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Quantifying Climate Change Effects on Land Use-Land Cover Through Geospatial Analysis

Shiwani [1]

[1]Centre for Climate Change and Water Research, SGVU, Jaipur, India

*E-mail: sshiwanisinhaa@gmail.com

ABSTRACT

For the effective utilisation of the world's resources, it is essential to monitor changes in land cover. The pattern of distribution of land use-land cover (LULC) is steadily influenced by climatic fluctuation. The creation of LULC classification maps using geospatial software is one of the most thorough and effective methods there is. These maps significantly improve the overall use of a region's urbanised commercial, and farming regions. The investigation showed how remote sensing and geographic information systems are capable of retrieving and analysing geographical and temporal data. In this study, an effort was made to create geographic information for Moinabad Mandal's LULC. In the present investigation, two Landsat photos that were gathered over time (2011 and 2022) and presented present-day and historic LULC circumstances for the Moinabad Mandal were classified under supervision. From the United States Geological Survey's Earth Explorer website, Landsat pictures of Moinabad Mandal's OLI/TRS and ETM+ are gathered. Following image preliminary processing, images were supervised image categorised into various land use classifications. Water, body of water, built-up area, forest, agricultural land, barren land, and vegetation have been recognised as the six land use classes. As a result, LULC were designed specifically for every investigation year. The difference between LU/LC in 2011 and 2022 calculated from satellite data suggests a significant increase in the amount of developed land, forest, bodies of water, and other areas. *The percentages of land used for vegetation, trees and shrubs, waterbodies, and barren terrain have all dropped over the past decades, correspondingly by 24.48%, 30.125% and 40.33%.* The large loss of agricultural and vegetative land over the study period is also underlined. This trend may be linked to the study area's growing urbanisation. This work has used spatial approaches to evaluate the current and earlier LULC in terms of urbanisation and fluctuation in meteorological indicators, such as precipitation and temperature. Research revealed the impending tendency of global warming and its effects on

LULC for improved utilisation of land assets. Also, the findings of this study will help in the development of environmental mitigation plans.

KEYWORDS: Land use, Land Cover, Remote sensing, Urbanization, Spatial temporal data, OLM (Operational Land Imager) and TIRS (Thermal Infrared Sensor), ETM+ (Enhanced Thematic Mapper Plus).

INTRODUCTION

Urbanisation shows the migration of people form countryside to urban regions and serves as a symbol for the growth and modernisation of cities. At present, cities are home to over fifty percent of the human race [1]. Cities are quickly growing with regard of both physical facilities and technological development as a result of growing populations in the past few decades [2,3], in an effort to build sustainable, long-term societies [4]. Land use is a generic term to feed human activities that occur on the outermost layer of a piece of property, including farming, homes or industrial regions. Land cover involves the physical and biological characteristics of the system of the earth, such as soil, rocks, plants, snow and towns [5]. The term ecosystem, natural, and geochemical reactions all depend on the cover of land, including activities like carbon sequestration in vegetation [6], biogeochemical nutrient cycling [7], nitrogen (N_2) fixation [8], and evapotranspiration [9]. In addition to human activity, natural processes such as recurrence and additional natural events also contribute to shifts in the landscape. The future use of land is determined by the expanding needs and activities of humans [10, 11]. An essential component of production for commercial activity, habitation, and other types of established infrastructures is a lack of land resources [12]. The agricultural sector operations, mineral extraction, communities, and additional established areas [13–17] are examples of anthropogenic practises that have an impact on the availability of freshwater, ecological systems, the quality of the air, global warming, and other necessities.

"Land conversions" or "the land use shift" refers to a persistent and essentially constant occurrence that goes hand in hand with economic advancement and growing populations [18]. Uncontrolled conversion of land, nevertheless, has negative effects on the ecosystem and has substantial implications. preparing, leadership, and efficient control all depend on having precise data on the pace and scope of these shifts [19,20]. The overabundance of natural resources surpasses the ability of nature to replace itself amid rising industrial development, urbanisation, and other forms of manmade activity. Land is the main focus of such human-caused events which represent significant risks of plant and animal life, food supplies, and forests. In order to protect the region's land assets for today and future, it is crucial to keep an eye on shifts in land utilisation and covering. Along with future study efforts on climate change [24] & improved utilisation of resources, data as well as associated data on land use and land cover (LULC) changes are extremely important for the effect evaluation of human-induced impacts on ecosystems [21–23]. Monitoring, followed by models, that differ in space and time, is crucial for understanding the mechanisms behind land dynamics [25]. For the appropriate comprehension, utilisation, and oversight of earth's resources, the link between individuals and the natural world, and the structure for future preparation, this based on information surveillance provides considerable information to managers across all stages (national and international) [26-27]. The breakdown and variation of three-dimensional structures may have got worse conventional landscape characteristics and organic landscapes in spite of better use of the available land for meeting various human needs [28-29], which could also negatively impact ecological diversity and the long-term sustainable development of a city. The breakdown and variation of three-dimensional buildings might have got worse conventional landscape characteristics and organic sceneries, in spite of better use of the land accessible to meeting different needs of people [30,31], and this could also have an impact on biodiversity and the long-term sustainable growth of a city [32]. Additionally, Moinabad's altered land usage had a negative effect on the area, and the building methods used were neither ecologically sound nor environmentally friendly.

