

AGRICULTURAL LAND USE CHANGE ANALYSIS USING REMOTE SENSING AND GIS: A CASE STUDY OF ALLAHABAD, INDIA

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ABSTRACT:

Urbanization is occurring at a fast rate in India. Population residing in urban areas was 11.4% according to the Census of 1901. This percentage has gradually increased to 31.16% according to the Census of 2011. Conversion of agricultural land into non-agricultural uses is the major side effect of urbanization. The objective of this paper is to identify the changes in the agriculture land and its conversion into other Land Use Land Cover (LULC) type. In order to achieve this objective, mapping of land use changes is done by using the GIS and remote sensing. This study utilizes satellite images along with field survey and statistical data to detect the change of farming land into other LULC type in different tehsils of Allahabad district. This study is carried out over the time period of 18 years that ranges from 2000 to 2018. This work provides the detail of expansion and shrinkage of agriculture and open land at tehsil level. Landsat data is used in this work which is open source and freely downloadable. Landsat images of study period i.e. from 2000 to 2018 are downloaded and then preprocessed. Supervised classification of images is performed using Gaussian maximum likelihood technique. The training samples are collected with the help of ground truth information. After this, identification of land use changes is done on pixel by pixel basis. This would find out the LULC class which is primary responsible for the shrinkage of agriculture land. This spatio-temporal and statistical research work will help to construct a base for a sustainable development model.

1. INTRODUCTION

Indian economy majorly depends upon the agriculture. India is considered as the agricultural country (Brien et al., 2004). Here the agriculture is continuously facing challenges because of climate change, crop diseases, insufficient irrigation and volatile market (Bhan and Behera, 2014). Agricultural land loss is a global problem (Ghar et al., 2007). In order to preserve nature and ensure output the sustainable agriculture concept has been given (Mendas and Delali, 2012).

GIS and remote sensing can be used to support the agriculture. Several papers were found where these techniques are utilised in agriculture. Some of these are discussed here. Ray and Dadhwal (2001) have applied remote sensing and GIS to compute evapotranspiration in disease free crops. Some researchers have utilised satellite imagery for land suitability assessment for agriculture which is a very essential feature for agriculture development and future planning (Abdelrahman et al., 2016; Bandyopadhyay et al., 2009). Panigrahy et al.(2005) used the temporal and multisensory data to obtain the crop related indices that predict the crop rotation, pattern and production. Other applications of GIS and remote sensing in the field of agriculture are land capability evaluation, assessment of crop damage and crop management (Huang et al., 2018; Kabanda, 2015).

Land Use Land Cover (LULC) informs the type of human activity or natural cover present at a particular location (Kassawmar et al., 2016). Temporal LULC class change models are very useful to assesses the causes and pattern of land use change (Lin et al., 2008). LULC classification is used in various applications that can be related to agriculture (Gibril et al., 2015), environment (Jiang et al., 2015) and urban growth (Wang and Maduako, 2018).

Remote sensing provides satellite data on which LULC studies are performed (Jiang et al., 2015). Change detection in LULC of any geographic location by using multi-temporal satellite imagery helps in understanding landscape dynamics (Rawat and Kumar, 2015). Conversion of agricultural land into non-agricultural use is the major problem of urbanization (Fazal, 2000). Classification of satellite image is used for converting the image into LULC map. It is the way for allocating pixels to particular classes. Pixel is an individual unit made out of values in several spectral bands (Lillisand et al., 2004).

There are many satellite missions launched by different countries which are used for research works but only some of them are freely available. Landsat images are used in this work. They are open source and freely downloadable (Hu et al., 2016). Landsat data are used in LULC change studies because of the continuous availability of images (Hansen and Loveland, 2012). It is consistently providing the images that are commonly used in identification of global LULC change since 1972 (Williams et al., 2006).

