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A Simulation of Land Use/Cover Change for Urbanization on Chennai Metropolitan Area, India

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1 ABSTRACT

Remote sensing and GIS technologies are very much useful for finding the Land Use/Cover maps. This is the paper which deals with the Land Use/Cover Change (LUCC) especially to urbanization in Chennai metropolitan area, India for past two decades till present. Chennai is the fourth largest metropolitan city in India with area of 1189 km2 with 4.68 million of population, which is developing rapidly into urban in past few decades. There is heavy need of urban planning for future in Chennai. This research will be a support for urban planning of the future.

The Land satellite data for three decades (1989, 2000 and 2012) and Digital Elevation Model (DEM) for present were collected with 30 meter resolution. Preprocessing of all images was completed. Image classification for mapping LUCC was performed by supervised classification through the maximum likelihood classification for four classes: Water, Rough land, Crop land and Urban. An accuracy assessment has been checked to find the accuracy of the Classification and the overall accuracy is about 87%. Transition probability matrices were calculated for all three time points and compared with each other (1989 with 2000, 2000 with 2012). The result shows that the increase in Urban and decrease in Rough land. Slope map has been created from DEM.

Analyses of neighborhood effects were done to find the probability of land changes due to existing urban cells, which is calculated for each cells surrounded by its three neighborhood cells. Analyses of slope effects for urbanization was done by comparing the slope and the possibilities of change from Rough land and Crop land to Urban. A simple model structure for simulation was created using VBA and GIS. The model applies the neighborhood effects which are similar to Cellular Automata but in this model it is modified by slope effects. Using the simulation urban map was predicted for future trends. These predicted urban maps will provide critical input to resource management and planning support applications, and have substantial social and economic benefit for metropolitan planning and development.

2 INTRODUCTION

2.1 Introduction and Background of the Study

"INDIA lives in its villages," said Mahatma Gandhi, over six decades ago. No longer. At least not in Tamil Nadu, the first major State to reach the historical threshold of 50:50 rural-urban distribution of population. Crowning Tamil Nadu's urbanisation is Chennai, the fourth largest metropolis of India. More people in Tamil Nadu have moved from rural to urban areas the last 10 years compared to other states, according to the 2011 Census data. Tamil Nadu tops the list of urbanised states with 48.45% of its population living in urban areas , followed by Kerala, Maharashtra and Gujarat. In the last 20 years, the rate of urbanization in Tamil Nadu has been rapid. According to the 1991 Census, only 34.15% of the total population in Tamil Nadu was classified as urban but in 2011, it has risen to 48.45%, an increase of 14.3%. Since the 2001 census, the percentage of urban population has risen by 4.41%.

Urbanization is a worldwide phenomenon where all mega cities are rapidly developing due to various factors including population increases, industrialization and rural-urban migration. Though urbanization is a worldwide phenomenon, it's more prevalent in India due to high growth rate over last few decades. Urban planning is a complex phenomenon hence accurate and updated information is needed to develop strategies for sustainable development. The land use maps are used to provide up to date information on the type, location, spatial, distribution and extend of land use/land cover.

In order to use the land optimally and to provide as input data in modeling studies, it is not only necessary to have information on existing land use/ landcover but also the capability to monitor the dynamics of land use resulting out of changing demands. Urban sprawl is a phenomenon that has to be monitored and understood. There are different approaches for modeling spatial dynamics. Models cannot work without data and satellite imagery is an excelent source of data. The rapid development of multi-spatial and multi-temporal remote sensing data has now made it possible to monitor urban land-use/land-cover changes in a very efficient manner. Remote sensing techniques have proven very useful in urban mapping (Batty 2008). There is a wide range of techniques used for land use land cover change detection. An attempt has been made here to demonstrate the potentials of remote sensing techniques in change detection analysis of urban land cover by using the technique of comparison of the classified images.

2.2 Research Objective

The aim of this paper deals with the Land Use/Cover Change (LUCC) especially to urbanization in Chennai metropolitan area, India for three time points (1989, 2000 and 2012). And to simulate the urbanization for future using the past data's.

The objectives of the study are

- To classify the Land Use/Cover based on processing the satellite data in three time points (1989, 2000 & 2012).
- To calculate the change of the Land Use/Cover during these periods.
- To analyze the transition probability of the LUCC, especially focusing on both the neighborhood effects and slope effects.
- To simulate the urban growth under the current trend case till 2024.

2.3 Study Area

Chennai is the fourth largest metropolitan area in India, with a population of about 7 million in 2001. The Chennai Metropolis (with a latitude between 12°50'49" and 13°17'24", and a longitude between 79°59'53"and 80°20'12") is located on the Coramandal coast in South India. Topographically plain terrain with few isolated hillocks in the south-west. Average annual rainfall is about 1,300 mm. Chennai has two administrative boundary, the outer boundary is Chennai metropolitan boundary – encompass the suburban areas; the inner one is the corporation boundary, which include only the urban area. Chennai is rapidly getting urbanized from past decades.