Our interactions with the environment, global warming, and socioeconomic factors [33–41] all contribute to the widespread LULC alterations. Therefore, variables like the human population explosion, urbanization, the quick industrialization, and the increase in human activities43 have caused ongoing, unanticipated alterations to the LULC [42–49]. Due to the effects of human increase on scarce resources, land cover has changed [50]. Urbanisation, also known as sprawling cities, is a global movement that is continuously influenced by different biological causes and manmade practices [52]. It involves advancement, economic variables, and growing populations. The LULC modifications are especially troubling on a global scale because they have a negative impact on organisms and their functions, economic growth, and the environment [53–55], in addition to changing the terrain, losing biodiversity, destroying forests, accelerating climate change, and causing floods and other natural disasters [56–58]. In order to develop a more effective land use policy [59, 62] modifications in LULC can be tracked in regard to the depletion of land for agriculture and urbanization [63] the degradation of flora and woods, and so on. Remote sensing (RS) techniques collect information from the surface of the earth without establishing physical contact. They have proven to be effective in studying land cover changes, evaluating urban LUCC and sustainability characteristics across various spatial scales, and even projecting future ecological and economic growth policies [64–65]. In order to develop a more effective land use policy modifications in LULC can be tracked in regard to the depletion of land for agriculture and urbanization the degradation of flora and woodlands, and so on.

By analysing multiple photographs of the same location, the method known as "change detection" can be used to spot changes in surface patterns over time. Urbanization, surveillance of changes in woodland and vegetation, wetland, the LULC change, and terrain monitoring are just a few examples of how change detection may be highly helpful for efficient resource preservation and administration. These methods for identifying changes rely on multi-temporal satellite pictures given by remote sensing (RS) and can be divided into two categories: object-based and pixel-based [66]. In India, a number of studies have reported about LULC change detection analysis. Change identification research relating to sprawling cities, growing populations, and the loss of land for agriculture in Saharanpur city was published with the aid of satellite images [67]. The findings showed that the main areas of landscape alteration were non-agricultural lands. The results of an examination of the highly populated Varanasi city [68] utilising remote sensing (RS) and a GIS (geographic information system) in Tirupati [69] showed that land used for agriculture in the area was lost to residential neighbourhoods and other uses as a result of urban expansion. Geospatial technology was applied in Sahibganj, Jharkhand, to track the LULC variation in agricultural system from 2005 and 2011[70]. According to reports, land use altered in a variety of categories, including related to agriculture, empty, and forest territory, which was transformed into a quarry class, and wasteland-dense brush, which was converted into a business sector. IRS 1A Linear Imaging Self Scanning

Sensor II (LISS-II) and IRS 1D LISS-III satellite observations for the years 1988 and 2011, accordingly, were used in the course of the research. Using the aid of remote sensing (RS) and geographic information systems (GIS), Leelambar and Katpatal reported the time series study of LULC and index of vegetation change using LISSIII data in Nagpur, Maharashtra [72]. Evidence from the study was supplied that is crucial for protecting biodiversity and wisely using them. Geospatial technologies aided in the tracking of LULC changes brought on by climate change. Geospatial technology was used by Basha et al. to conduct the LULC investigation at Somavathi River Anantapur, Andhra Pradesh, India [73]. The LULC maps was created using ArcGIS & ERDAS Imagine 9.3 software with IRS P-6 LISS-III multi-temporal sets of data from 2005–2006 and the end of 2010 [74]. The findings showed that while ground traits like built-up areas and unused land have shifted slightly, crops have shrunk over this time. Remote sensing satellite photos can be classified using a variety of methods, including supervised and unsupervised classification. To identify changes in LULC, supervised classification is used to categorise image pixels into various attributes. The classification method, in which images are clustered into various specified classes96, is used to analyse temporal satellite images and subsequently extract various attributes [75].

Detection Based on (MLC) Maximum Likelihood.

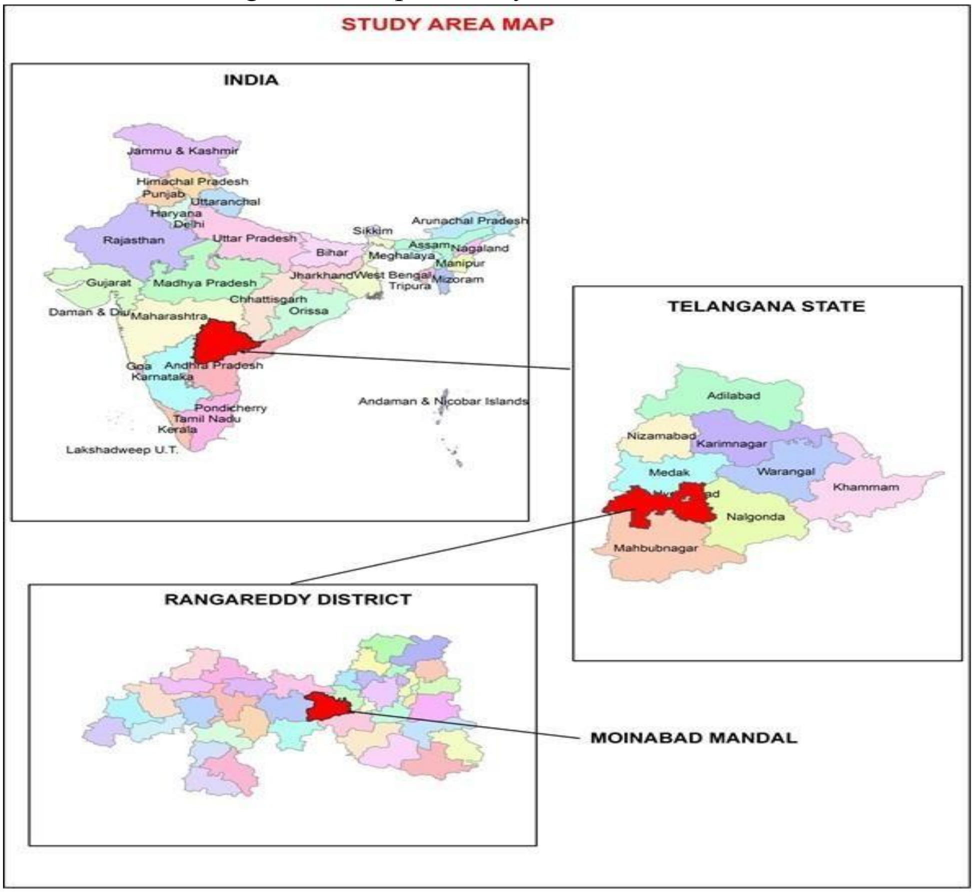
The MLC, that relies on the most probable membership of pixel of an uncertain class assigned to a specific land use class, is one among the more effective algorithms for classifiers now available [76]. The MLC (Multilevel Classifier) is a parametric classification that performs significantly better when compared to other parametric classifier because it is based on Baye's theorem, which takes into account the variance-covariance in the class distribution data. The MLC method really calculates the likelihood that a pixel98 will fall into the class that is most likely to be associated to a characteristic. Throughout this research, agricultural use–land covering maps produced from satellite photographs that were classified into distinct classes based on maximum likelihood (MLC) method were subjected to the detection comparing (pixel by pixel) method.