The present study has been taken to understand the changes in agriculture and open land in Allahabad district from the years 2000 to 2018. The objective of this study is to identify the changes in the agriculture and open land along with its conversion into other LULC types. For this the mapping of land use changes is done with the help of GIS and remote sensing. It would provide the details of expansion or shrinkage of agriculture and open land.

2. STUDY AREA AND DATASETS

Study area of the present work is Allahabad district of Uttar Pradesh as shown in Figure 1. Allahabad is recently renamed as Prayagraj. The geographical extent of the study area is from

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81.5°E to 82.5°E longitude and from 24.8°N to 25.8°N latitude. Its total area is 5,482 km². This region falls in the lower Indo-Gangetic plains and Ganga-Yamuna Doab. This place is extremely suitable for agriculture because of high soil fertility and topography. As per Census of 2011, total population in this region is 59,54,391 with population density of 1,086 persons per km². This makes Allahabad the most populous district in Uttar Pradesh. There are total eight tehsils in Allahabad district which are Karchhana, Koraon, Phulpur, Bara, Meja, Allahabad, Soraon and Handia. The high population growth rate resulted in the LULC type conversion and resource exploitation.

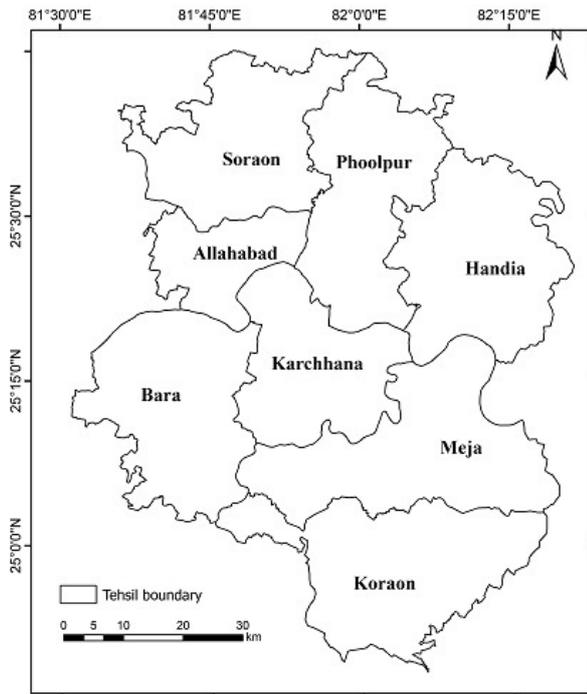


Figure 1. Study area map showing Allahabad district with tehsil boundary of all eight tehsils.

Landsat satellite images are used in this work which are open source and freely downloadable. As per available data, images of Landsat Enhanced Thematic Mapper plus (ETM+), Thematic Mapper (TM), and Operational Land Imager (OLI) sensors are used for 2000, 2010 and 2018 respectively. The spatial resolution of images is 30m. The images of the study area are delineated with the help of Survey of India (SOI) toposheets. Thirteen SOI topographical maps of OSM series cover the whole geographic extent of the study area. These maps are at the scale of 1:50,000.

3. METHODOLOGY

The study involves the analysis of agricultural and open land use change in Allahabad district. Seven major LULC classes are present in the Allahabad district. For getting LULC information from satellite imagery visual interpretation and digital image processing methods has been used. To recognize and delineate objects in the image various elements of visual image interpretation is used like size, shape, tone, surface and association. On other hand, image classification is the way toward allocating pixels to particular classes. The overall methodology of this work is shown in Figure 2.

