clay mixed by kankar at a few places. The area comes under sub tropical monsoonal climate characterised by seasonal extremities. January is the coldest month with a mean maximum temperature of 23^{o}C. Sometimes, the minimum temperature may goes around 5^{o} C during December and January coupled with occurrence of dense fog. June is the hottest month with mean maximum temperature around 35^{o}C. However, temperatures' soaring above 40^{o} C is not uncommon with the occasional rise in mercury above 45^{o}C under the impact of heat wave and hot air blowing in month of 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 is the rainiest month.

3. 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 were compared 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 correction were made at required places. Then, the software such as Arc GIS 10.3 and Erdas imagine14 was used to prepare the urban settlement cover changes during 1990-2016.

3.1 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.

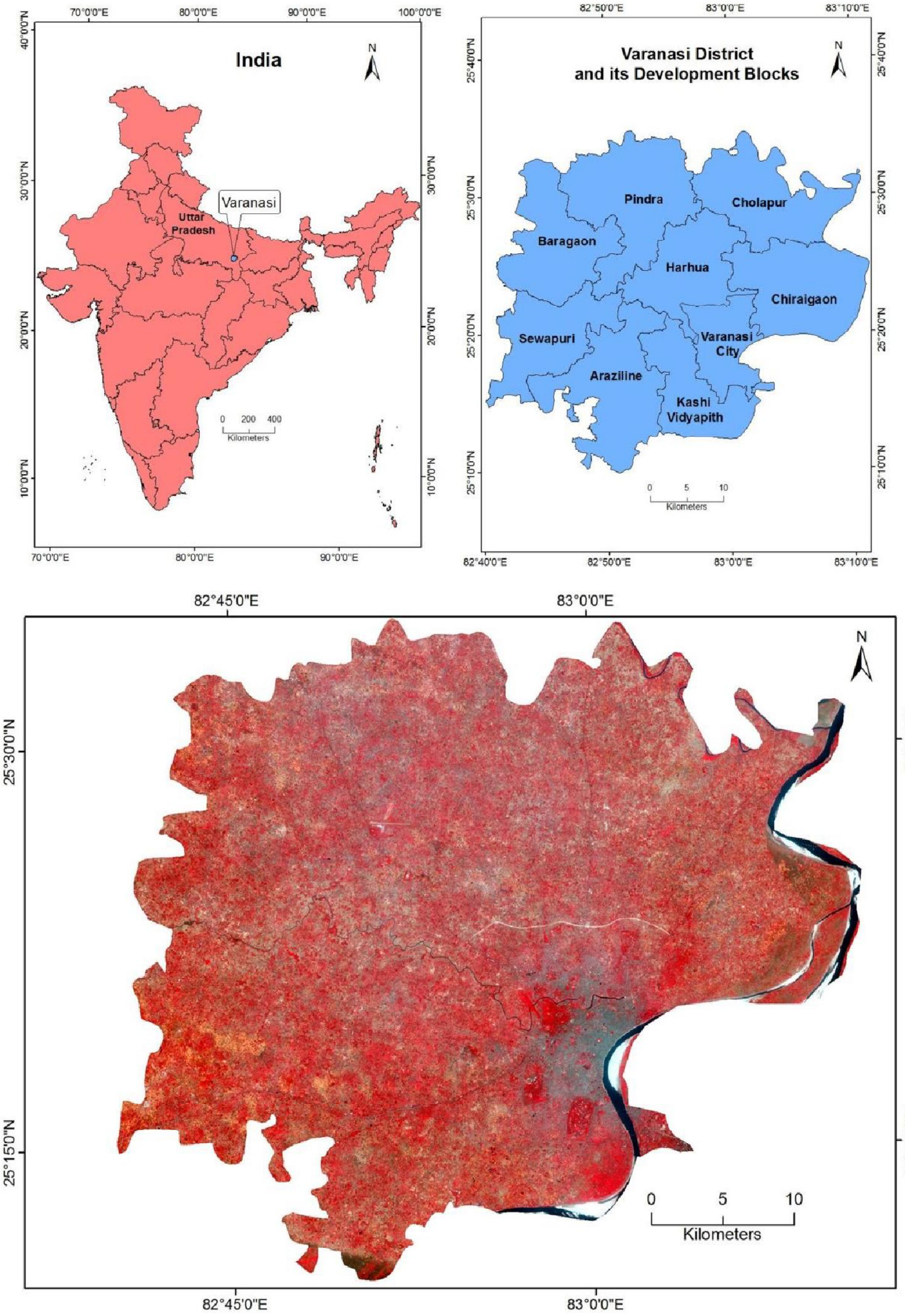

Fig. 1. Location of study area

Table 1. Details of Landsat images used in the study

Satellite-sensor	Path/row	Date of acquisition	Cloud coverage
Landsat-5 TM	142/42 142/43	18 February. 1990	No
Landsat 8-OLI TIRS	142/42 142/43	03 February, 2016	No

3.2 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 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.