Material and Methods

Study Area - There are 27 mandals total in the state of Telangana of the nation's Ranga Reddy district, including Moinabad. Its headquarters are at Moinabad, and it is run by the Chevella revenue division.

Moinabad is located 29.8 kilometres from Hyderabad, the state's capital city. The current research region covers an overall area of 206 square kilometres and is located between the latitude of 78 11'26"E and 78 20'50"E, as well as its longitudes of 17 14'36"N and 17 24'34"N. RajendraNagar, Shankarpalli, Chevella, Shabad, and Shamshabad in Mandals are located on either side of Moinabad Mandal.

Figure: 1- Map of Study area



METHODOLOGY

Using two sets of imagery from satellites that were acquired for two separate time periods (2011 and 2021) it was possible to determine the land cover and use of MOINABAD Mandal. We used supervised land use and land cover categorization as a processing strategy. The foundation of supervised classification is the idea that a user can select a sample of pixels from an image that best represent particular classes, and then instruct the system that processes images to utilise these training sites as models for classifying the other pixels in the picture. The user's perspective informs the selection of the training locations. The user also chooses a limit for how similar the pixels must be in order to join them. These bounds are often defined by the spectral properties of the test zone, plus or minus a specific increment. The user can also filter out the number of categories that an image

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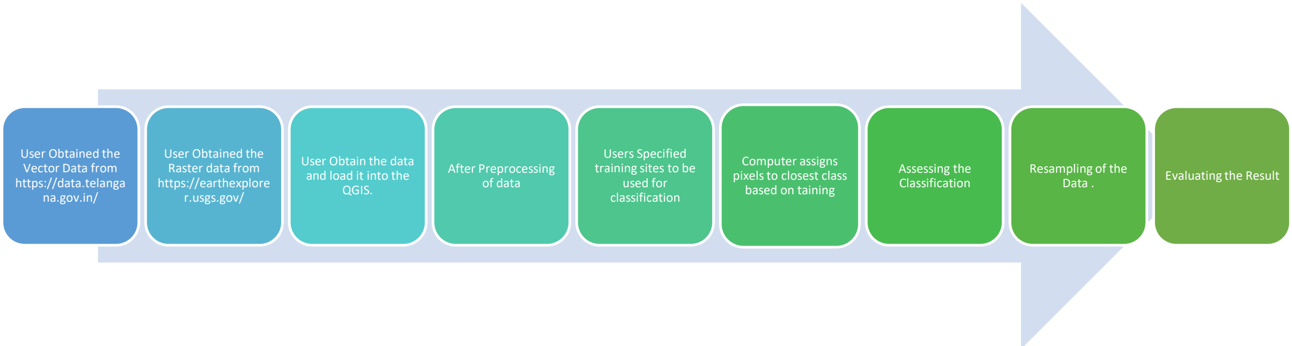
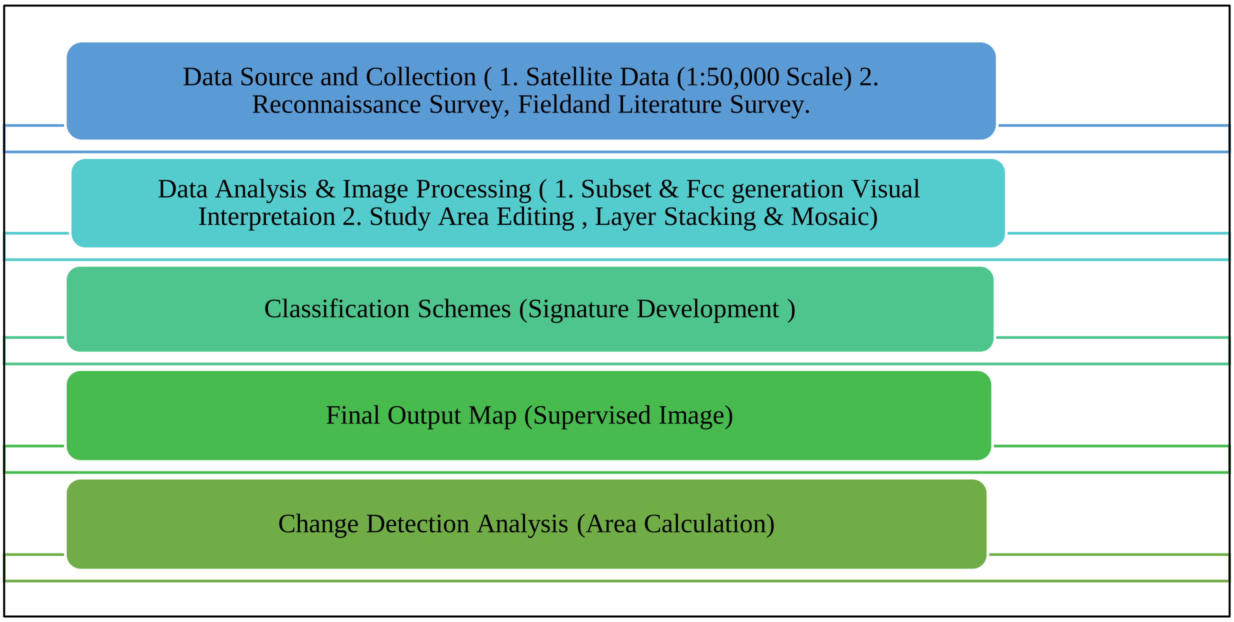
is divided into. Numerous analysts combine supervised and unsupervised classification techniques to generate final output analysis and classified maps. The schematic of the steps used in supervised classification are given below.