3.1 Extraction of study area administrative boundary

The administrative boundary of the study area is obtained through SOI topographical maps. As these maps are in hardcopy form, therefore conversion of paper maps into digital format is required. For this purpose, scanning of these topographical maps has been done. Subsequent operations are

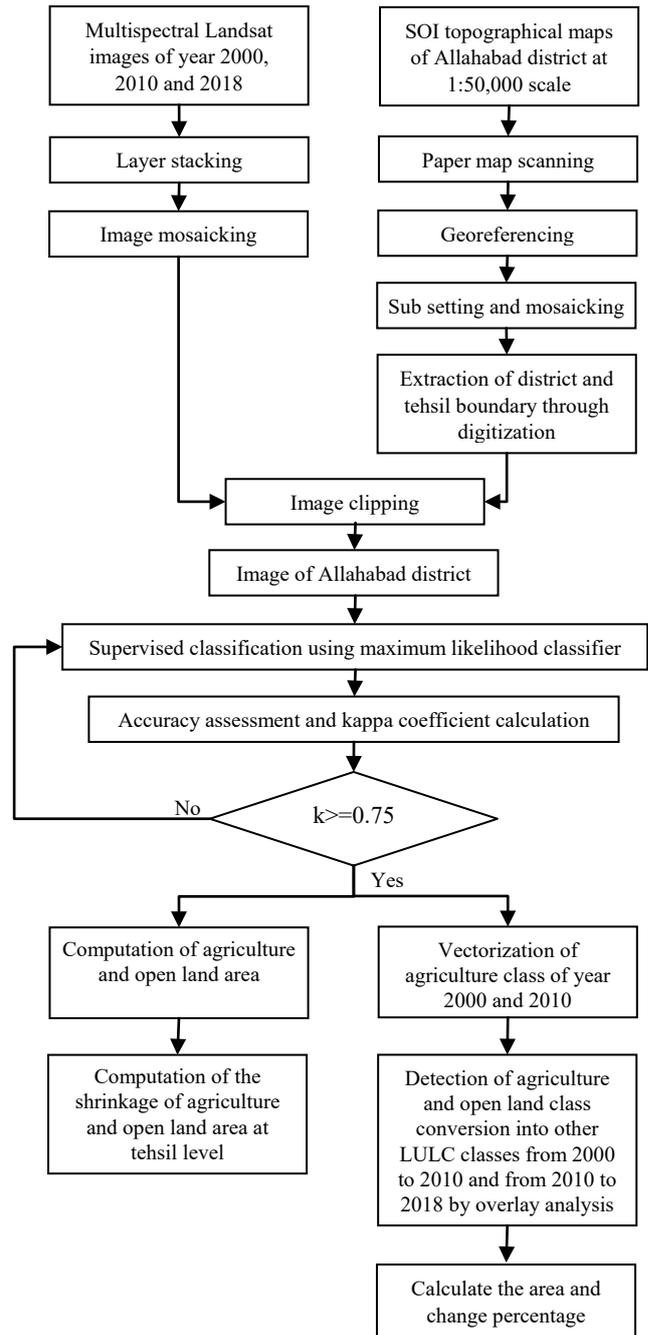


Figure 2. Flowchart of methodology

performed on ArcGIS software. After scanning, georeferencing is performed using affine transformation and nearest neighbourhood interpolation technique. In this datum is set to WGS 84 and projection is set to UTM. Then sub-setting and mosaicking of all maps is done. Map digitization is performed to extract the district and tehsil boundaries.

3.2 Image Preparation

Images of different years of the study area are downloaded from the USGS Landsat archive. As the downloaded multispectral images are in different layers therefore it is necessary to stack them together. Thus layer stacking is performed on all images. Then image is clipped to obtain the image of study area only.

3.3 Image Classification

Supervised classification of each of the multispectral image is performed for detecting the changes that have occurred in different time interval. Gaussian maximum likelihood technique is used for supervised classification. The maximum likelihood classifier algorithm relies on the second-order Gaussian probability density function model for each class (Ganasri and Dwarkish, 2015). Training samples are collected with the help of ground truth information. The classes were selected according to the area containing by the particular feature and intensity of acquiring land. After the image classification, accuracy assessment is done on the basis of class by class division. Kappa coefficient (k) is calculated that shows the agreement between the classified data and ground truth. If the value of kappa coefficient is 0.75 or more then the classification is considered as good. Therefore, in this work the next step is proceeded only if the kappa coefficient is 0.75 or more. If the value of kappa coefficient is less than 0.75 then classification procedure is repeated till the coefficient value reaches 0.75 or more.

