USING THE CELLULAR AUTOMATON MARKOV MODEL FOR FORECASTING AND ASSESSING OF LAND USE CHANGE IN THE FUTURE IN NAKDONG RIVER BASIN IN KOREA

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Abstract: *The forecasting and assessing of landuse change in the future is not only a plays a significant role to assess change of land use changes but also great significance in help for water resources management, land use resources planning and management in region. Therefore, the main objective of this study is to forecast and assess of land use change by combined using both of Cellular Automaton and Markov (CA_Markov) model, which was simulated to Nakdong river basin. The forecasted results of the land use change showed the large change of two land use types that was an increase of urban land area from 1.44% to 5.59%, while agriculture land area was significantly decreased from 25.99% to 21.26% from year of 2000 to 2080, respectively. Other periods of land use future of 2030, 2050 with increasing of urban land percent of 3.42%, 4.25%, while decreasing of agriculture land percent of 23.82%, 22.85% respectively. Others land use types is not so much to change. These results of paper showed the land use change which is really necessity to consider long-term adaptation and mitigation strategies for land use management in the future in study area.*

Keywords: Land sue change model, Nakdong river basin, Markov chain

1. INTRODUCTION

Land use changes is a main issue of global environment change, is central to the sustainable development debate. Landuse and land-cover changes have impacts on a wide range of environmental and landscape attributes including the quality of water, land and air resources, ecosystem processes and function, and the climate system itself through greenhouse gas fluxes and surface albedo effects. Whilst, a few years ago, most land-use and land-cover change research was focused on land-cover conversions (e.g., deforestation, urbanisation), researchers have increasingly realized that more subtle processes leading to a modification of land cover deserves greater attention. Land-cover modification is frequently caused by changes in the management of agricultural land use including, e.g., changes in levels of inputs and the effect of this on profitability or the periodicity of complex land-use trajectories, e.g., fallow cycles, rotation systems or secondary forest regrowth. There are several models which used to assess land use change as included Markov models, logistic function models, regression models, econometric models, dynamic systems models, spatial simulation models, linear planning models, nonlinear mathematical planning models, mechanistic GIS models, and cellular automata models. (Alexandra D et al., 2005) used a cellular automata model to forecast the effects of urban growth on habitat pattern in southern California, (Kok et al., 2001) Evaluating impact of spatial scales on land-use pattern analysis; (Brown et al., 2002) Stochastic simulation of land-cover change using geostatistics and generalized additive models; (Clarke et al., 1998) Long-term urban growth prediction; (Eastman et al., 1998) Multi-criteria and multi-objective decision making for land allocation using GIS; (Eastman et al., 2005) Transition Potential Modeling for Land-Cover Change; (Jiao et al., 2006) Transition rules elicitation methods for urban cellular automata models; (Almeida et al., 2003) Stochastic cellular automata modeling of urban land use dynamics.

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(Agarwal et al., 2002) A review and assessment of land use change models.

These land-use changes have important implications for future changes in the Earth's climate and, consequently, great implications for subsequent land-use change. Impacts of land-use change scenarios on hydrology and land-use patterns. Some studies have been carried out to estimate the effect of land use changes on the hydrologic response of catchments. The principle of the paired watershed design has served as the reference for all research of the impact of land use changes on hydrology. Moreover, the selection of the watersheds is such that land use and land cover change that is also change in different spatial in river basin and it can be the results of change of flood frequency, base flow (Wang et al., 2006), water quality (Lee et al., 2008), Estimating the effect of climate change and land use change on surface runoff change hydrology and water quality (Jong et al., 2009); Tests the generalized watershed loading functions model using predicted land-use from the CLUE-S model (Verburg et al., 2004). Therefore, main objective of study is to forecast and assess the future land use change on study area, which provide a novel approach by a land change models. This is new and essential for evaluating the spatially distributed and temporal effects of land use changes in Nakdong river basin in Korea.

2. STUDY AREA

The Nakdong River basin is situated in the monsoon region of South Korea (35–37° N, 127–129° E) (Finger 1).

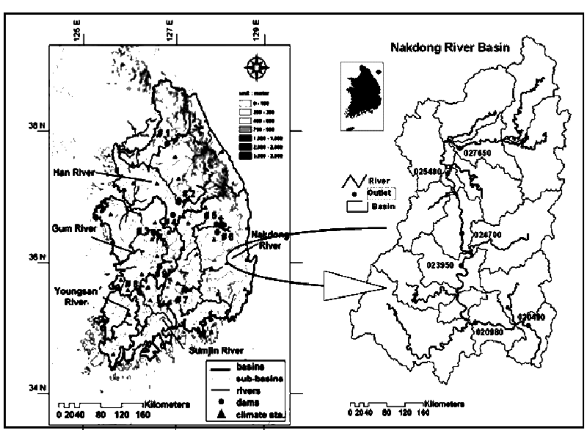

Figure 2.1. Location of study area

This region is characterized by heavy rainfall in the monsoon season in early summer from June to August. The river drains an area of 23.817 km2 and length of the main stream is over 525 km.