Figure: 2- Process Chart of the LULC



All forms of data pertaining to the geography of the earth's system are gathered, stored, handled, examined, managed, and finally displayed using a geographic information system (GIS) [77]. Various data sets are initially gathered and created from sources such topography maps and satellite photos) for the study of LULC movements. Then, using image processing tools like ERDAS Imagine 2014 and QGIS 3.12 software, georeference satellite pictures or topographical maps were done. Using the processing of images, false colour composite (FCC) production, visual comprehension of ground characteristics, and image classification techniques, the georeferenced photos were then used to create maps of land use and cover. The output data/land use/land cover map, which provides general data about the region's entire area extent, the area covered by various features, and its subsequent modifications over time. To identify modifications to land cover attributes, it is necessary to have verified algorithms for classification (Maximum Likelihood Classifier - MLC) before supervised classification of FCC images for different ground features such as water bodies, agricultural land, vegetation/trees, fallow/barren land, and forests. Figure 3 presents an overview of the process.

Figure :3- Overview of Methodology



Information collected by the Linear Imaging Self Scanning Sensor-III (LISS-III) for the years 2011 and 2021 were obtained for change detection investigations via the National Remote Sensing Centre (NRSC), Hyderabad. Following this, interpretive keys (Table 1) based on FCC images of various ground characteristics in the study region were prepared [78]. The region was divided into different groups according to numerous surface characteristics including water bodies, urban area areas/human towns, land used for agriculture, plants, forests, and fallow land using the maximum likelihood classification (MLC) algorithm as the basis for the classification approach. With the aid of the QGIS software, the satellite photos were supervised classified.

S. No	**Ground Feature**	**Size/Shape**	**Tone**	**Pattern**	**Texture**
1	Water	Regular	Light to Dark Blue	Dispersed	Smooth
2	Agricultural land	Fixed	Light to Dark Pink: Light Brown	Regular	Smooth
3	Built-up area	Irregular	Grey: Cyan	Clustered	Mottled
4	Vegetation/Forest Cover /Tree	Irregular	Dark Pink: Light Red	Dispersed	Rough

5	Fallow Land /Barren Land	Irregular	Bright White: Grey mixed	Dispersed	Medium to Course

Table :1- Visual Interpretation Key of Satellite Data

Data Set

Earth Explorer (*earthexplorer.usgs.gov*), a website run by the United States Geological Survey, provided Landsat satellite pictures of Moinabad Mandal for the research's information sources for the years 2011 and 2021 (Table 2). Additionally, the governing state border was drawn in zone 43 using the universal Mercator projection, and later, the administrative limits of Moinabad were trimmed using satellite pictures [79].

Satellite	Date	Sensor	Resolution	Path	Row
Landsat 8	05-05-2011	OLI/TRS	Spatial(30m)	144	48
Landsat 7	10-11-2011	ETM+	Spatial (15m for pano and 30m for VNIR/SWIR)	144	48

Table :2- Satellite Datasets used for study area

Software and Platforms Used

Image processing was carried out using QGIS version 3.12.3. Prior to processing, radiometric adjustments were made to the digital satellite data. Additionally, the Google satellite Hybrid was utilised for picture interpretation, and features from digital images such tone, texture, shape, position, association, pattern, etc., were employed to detect land usage. The Land Acquisition Tool is employed to determine the PATH and ROW of the study area [80].

