

Detection Of Change In Land Cover In Jabalpur District From 1991-2021 Using Remote Sensing

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Research Article

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Abstract

Land use/ land cover is an important component in understanding the interactions of human activities with the environment and thus it is necessary to monitor and detect the changes to maintain a sustainable environment. In this paper, an attempt has been made to study the changes in land use and land cover of Jabalpur district in the last 4 decades from 1991 to 2021 classifying majorly in Forest (Medium to Dense), Trees, Waterbody, Settlements & Agricultural fields. The study was carried out through the Remote Sensing and GIS approach using High-resolution Imagery from Google Earth, and LANDSAT 8, 7, 5 imagery of 2021, 2011, 2001, 1991 respectively. The land use/land cover classification was performed based on the Supervised Classification approach available in ArcGIS. GIS software is used to prepare the thematic maps and ground truth observations were also performed to check the accuracy of the classification. The present study has brought out that the Tree cover has been decreased from 12.97–5.40% during 1991-2021 showing a considerable decrease in Forest area as well. The settlement area increased from 4.26% in 1991 to 12.46% in 2021. The areas under natural streams, have shown no significant change and can be considered as a positive sign for sustainable development.

Introduction

Satellite-based remote sensing data are extensively used in the mapping of Land Use/Cover (LUC) of the earth's surface. The impact of LUC changes is noticed globally with significant effects on urban areas vis-a-vis rural areas. LULC mapping is one of the most important applications of remote sensing. Land use is widely used in the development of groundwater resources. The hydrogeological processes such as Infiltration, evapotranspiration, surface runoff, etc. were controlled by land use. The surface cover provides roughness to the surfaces, reducing discharge thereby increasing the infiltration. In the forest areas, infiltration will be higher and runoff will be less whereas in urban areas rate of infiltration may decrease. Remote sensing techniques will give detailed information with respect to the spatial distribution of land use and vegetation type in minimum time and low cost in comparison to other conventional data.

Related Studies

A similar conducted by N.C.Anil, G.Jai Sankar, M. Jagannadha Rao in the southern part of West Godavari district. Their objective was to determine the trend, nature, rate, location, and magnitude of land use/land cover change. GIS software is used to prepare the thematic maps and ground truth observations were also performed to check the accuracy of the classification. Their study showed that the aqua-culture tanks have been decreased from 33.02% to 25.66% during 2000-2010 with a net decrease of 7.34%. Agriculture was also decreased from 43.32% to 37.75% with a net decrease of 5.56% during 2000-2010 (Anil 2011). They classified the land into "Agriculture Fields", "Aquaculture Tanks", "Drains", "Fallow Land", "Mangroves", "Mud Flats", "Plantation mixed with the crop", "Rivers", "Settlements". Their study concluded that one decade the significant positive observations as per environment is concerned is the natural systems represented by natural drains, mudflats, mangroves, and river systems indicated significant change. Another study was conducted by Anitha Selvasofia, S Shrividya, S Karunya, in

Coimbatore District in Tamil Nadu state in 2008. Their paper describes adjustments in the Land use/land cover pattern of Coimbatore District. Their study found that the cropland is decreasing at the cost of hazard growth of plantations and settlements (Anitha, 2021). The Study conducted by Vineela Nandam & P. L. Patel on the western coast of Gujarat state in India proved to be helpful in a wide range of applications including the development of flood risk maps, systematic planning of urban infrastructure, analysis of urban heat islands, and averting the coastal disasters in the future. They did a critical comparison of SVM and RFC classifiers, finally, a hybrid approach is proposed as a combination MNDWI-CBI-SVM for mapping of the study area with Overall Accuracy of 90.5% and a Kappa value of 0.87. The performance of classified LUC maps was validated using reference data of high-resolution images of Google earth and sentinel satellite images (Nandam & Patel, 2021). Phukan, Thakuria, & Saikia performed analysis using imagery from the satellite LANDSAT ETM and IRS LISS III 1989 and 2009 are used which are obtained from National Remote Sensing Centre, Hyderabad. Both are acquired between February and April during the dry season. The resolution is meter/pixel in LANDSAT and 23 meters in LISS III image. Digital land use land cover classification through supervised classification method is done to perform the LULC classification in ERDAS IMAGINE 9.1 software environment. They classified land into "Dense forest", "Sand Bar", "Water Body", "Open Forest", "Cropland", "Settlement", "Riverine grassland", "Scrubland" & "Tea plantation". Their study showed major changes occurred in cropland and scrubland (Phukan & Saikia, 2013). The study was conducted by Sarma, G Murali, Malini in Godavari Delta region conclude that land use/land cover alterations might be responsible for local level climatic changes. In their study, Landsat MSS image of 1973 on 1:250,000 scale and IRS-LISS-II imagery of 1992, LISS III imagery of 1997 and 1999 (each on 1:50,000 scale) have been used & features were categorized into three broad types namely, intensive agriculture/plantation, seasonal fallow/barren land and wetland. It also concluded, decreasing trend in daytime temperatures and increase of nighttime temperatures, besides increased rainfall during the past three decades in the Godavari deltaic region are the result of a large-scale increase in vegetation cover as well as wetlands in the form of shrimp/fish ponds in the region (Sarma & Krishna, 2001).

