Markov Chain Modelling of Land Cover Changes in Jodhpur City

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***Abstract*—The aim of this research study is to predict and analyze the future urban land cover change of Jodhpur City. Landsat satellite data of 1990 and 2000 were used for examine the land cover pattern. For classification and mapping, identified five classes i.e. (1) built-up, (2) other area, (3) vegetation, (4) mining area, and (5) water body. Using supervised classification algorithm, classified images of 1990 and 2000 were derived. To study land cover dynamics and Prediction land cover map (2010 and 2020) in the Jodhpur city , Stochastic Markov (St_Markov) with RS and GIS data is used. The study find out the rate and dynamics of change land cover types in spatial extent. This output result would help to have a assessment of the future situation of urban land changes which would guide the policy managers.**

***Keywords* —Land Cover Change; Markov Chain; Transition Probability, GIS.**

I. Introduction

Markov chain analysis is named after the Russian mathematician Andrei Andreevich Markov (1856-1922). He developed the Markov chain as natural extension of sequences of independent random variables. A Markov chain analysis is that in which the state of system at time (t2) can be predicted purely on the basis of the immediate preceding state of a system at time (t1) (Thomas and Laurence, 2006). The Markov chain analysis describes the change of one land cover to another land cover and further utilizes this to predict. Modeling of land cover change plays a key role to understand the impacts of the changes. This shall assist for environmental management, resources use, development policy and decision making. The model result is compared and validated with a base land use map. The model applied for further prediction analysis once the output of the validation are successful.

II. Study Site

Jodhpur is centrally situated in western region of the Rajasthan state. Jodhpur city is located at 26ºN 18' latitude and 73º E 04' and at an average altitude of 224m above mean sea level. In general, the contours are falling from North to South and from North to Southeast with maximum level of 370m and minimum of 210m. The present population is about 1.05 million and admeasures 230sq.km. Alongside, Jodhpur has been functioning as one of the engines powering the Indian economy. The establishment of large-scale core industries has led to the growth of ancillary and small-scale industries in and around this industrial belt. The landscape saw significant changes with each passing year as long stretches of farmland giving way to clusters of enclosed factory campuses. The location site is given in Fig.-1.

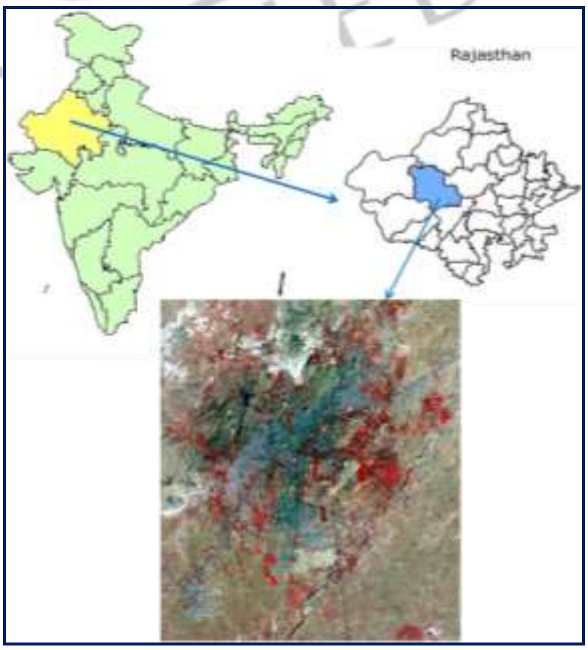

Fig.1: Study Site Map.

III. Data Used and Methodology

A. Data Used

Precision geo-reference cloud free Landsat TM and IRS L-3 satellite data on 1:50,000 scale used for land use cover mapping in the study area. Landsat satellite images (1990 and 2000) used in this paper, downloaded from the USGS website. Projection of data is UTM within Zone 43 N, WGS-84 and the spatial resolution is 30 m. The Landsat satellite images detailed is shown in Table 3.1. Survey of India (SoI) map has been also used for geo-registration and ground truth data collection in the study area. To understand the theory of urban land change analysis and prediction, literature study from many papers and documents have been done.

