CLASSIFICATION FOR URBAN SPRAWL ANALYSIS OF MUMBAI METROPOLITAN REGION (MMR)

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ABSTRACT: The rapid Urban growth in metro cities has introduced serious environmental challenges in many megacities hindering the goals of sustainable development which includes natural resource management, maintenance of infrastructure facilities, sanitation etc. and it is a cause of concern for Urban and town planners for efficient Urban Planning. The Land Use and Land cover (LULC) Classification is important for Urban growth analysis.

The Mumbai Metropolitan region (MMR) in Maharashtra, India comprising of 9 districts has seen such Haphazard and explosive growth especially in past 3 decades. The population of Mumbai has more than doubled since 1991, when the census showed that there were approximately 12.5 million people living in the area. Population growth from 12.5 million to 23.5 million in 2021 is seen. This has led to cities expanding towards periphery and rural neighborhood causing urban sprawl.

This study focuses on finding the LULC for the MMR for last three decades so that it may help the Urban Planners to understand the growth. With the Spatial and Temporal analysis an attempt has been made to understand the changing dynamics of LULC in Mumbai Metropolitan region. This change was found using Maximum Likelihood Classifier. Further for modelling and prediction CA Markov model was used.

Results show the change in land from 2000 to 2020 and mainly sprawling outward. Modelling using CA-Markov pointed out that urban growth to increase by 2030. The notable observation of our study is that urban growth would have an infill growth in the city completely and then starts sprawling outward and emphasizes need for policy planners and urban managers to provide immediate interventions for infrastructure development necessary for sustainable growth of Indian urban agglomerations.

1. Introduction

The environment, one of the most significant frameworks for the endurance of individuals is seen to be persistently evolving. The Land Use Land Cover (LULC) and its change is an important element in the studying Urban Growth.

The LULC pattern have been continuously changing due to urban expansion because of growth of population, movement of people from rural to urban areas, economic growth, industrialization, infrastructure initiatives like construction of roads, rails, provision of infrastructure development, etc .(Yeh, A.G.O., and Liu, X., 2001)

The most noteworthy land use change in most recent two decades is urban development, which changes over barren or rural regions to developed land. The urban communities everywhere throughout the world proceed with unabated extension so as to take into account the necessities of an ever-requesting populace. Land use change from undeveloped or agriculture to developed has two inverse components. From one perspective, urban area go about as motors of monetary and social development. Urban territories contribute fundamentally to the country's economy and keep on opening entryways for development and advancement. Subsequently, the rapidly increasing urban development has frequently been seen as an indication of the imperativeness of the local economy (Ramachandra, T.V., Jeffery M.S., Bharath, H.A., Vinay, S., 2020). On the flip side environmental and ecological degradation is observed due to rapid urban growth. The development of urban regions brings about the change of agricultural land or open space into urban land use, which infringes onto various important agrarian, forest and natural land. The Urban development also brings about expanding surface temperatures in and around urban areas and this prompts a few other neighborhood and worldwide atmosphere changes. Thus changes of land use pattern, if left unattended, would hinder sustainable development for the future and disturb the ecological balance(Yang, X., and Lo, C. P., 2003). Understanding the multifaceted nature of change of land use and assessing its effects involves procedures of both measurement and modelling.

Land Cover data show how much of a region is covered by forests, wetlands, impervious surfaces, agriculture, and other land and water types. Water types include wetlands or open water. Land Use shows how people use the landscape for development, conservation, or mixed uses.

Remote Sensing and GIS are the most advanced tools for Land use/Land cover study. In recent times the use of remote sensing image classification has increased as ground efforts and time are saved to achieve multiple objectives using these smart tools and models. Satellite Image Classification is a process to carry out change study of area as it gives an idea of the Earth's surface with the help of satellite imageries over the period.

Land-Use mapping has great importance in research and decision making. Land use and land cover has become increasingly important component of plans to overcome the problems of haphazard, uncontrolled development, deteriorating environmental quality, loss of prime agricultural lands, destruction of important wetlands, and loss of fish and wildlife habitat. Land use data are needed in the analysis of environmental processes and problems that must be understood if living conditions and standards are to be improved or maintained at current levels. Many Federal agencies need current action plan using Land-Use to predict the future scenario in compare to existing activities on public lands combined with the forest and vegetation area and its impact on biodiversity and human population.

