

Effect of Urban Land Use on Agriculture, Forest, and River Beds: A Case Study of Dehradun City, Uttarakhand, India



Kunal Sawant, Rishi Prakash, and Nitin Mishra

Abstract Urbanization has led to a tremendous pressure on available land in Dehradun, Uttarakhand, India. Therefore, proper land planning measures are required to mitigate the effect of urbanization on agriculture, forest, and water bodies. This study illustrates the use of remote sensing and GIS to detect the change in urban sprawl of Dehradun region during the period 2013–18 and its effect on agriculture, forest, and water bodies. Landsat 8 imagery has been used in this study. Supervised classification has been adopted in Landsat 8 images of the study area. Four different land cover classes have been considered in classification stage. These are urban, forests, agriculture and vegetation, and seasonal river beds. The accuracy obtained for both the images after classification was above 85% for good change detection results. The change detection technique used is post-classification comparison method which is the matrix union method. The study has shown that the built-up area in Dehradun city has expanded from 75.07 km² in 2013 to 105.51 km² in 2018 and 0.26 km² of forest area, 34.40 km² of agricultural land, and 2.56 km² of water beds have been converted into built-up area in the duration of 5 years. The increase in built-up area from 2013 to 2018 is 40.54%.

Keywords Landsat 8 · Change detection · Recoding · Supervised classification

1 Introduction

The term land can be defined as a figure on the earth's surface including all physical attributes of the biosphere and the environment which focuses on the soil and rock forms, major water bodies (river, shallow lakes, swamps, marshes, and even underground water reserves), major biodiversity and their respective distribution, and major physical changes due to human activities [1]. Change detection is the process of visualizing the difference in a body or phenomenon by observing at different times. The study about change in land cover is one of the important areas to understand the

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degree of interaction between man and ecology. To implement adequate development plans, a highly maintained and timely organized data regarding land use detection is must. The change in land use patterns affects aquatic life, water quality, and other processes that combine together to affect weather and biosphere. Uttarakhand is a state in the northern part of India formed after its division from Uttar Pradesh in 2000 [2]. Dehradun, the capital city of Uttarakhand, has witnessed a tremendous growth in construction and built-up area. Therefore, a balanced land use planning is required for the proper development of Dehradun city. The goal of my project is to identify the urban sprawl of Dehradun city over time using satellite imagery.

2 Datasets Used

2.1 Study Area

Dehradun extends over an area of 300 square kilometers. It lies between $77^{\circ} 34'$ E and $78^{\circ} 18'$ E longitudes and $29^{\circ} 58'$ north to $31^{\circ} 2'$ N latitudes [3]. Dehradun comprises Song River in the east, the Tons River in the west direction, and the Himalayan Mountains in the north and covered by Sal Forests in the south as shown in Fig. 1.