Table-1: Properties of Landsat image

Year	Date Acquired	Spacecraft ID	Sensor ID
1990	Oct - 1990	LANDSAT_5	"TM"
2000	Oct - 2000	LANDSAT_7	"ETM"

B. Methodology Adopted

Using supervised classification method, classified images of 1990 and 2000 were derived. Techniques like Land use Change Modeling (LCM), Transition Potential Modeling with LCM were used for the analysis of land use changes and modeling. Stochastic Markov Model (St_Markov) has been used for analysis and prediction of land cover change modeling. Techniques like Land use Change Modeling (LCM), Transition Potential Modeling was used for analysis of land changes and modeling. Stochastic Markov Model is used for prediction (2020) analysis of land change modeling. Detailed methodology is given in Fig.2.

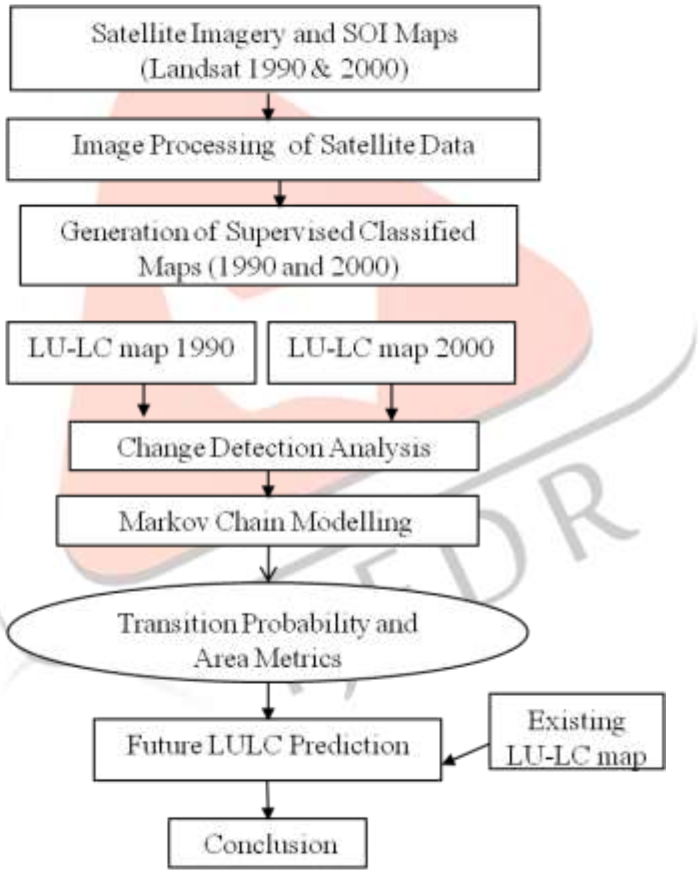

Fig.2. Reserch Methodology

IV. Result and Discussion

A. Stochastic Markov Model

A Markov chain is a stochastic process based on probabilities with discrete state space and discrete or continuous parameter space. In this random process, the state of a system at time (t+1) depends only on the state of the system at time t, not on the previous states. Markov Chain Analysis, on the other hand, is a system in which the future state of a system is modeled on the basis of the immediate proceeding state. It is based on the principle that given the present state, future states are independent of the past states.

Analysis with Stochastic Markov Model

The 'Stochastic Markov Model (St_Markov), is a combines both the stochastic processes as well Markov chain analysis techniques. This kind of predictive land cover change modelling is suitable when the past trend of land-cover change pattern is known. Markov chain produces a transition matrix (Table 2), a transition areas matrix (Table 3) and a set of conditional probability images by analyzing two qualitative land cover images (Fig. 3) from two different dates (1990 and 2000).