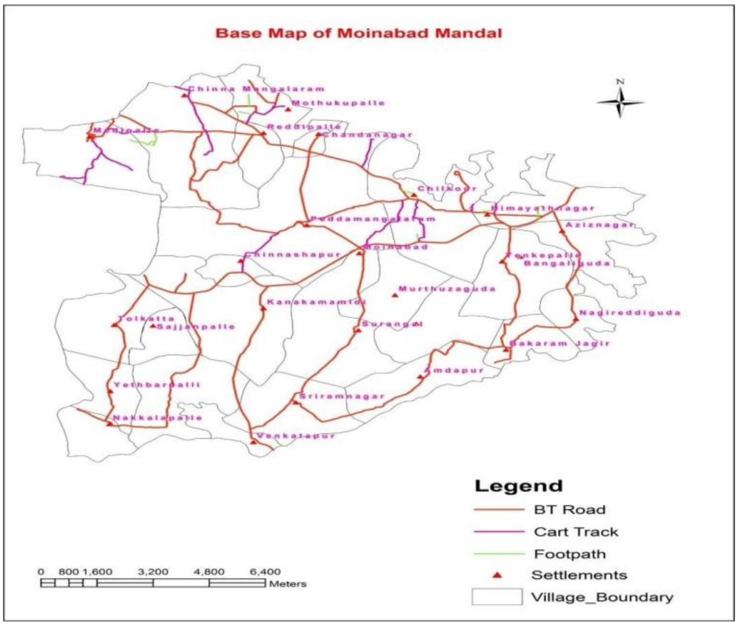
Result and Discussion

Land use Land Cover Classification- After radiometric rectification or picture improvement, the image is next classified using supervised classification techniques. According to the training classes (signature) supplied by the consumer based on his field expertise, the maximum probable hood approach will classify an image in supervised classification approaches (Lewinski et al., 2004). The method receives instructions from the user's training set regarding the proper pixel types to employ for various forms of land cover [81]. Last but not least, the classification paints a picture of the land use as well as the land cover of the area beneath study. Four types of topography were found in the study area: build up, open space, vegetated, and water bodies. The six Level-I groups that make up the Mandal's land use/land cover categories are: Waterbodies, Built-up Area, Forest, Vegetation, Agricultural Lands, and Other.

False Color Composite (FCC) image generation- The FCC pictures of the satellite imagery were created on a 1:50000 scale for the years 2011 and 2021 using the "Layer stacking" and "Mosaic" techniques. The '432' frequency combo was employed for each satellite data set between the years of 2011 and 2021 for the 'layer stacking' process [82]. Each image for the Moinabad Mandal is made up of two sceneries (with different Path/Row), which were combined using a "mosaic process." The Moinabad Mandal's shape file was then used to build subsets for each satellite data collection.

Base Map - A base map is a diagram containing geographic features that are used as points of reference for location. Roads, rivers, settlements, and other elements are typically depicted on base maps. The architecture of a base map frequently includes a geodetic control network

Figure: 2 – Base Map of Moinabad Mandal



Changes Found in LU/LC - Several years Land Use/ Land Cover (LULC) maps have been contrasted. Over a decade, the LULC of the study region saw significant change [84]. As a result, the contrast of LULC for two separate eras serves as the foundation for data analysis and interpretation. The research area will undergo significant changes between 2011 and 2021 (Table 2).