3. MATERIALS AND METHODS

In this study CA_Markov model is used to forecast land use change in the future whichs is a powerful tool and combined of Cellular automata models and the Markov model. In specific, the Markov chain analysis describes the probability of land use change from period to another by developing a transition probability matrix between t1 and t2. The probabilities may be accurate on a per category basis but there is no knowledge of the spatial distribution of occurrences within each land use classes. Howevere, In order to add the spatial character to the model, therefore, Cellular automata (CA) model is integrated to the approach. In the CA analysis, it operates on a grid based cells or pixels and transition rules that are applied to determine the state of a cell, the land use was treated as a dynamic system in which space, time and the states of the system were treated discretely. The Cellular Automata model allows the transition probabilities of one cell to be a function of neighboring cells. In conclusion, the Markov chain process controls temporal dynamics among the land use classes based on transition probabilities, while the spatial dynamics are controlled by local rules determined by the Cellular Automata. (i) First, creating transition probabilities matrix: This research use CA-Markov to analyze the two images to output a transition probability matrix, a transition areas matrix, and a set of conditional probability images. it records the number of pixels that are expected to change from each land cover type to another type over several time units. (ii) Second, creating group of suitability maps: transition suitability maps were produced by constraints and factors from land use types. (iii) Third, Spatial distribution of simulated land-use probability: In CA_ Markov model, the transformation rules participation simulation process in the form of land use transition probability. Then CA_Markov will use the transition areas and the conditional probability images to predict land cover change over the period specified in Markove chain analysis. (iv) Finally, specify of period for interactions to simulate land use change in the future result

In this study, required two observed land use maps from two different periods that is used to develop the transition probability matrix and transition area matrix as the land use maps of 1980 and 1990. The file of transition area matrix determines the number of cells that are expected to change from each land cover type to each over next time. A specific Markov chain matrix was deriver for each period of land cover projections. In this study, three of land use forecast of 2030, 2050, and 2080 that were used to forecast land change in this study. All of the structure and concept of the model are shown in flow chart in Figure 3.1 that described the methodology applied to calibrate, validate, and simulate of the model to achieve objective of study.

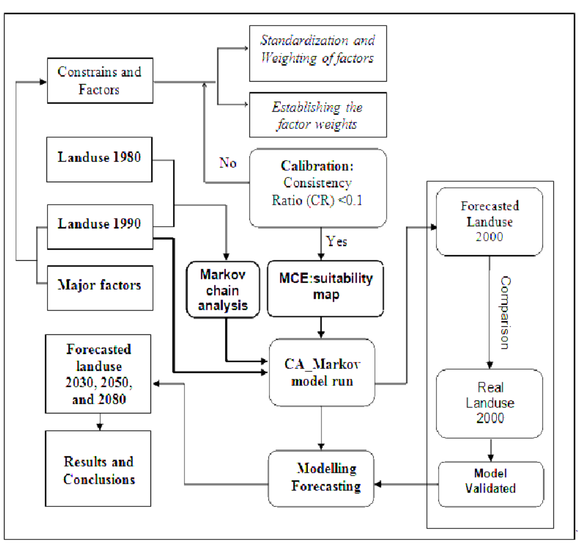

Figure 3.1. Schematic diagram of the proposed modeling framework

4. RESULTS AND DISCUSSIONS

4.1. CA_Markov model calibration

These results of calibration is based on known land use maps for two different time periods for the Nakdong river basin of 1980 and 1990 for calibration and land use map of 2000 for validation. Result of calibration is control by a hard rule because a location is considered suitable by exactly meeting all the criteria. In the boolean approach all the factors were given equal importance in the final suitability map, the boolean approach was further standardized to represent the probability with range from 0 (the least suitable) to 255 (the most suitable) of a cell to be suitability for land use using weighting factor and this result was accepted based on suitable weights. The results of calibration from building the constraints were obtained as shown in Figure 4.1. Transition rules (suitability maps) were developed in a binary scale boolean approach of 0 and 1 as shown in figure 4.1

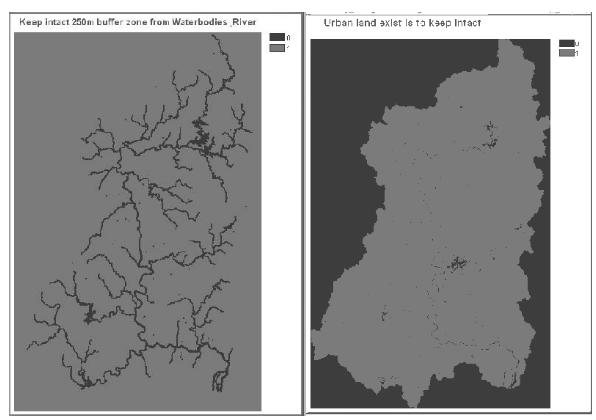

Figure 4.1. The maps of constraints

In addition, the membership functions used for standardizing the variables in this study which was based on determined the standardization of variables. The result of variable factors after standardization as simulate in Figure 4.2 below which shows the map variables derived by standardizing the criteria in a continuous scale from 0 (the least suitable) to 255 (the most suitable).

