Modelling Urban Revolution in Greater Bangalore, India

T.V. Ramachandra[1], H. Bharath Aithal[1], S. Vinay[1], N V Joshi[1], Uttam Kumar[1] and K. Venugopal Rao[2]
[1]Centre for Ecological Sciences, Indian Institute of Science, Bangalore 560012, http://ces.iisc.ernet.in/energy
[2] National Remote Sensing Centre, Hyderabad, http://nrsc.gov.in
E Mail: cestvr@ces.iisc.ernet.in, bharath@ces.iisc.ernet.in, nvjoshi@ces.iisc.ernet.in, venu_koppaka@nrsc.gov.in

***Abstract*- Land-use change is a main driving force for the development of the human and his surrounding environment and effects largely on local ecology, hydrology and environment and also globally. This has necessitated understanding changing land use spatial pattern for an effective planning. Remote sensing data enables the synoptic monitoring and visualization of urban growth patterns and dynamics. This study addresses the issue of urban sprawl through the perspective of simulation modeling over an urbanising landscape with a buffer of 10km. Bangalore, Silicon Valley of India is facing numerous challenges and problems of loss of green space, mobility constraints, etc. This study essentially brings out comparison of effective modelling algorithm considering three prime methods.**

Land Change Modeler (LCM), Markov Cellular Automata and Geomod were used to predict likely land use in 2020 with the knowledge of land use changes during 2006-2012 with the constraint of no-change in land use of water category. The results showed a drastic change in the land use, which were converted to urban. Thus necessitating the land use managers and city planners to understand future growth and plan the further developments.

I. INTRODUCTION

Large scale land-use land-cover (LULC) dynamics is leading to the drastic change in global climate changes and alteration of biogeochemical cycles. Human induced environmental changes and consequences are not uniformly distributed over the earth. Large scale industrialization during 90's era paved way for major LULC changes, caused by migration of people from different parts of the country, also from other parts of the globe and country for the employment opportunities. These led to intense urbanisation of major cities that in turn led to unplanned urbanisation. Unplanned urbanisation is charecterised by drastic landscape and local ecology changes that leads to conversion of ecological land use (such as vegetation. Open area, cultivable lands, water) into impervious layers on the earth surface. Increasing unplanned urbanisation is an important cause for depletion of natural resources [1, 2]. The unplanned urbanisation has various underlying effects such as sprawl that effect largely the natural resource and leading to depletion.

Urban Sprawl refers to an unplanned and scattered growth of paved land [2, 3], the sprawl occurs basically in the periphery and the outskirts and regions devoid of basic amenities.

Megacities or the metropolitan continue to evolve and grow [4] with leads to further environmental degradation [5]. This phenomenon is most prevalent in developing countries [3] such as India [6, 7]. Demographic and the degradation of the surrounding natural ecology at longer timescales has a large impact on land use in a region. Hence there is a need for better planning and administration. For better land use planning changes in current land use patterns temporally is essential [8].This necessitates the analysis of land use changes and the prediction of likely changes in the future.

Availability of spatio-temporal data and the advancement of remote sensing [9] has enabled unbiased land use analysis. Analysis of land use dynamics has attained research attention both at global and Indian contexts focusing on dynamically evolving cities [10]. Several studies have assessed urban growth in various megacities around the world [1, 8, 11, 12, 13]. These studies though mapped and focused on temporally evolved current land use across various cities, have not addressed the likely growth required for the regional planning. Prediction of future growth are essential to control the uncontrolled development and plan for sustainable cities. Predictive models become very significant as they foresee spatial changes based on the historical land uses, which helps the decision makers in planning the growth including sprawl across the city periphery.

CA with markov considering spatial context based on neighbourhood configuration generates transition potential maps [14, 15]. However, for models to be effective there is a need for incorporating the agents such as social factors, economic factors, geography of an area which have decisive role in the urban process of a region. This has been demonstrated through incorporation of socioeconomic data into CA-Markov to predict land use changes [16]. Geomod which is also determined using structure of CA markov is also proved as one of the main methods in modeling urban pattern this highlights the need for research, which still remains a research challenge. This communication analyses three different algorithms such as Geomod, CA Markov and land use change modeler, for modelling rapidly urbanising landscape, which will help the decision makers and city planners in planning further developments.