Study Area

Jabalpur district, the present study area is a physiographical part of the Narmada valley of Madhya Pradesh covering about 5,655 km² (Figure-1). Although the valley exhibits quite a monotonous landscape, the study area is a combination of landscape with altitudinal variation in the valley itself from flood plain areas of the Narmada and its tributaries through high old alluvium to still higher foothills areas of the tertiary folds in Madhya Pradesh.

Jabalpur boundary ranges from 23° 18' 5.884" - 23° 11' 9.1824" in Latitude, 79° 97' 43.80" - 79° 58' 27.76" in Longitude coordinates. Jabalpur district covers an area of 519,800 hectares. The boundary is demarcated by Katni-Damoh district in North, Mandla in South, Shahdol in East & Narsinghpur district in West. Administratively Jabalpur district is divided into 1458 villages, 542 village panchayat & 7 Blocks/towns. According to the 2001 census, the total population of the study area is 24,63,289 persons. The climate of Jabalpur District M.P. is characterized by a hot summer and general dryness except during

the southwest monsoon. The cold season, December to February is followed by the hot season from March to about the middle of June. The period is the middle of June to September in the southwest monsoon season. October and November form the post-monsoon or transition period. The average annual rainfall of Jabalpur District is 1279.50mm. Jabalpur received maximum rainfall received during the southwest monsoon period i.e. June to September. About 90% of the annual rainfall is received during the monsoon season. Only 10% of the annual rainfall takes place between October to May period. Thus, surplus water for groundwater recharge is available only during the southwest monsoon period.

Remote Sensing

Remote sensing refers to a wide range of technologies used to detect Earth's surface, usually using aerial or satellite platforms. The earliest use of remote sensing in soil science was the development of aerial photographs as base maps for soil survey in the United States in the 1920s and 1930s (Bushnell, 1929), which represented a major advance over creating base maps using plane tables and odometers (Worthen, 1909) or using topographic maps when they were available as was common prior to the use of aerial photography (Miller and Schaetzl, 2014). Digital remote sensing information was made widely available in the 1970s when the United States launched the Landsat program, one of the most popular sources of data for digital soil mapping. Seven Landsat satellites were launched during the 20th century with progressively increasing resolution and capabilities (Table 1.3). Another remote sensing technique developed in the 20th century that is seeing increasing use in modern soil science is LiDAR (McBratney et al., 2003; Brubaker et al., 2013).

Imaging in remote sensing can be carried out from both satellite and aircraft platforms. In many ways, their sensors have similar characteristics although differences in their altitude and stability can lead to very different image properties. There are essentially two broad classes of satellites: those satellites that sit at geostationary altitudes above the earth's surface and which are generally associated with weather and climate studies, and those which orbit much closer to the earth's surface and that are generally used for earth surface and oceanographic observations. Usually, the low earth orbiting satellites are in a sun-synchronous orbit, in that their orbital plane processes around the earth at the same rate that the sun appears to move across the earth's surface. In this manner, the satellite acquires data at about the same local time on each orbit. Lower earth-orbiting satellites can also be used for meteorological studies.

LANDSAT:

Landsat is part of a global research program known as NASA's Mission to Planet Earth, a long-term program that is studying changes in Earth's global environment. The goal of Mission to Planet Earth is to provide people with a better understanding of natural environmental changes. Mission to Planet Earth data, which will be distributed to researchers worldwide at the cost of reproduction, is essential to people making informed decisions about their environment.

Methodology

To perform change analysis of the study area, images from the satellite LANDSAT are used which are obtained from USGS. The images are acquired for the same study period to retain consistency. Digital land use land cover classification through the supervised classification method is done to perform the LULC classification in ArcGIS 10.8.0, and the results were compared. Area statistics of each land use category are calculated in square kilometers in the attribute table in ArcGIS.