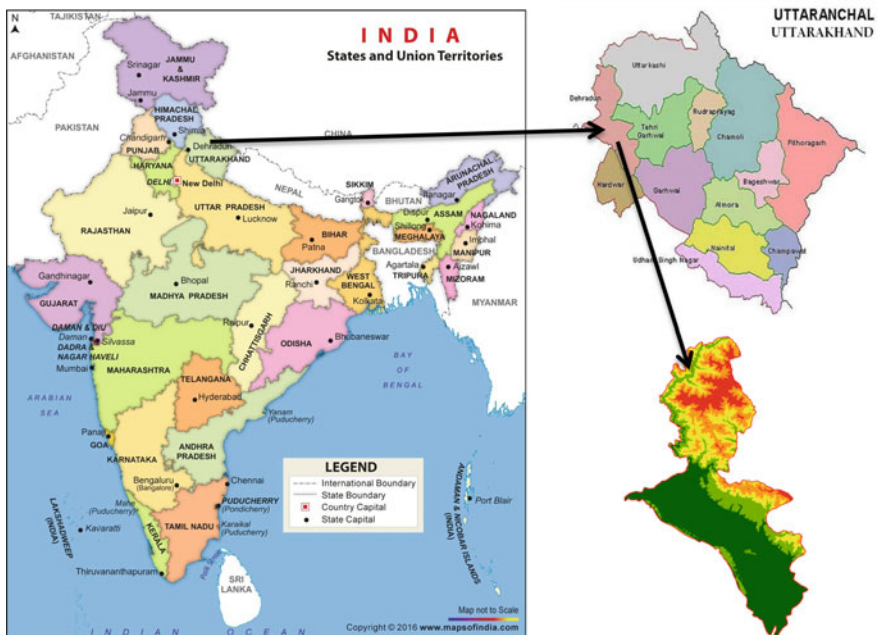


Fig. 1 Study area showing Doon Valley

2.2 Dataset Used

- Landsat 8 images of the year 2013 and 2018 have been used to study urban land cover changes in Dehradun city. Landsat 8 satellite was launched on February 11, 2013. It consists of 11 spectral bands. It has a spatial resolution of 30 m, thermal resolution of 100 m, and panchromatic resolution of 15 m.
- Two images of Dehradun city were downloaded from United States Geological Survey (USGS) Web site of same place but different dates of duration of 5 years. Landsat 8 image of Dehradun city of date May 29, 2013, and Landsat 8 image of Dehradun city of date May 11, 2018, were used.
- Both the images of Landsat 8 were used. We have used band combination of 2, 4, and 7 for layer stacking.

3 Methodology

Following steps have been used for urban land change detection of Dehradun, Uttarakhand (India):

Step 1: Layer stacking of two Landsat 8 images is performed of dates May 29, 2013, and May 11, 2018.

Step 2: Sub-setting of Dehradun area from both the layer stacked images.

Step 3: Supervised classification of both the subset images.

Step 4: Recoding of all urban and non-urban classes using Thematic Recode option.

Step 5: Change detection using matrix union method. Change detection matrix generation. The methodology adopted is shown in Fig. 2.

3.1 Layer Stacking

Landsat 8 images of 2013 and 2018 were downloaded using the earth explorer option of United States Geological Survey (USGS). The images downloaded are of dates May 29, 2013, and May 11, 2018. Once the images were downloaded, they were imported into ERDAS Imagine software. Layer stacking is a preprocessing operation which combines several bands of Landsat and provides a single image with improved quality and resolution. The band combination used is 2, 4, and 7 for layer stacking in both the images.

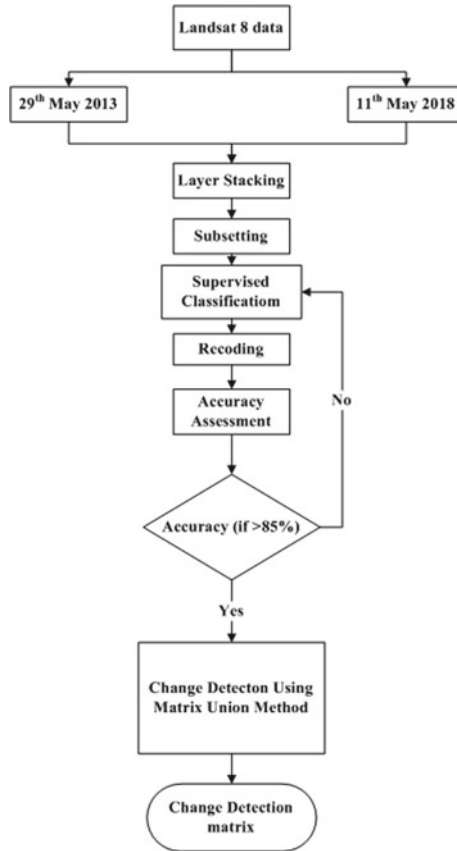


Fig. 2 Flowchart of methodology adopted

3.2 *Subset of Stacked Images*

After the process of layer stacking, we need to extract or cut our study area from the stacked images because our study area is a very small part of the stacked image. Therefore, we do not require the entire stacked image for further processing. Figure 3a shows the subset image of year 2013, and Fig. 3b shows the subset image of year 2018.