Now a days due to rapid growth in urbanization and industrialization, there is an increasing pressure on land, water, and environment. There are many problems related with conversion of agricultural land to urban built-up. As most cities are expanding in all directions resulting in large-scale changes in urban land use.

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2. STUDY AREA AND DATA SET

2.1 Study Area

Mumbai Metropolitan Region (MMR) is considered as the study area. Mumbai is located between Latitude 19° 0' 33'' N and Longitude 72° 52' 39'' E in western India (Figure 1).

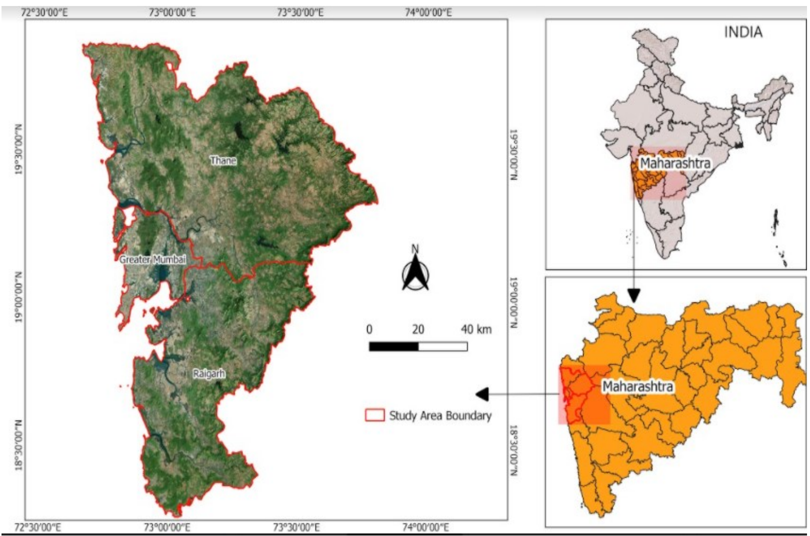

Figure 1: Study Area, Mumbai Metropolitan Region

Mumbai Metropolitan Region (MMR) is a metropolitan area in Maharashtra state, consisting of the state capital Mumbai (previously known as 'Bombay') and its satellite towns. It consists of 8 Municipal Corporations viz. Greater Mumbai, Thane, Kalyan-Dombivali, Navi Mumbai, Ulhasnagar, Bhiwandi- Nizamapur, Vasai-Virar and Mira-Bhayandar; and 9 Municipal Councils viz. Ambarnath, Kulgaon-Badalapur, Matheran, Karjat, Panvel,

Khopoli, Pen, Uran, and Alibaug, along with more than 1,000 villages in Thane and Raigad Districts. (https://mmrda.maharashtra.gov.in/about-mmr)
It is one of the most vibrant and happening city of India, as well as main city of western state of Maharashtra. It covers five districts of Mumbai city (Complete), Mumbai Suburb(Complete), Thane(Complete), Palghar (Partial) and Raigad(Partial)

The entire area is overseen by the Mumbai Metropolitan Region Development Authority (MMRDA), a Maharashtra State Government organisation in charge of town planning, development, transportation and housing in the region. MMRDA is responsible for the balanced development of the MMR. (https://en.wikipedia.org/wiki/Mumbai_Metropolitan_Region_Development_Authority)

The MMRDA was formed to address the challenges in planning and development of integrated infrastructure for the metropolitan region. Some areas outside Brihan Mumbai (Greater Mumbai) and Navi Mumbai have lacked organised development. Navi Mumbai, developed as one of the largest planned cities in the world, was promoted by a Maharashtra Government-owned company, City and Industrial Development Corporation (CIDCO).

The region had problems related to haphazard and illegal development as a result of rapid urbanization. Villages along NH3 in Bhiwandi Taluka are examples of Haphazard development in the MMR with some of the largest warehousing areas in India.

The Mumbai Metropolitan Region (MMR) is spread over 6,640 Sq. kms. and has a population of 235.98 Lakhs as per 2011 Census.