3.3 Image Analysis

3.3.1 Image classification techniques

In this study, Anderson classification system (Level 1) was adopted for the selection of LULC classes. This approach is most appropriate to prepare land use/cover maps from remote sensing data, specifically Landsat data ([12,13], Zhu and Woodcock 2014). A total of 100 training areas were selected on the image, checked with field survey and seven LULC 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.

3.3.2 Post classification processing

Supervised classification provides unsatisfactory classification results resulting from 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 LULC 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 digitised polygons were converted into AOI and within AOI LULC image were changed by recoding. Finally, to remove 'salt & paper' noise that quite appears in digital image processing, a majority filter (3 X 3 filter) was employed for three classified images.

4. RESULTS AND DISCUSSION

4.1 Change Detection

The analysis reveals the following information and changes also shown in clearly in the Table 2. This will help the planners and other researchers for further research at 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 and 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 the Varanasi city and more general economic development. The marsh area has decreased from 0.69 % in year 1990 to 0.07 % 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 %) to 2016 (9.65 %). It shows gradually increase from 1990 to 2016 due to awareness of the people and a government plan.

4.2 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 less 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 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).

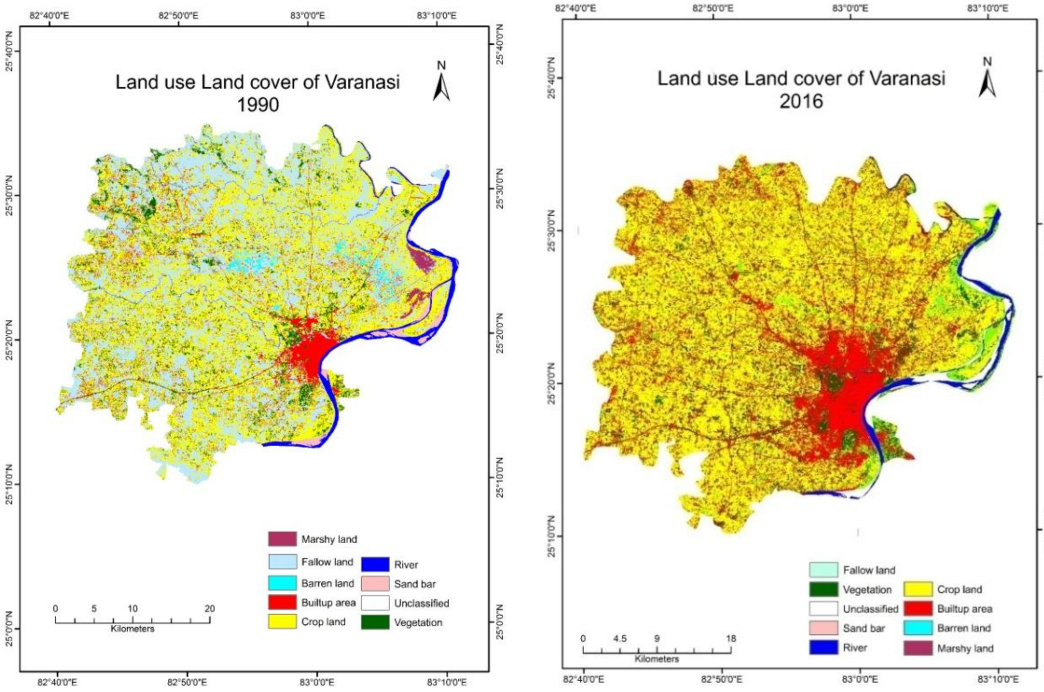

Fig. 2. LULC Map of 1990 & 2016

Table 2. Area distribution of land use land cover (%) and change in area (%)

LULC 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 (+) value indicate gain in the area whereas negative (-) value indicate loss in area

The two NDVI result shows that there is an 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.

4.3 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 3.