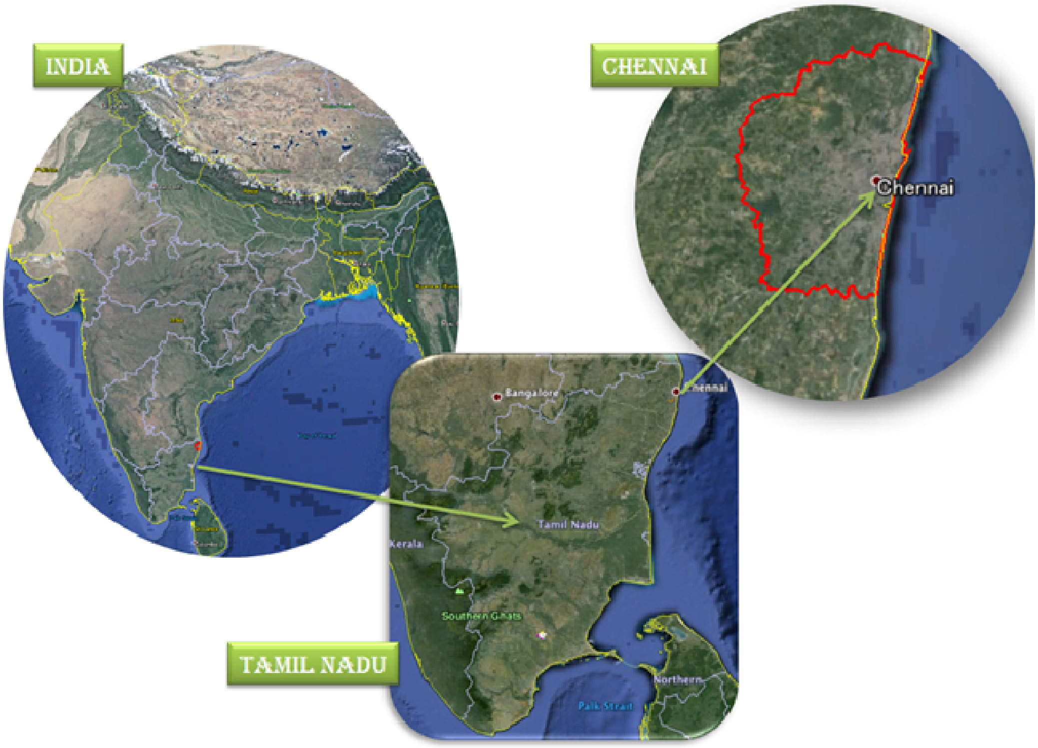

Fig. 1: Location map of Chennai metropolitan area, Tamil Nadu, India

2.4 Existing Research

There are many types of landuse classification (Anderson et al., 2001). It is infered that the land cover change analysis can be done using simulation modelling (Bhatt et al., and Parker et al., 2003). Change analysis can be done using Erdas imagine (Harika et al., 2012) and modelling of land use change can be done using GIS (Laura and Pontius, 2001; Geogr and Fina, 2007). Urban sprawl mapping and land use change analysis using GIS should be given importance while planning (Monalisha et al., 2005)

This research focuses on forecasting urbanization for future using two factors as major, neighbourhood and slope effects. As existing research on relationship between neighbourhood and land use by Muranaka and Arai (2013) has been reported. In their approach, they showed the relationship between neighbourhood and land use, especially the propotion of the number of grid cells each of which has changed its land use from non-urban to urban between time (t and t+dt) and which has k urban cells within its neighbourhood. A simple and stable relationship between the state of the neighbourhood and the land use change in the central site was found by simple calculation of published land use data in Japan. By referring these past researches, neighbourhood effects also plays major role in this research.

3 DATA PREPARATION AND PROCESSING

3.1 Pre Processing

Landsat 5 TM is a best data for classifying Land Use/Cover. Landsat 5 TM data has been downloaded for three times points (1989, 2000 and 2012) with 30 meter resolution. DEM data also has been downloaded for the year 2010 with same 30 meter resoulution from open source. The data specifications has been shown in Table 1.