3.4 Change detection

3.4.1 Agriculture and open land use area calculation

After classification, the agriculture and open land use area of all the three years i.e. 2000, 2010 and 2018 is calculated. This is performed by pixel based area calculation. In order to see this change at tehsil level, area of agriculture and open land of each tehsil is computed with the help of tehsil boundary shapefile overlay. The loss of agriculture and open land between the consecutive time intervals is computed through comparing the area of temporal classified images.

3.4.2 Transformation study of agriculture and open land use area into other LULC classes

Transformation of agriculture and open land into other LULC is also identified for each of the study year. For this agriculture and open land of classified image is vectorised. Then by clipping it from the consecutive year image the transformation is identified. Change table is prepared that gives the information about transformed land into different other LULC classes.

4. RESULT AND DISCUSSION

4.1 LULC mapping

The LULC map has been generated from the integration of remote sensing data i.e. pixel values with thematic features present on the earth surface. The image is classified into seven LULC classes viz agriculture, built-up, forest, open land, scrubland and water.

Accuracy assessment of this classification is then performed. The ground information or previous knowledge of ground truth for assessment of classified image accuracy is required. This information is collected through SOI topographical maps, Google Earth and field survey. One of the most common ways to express the classification accuracy is by the preparation of classification error matrix which is also known as contingency matrix or confusion matrix. Error matrix comparison is done on the basis of class by class division. In this classification, overall classification accuracy and kappa coefficient are calculated which are shown in Table 1.

S.No	Year	Overall accuracy	Kappa coefficient
1	2000	85%	0.82
2	2010	83%	0.79
3	2018	82%	0.78

Table 1. Values of overall accuracy and kappa coefficient

As the value of Kappa coefficient is more than 0.75 in each of the classification, therefore it can be concluded that there is a fine agreement between the classified data and ground truth.