Table 3. Overall accuracy of classified images

Year	Overall accuracy
1990	84%
2016	90%

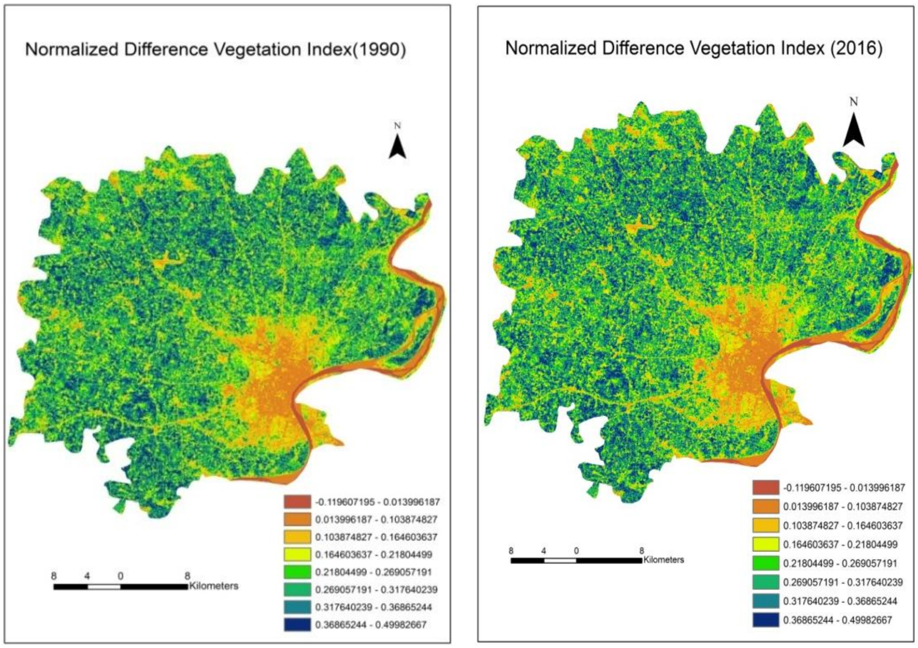

Fig. 3. NDVI Map of 1990 & 2016

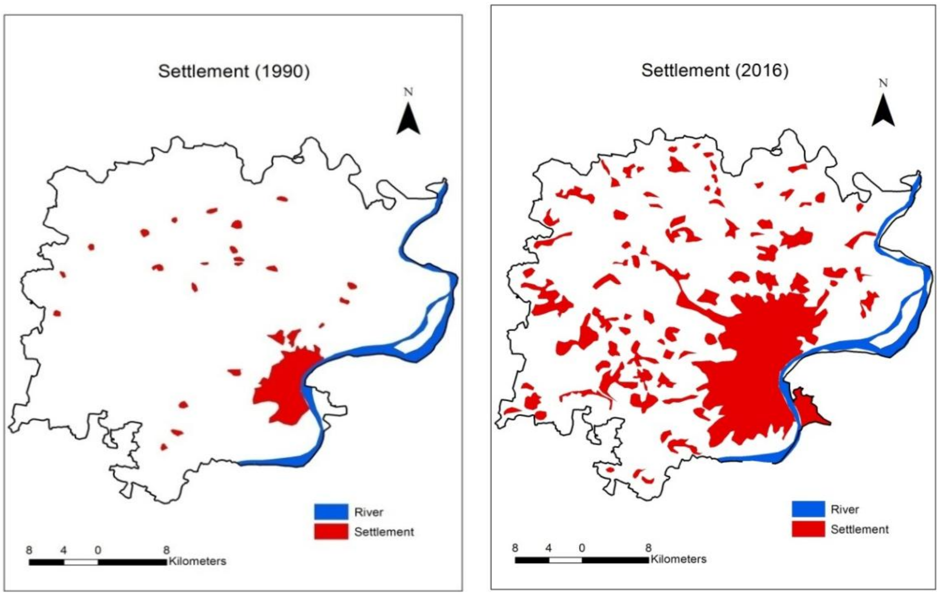

Fig. 4. Settlement Map of 1990 & 2016

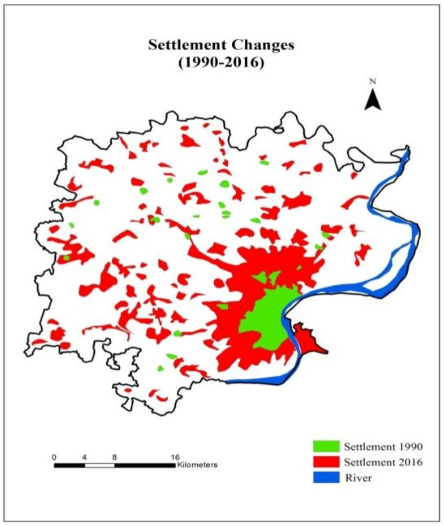

Fig. 5. Settlement changes 1990 & 2016

5. CONCLUSION

This paper presented the importance of using remotely sensed data as a means for the mapping and the detection of changes of land use land cover (LULC) in the Varanasi district. The results reveal clearly 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 LULC during the study period 1980-2016. The study has identified several patterns and trends of the changes in LULC in the area. 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 agricultural land use and vegetation during the study period. It is thought that the primary explanation for the rapid increase in urban area is population growth, migration from rural areas to the Varanasi city and more general economic development. The combined findings will provide policymakers with scientific evidence of land use change and will identify the problems and/or opportunities for the study area.

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COMPETING INTERESTS

Author has declared that no competing interests exist.

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