Name	Source	Resolution	Year of capture
LandSat 5 TM	U.S. Geological Survey (Open source)	30 Meter each	1989, 2000 and 2012
Digital Elevation Model	Advance Spaceborne Thermal Emission Reflection Radiometer (Open source)	30 Meter each	2010

Table 1: Data specifications

Preprocessing of satellite images prior to image classification and change detection is essential. Preprocessing of image data often will include radiometric correction and geometric correction. Geometric rectification of the imagery resamples or changes the pixel grid to fit that of a map projection or another reference image. This becomes especially important when scene to scene comparisons of individual pixels in applications such as change detection are being sought. Geometric corrections are made to correct the inaccuracy between the location coordinates of the picture elements in the image data, and the actual location coordinates on the ground. Radiometric corrections are made to the raw digital image data to correct for brightness values, of the object on the ground, that have been distorted because of sensor calibration or sensor malfunction problems. The distortion of images is caused by the scattering of reflected electromagnetic light energy due to a constantly changing atmosphere. This is one source of sensor calibration error. Now after correcting both the Geometric and Radiometric corrections, now all three years of Landsat Image is ready for classification.

3.2 Image Classification

To examine the urbanization on LUCC, there are four important classes to be classified. They are Water, Roughland, Cropland and Urban. The description of these has been shown in Table 2. All of the visible and infrared bands (bands 1-5 and 7) were used for image classification. Supervised classification through maximum likelihood algorithm was applied to perform image classification. It was preferred because the prior knowledge of study area was known and the data of the study area were also available. In addition, this classification has been found to be the most commonly and widely used classifier. The supervised classification requires training areas for each class. The traning areas were used to define spectral reflectance patterns/signature of each class. The signatures would then be used by classifier to group the pixels into a certain class which has the same spectral patterns. Training areas of each class were created with the assistance of visual analysis on the images through displaying RGB combination and also supporting by the ancillary information from the google earth and the prior knowledge of the study area. This classification was done for all three years, 1989, 2000 and 2012.

Land Use/Cover classes	General Description
Water	An area covered by open water such as ocean, river, ponds and artificial aquacultures or fishponds.
Roughland	An area that is covered by shrubs and bare lands.
Cropland	An area that is used for any kind of cultivation such as agriculture, tree crops, or food crops.
Urban	An area has all residential, commercial and industrial areas, villages, settlements and transportation infrastructure.

Table 2: Description of Land Use/Cover classes

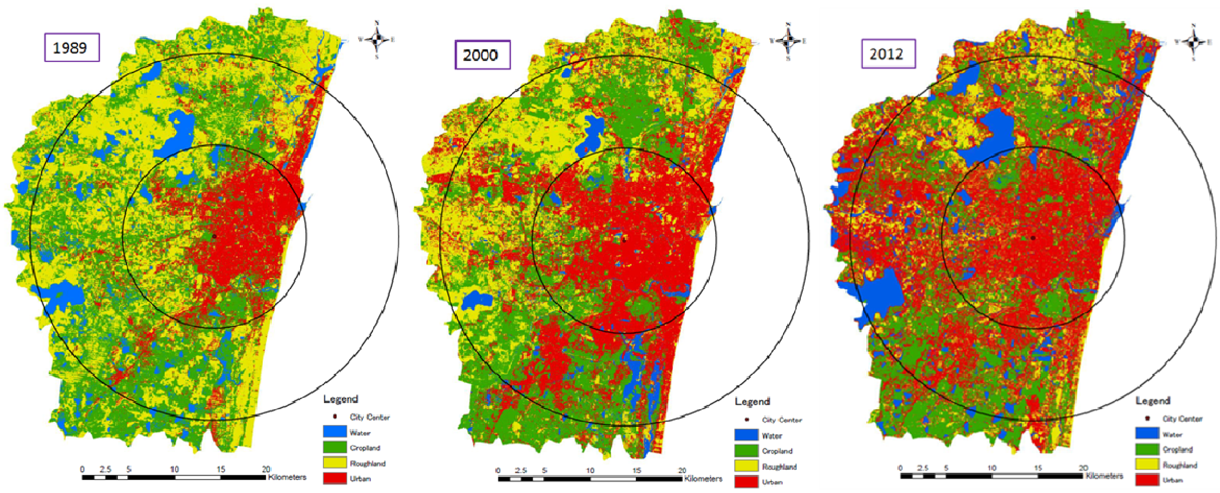

Fig. 2: Land Use/Cover classification for three years (1989, 2000 and 2012)

