Estimating Land Use Change in the Kathmandu Metropolitan Area Using a Markov Chain Model

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(1) Introduction: Since the 1960s, the agriculture landscape of the Kathmandu metropolitan region transformed dramatically into an urban form driven by the vehicular arteries and migration into the city. High population influx and rapid land use change may cause a serious pressure to the limited resources with undesirable impact to the environmental conditions and livelihoods of inhabitants in the city area.

(2) Objective: The main objective of this paper is to monitor and estimate the land use change in the Kathmandu metropolitan area using Landsat satellite data and a Markov chain model.

(3) Data: Two images of Landsat satellite acquired on 31st October, 1989 and 4th November, 1999 covering the Kathmandu metropolitan area were classified using the supervised maximum likelihood method. The accuracy of classification results achieved were 91% and 92% for the year 1989 and 1999. The land use change matrix between the years was prepared for analyzing major land use changes in the city. The matrix was limited to four categories of land use change (built-up, agriculture, water and forest).

(4) Methodology: Markov chains models have been widely used to model land use changes in urban areas, since the 1960s. This paper assumed land use change from time T_1 to T_2 is a Markov chain with stationary transition probabilities, and different categories of land uses were the state of a chain. Furthermore, the current process of land use change can affect the results of land change in future. A Markov chain equation (P_{ij} *x* $L_j = L_{j+1}$) was used. P_{ij} is transition probabilities where land is changed from state *i* to state *j* at given time period. A probability vector of P_{ij} with row components entries are non-negative and sum to 1. L_j is a vector of land use at state *j*. L_{j+1} represents the projection of land use properties for the next time period. In this study, we projected the land use change in the metropolitan area for the year 2009 and 2019 by computing first and second orders of Markov chain.

(5) Results: Fig. 1 (A and B) presents the land use patterns in 1989 and 1999. Fig. 1 (C) shows the locations of land use change between the years 1989 and 1999. Four land use classes, namely Built-up (consisting of HMG Secretariat, Industrial area, Institutional area, Open field and Urban built-up), Agriculture, Water and Forest were used to compute Markov transition probabilities and to predict the land use change statistics for the years 2009 and 2019 (Fig. 2). The quantitative result (Fig. 2) shows very low existence of water (<5%) and forest cover (<10%). The water cover appears to be almost constant in the past and in future. The forest cover shows slightly decreasing pattern in the past but it will be constant in next decade. The trend of built-up land is being rapidly increased since 1989 which will be doubled by the year 2019 (>60%) where agriculture land will be half during the same period. The overall result showed the trend of rapid expansion of urban built environment and shrinkage of the cultivated land.

(6) Conclusions: This paper is able to identify the urban land use change thematically from remote sensing data. The Markov chain model has shown the capabilities of descriptive power and simple trend estimation for land use and land cover change in the Kathmandu metropolitan region. The integration of satellite remote sensing, GIS and Markov chains modeling provided a means to study changes in urban land use.

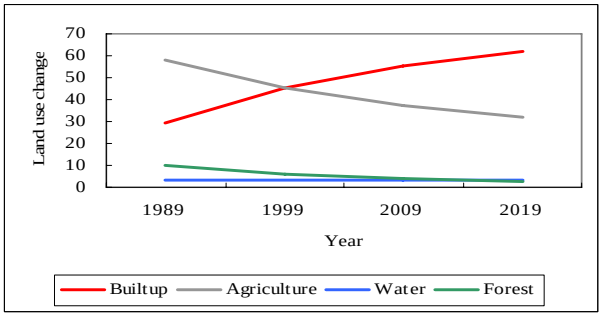

Fig. 2: Land use change estimates for next decade

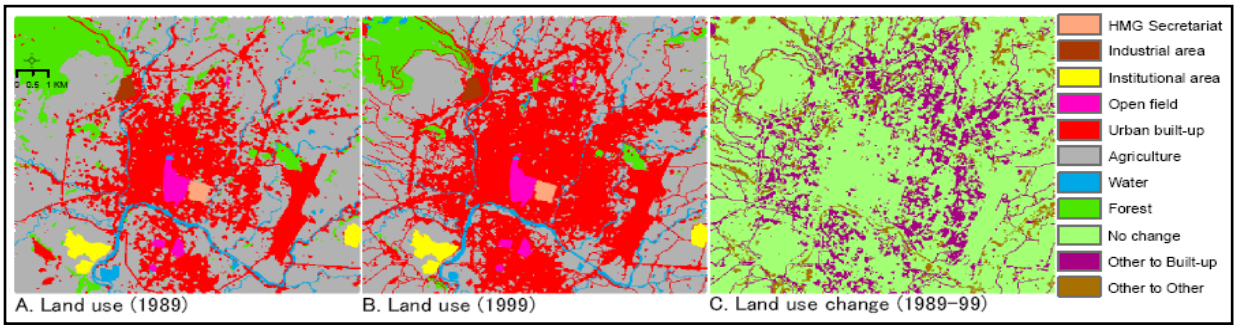

Fig. 1: Land use changes in Kathmandu metropolitan area