II. STUDY AREA:

Bangalore the IT hub of India is located in the southern part of the country of Karnataka state. With the spurt in IT industries in the region during late 1990’s, the city was termed “Silicon Valley”. This policy interventions created job opportunities to different category of people. The city has grown spatially during the last year by 10 times and the current spatial extent is about 741 km^2. Geographically Bangalore is located in the Deccan plateau, toward the south east of Karnataka state extending from 12°49’5”N to 13°8’32” N and 77°27’29” E to 77°47’2”E. To account for developments in the peri urban regions, the study area includes ten km buffer (from the administrative boundary) with a gross area of over 2250 km^2 as shown in Fig. 1. Bangalore has spatially increased from 69 sq.km (1901) to 741 sq.km (2006).The decadal (2001 to 2011) increase in population for urban areas of India is 31.8% and in Karnataka is 31.5%, but Bangalore has a decadal increase of 44% very large compared to that of the state and country.

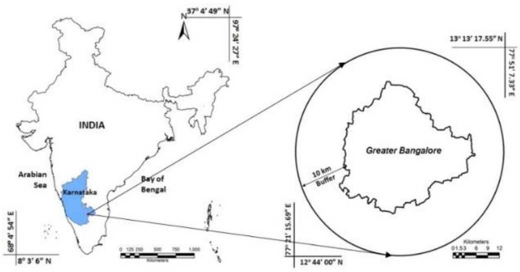

Fig.1. Study Area- greater Bangalore with 10 km buffer

III. DATA USED

Temporal remote sensing data of Landsat 7 TM AND ETM+ sensors for the year 2008, 2010 and 2012 with resolution of 30 m were downloaded from public domain (http://glcf.umiacs.umd.edu/data). Ground control points to register and geo-correct remote sensing data were collected using hand held pre-calibrated GPS (Global Positioning System), Survey of India topo-sheet (1:50000 and 1:250000), Google earth (http://earth.google.com) and Bhuvan (http://bhuvan.nrsc.gov.in).

IV. METHOD

The process of urbanisation and sprawl in Bangalore (study area) have been assessed which includes (i) Land use analysis, (ii) Modeling and prediction. Land use data was used from the previous analysis (Bharath S et al., 2012). This data was reclassified into Urban and non-urban for Geomod analysis. But other modelling techniques such as CA Markov and LCM same data with 4 classes as described in table 1 was considered.

Modeling and Prediction: CA MARKOV: The land use pattern is evolving dynamically and follows the Markovain random process properties with various constrains that include average transfer state of land use structure stable and different land use classes may transform to other land use class given certain condition (Such as non-transition of urban class to water or vice versa). Thus Markov was used for deriving the land use change probability map for the study region and was applied using Markov module of IDRISI. The probability distribution map was developed through Markov process. A first-order Markov model based on probability distribution over next state of the current cell that is assumed to only depend on current state . CA was used to obtain a spatial context and distribution map. CA’s transition rules use its current neighborhood of pixels to judge land use type in the future. State of each cell is affected by the states of its neighboring cells in the filter considered. Besides using CA transition rule and land use transition is governed by maximum probability transition and will follow the constraint of cell transition that happens only once to a particular land use, which will never be changed further during simulation. CA coupled with Markov chain was then used to predict urban land use state in 2020

Land use class	Land use included in class
Urban	Residential Area, Industrial Area, Paved surfaces, mixed pixels with built-up area
Water	Tanks, Lakes, Reservoirs, Drainages
Vegetation	Forest, Plantations
Others	Rocks, quarry pits, open ground at building sites, unpaved roads, Croplands, Nurseries, bare land

Table 1. Land use categories

Land use Change Modeller (LCM): an ecological modeller module in IDRISI Taiga was used for modelling the land use scenario based on the data of 2008, 2010 and 2012. LCM module provides quantitative assessment of category-wise land use changes in terms of gains and losses with respect to each land use class. This can also be observed and analysed by net change module in LCM (IDRISI manual). The Change analysis was performed between the images of 2008 and 2010, 2010 and 2012, to understand the transitions of land use classes during the years. Threshold of greater than 0.1 ha. Were considered for transitions. CROSSTAB module of IDRISI was used between two images to generate a cross tabulation table in order to see the consistency of images and distribution of image cells between the land use categories. Multi-Layer perceptron neural network was used to calibrate the module and relate the effects of agents considered and obtain transition potential sub models. Further markov module was used to generate transition probabilities, which were used as input in cellular automata for prediction of future transitions. This has been analysed with an inbuilt module of LCM or using the CA_Markov in IDRISI.