2.2 Data Set

The time series spatial data of LANDSAT 5 and LANDSAT 8 images for three years (different decades 2000, 2011 and 2020 was used. Landsat 8 (30 mts) and L-8(OLI). The georeferenced data was obtained from USGS site. The images for the month of April were considered for all the three years as it is Sunny during the said period. Having the images of the same month would also give results as per the atmospheric condition of the MMR regions.

For this study the time series spatial data of LANDSAT 5 and LANDSAT 8 images with spatial resolution of 30 mts. has been used with 6 bands (Blue, Green, Red, NIR and SWIR1 and SWIR 2 for three years (in different decades 2000, 2011 and 2020) was used.

The period of imaginary considered was during the months November, December (2000 & 2020) and January (2011) due to lack of suitable satellite images in 2010. Around 12 satellite images (tiles) were utilized. The georeferenced data was obtained from USGS site. Having the images of the nearly of same month would also give results as per the atmospheric condition of the MMR regions. SRTM DEM (Digital Elevation Model) was also used as it is required as spatial input for the prediction of 2030 LULC.

Satellite Data	Year
Landsat Series(30m): L-5	2000
Landsat Series(30m): L-8(OLI)	2011
Landsat Series(30m): L-8(OLI)	2020

Table 1: Data used for Analysis

- Landsat-5 (2000-(Nov-Dec); 2011-(Jan)) TM (30m Spatial Resolution) (Post Monsoon).
- Landsat-8 (2011 (Nov-Dec) OLI (30m Spatial Resolution) (Post Monsoon).
- Landsat-8 (2020 (Nov-Dec) OLI (30m Spatial Resolution) (Post Monsoon).
- MMRDA Boundary; DEM SRTM (30m Spatial Resolution).
- DIVA-GIS
- USGS Earth Explorer
- QGIS Software 3.10 with SCP Plugin was use for LULC classification for 2000, 2011 and 2020 QGIS 2.18 with MOLUSCE Plugin was used for 2030 Simulation.

3. METHODOLOGY

The data obtained for the above-mentioned years from USGS (Satellite image) was processed and analysed using remote sensing and GIS techniques to collect information on Land usage pattern to understand the growth/development/change during the considered years.

The data has been properly georeferenced and corrected from Image pre-processing point of view and atmospheric conditions. Layer stacking was done in QGIS software using all 6 bands (30m resolution), other bands were neglected as resolution of those bands were less in comparison to these bands. Images were clipped by study area shape file to set area prefix True Colour image was generated and converted to False Colour Composite (FCC) for better understanding of Unsupervised/Supervised classification.(Anderson JR et.al. 1976) The figure 2 depicts the process.

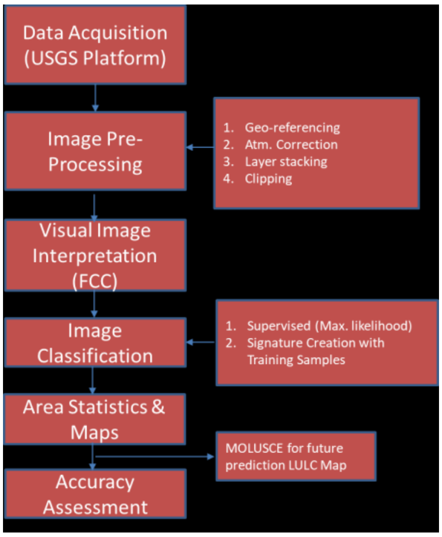

Figure 2: Methodology

Visual Image interpretation is defined as the act of examining images to identify objects and judge their significance. An interpreter studies remotely sensed data and attempts through logical process to detect, identify, measure, and evaluate the significance of environmental and cultural objects, patterns, and spatial relationships. After the generation of FCC, data has been observed by Visual Image interpretation for the better understanding of all features over earth surface in and around study area. Majorly shape, colour, size, texture, shadow, and pattern has been observed for the period of various Land-Use classes.