3.3 *Supervised Classification*

The classification method used for this project is supervised classification technique. In supervised classification, the user himself performs the pixel classification process

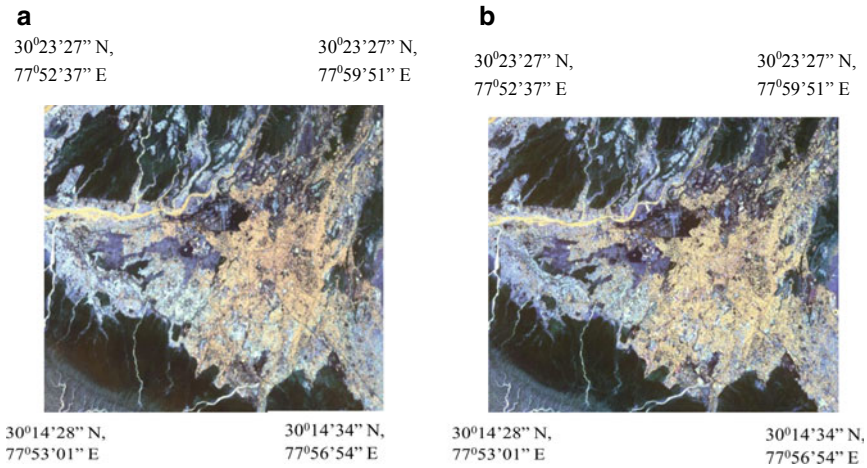


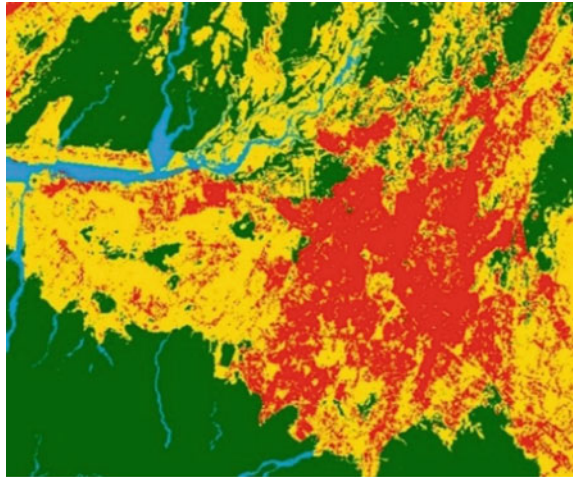
Fig. 3 a Subset image of year 2013 and b subset image of year 2018

[4]. The user creates training samples consisting of various pixels that should be associated with each class. This is done by choosing sample sites of known cover type called training areas. Signature editor method is employed to select the training samples and technique used is maximum likelihood classification. Figure 4a displays the classified image of year 2013, and Fig. 4b illustrates the classified image of year 2018. There are a total of four classes taken in classification: Red is for urban, green is for forestland, yellow is for agricultural land, and blue is for seasonal water beds. The samples taken for forest area are 25, for agriculture and vegetation is 40, 25 samples for urban area, and 15 samples for seasonal river bed. Supervised classification is different from unsupervised classification in the sense that it requires external training samples to execute the classification operation [5].