The matrix of transition probabilities shows the probability that each land cover category will change to other categories in 2010. Table 5.2 represents the number of cells/pixels (30 m × 30 m) that will be transformed over time from one land cover type to other types. Markov Chain Analysis also produces related conditional probability images (Fig.3) with the help of transition probability matrices. These images are called conditional because the probability is conditional to the current state. It is clear after analyzing Fig 3 that most areas will convert into built-up areas. The Markovian conditional probability of being built-up area ranges upto 0.70 which is the highest among all the land cover types. This probabilistic prediction is dependent upon the past trend of last ten years (1990-2000).It is found from change detection analysis that most areas are being converted to built-up areas and the Markovian conditional probability images also substantiating the same trend.

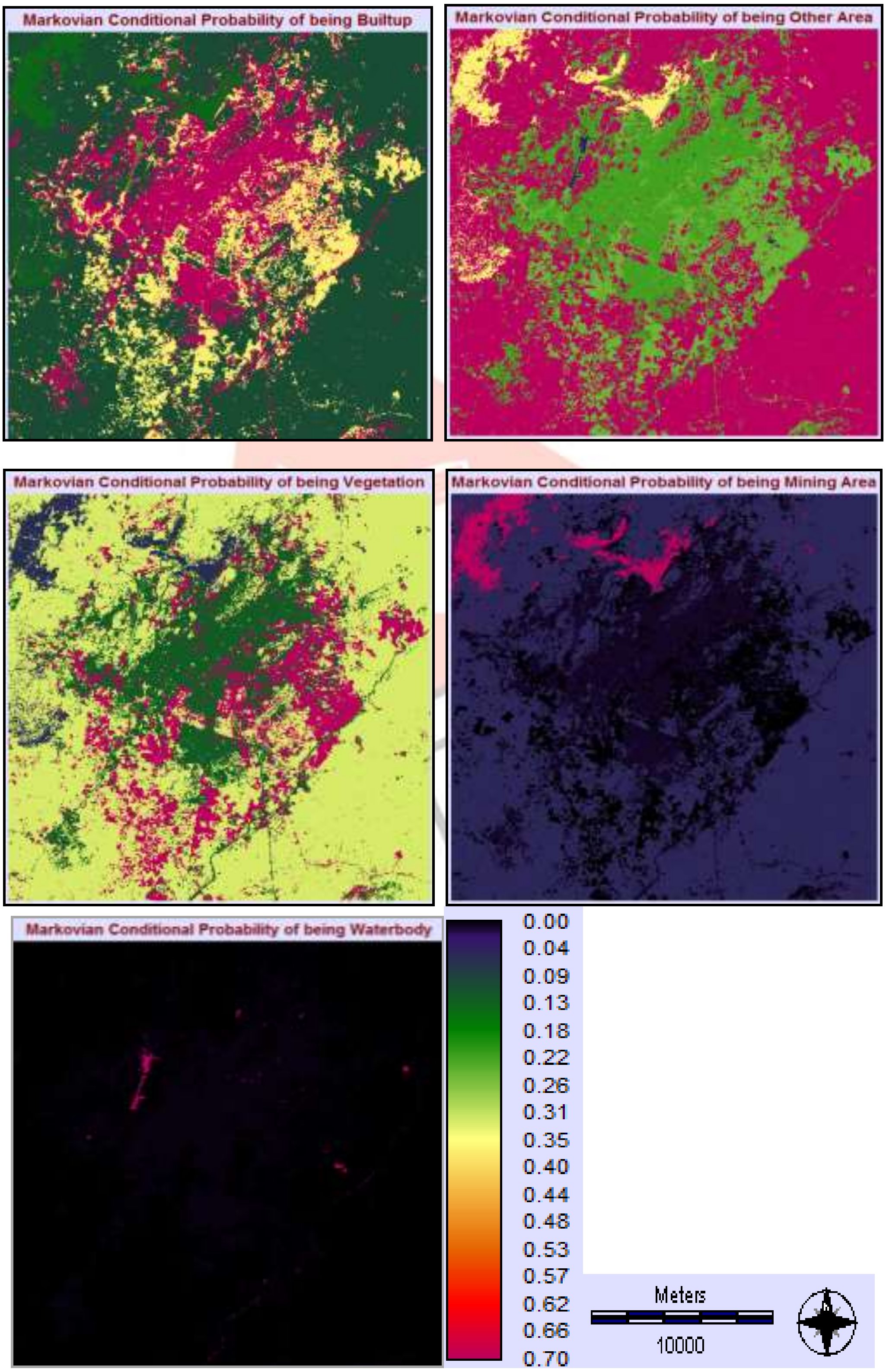

Fig 3: Markovian Conditional Probability Images

Table-2: Markov Probability of Changing among Land Cover Types

	Built-up	Other Area	Vegetation	Mining Area	Waterbody
Built-up	0.7039	0.2139	0.0689	0.0070	0.0063
Other Area	0.1066	0.6792	0.1774	0.0362	0.0006
Vegetation	0.3710	0.2389	0.3865	0.0016	0.0021
Mining Area	0.1406	0.3514	0.0341	0.4714	0.0026
Waterbody	0.2143	0.0423	0.1666	0.0099	0.5669

Table-3: Cells Expected to Transition to Different Classes

	Built-up	Other Area	Vegetation	Mining Area	Waterbody
Built-up	89496	27201	8758	889	797
Other Area	43640	278003	72594	14817	245
Vegetation	35600	22922	37086	149	198
Mining Area	3651	9128	885	12245	66
Waterbody	351	69	273	16	928

Future Prediction Using Stochastic Markov Model

To make one single land cover map for future prediction aggregating all the Markovian conditional probability images. The final predicted land cover map of 2010 will be based on the past ten year's land cover change pattern on the basis of Markov chain analysis. This prediction is to be performed by a stochastic choice decision model. This decision model gives a random value from 0.0 to 1.0 for each pixel and for each type of land cover. Then for each pixel this process continues cumulatively adding conditional probabilities in the order of the Markovian conditional probability images. The Stochastic Markov (St_Markov) predicted land cover maps of 2010 is shown in Fig.4. A Mode filter has been applied to generate a much clear St_Markov predicted map of 2010 and 2020 (Fig.5 &6).