Following are the steps followed:

1. The very first step is to download the LANDSAT Image tile, for the study area. For this study, our study area is Jabalpur District & the data is downloaded from USGS Earth Explorer. we go to the study area for which we need to download the LANDSAT Data.
2. After zooming, up to a level, where our study area is roughly visible, using the coordinates make a polygon covering the study area.
3. Now, when our study area is marked, the next step is to select what kind of data we, are looking for? Here in this study, we are looking for LANDSAT Data, so using Dataset Tab, we will select Landsat > Landsat Collection 1 > Landsat Collection 1 Level 1 > Landsat 8 OLI/TIRS C1 Level – 1. For the year 2011, Landsat 7 ETM data is selected, & for years 2001, 1991 Landsat 5 is selected.
4. Now using the additional Criteria Option, data with less than 20% cloud cover and for the specific time (see Table.1) the period for which data is required is selected. We need data from 1991-2021, specifically recorded in the first two months of the year to increase uniformity.
5. Now Results, show a list of tiles available for various dates, the necessary tiles, covering the full study area with specific data which is required is selected & downloaded.

Performing Supervised Classification:

1. The downloaded dataset consists of 12 processed Black & white .TIF images representing each band/sensor from which data was recorded.
2. Using the Composite tool available in the ArcTool Box, Band 1 to Band 7, images are merged into one RGB image.
3. If there are more than 2 images tiles area covering the study area, using Composite to a New Raster tool available in ArcTool Box, 2 tiles are combined into 1 image.
4. The images consist of background values which does not contain any values, shown by black color. By going into Properties > Symbology > Unique values > Show List > Remove > Apply, the non-data values are removed. When working with more than two images, removing background values helps when extracting only the area which needs to be studied. Next, using a shapefile, of Jabalpur district only, the RGB image is clipped into a new Raster image using the Extract by Mask tool available in ArcTool Box.
5. Now, to perform the Supervised Classification, we need to collect Training Data values for the model to learn and perform Supervised Classification. Using SAS-Planet Software, High-Resolution Georeferenced imagery from 7 different places within the study area is downloaded for specific

dates for which imagery is downloaded. And using the Polygon tool available in Spatial Analysis Extension in ArcTool Box, we collect as many training samples as possible to increase better classification. In total 10 categories in which land is classified:

- a. Barron Land
- b. Dense Forest
- c. Medium Forest
- d. Open Field
- e. Agricultural Land (No Vegetation)
- f. Agricultural Land (With Vegetation)
- g. Sandy Area
- h. Settlements
- i. Water Body
- j. Trees

6. After collecting the training samples, the file is saved into a Signature File and as a Shape layer for future reference.

7. Next step is to perform Supervised Classification, this is implemented by using the Maximum Likelihood Classification tool available in Spatial Analysis Extension in the ArcTool Box. First, the RGB Study area is given, followed by the Signature File and an output path and name where the new file will be saved.

8. After running the Supervised Classification, a new file is created. Now our main goal is to calculate the area, to do that we need to convert the Raster into Polygons. This is done by Raster to Polygon (Conversion) tool available in the ArcTool Box.

9. After converting all Rasters into Polygons, by using the Dissolved tool in the Geo-Processing Tool Box, All Small Polygons are dissolved into 1 polygon based on their Class.

Results And Discussion

The results clearly indicate a reduction in individual trees and medium forest area in the Jabalpur district. Settlements have been constantly increased. Barron land & waterbody has not changed much in last 4 decades.

Years →	2021	2011	2001	1991
Class Name	Area (Percentage)			
Barron land	24.19	25.24	24.47	28.06
Dense Forest	5.28	4.80	5.42	6.21
Medium Forest	9.86	9.66	11.06	6.19
Open Field	9.56	11.22	9.83	12.30
Agricultural Field (No Vegetation)	26.47	20.44	21.35	9.04
Agricultural Field (With Vegetation)	7.42	7.16	6.12	14.70
Sandy Area	3.18	4.46	4.62	2.54
Settlement	4.84	4.58	4.40	4.26
Trees	5.40	8.66	8.95	12.97
Waterbody	3.81	3.80	3.79	3.73
Total	100	100	100	100

Table 2. Changes in Land-use of Jabalpur District from 1991 to 2021.

Conclusion

Supervised classification using LANDSAT satellite imagery on ArcGIS is a very quick, easy & powerful way to detect changes in land features. In this study, we classified land use majorly in Forest, Trees, Waterbody, Settlement Agricultural fields. The results clearly show major increment in Settlements in Jabalpur district & reduction in Trees & Forest see figure 3. Agricultural fields clearly show major increment as more and more land is being used for farming to support the food demand of the population.