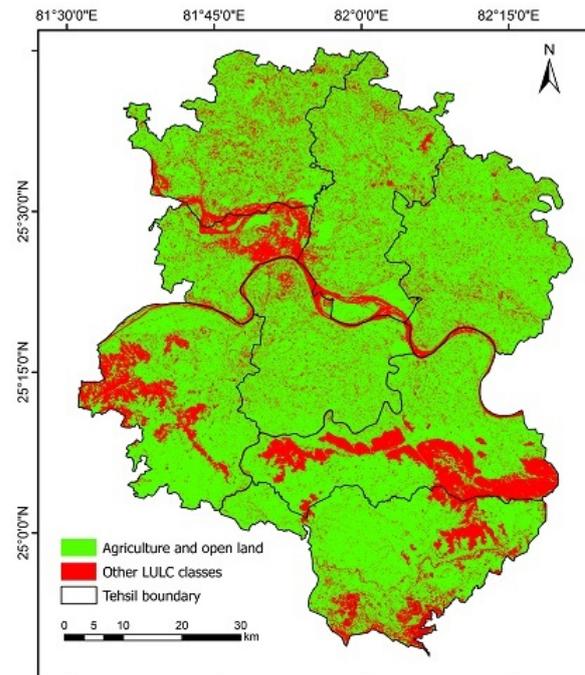


Figure 3. Allahabad district LULC map of year 2000

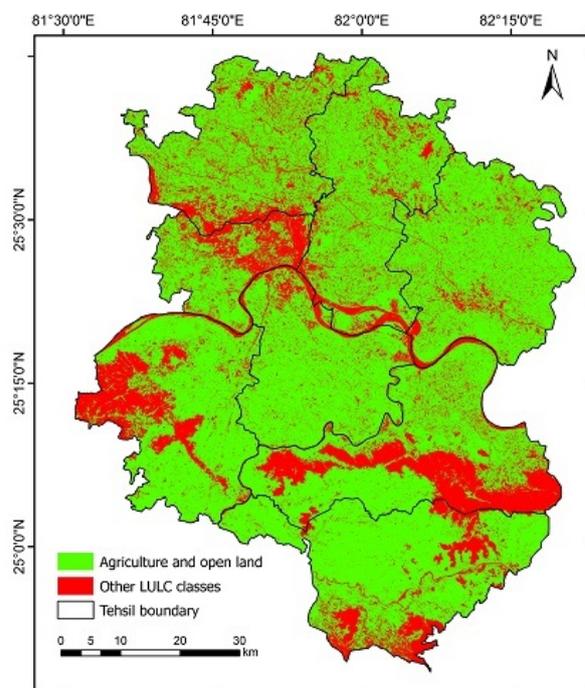


Figure 4. Allahabad district LULC map of year 2010

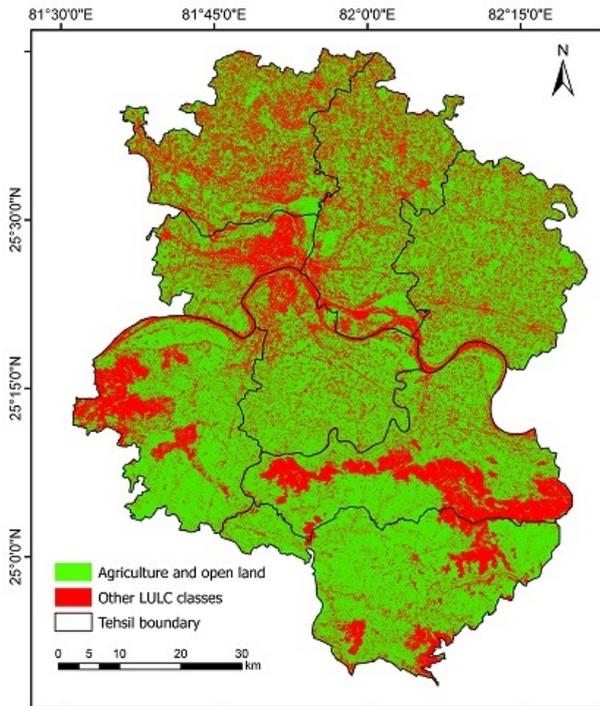


Figure 5. Allahabad district LULC map of year 2018

Figure 3, 4 and 5 are the maps of Allahabad district which are showing two LULC classes of the year 2000, 2010 and 2018 respectively. This map is obtained after supervised classification. In the map, agriculture and open land classes are clubbed together and is shown by the green color. Remaining LULC classes *i.e.* built-up, forest, scrubland and water are merged together and depicted by the red color. From the maps it can be clearly visualized that the area of green color is continuously shrinking while the red color area is increasing. From this it apparent, that over the years there is a significant loss of agriculture land and the open land where agriculture could be done. This loss is more from 2010 to 2018 as compared from 2000 to 2010.

4.2 Agriculture and open land use area change

The computation of different features acreage is performed from the pixel information of the classified image. The area of LULC of different years is shown in Table 2. From the table it is clear that the agriculture and the open land where agriculture can take place are continuously decreasing from the year 2000 to 2018 while the area of other LULC classes is increasing gradually. In year 2000, the area of agriculture and open land was 4202.54 km² which was reduced to 4097.92 km² in year 2010. The 104.62 km² area of agriculture and open land had been transformed into other LULC classes in these ten years. The reduction of agriculture and open land is more severe in next eight years. As per classified image of year 2010, the area of agriculture and open land was 4097.92 km² which was reduced to 3642.74 km² in year 2018. The 455.17 km² area was converted into other LULC classes.

S.No	Class	Area in 2000	Area in 2010	Area in 2018
1	Agriculture and open land	4202.53	4097.92	3642.74
2	Other LULC classes	1281.02	1385.63	1840.81

Table 2. Change in features area from year 2000 to 2018. All values of area are in km².