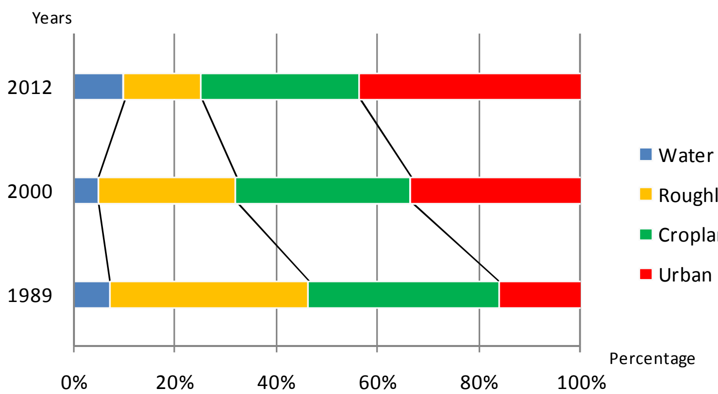

Fig. 3: Comparisons of Land Use/Cover classification between three years

Now after classifying for three years, by seeing the Fig. 2 and 3 it can be understood that, in 1989 the Urban was only 16% but it has been rapidly increased from 16% to 34% in 2000 due to various factors and there was a gradual increase from 34% to 44% in 2012. Hence from this classification and analysis we can understand that Chennai is now urbanizing nearly 50%. And when we see for Cropland on 1989 with 38% which has been slightly decreased from 38% to 34% in the year 2000. And again slightly decreased from 34% to 31% in 2012 . And Roughland has decreased rapidly in the year 2000 from 39% to 27% and it has been again decreased to 15% in the year 2012. Here in our analysis we omit water from analysis, because water won't change much.

3.3 Post Processing

After the image classification, post processing has done to check the accuracy of the classification. Error matrix says how much error the classified image has, and from that it can be known either to reclassify the image or it has good accuracy. Here in this classification the overall accuracy is about 0.87. After checking the accuracy, the kappa coefficient has to be applied. The kappa coefficient is frequently used to summarize the results of an accuracy assessment used to evaluate land-use or land-cover classifications obtained by remote sensing. The standard estimator of the kappa coefficient along with the standard error of this estimator require a sampling model that is approximated by simple random sampling. Formulas are presented for estimating the kappa coefficient. Kappa coefficient is calculated and it is found to be 0.82. After checking the overall accuracy and the kappa coefficient the change maps can be created.

3.4 Slope map

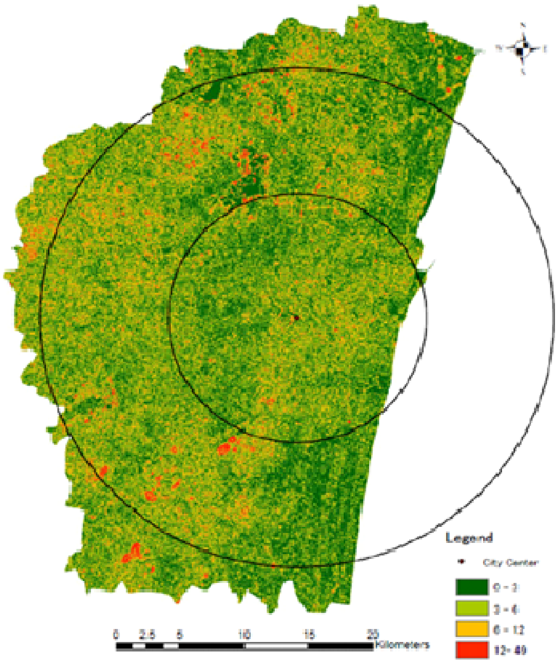

Fig. 4: Slope map for 2010

As said earlier, Chennai has a flat terrain surface. The Fig.4 shows the output of Slope of Chennai metropolitan area. This slope map describes that the red areas reflects the greater slope and green area reflects the lesser slope. It is shown clearly in the map, that Chennai has more than 80% of slope is lesser. The slope is calculated for each pixels. The values of slope of each cell have been extracted for further analysis.

3.5 Change maps

Change detection is the use of remotely sensed imagery of a single region, acquired on at least two dates, to identify changes that might have occurred in the interval between the two dates. This study deals with the urbanization on LUCC, therefore the change from Roughland to Cropland, Roughland to Urban and Cropland to Urban are created. And it has been found that the change from Roughland to Urban is more than the change from Cropland to Urban.The results of the change maps and graphs says that, the change from Roughland to Urban in the period 1989 to 2000 is 7% it has been increased from 7% to 9% in the period 2000 to 2012. And as an average there was a change of 14% from Roughland to Urban in the period 1989 to 2012. The change from Cropland to Urban on the period 1989 to 2000 is 9% it has been decreased from 9% to 5% in the period 2000 to 2012. As a average there was a change of 13% from Cropland to Urban in the period 1989 to 2012. It says that there is always an increase in change from Roughland to Urban. But in change from Cropland to Urban there is some increase in the period 1989 to 2000 and some decrease in the period 2000 to 2012. The percentage of change from Roughland to Urban is more than the change of Cropland to Urban. And there is a minimum change from Roughland to Cropland.

4 ANALYSIS OF LAND USE/COVER CHANGE (LUCC)

4.1 Analyses on Net Change and Transition Probability of LUCC

An important aspect of LUCC study is to address the transition "from-to" processes information of each class over a certain period (1989 to 2000, 2000 to 2012 and from 1989 to 2012). This can be found by the

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Net change matrix. These Net change matrices are calculated from the Cell count matrix. The cell count matrix states, “The diagonal elements represent the area of each class which remains unchanged while the off diagonal elements represent the changes area”. The Cell Count Matrix has been shown in Table 3.