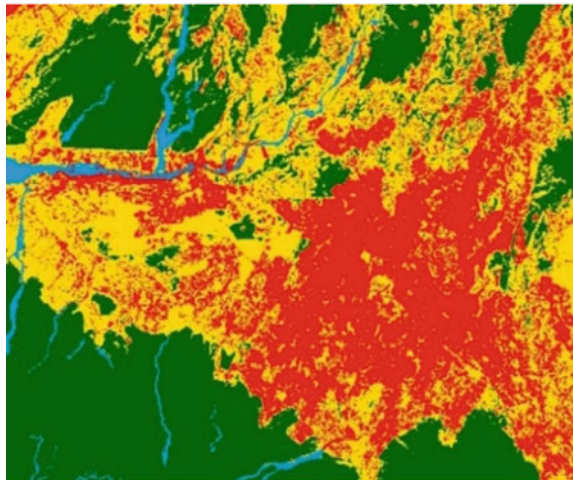
3.4 Recoding

Recoding is the process of reclassification of the classes. This is done by combining them based on similar characteristics and having a more general class. The goal of this project is to identify the change of the urban class. Recoding is done using thematic option in the raster tab and all the urban classes were recorded as 1, all the forest classes were recorded as 2, all the agriculture and vegetation classes were recorded as 3, and all water classes were recorded as 4. These recoded images will be further used as inputs in the matrix union for change detection. In case, the pixels of a particular class are showing in some other class, thematic recoding helps in this error correction process by first drawing a polygon around the boundary of the area in which the error in pixels is showing and then using the thematic recode option, we correct the pixels in that area. In this project, water beds were getting classified

Fig. 4 **a** Classified image of year 2013 and **b** classified image of year 2018. Red is for urban, green is for forests, yellow for agriculture, and blue for river beds



(a)



(b)

under the urban region due to same reflectance of rocks and sand in both river beds and urban regions so we were able to solve this discrepancy using thematic recode option which enabled us to recode the wrong classes to correct one. Recode option is available in raster tab of ERDAS IMAGINE.

3.5 Accuracy Assessment

After performing recoding and thematic corrections, accuracy assessment is performed on both the recoded images. Accuracy assessment is performed to evaluate the accuracy of classification of our images. The accuracy of 2013 image is 88% and of 2018 image is 85% which is desirable and good for change detection.

3.6 Change Detection Using Matrix Union Method

Change detection is defined as a process used to identify the change that occurred in a specific area over a span of time. By observing the same area at different time intervals using satellites or aerial photography, the user can identify the change of land use and land cover in that area. Several other analyses can also be done with the help of change detection techniques such as change in the condition of the water or the degrading of a plant species. Since the images used for this study were already classified, the post-classification comparison method was used. This is a simple and more promising method which produces accurate results if the classification is done accurately. Since the images taken at the different times were already independently classified, these classified images can be used to produce change maps that will visualize the pixels that have changed from one class to another.

The method used for change detection is matrix union method present in thematic option of the raster tab. It takes both the recoded images as input and can be used to create a visualization map which will display the change of pixels from 2013 to 2018. We saved the matrix union file by the name 2013–18. We have to open this file in Arc GIS software to generate a change detection matrix in Excel sheet from there which will display the change in pixel count between 2013 and 2018 and also the change in area. The matrix union function will create a matrix from two input thematic rasters. To open this dialog, go to the raster tab, raster GIS group, click the drop down below thematic and select matrix union. Figure 5 shows the matrix union image 2013–18 opened in Arc GIS software. We will open the attribute table of this image in Arc GIS software from which we will generate a change detection matrix in Excel sheet denoting the change in area during the time duration of 2013–18.

3.7 Change Detection Matrix

A change detection matrix helps us to detect the change in pixel count during a given time duration from which we can compute the change in area in km² [6]. Table 1 shows the attribute table of matrix union file 2013–18 opened in Arc GIS from where we extract its information to generate a change detection matrix [7, 8].