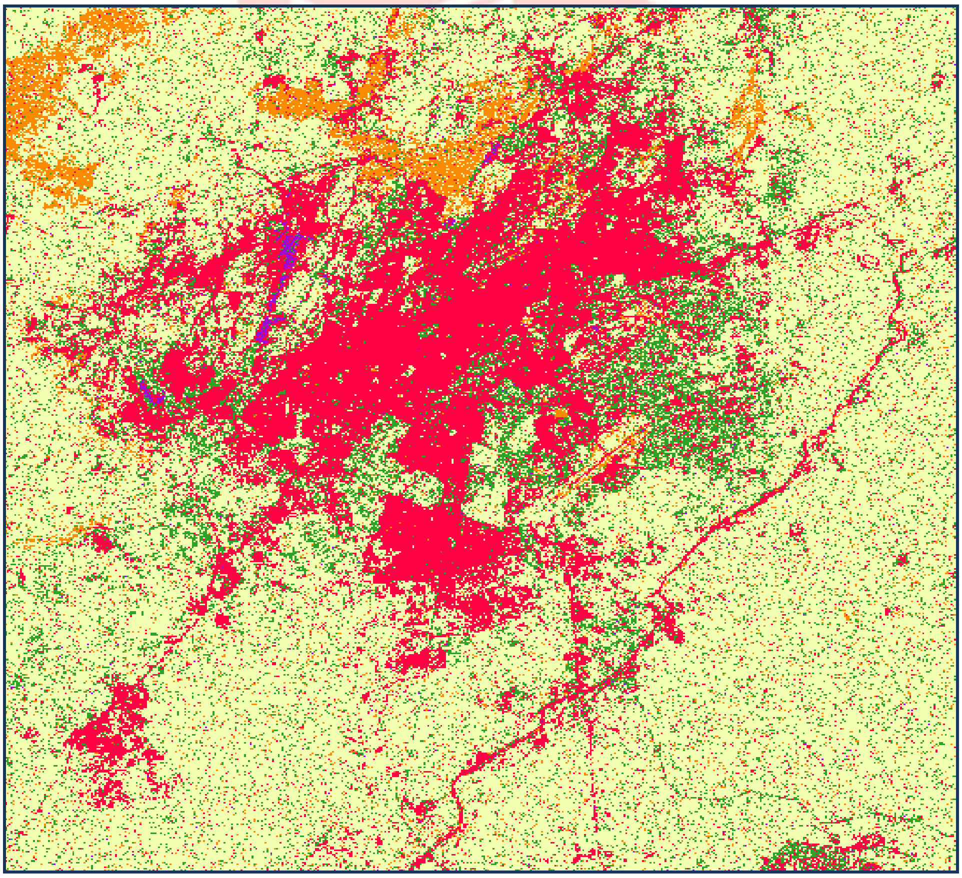

Fig.4. The Stochastic Markov Predicted Land Cover Map 2010.