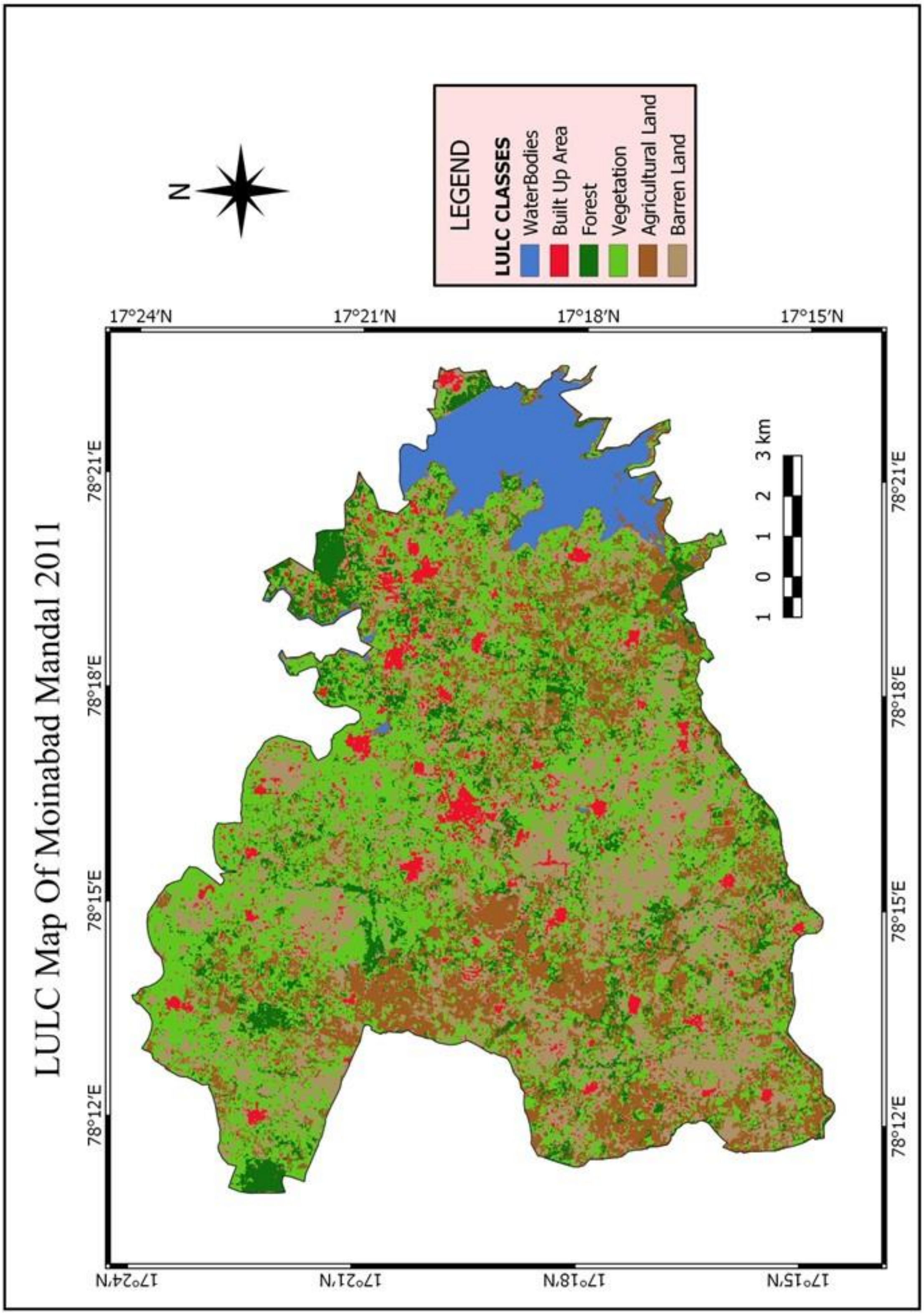


Figure :2- LU/LC Map of Moinabad Mandal in the year 2011

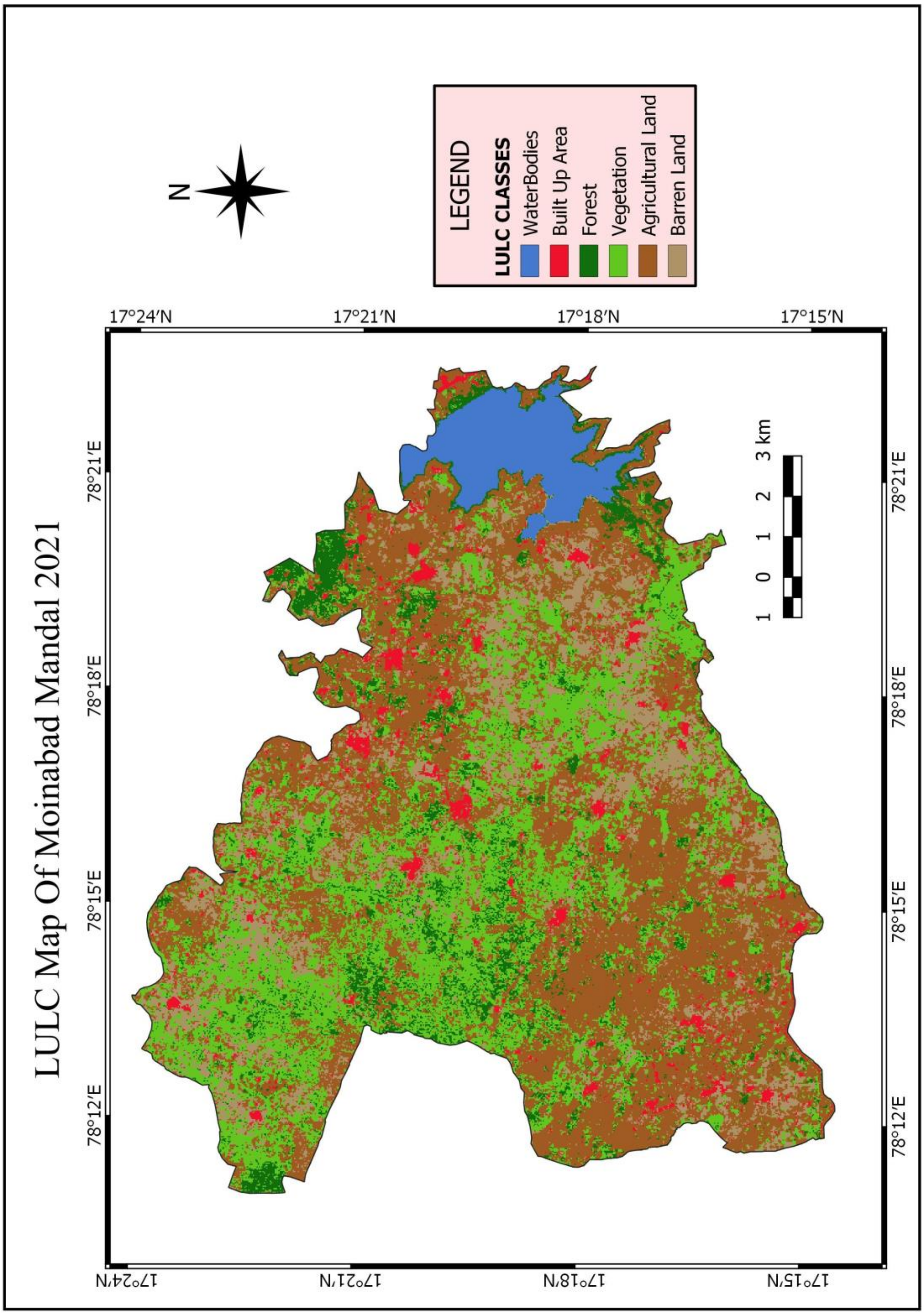


Figure :3- LU/LC Map of Moinabad Mandal in the year 2021

Table :3 - LU/LC classification of study area in Sq Km

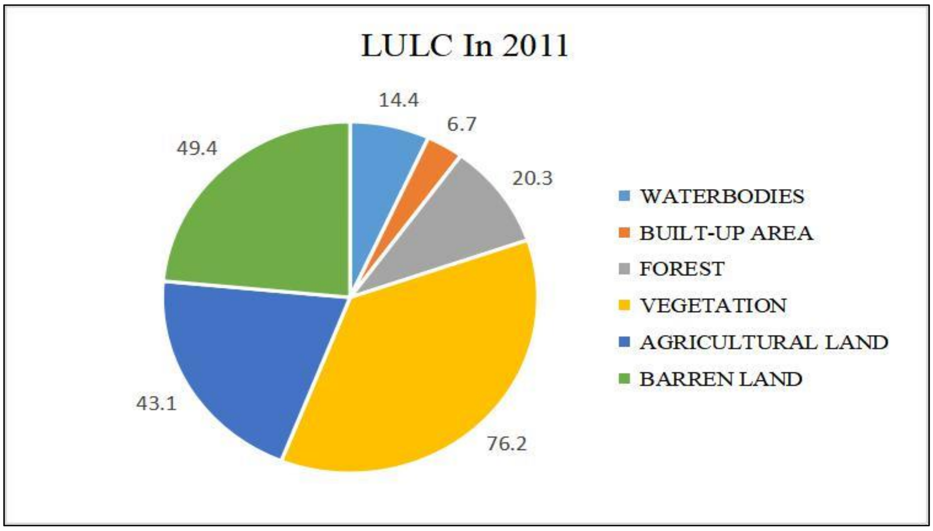
LU/LC Category	2011	2021	Difference in Area	Percentage (Inc. and Dec.)
Water Bodies	14.385	10.052	4.3335	30.125 % (Dec.)
Build-up Area	6.709	10.6758	-3.9663	59 % (Inc.)
Forest	20.311	16.181	4.1301	20.334 % (Dec.)
Vegetation	76.211	57.548	18.6633	24.48 % (Dec.)
Agricultural Land	43.0812	86.1705	-43.0893	100 % (Inc.)
Barren Land	49.410	29.4813	19.2987	40.33 % (Dec.)
Total	210.0456	210.0456	0	

Image Classification: The maximum likelihood classification (MLC) approach, which outperforms various classification techniques including hybrid and parallelepiped classification [85], was used to classify satellite imagery through supervised classification. The spectral variability that served as the foundation for supervised classification is revealed by unsupervised classification. As demonstrated in Figure 3, training samples for supervised classification were created up of five distinct the ground features: water, built-up areas, agricultural land, vegetation/trees, and fallow land. Utilizing the "Areas of Interest (AOI) tool," a spectral signature file was made based on the training samples. The selection of categories of interest for every attribute came next. The satellite pictures were classified into similar/corresponding classes according to the classifier utilized using spectral signatures (input to MLC) and training data [86].

The issue of biogeochemical cycles, the decline in productive biological diversity, degradation in environmental excellence, degradation of farming lands, depletion of wetland areas and degradation of wildlife and fish habitats has made understanding of land use and land cover crucial [87]. Rapid population increase, rural-to-urban migration, undervaluation of environmental services, impoverishment, knowledge of geophysical constraints, and usage of environmentally unfriendly technologies are some of the key causes of LU/LC shifts [88].

The finished output gives a general picture of the Moinabad Mandal's key land use characteristics between 2011 and 2021 (Figures 2 and 3). The available space in each class has been computed using the QGIS software environment's geometry and fundamental statistics tools, and it has been graphically depicted (Figures 4 and 5).

Figure:4 – LU/LC Pie Chart of 2011



Regarding the state of the general landscape and the kinds and extent of change that have taken place, graphs and area estimates offer an extensive collection of information (Table 3). Following the contrast of the picture interpretation findings for the photos from 2011 and 2021, Table 3 displays the predicted land use changes. The findings also indicate that population increased from 6.7095 square kilometres in 2011 to 10.6758 square kilometres in 2021.