Fig. 5 Matrix union image 2013–18 opened in Arc GIS software

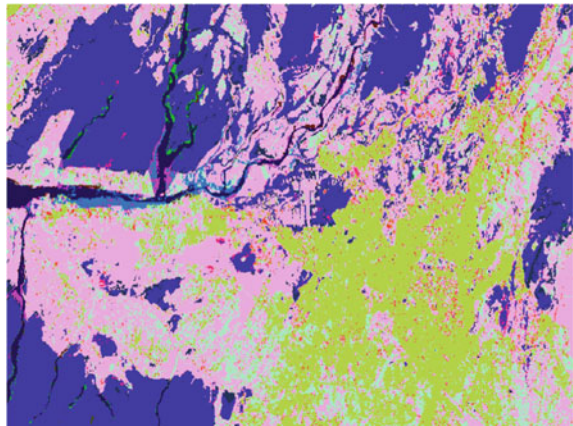


Table 1 Attribute table of matrix union file 2013–18 in Arc GIS

OID	Value	Count	Recode2013	Reccode2018
0	0	0	0	0
1	1	75,884	1	1
2	2	42	1	2
3	3	7429	1	3
4	4	53	1	4
5	5	288	2	1
6	6	131,784	2	2
7	7	15,350	2	3
8	8	1161	2	4
9	9	38,218	3	1
10	10	2348	3	2
11	11	124,032	3	3
12	12	759	3	4
13	13	2845	4	1
14	14	156	4	2
15	15	1689	4	3
16	16	7734	4	4

Table 1 shows the change in pixel count from year 2013 to 2018 between the recoded classes: 1 (urban), 2 (forests), 3 (agriculture and vegetation), and 4 (seasonal river beds). We can use this information to generate a change detection matrix from where we can also calculate the urban land change detection in km². We will create the change detection matrix in Microsoft Excel 2016 for better reliability and performance. A change detection matrix represents the change in pixel count between 2013

Table 2 Change detection matrix for change in pixel count

	1	2	3	4	2018
1	75,884	288	38,218	2845	117,235
2	42	131,784	2348	156	134,330
3	7429	15,350	124,032	1689	148,500
4	53	1161	759	7734	9707
2013	83,408	148,583	165,357	12,424	409,772

Table 3 Change detection matrix for area count in km²

	1	2	3	4	2018
1	68.30	0.26	34.40	2.56	105.51
2	0.04	118.61	2.11	1.14	120.90
3	6.69	13.82	111.63	0.52	133.65
4	0.05	1.04	0.68	6.96	8.74
2013	75.07	133.72	148.82	11.18	368.79

and 2018 of urban area and also detects how much area of forests, agriculture, and rivers have been converted into built-up or urban area during this time period and how much urban area has been converted into forests, agriculture, and water beds. From Table 1, it is seen that 288 pixels of forest lands, 38,218 pixels of agriculture and vegetation, and 2845 pixels of seasonal river beds have been converted into urban land. Table 1 also shows that 42 pixels of urban area have been converted to forests, 7429 pixels to agricultural land, 52 pixels to river bed, and 75,884 pixels remained unchanged during this time period. Table 2 shows the change detection matrix between the years 2013 and 2018 depicting the change in pixel count. Table 3 shows the change detection matrix depicting the change in area in km². Table 3 shows that the urban area was 75.07 km² in 2013 and has been increased to 105.51 km² in 2018 and has been increased by 30.44 km², and percentage increase in area is 40.54%. From the year 2013 to 2018, 0.26 km² of forestland, 34.40 km² of agriculture and vegetation, and 2.56 km² of seasonal river beds have been converted into urban area, and 68.30 km² of urban or built-up area remains unchanged during a span of 5 years. Our main focus is on the change of pixels in urban class, and hence, there is an increase of 33,827 pixels in urban class from 2013 to 2018. In order to convert pixel, count into km², it is necessary to know about the cell size of the classes and then multiplying them by their corresponding pixel count to compute the area.

4 Conclusion

Preprocessing operations of layer stacking and sub-setting are performed on both the Landsat 8 imagers of years 2013 and 2018. Supervised classification technique is used for land cover classification, and accuracy obtained for both the images is above 85%. After the classification process, recoding is performed such that all urban classes are recoded to 1, forest class to 2, agricultural land to 3, and seasonal river beds to 4. After that matrix union method is used for land change detection. A change detection matrix is generated which depicts the change in pixel count from which change in km² can be computed during a span of 5 years. The change in urban area observed in the duration of 5 years is 30.44 km², and percentage increase is 40.54%. From 2013 to 2018, 0.26 km² of forestland, 34.40 km² of agriculture and vegetation, and 2.56 km² of seasonal river beds have been converted into urban area during a span of 5 years. This study is very important for monitoring and future planning of Dehradun city and its natural resources.

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