3.1. Image Classification

Classification is the process of sorting pixels into a finite number of individual classes, or categories of data based on their data file values. There are 2 types of classification (Un-super/Supervised). (Dietzel, C., Herold, M., Hemphell, J.J., Clarke, K.C., 2005)

Unsupervised classification has been made using ISO cluster technique over study area. Unsupervised significance lead to the understanding that around 10 classes (Level-1) are available over the study area. Training class samples made of various reflectance signatures had been generated in ample of numbers to increase accuracy level for verification of FCC using VISUAL IMAGE INTERPRETATION method.

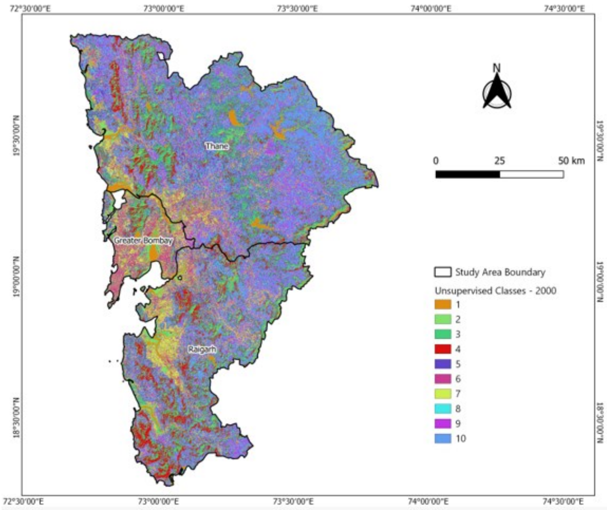

Figure 3 Land Use Land Cover 2000
Unsupervised Classification

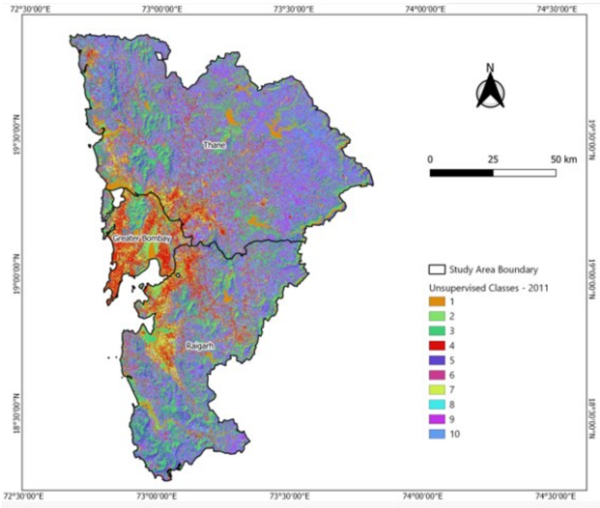

Figure 4 Land Use Land Cover 2011
Unsupervised Classification

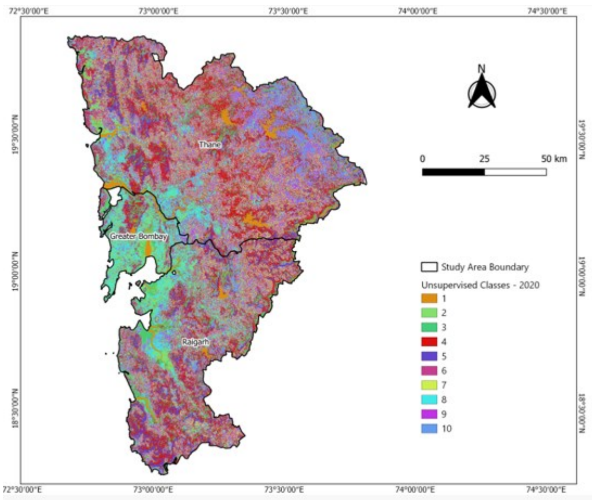

Figure 5 Land Use Land Cover 2020
Unsupervised Classification

From number of techniques available for Supervised classification, Maximum likelihood Classification technique has been used for supervised classification for minimum error due to its statistics-based classification which uses covariance matrix. Maximum likelihood classification assumes that the statistics for each class in each band are normally distributed and calculates the probability that a given pixel belongs to a specific class. Unless a probability threshold is selected, all pixels are classified.