1989 \ 2000	Water	Roughland	Cropland	Urban	Grand Total
Water	32379	37106	23851	5945	99281
Roughland	12425	203195	177152	126481	519253
Cropland	17186	97695	238985	147984	501850
Urban	3491	25672	18697	166754	214614
Grand Total	65481	363668	458685	447164	1334998

2000 \ 2012	Water	Roughland	Cropland	Urban	Grand Total
Water	33843	5856	14505	11277	65481
Roughland	61734	107100	53290	141544	363668
Cropland	29173	44504	273264	111744	458685
Urban	9369	44716	75951	317128	447164
Grand Total	134119	202176	417010	581693	1334998

1989 \ 2012	Water	Roughland	Cropland	Urban	Grand Total
Water	62574	2587	16507	17613	99281
Roughland	40459	132052	144381	202361	519253
Cropland	25150	52195	230069	194436	501850
Urban	5936	15342	26053	167283	214614
Grand Total	134119	202176	417010	581693	1334998

Table 3: Cell Count Matrix between 1989, 2000 and 2012

Now using these cell count matrices, the Net change matrices are calculated. In this study the Water is omitted because there will be only minor changes happen in Water. The Net Change Matrix is calculated for other three classes(Roughland, Cropland and Urban). The Net Change Matrix is calculated by subtracting the earlier year to later year, such as subtracting the Cropland to Roughland in the year 1989 with Cropland to Roughland in the year 2000, and entering the result in the later year. It has been shown in Table 4.

1989 \ 2000	Water	Roughland	Cropland	Urban	Grand Total
Water	-	-	-	-	-
Roughland	-	203195	79457	100809	383461
Cropland	-	-	238985	129287	368272
Urban	-	-	-	166754	166754
Grand Total	0	203195	318442	396850	918487

2000 \ 2012	Water	Roughland	Cropland	Urban	Grand Total
Water	-	-	-	-	-
Roughland	-	107100	8786	96828	212714
Cropland	-	-	273264	35793	309057
Urban	-	-	-	317128	317128
Grand Total	0	107100	282050	449749	838899

1989 \ 2012	Water	Roughland	Cropland	Urban	Grand Total
Water	-	-	-	-	-
Roughland	-	132052	92186	187019	411257
Cropland	-	-	230069	168383	398452
Urban	-	-	-	167283	167283
Grand Total	0	132052	322255	522685	976992

Table 4: Net Change Matrix between 1989, 2000 and 2012

Transition Probability Matrix describes the probabilities of shifting from one state to another in a dynamic system. In each row are the probabilities of shifting from the state represented by that row, to the other states.

The Transition probability matrix is calculated from the Net Change Matrix. The Net Change of each class is divided by its total change and it has been done for all classes and it makes Transition Probability of each class. This Transition Probability Matrix is used to find the probability of transition of each class. As said earlier, this study concentrates only the transition from Roughland to Urban, Roughland to Cropland and Cropland to Urban. The Transition Probability matrix has been shown in Table 5.

1989 \ 2000	Water	Roughland	Cropland	Urban
Water	-	-	-	-
Roughland	-	0.5299	0.2072	0.2629
Cropland	-	-	0.6489	0.3511
Urban	-	-	-	1.0000

2000 \ 2012	Water	Roughland	Cropland	Urban
Water	-	-	-	-
Roughland	-	0.5035	0.0413	0.4552
Cropland	-	-	0.8842	0.1158
Urban	-	-	-	1.0000

1989 \ 2012	Water	Roughland	Cropland	Urban
Water	-	-	-	-
Roughland	-	0.3211	0.2242	0.4547
Cropland	-	-	0.5774	0.4226
Urban	-	-	-	1.0000

Table 5: Transition Probability Matrix between 1989, 2000 and 2012

4.2 Analyses on Neighborhood effects of LUCC

There are many factors which influence the LUCC, but in this study it focus how the neighborhood has been effected the LUCC. This analysis has been done for three periods such as, 1989 to 2000, 2000 to 2012 and 1989 to 2012. The analysis is done for the cell which represents Roughland and Cropland. For the each cell of Roughland and Cropland, the neighborhood cells have been counted for all classes, except Water.