In the future, the imagery will be processed using Artificial neural networks, with more land classes, including smaller features like roads natural streams/ rivulets, mangroves, etc.

Declarations

Conflict of Interest Statement:

The authors whose names are listed immediately below certify that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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Tables

Tables 1 and 1.3 are not available with this version

Figures

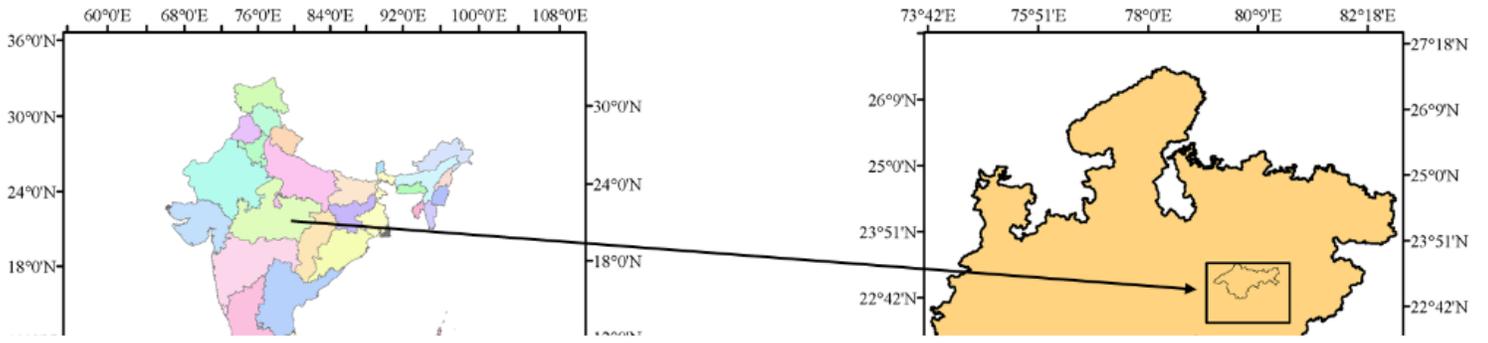


Figure 1

Study area Jabalpur District.

Figure 2

3D Graph showing changes in Land use in Jabalpur District from 1991 to 2021

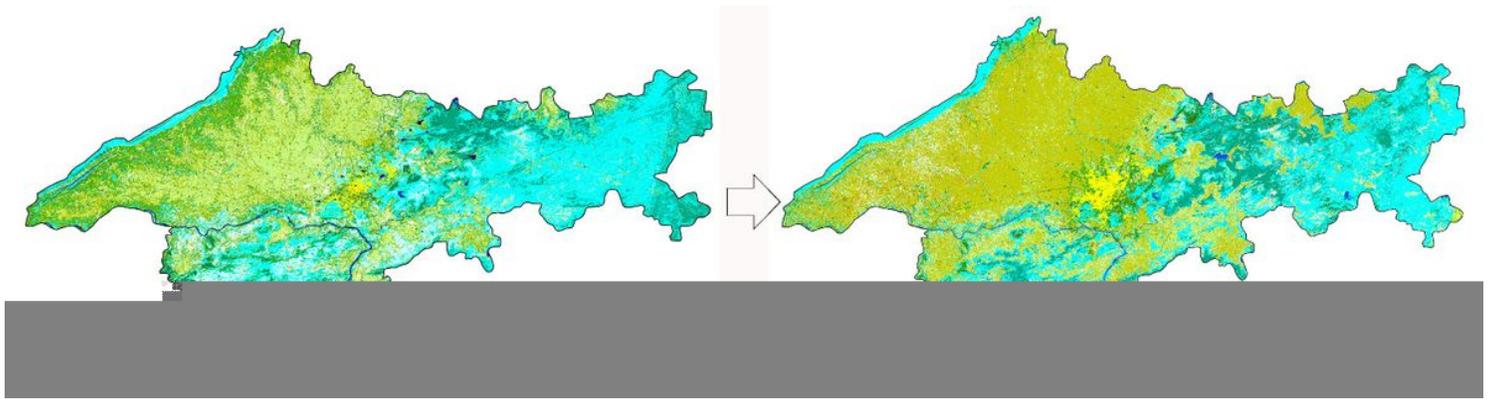


Figure 3

Change Illustration in 4 Decades

Figure 4

Jabalpur District Land Use Classes in 2021