Using QGIS as the tool for processing data Training polygons were selected from heterogenous patches in the landscape on the FCC image obtained. The land use types considered for generating the training signatures are as given in the table below:

Class	Includes
Water	Includes Seas, rivers, lakes, ponds, and other small water bodies
Built-up	Includes human constructed structures such as buildings, roads, and other impervious surfaces.
Forest Patches/ Plantation /Other	Forests, Grasslands, and other green areas of vegetation

Vegetation	
Agricultural/Cropland	Agricultural land with Crops
Fallow land	Farming land with no crops
Barren land / Wasteland	Includes pervious surfaces such as Open plots

Table 3: Land Use type Categorization

3.2. Land Use Analysis

The Land use, Land cover analysis was found for 6 different categories Water, Build up, Forest Patches/Plantation/ Other Vegetation Agricultural/Cropland, Fallow land and Barren land. The temporal and land use analysis were done using Gaussian Maximum Likelihood Classifier method. It shows that land use pattern of the MMRDA for the period 2000–2020. The accuracy assessment found using overall accuracy and Kappa statistics. The temporal data shows increase in the Built-up areas

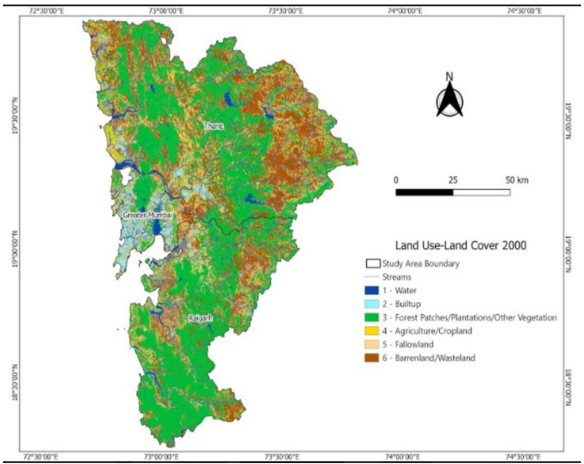

Figure 6 Land Use Land Cover 2000
Supervised Classification

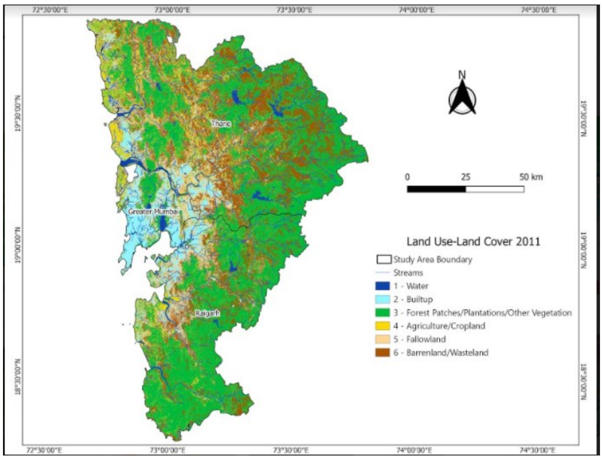

Figure 7 Land Use Land Cover 2011
Supervised Classification

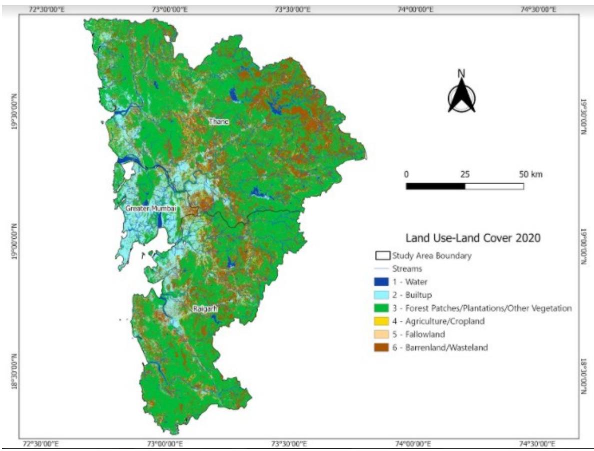

Figure 8 Land Use Land Cover 2020
Supervised Classification

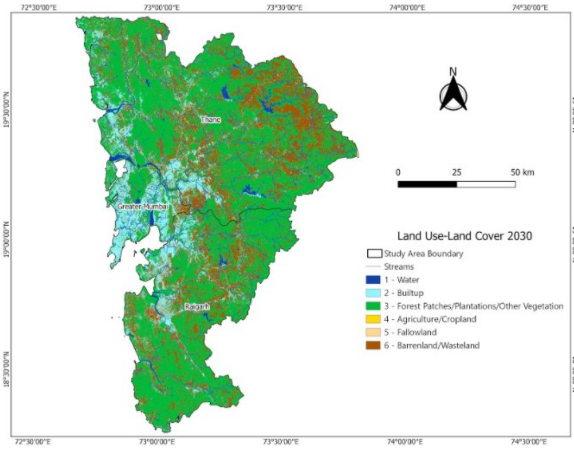

Figure 9 Land Use Land Cover 2030
Supervised Classification

Table 4 gives the details of the change in LULC classes over the period of 3 decades. It also predicts the change for 2030.

LULC Class	Total class Area (ha) 2000	Total class Area (ha) 2010	Total class Area (ha) 2020	Total class Area (ha) 2030 (After Prediction)
Water	38,552.04	48,896.64	27,398.52	24,799.41
Built up	47,789.01	78,291.90	126,589.50	143,915.94
Forest Patches/Plantations/ Other Vegetation	482,736.42	513,062.82	639,013.95	654,021.18
Agriculture/Cropland	77,357.07	102,457.26	30,550.59	1,939.32
Fallow land	130,821.57	106,255.44	11,131.74	3,525.30
Barren land/Wasteland	325,488.33	253,704.51	267,809.31	274,292.46
Total	1,102,744.44	1,102,668.57	1,102,493.61	1,102,493.61

Table 4: Change in LULC

Table 5 gives the details of the % change in LULC classes over the period of 3 decades