The consideration is to find the changes of each class between each period but the class water and Urban are omitted in the consideration. It has been checked for each cell surrounded by its 3 surrounding cells from each side.It can be said as the neighborhood cells has been found for 7*7 matrix or neighborhood cell range K= 3. This has done using a VBA program. After counting the neighborhood cells, Urban Ratio is calculated using the simple formula.

$$u_i^T = \frac{\#U}{\#C + \#R + \#U}$$

u_i^T: Urban Ratio during T at cell i

#U: Count of Urban cells in the neighbor during T

#C: Count of Cropland cells in the neighbor during T

#R: Count of Roughland cells in the neighbor during T

Urban Ratio states that the possibility of change to Urban due to neighborhood. After calculating the Urban Ratio, Transition Probability has been found. For example, Transition Probability for Cropland to Urban is shown in this formula.

$$TP_{ij}^{T} = \frac{\#CU}{\#CC + \#CU}$$

TP_{ij}^{T}: Transition Probability of Urban

#CU: Count of cells from Cropland to Urban

#CC: Count of cells from Cropland to Cropland

Transition Probability ratio is calculated with respective to the Urban Ratio and Change Ratio. The name by itself defines that the Transition Probability Ratio of Neighborhood effects states that the probability of transition for Urban Ratio.These are shown in the graph for three periods.

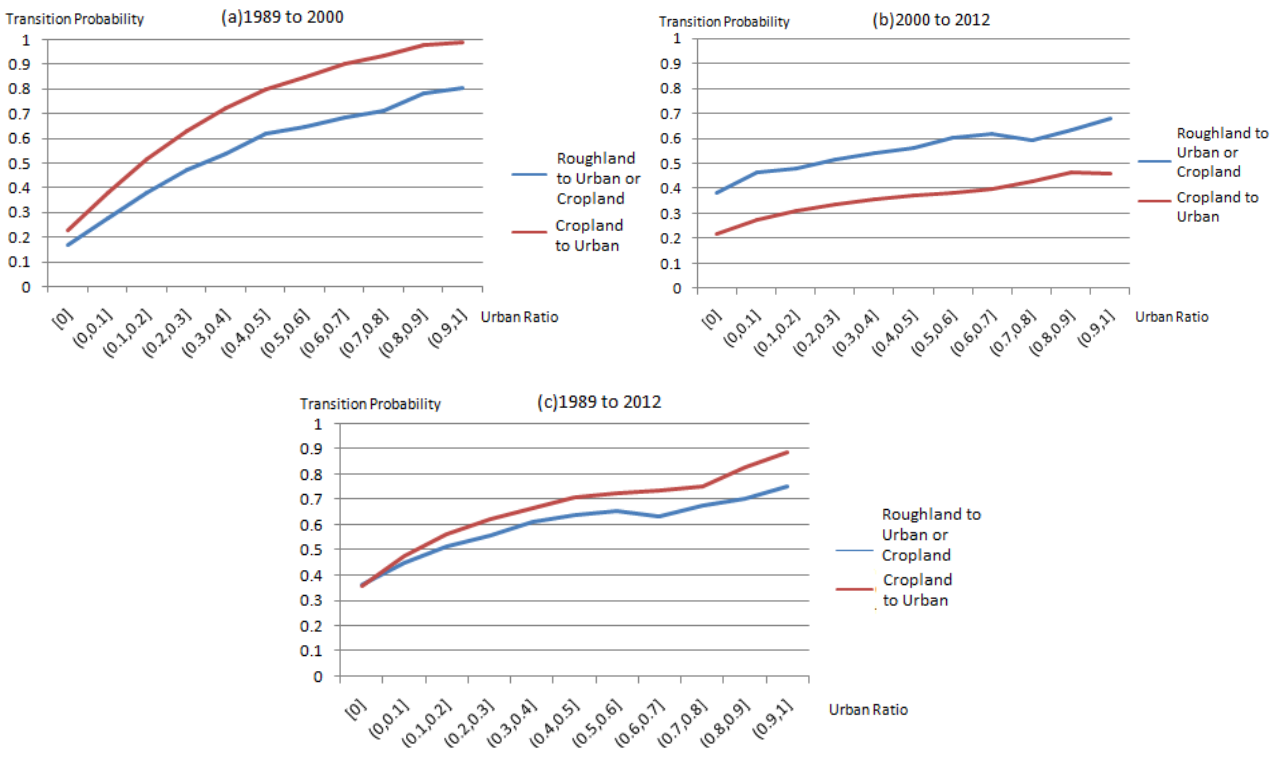

Fig. 5: Relationship between transition probability and urban ratio for three periods

The Fig. 5 shows how much are the possibilities of change to Urban due to the neighborhood effects. Transistion Probability has been found with respect to Urban Ratio. In the inner ring from the city, it is covered by Cropland from 1989 and the outer ring of the city is covered by Roughland.

From the analysis in 1989 to 2000, there is high transition probability of Cropland to Urban, because the Urban growth has been towards south west, and has been grown in inner ring from the city.

But in 2000 to 2012, the Urban development was towards the outer ring, so the high concentration of transition probability change from Roughland to Urban.