Figure: 5- LU/LC Pie Chart of 2021

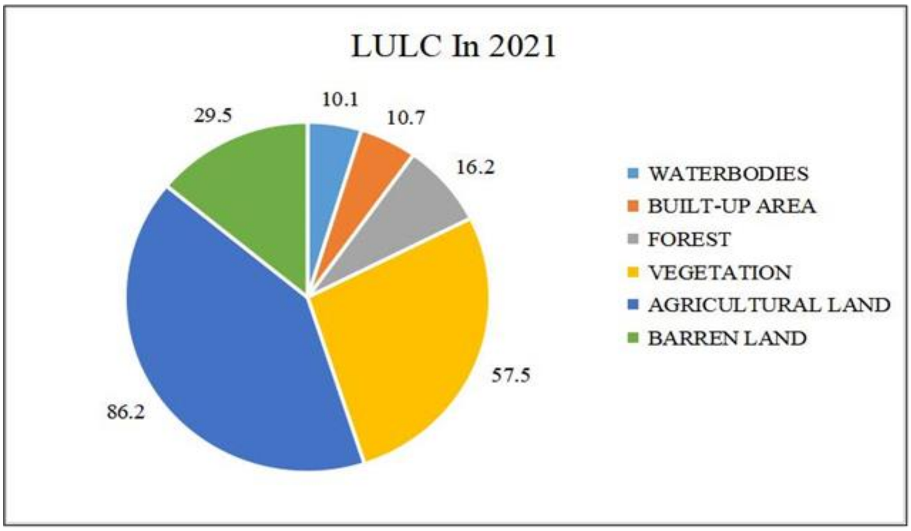
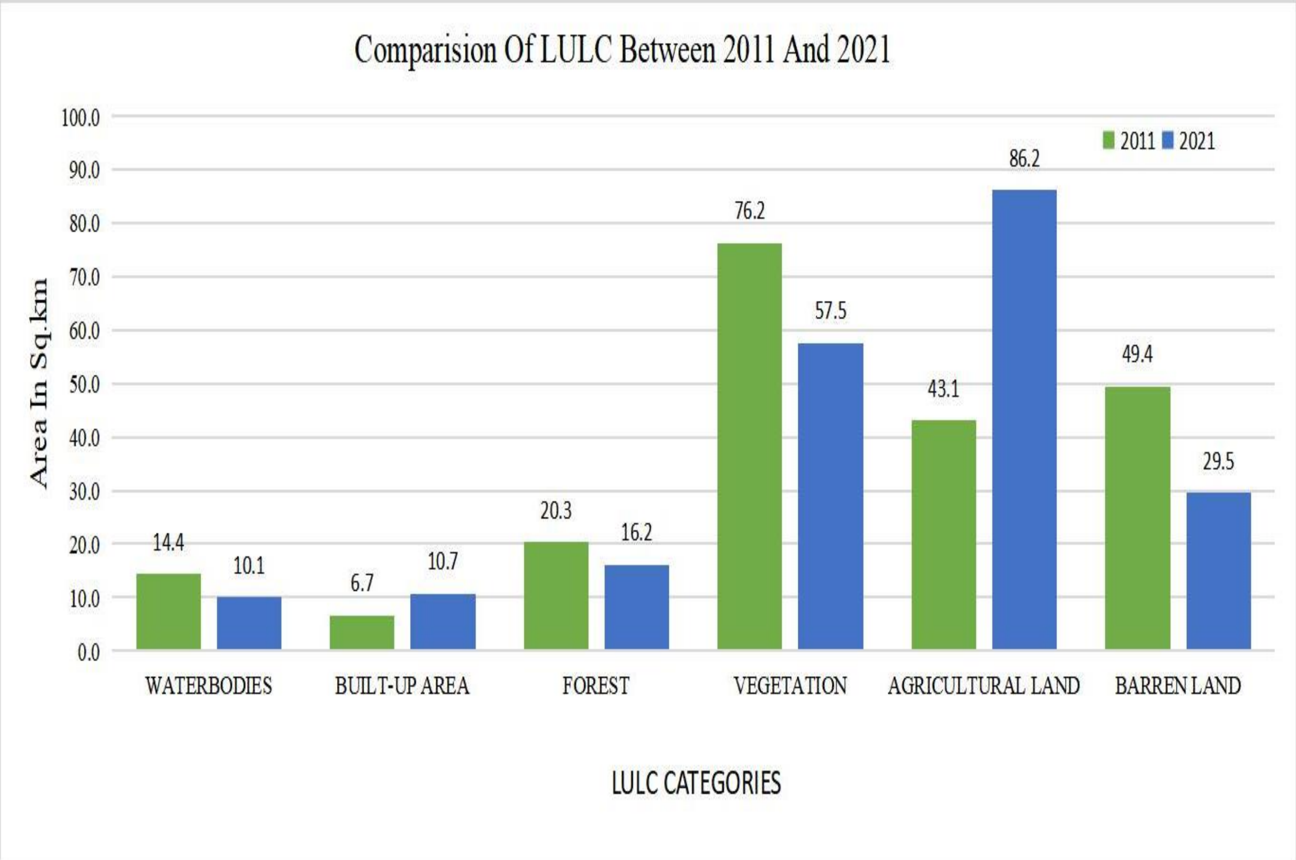


Figure 6 (below) shows the comparison of LU/LC between 2011 and 2021



The requirement of buildings in Moinabad Mandal, where the population has grown, is the main cause of the increase. The graph above displays changes that have occurred in Moinabad. 2011 through 2021 According to observation and analysis of the data gathered from the years 2011 to 2021, we can see that the vegetation in Moinabad has changed significantly throughout a region of 18.663 square kilometres. And the built-up area has grown by 3.966 square kilometres. Figure 6 (below) shows the comparison of LU/LC between 2011 and 2021.

CONCLUSION

The Moinabad Mandal served as the site of the study. The study demonstrated how effective satellite remote sensing combined with GIS can be for tracking and analyzing changes in land use/land cover in a particular area. Throughout the study time during the years of 2011 and 2021, there were considerable changes in land use and land cover, which resulted in some interesting findings. The findings showed that various human activities were to blame for the changes in various geological characteristics, such as urban areas or land used for agriculture. The study found that built-up areas and the agricultural sector had seen significant changes, with built-up area land area increasing and agricultural land area trending downward over the previous 10 years. Modifications have also occurred in the categories of water bodies, vegetation/trees, and fallow land. According to the study, there have been significant changes in both agricultural land and vegetation, which are related. The patterns of agricultural activity have changed, and there has been an increase in urbanization activity, which are the explanations given for this. In general, the data on land use and land cover in the study area from 2011 to 2021 showed some major changes that may have had a large influence on the ecosystem. For the environment's long-term viability, these patterns must be closely watched. In comparison with other land use categories, it was discovered that built-up areas, agricultural land, and vegetation used the most space. Actual land loss and gain are revealed through change detection analysis for LULC Categories. It goes without saying that between 2011 and 2021, the aerial size of waterbodies like rivers and lakes has grown. The population expansion also played a role in the significant change. The expansion of areas, particularly the vegetation and tree cover, would aid in the fight against UHI, global warming, and to some extent, in the regeneration of damaged forest regions.

The use of satellite data information combined with geospatial technology, along with various land use policies and plantations programmes recently introduced by the federal and state governments of India, demonstrated that tracking LULC changes and subsequent resource management is possible.

Future Scope of Work

Through changes in land-use and land-cover (LULC), which have a direct impact on Land Surface Temperature (LST), humans continuously participate in the exchange of energy from the earth's surface to the atmosphere. The population is increasing and cities are becoming more urbanized, which are the causes of LULC changes. Urbanization is one of the most significant global issues that modifies the characteristics of the atmosphere and land surface. The influence of urban heat islands (UHI) on variables related to exterior temperature and component properties may be quantified by this study. Urban heat island (UHI) effects come from fast changes in land use and land cover (LULC) brought on by urbanization, which modifies an area's thermal characteristics at a local scale. In the future, LULC will be measured at the Mandal level and connected with surface urban heat island intensity (SUHI) and land surface temperature (LST).

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