LULC Class	Total class Area (%) 2000	Total class Area (%) 2010	Total class Area (%) 2020	Total class Area (%) 2030 (After Prediction)
Water	3.50	4.43	2.49	2.25
Built up	4.33	7.10	11.48	13.05
Forest Patches/Plantations/ Other Vegetation	43.78	46.53	57.96	59.32
Agriculture/Cropland	7.01	9.29	2.77	0.18
Fallow land	11.86	9.64	1.01	0.32
Barren land/Wasteland	29.52	23.01	24.29	24.88
Total	100.00	100.00	100.00	100.00

Table 5: Change in LULC (%)

4. ACCURACY ASSESSMENT

After the classification process, it is useful to assess the accuracy of land cover classification, in order to identify and measure map errors.

Stratified Random Sampling was done with 122 Accuracy points for the LULC maps using robust AcATaMa Plugin in QGIS in order to accomplish data verification for further classification and accuracy check purpose using base maps. These data were used to check accuracy of the supervised classified map to compare features and satellite data to generate correct statistics.Usually, accuracy assessment is performed with the calculation of an error matrix, which compares map information with reference data for several sample areas. All of our study years for LULC showed high accuracy (>92%). Table 6 shows the Accuracy Assessment

Year	Overall Accuracy
2000	92.50 %
2011	93.00%
2020	95.09%

Table 6: Accuracy Assessment

5. PREDICTED LULC FOR 2030

For future prediction for the year 2030, MOLUSCE Model Plugin was used in QGIS 2.18. It is abbreviated as Modules for Land Use Change Simulations. For the model, Artificial Neural Network technique was chosen for prediction. It was observed that there was increase in the built area especially around greater Mumbai area indicating Urban Sprawl.

CONCLUSION

To summarize, the general trend in our study area show built-up area increasing in every decade indicating more urbanization. Also, Agriculture (Cropland) area has significantly reduced whereas the study shows increase in Plantations. Water shows significant reduction over the years and the Fallow land conversion to Urban Built-up areas is also observed and predicted. Barren land / Wasteland shows almost more or less the same status. Detailed Accuracy Assessment and classification report was produced which provides area (in hectares, ha) for each LULC class and Overall accuracy. Further studies can be done by implementing and analyzing the performance of various Machine Learning algorithms by considering a given study area

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