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4.3 Analyses on Slope Effect of Transition Probability Ratios for Urbanization

This analysis is to find how slope has been affected the LUCC. Using the surface analysis tool in ArcGIS the degree of slope for each cell of Chennai has been calculated.

It has been found that Chennai has the highest slope as 49 degree. Here the consideration is to find the probability of change between the Roughland to Cropland, the Roughland to Urban and the Cropland to Urban for three periods is calculated.

The slope has been separated into 13 intervals. For each interval of slope the count of each class has been calculated for each period. Net change has been found from the cell count matrix. Transition probability of each class has been found from net change with slope effects as considerations.

$q_{ij}^{T}(s)$: Transition Probability from i to j during T under slope degree s. $q_{ij}^{T}(s)$ is defined as a stair–shape function of slope degree s. slope degree s have 13 intervals.

Transition Probability has been calculated with respect to the slope modified functions. Then finally the relationship between the Transition Probability and slope has been calculated and shown in the graphs for each period.

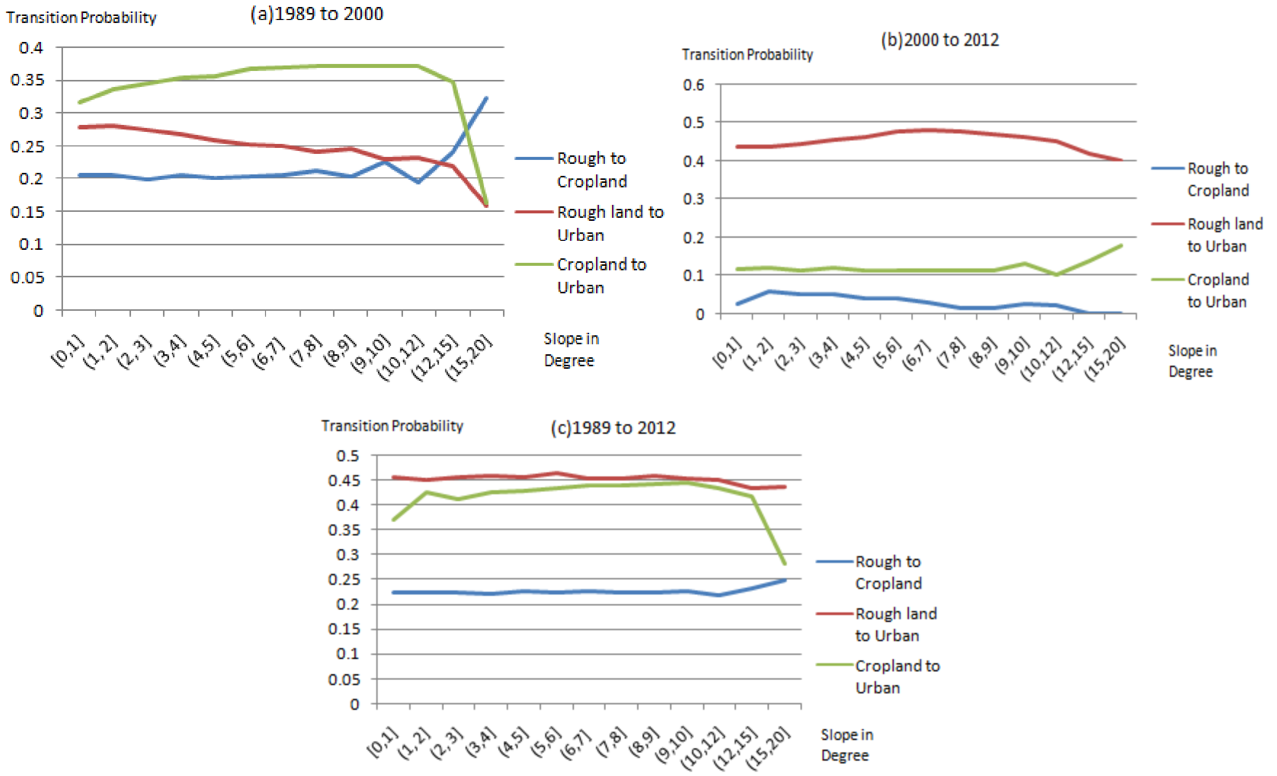


Fig. 6: Relationship between transition probability and slope for three periods

The Fig.6 shows the relationship between the probability of change from Roughland to Cropland, Roughland to Urban and Cropland to urban to the slope slope effect modified functions. While seeing this graph it has been clearly understood that slope and probability of change to Urban are inversely proportional to each other.There is high transition probability from Cropland to Urban in 1989 to 2000, because there is less slope in the inner city when compared to the outer ring from the city. However from 2000 to 2012, Roughland has the high probability to change to Urban because in the period of 2000 to 2012 the transition has done in outer ring that is covered by Roughland.