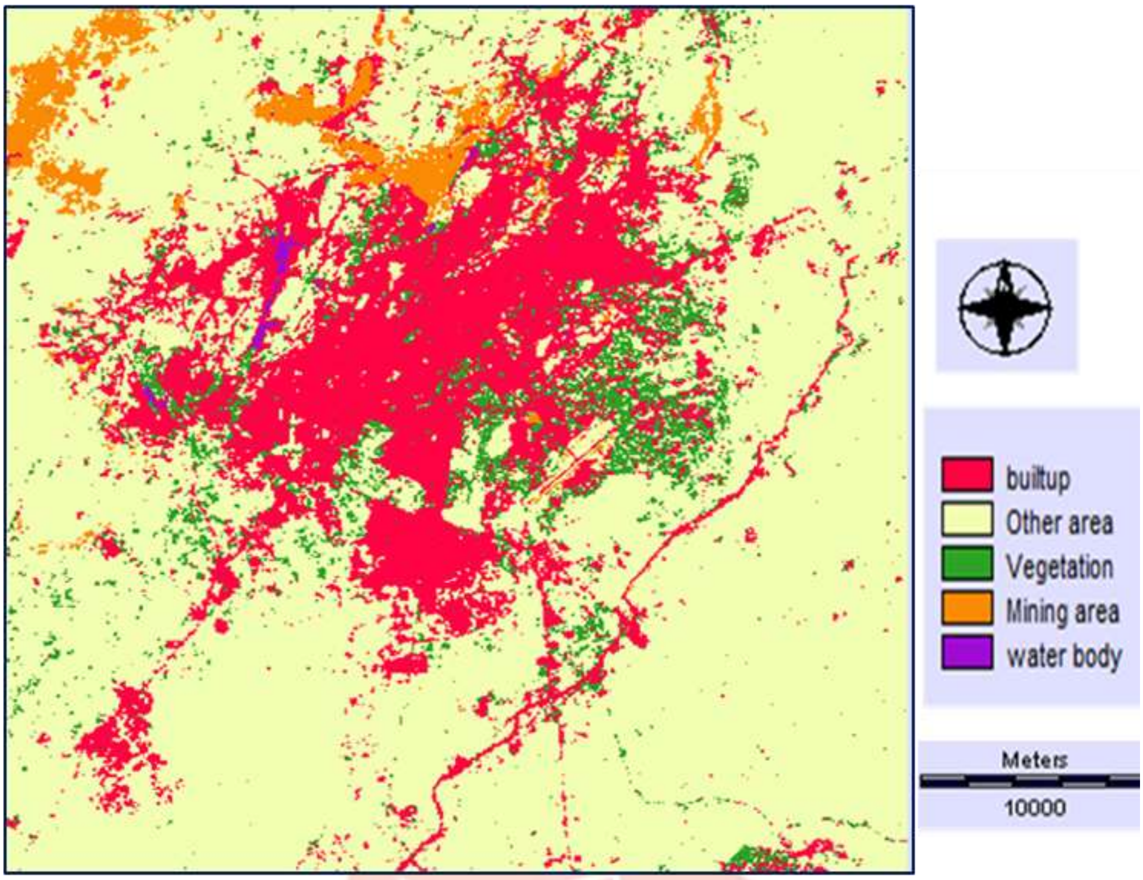

Fig.5. Mode Filter Output St_Markov Predicted Land Cover Map 2010.