GEOMOD: GEOMOD was used for modeling the spatial patterns of urbanisation and predict likely land use changes. GEOMOD simulates the spatial pattern of land use changes [56], or change between two land categories (Binary images of urban and non-urban). GEOMOD selects the location of the grid cells based on the following decision rules:

[1] Persistence: simulates one way change.
[2] Regional stratification: simulate land use changes within a series of regions called strata.
[3] Neighborhood constraint: It is based on a nearest neighbor principle, whereby restricting land change within any one time step to cells that are on the edge between landscape A and landscape B
[4] Suitability map considering drivers.

If there is a net increase in the Class A category as the simulation proceeds from a beginning time to the ending time, then GEOMOD will search among the Class B grid cells in order to select the cells that are most likely to be converted to become Class A during the time interval and vice versa [56][57][58].

Suitability map is created using GEOMOD Module in IDRISI TAIGA (http://clarklabs.org) considering drivers. Each driver is considered as real number (%), obtained by comparing the driver map to the beginning time land-cover map. Site suitability of each cell is calculated using the equation (1) below, based on each reclassified attribute,

$$\boldsymbol{R(i)} = \sum_{a=1}^{A} \{\boldsymbol{Wa} * \boldsymbol{P_a(i)}\} / \sum_{a=1}^{A} \boldsymbol{Wa} \quad ..(1)$$

Where: R(i) = suitability value in cell(i), a = particular driver map, A = the number of driver maps,
Wa= the weight of driver map $\boldsymbol{a}$, and P_a (i) = percent-developed in category a_k of attribute map a, where cell (i) is a member of category a_k. Predictions were done considering three population growth rates of 5% (current average population growth of Karnataka)

V. RESULTS

Land use analysis: Land use analysis was done using Maximum Likelihood classifier (MLC) considering training data collected from field. Land use analysis show an increase in urban area from 49915.42 (2008) to 59103 hectares (2012) which constitute about 30%. Fig. 2 illustrates the increase in urban area and the same is listed in table 2. Overall accuracy and Kappa was calculated using the module r.kappa in GRASS and results shows an accuracy of 85% and 0.9 kappa was obtained on average.

Validation: Predicted land uses of 2010 and 2012 were compared with actual land uses of 2010 and 2012 classified based on remote sensing data with field data. The weights for each scenario was then obtained based on validation per pixel basis so that the developed semantics match the original land use. Validation of predicated land use was done using the actual land uses as reference and accuracy assessment was done with Kappa values which are given in table 5. Results reveal that predicted and actual land uses are in conformity to an extent of 87 to 91%. The prediction exercise is repeated for 2020 keeping 2012 as base year.

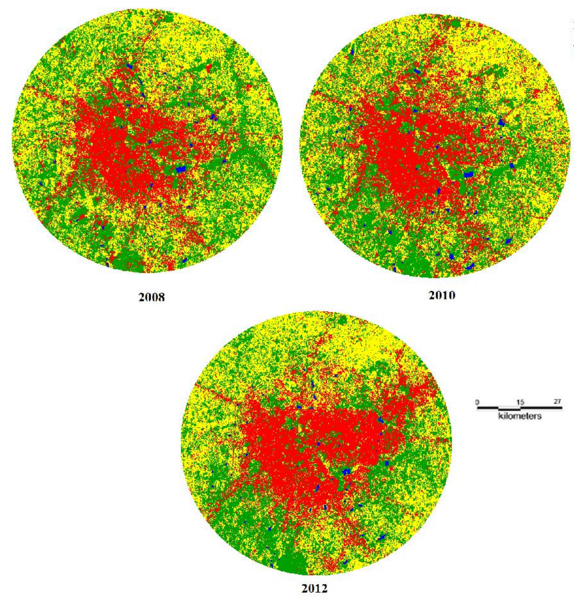

Fig. 2. Land use transitions during 2008 to 2012

Class Year	Built-up Area		Water	
	Ha	%	Ha	%
2008	49915.42	24.85	1068.94	0.53
2010	57208.40	28.48	1571.41	0.78
2012	59103.90	29.33	1169.82	0.58