5 URBANIZATION SIMULATION OF CHENNAI METROPOLITAN AREA TILL 2024

5.1 Model and System Structure

This simulation is a Monte Carlo model by considering neighborhood effects in Cellular Automata model. The model especially predicts the LUCC for future from the past data of 2012. This model predicts for the year 2024 of Chennai metropolitan area. Three major factors has been considered in this model. They are neighborhood effect, slope effect and other effects (population, road effects, and other factors). The neighborhood effect states the transition probability with respect to the neighborhood cell range K = 3. This is as same as the analyses which have been done in the previous chapter. The slope effect states the transition probability with respect to the slope in degree. The other effects have been considered as random factor in this simulation. As this study is based on the urbanization on LUCC, this model only focuses on the growth of Urban from Roughland, Urban from Cropland and Cropland from Roughland. Water and Urban are ignored because there won't be huge change from these too to Urban.

5.2 Trend case and Implications

The Land Use/Cover map of 2012 has been prepared in ArcGIS. The slope map was also prepared in ArcGIS. Both are combined and the output of these both is taken as input for the simulation.Here the simulation is done from 2012 to 2024 under considering the current trend case.

This simulation is a Monte Carlo method by considering neighborhood effects in the Cellular Automata analogy. Transition Probabilities are given as follows.

$$P_{ij}^{T} = \frac{q_{ij}^{T}(s) * r_{ij}^{T}(u)}{trans_{ij}^{T}}$$

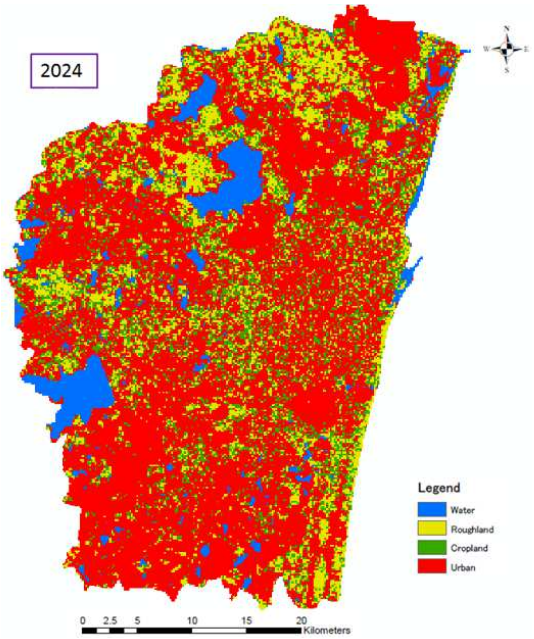
T: Period (2012 to 2024)

P_{ij}^{T}: Transition Probability for i to j using T

$q_{ij}^{T}(s)$: Transition Probability from i to j during T under slope degree s

$r_{ij}^{T}(u)$: Transition Probability from i to j during T under Urban Ratio u

$trans_{ij}^{T}$: Base Transition Probability Ratio from i to j during T



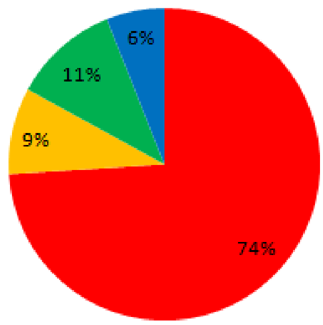


Fig. 7: Forecasted Land Use/Cover classification in 2024 in trend case

This simulation result shows how the city will be in 2024 of the study under current trend. The result of simulation shows that the Urban has increased from 44% to 74%, Cropland has decreased from 31% to 11%, Roughland has decreased from 15% to 9%. Here in this simulation the water is not under consideration so there is no change in Water. The Urban is growing in the south west direction. This simulation is excuted based on only two main factors that are the neighborhood effect and the slope effect. Even though this simulation is simple but it warns that such kind of urban sprawl needs to be controlled based on metropolitan planning. The planners must avoid wasteful land consumption. Policy simulations through the revision and elaboration of the model are hopeful for planners. We illustrate that they planners can using these kinds of simulation methods for future.

6 CONCLUSION

We reported a series of data works on Land Use/Cover Change in Chennai, at three time points of 1989, 2000 and 2012. As the results, first we had identified high-performance classification on Land Use/Cover with overall accuracy of 0.87 and Kappa coefficient as 0.82. Then we had examined the transition probabilities of Land Use/Cover and had found both the effects of neighborhood and slope for urbanization. These facts should be emphasized. Analyzing these effects, lastly we had also tried a simulation in the current trend case. The result of the simulation shows that there can be seen 30% increase of Urbanized area in 2024. Validity checks and policy simulations remain the further works.

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