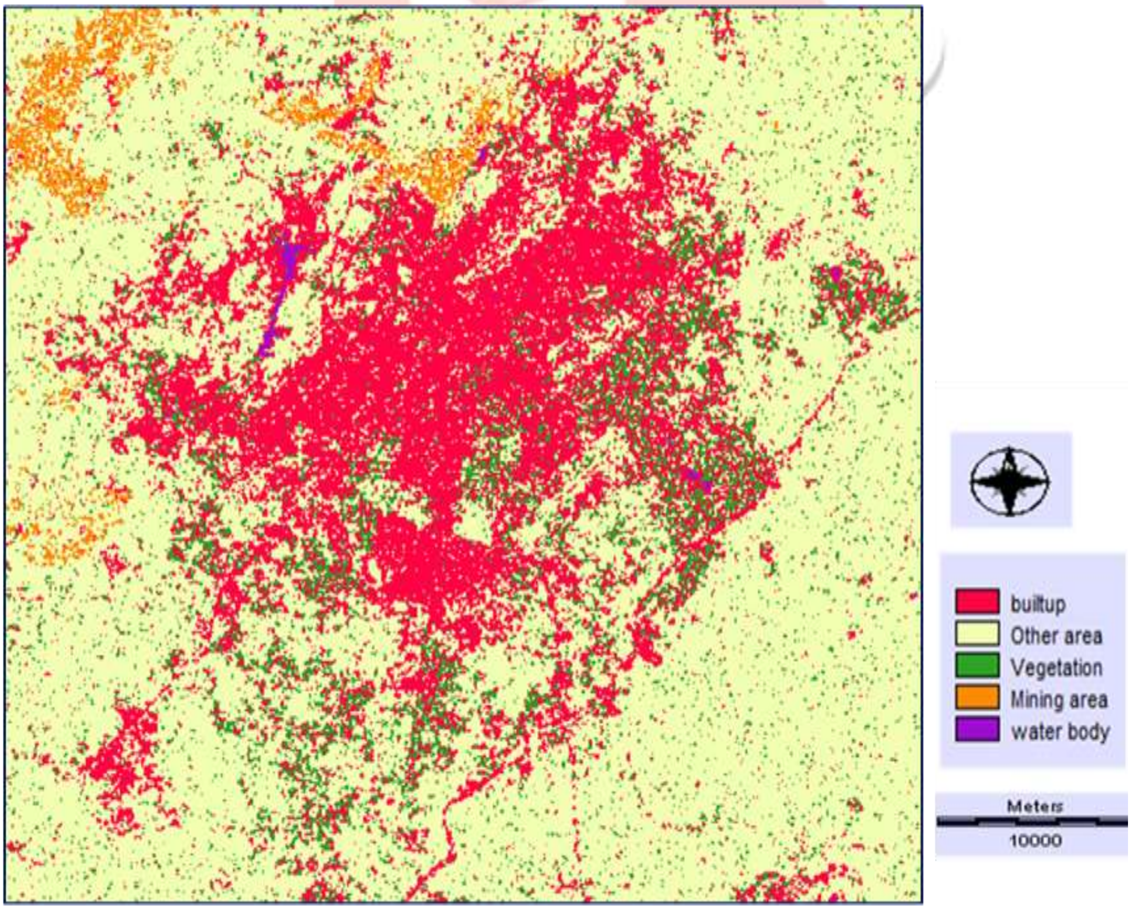

Fig.6. .Mode Filter Output St_Markov Predicted Land Cover Map 2020.

V. CONCLUSION

This study utilizes two time period changes to better account for the trend and the modelling exercise. The Markov chain analysis describes the change of one land cover to another land cover and further utilizes this to predict. Modeling of land cover change plays a major role to understand the impacts of the changes. The results shows that the Remote Sensing and GIS technology is an effective approach in analysis of land use change modelling with Markov. Finally using Markov chain analysis land cover area statistics was predicted for the year 2020. This analysis would help to have a aggregate view of the future setting of urban land use which would guide the policy makers.

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