Further the study is carried out at the tehsil level. For this area of agriculture and open land is calculated for each tehsil. The area change from 2000 to 2010 and from 2010 to 2018 is shown in Table 3 and Table 4 respectively.

S.No	Tehsil Name	Agriculture and open land area in year 2000	Agriculture and open land area in year 2010	Agriculture and open land area change
1	Allahabad	205.10	194.14	10.96
2	Bara	555.76	526.38	29.38
3	Handia	645.82	642.74	3.08
4	Karchhana	487.16	496.74	-9.58
5	Koraon	643.43	654.40	-10.98
6	Meja	568.76	527.54	41.21
7	Phulpur	580.23	562.48	17.75
8	Soraon	514.90	492.17	22.73

Table 3. Tehsil wise change in agriculture and open land area from year 2000 to 2010. All values of area are in km².

S.No	Tehsil Name	Agriculture and open land area in year 2010	Agriculture and open land area in year 2018	Agriculture and open land area change
1	Allahabad	194.14	178.21	15.92
2	Bara	526.38	510.43	15.95
3	Handia	642.73	543.33	99.39
4	Karchhana	496.74	416.08	80.65
5	Koraon	654.4	639.02	15.38
6	Meja	527.54	516.77	10.77
7	Phulpur	562.47	451.78	110.68
8	Soraon	492.17	385.86	106.31

Table 4. Tehsil wise change in agriculture and open land area from year 2010 to 2018. All values of area are in km².

From the above data it clear that there is a rapid change in LULC from year 2010 to 2018. All tehsils are affected from this change. The agricultural land loss rate was slow for first decade but from 2010 to 2018 agricultural land loss rate became very rapid. The LULC change in the Soraon and Phulpur tehsils is comparatively more than other tehsils. The less affected tehsils are Koraon followed by Meza and Bara.

4.3 Transformation of agriculture and open land use area into other LULC classes

As per the above discussion about the area of different LULC classes, it can be concluded that a large amount area of agriculture and open land is converted into other LULC classes. To study this, the class transformation of the agriculture and open land area from 2000 to 2010 and from 2010 to 2018 is identified. In year 2000 and 2010, the area of agriculture and

open land was 4202.54 km² and 4097.92 km². The 610.49 km² area out of 4202.54 km² and 1000 km² out of 4097.92 km² is converted into other LULC classes as shown in Table 5. From this table it can be seen that the maximum loss of agriculture and open land is due to increase in built up land and scrubland.

Class	Transformation of agriculture and open land into other LULC classes			
	From 2000 to 2010		From 2010 to 2018	
	Area	%	Area	%
Built-up	152.84	3.64	799.47	19.51
Forest	35.7	0.85	92.22	2.25
Sand	53.38	1.27	13.4	0.33
Scrubland	346.44	8.24	86.24	2.1
Water	22.13	0.53	8.66	0.21

Table 5. Agriculture and open land transformation into other LULC classes. All values of area are in km².

5. CONCLUSIONS

The aim of this paper is to investigate the agriculture and open land changes occurred in Allahabad district due to rapid urbanisation from year 2000 onwards using satellite image processing. From the analysis it is concluded that the rate of agriculture shrinkage is increasing day by day.

The image classification is performed to create the LULC mapping of the Allahabad district. On the basis of this classification it is concluded that there is a constant reduction in the agriculture and open land use area. As per the GIS based calculations the agriculture and open land use area was 4202.53km², 4097.92km² and 3642.74km² in the year 2000, 2010 and 2018 respectively. The total reduction from 2000 to 2018 is 560 km². Further this land use shrinkage study is carried out at the tehsil level. From this it is concluded that the reduction of agriculture and open land use area is very high in Soraon and Phulpur tehsils.

As there is a constant shrinkage of agriculture and open land use area, therefore it is required to identify the LULC classes in which they are converting. For this LULC transformation study is carried out. From this it is concluded that most of the agriculture and open land use area is converted into the built up area. This conversion was 3.64% in between year 2000 to 2010 and 19.51 % for the next eight years.

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