Class Year	Vegetation		Others	
	Ha	%	Ha	%
2008	77036.96	38.35	72851.95	36.27
2010	73460.57	36.57	68,656.40	34.17
2012	67883.85	33.68	73385.73	36.41

Table 2: Land use during 2008, 2010 and 2012

Modelling: Using *cellatom* module of IDRISI the results of CA_MARKOV were obtained as illustrated in Figure 5. The likely land use is indicated in Table 3. The land use change modeler of IDRISI was used to obtain the prediction, results of which are as shown in Figure 6 and tabulated in table 4. Geomod analysis required the land use derived data to reclassified into two classes: Urban and non-urban. Results of this analysis is as shown in Figure 7 and tabulated in table 5.

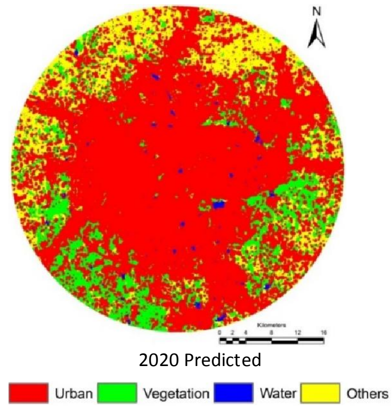

Fig.5. Predicted land use map for 2020

Year	2020 - Predicted
Land use	%
Urban	70.64
Vegetation	13.55
Water	0.74
Others	15.07

Table 3: Land use 2020

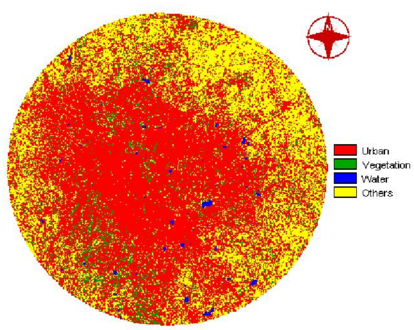

Fig. 6: Predicted growth of Bangalore by 2020 using LCM

Year	2020 - Predicted
Land use	%
Urban	61.27
Vegetation	7.00
Water	0.55
Others	31.18

Table 4. Land use statistics of Bangalore for 2020.

VI. Discussion

Three modelling techniques considered show relatively good accuracy with validation dataset. But Geomod gives a conclusive output considering the better validation results and proposed city development plan. But Geomod has a capability of using only two land use classes. Comparatively using 4 land use classes LCM provides better visual interpretation since it uses agents to derive the growth. CA-Markov is dependent on neighborhood and rules and shows an exaggerated output of further aggregation of already urbanised city.

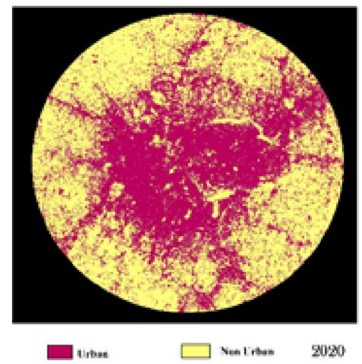

Fig. 7: Predicted growth of Bangalore by 2020 using Geomod

Year	Non-Urban	Urban
2020	49.62%	50.38%

Table 5: Land use 2020 using Geomod

The predicted land use reveals of similar patterns of urbanisation of last decade. The main concentration will be mainly in the vicinity of arterial roads and proposed outer ring roads. Predicted land use also indicate of densification of urban utilities near the Bangalore international airport limited (BIAL) and surroundings. Further an exuberant increase in the urban paved surface growth due to IT Hubs in south east and north east. The results also indicated the growth of suburban towns such as Yelahanka, Hesaragatta, Hoskote and Attibele with urban intensification at the core area in almost all modelling techniques used. The results indicate that the urban area would cover close to 50 to 60 % of the total land use in and surrounding Bangalore. Thus providing insights to relevant information. Further modelling can be improved using nature and bio inspired techniques.

VII. Acknowledgement

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