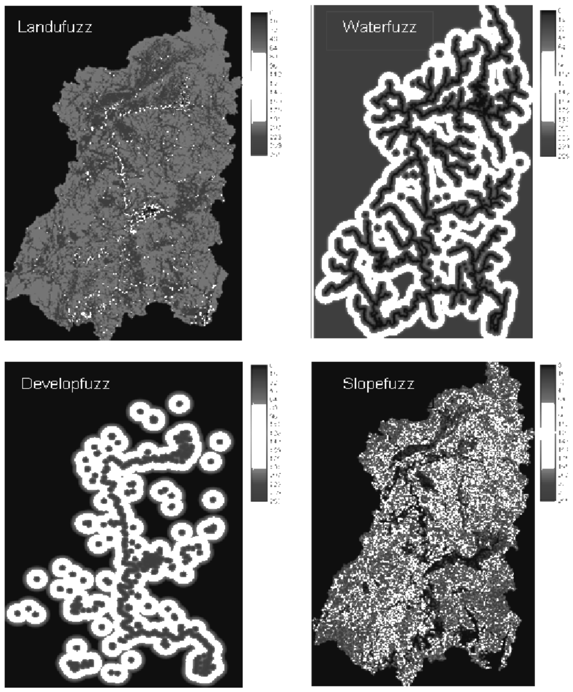

Figure 4.2. The maps of variable factors after standardization

The establishing the factor weights: The rating is subjective and entirely depends on the analyst. The weights and a consistency ratio (CR) were calculated to identify inconsistencies and develop the best fit weights in the complete pairwise comparison matrix. The researches indicated that matrices with a consistency ratio greater than 0.1 should be re-evaluated. Therefore, in this study, the consistence ratio was calculated to be 0.08, so the pairwise comparison matrix rating and weights are acceptable.

Table 4.1. Weights assigned to the variables

Factors for variables	Factor Weights
Land use	0.2052
Distance from water bodies	0.3177
Distance from developed	0.1830
Slope	0.2941
Consistency Ratio (CR) of 0.08	

The result of the forecasting might be significantly affected by a number of factors and suitability maps where the suitability maps had a great influence on the land use forecasting, and this is because the suitability maps acted as the rules for the CA model, that is shown in Figure 4.3.

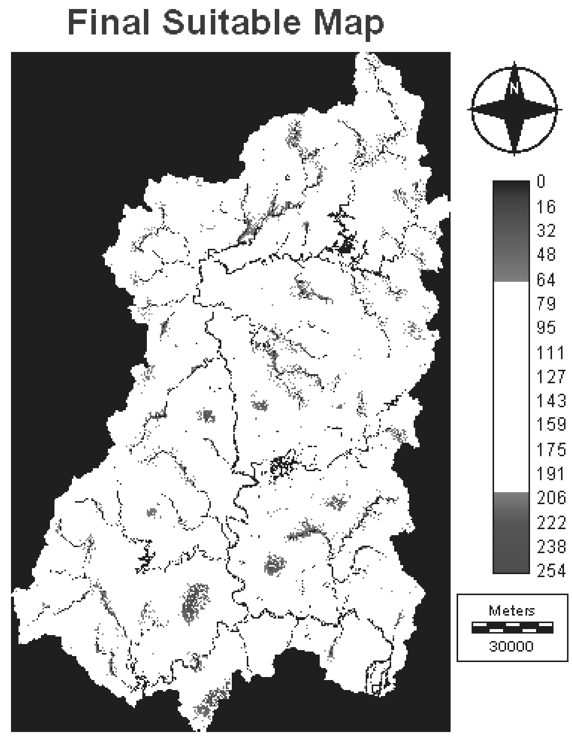

Figure 4.3. Suitability map

4.2. CA_Markov model validation

Validating the projected land use is an important step in the modeling process because results of the simulation would give a misleading result. In this study, model validation is compared between simulated (forecasted) land use map for 2000 and the actual (observed) land use map of 2000 as shown in Figure 4.4. Validation was based on analysis of the Kappa spatial correlation statistic index for assessment the level of agreement between the forecasted and observed land use maps. Visual analysis of the results reveals that the forecasted map are close to the observed map. In addition, in this case, the result of Kappa index is determined with success of 82% for validation that is acceptable for the result of validation.

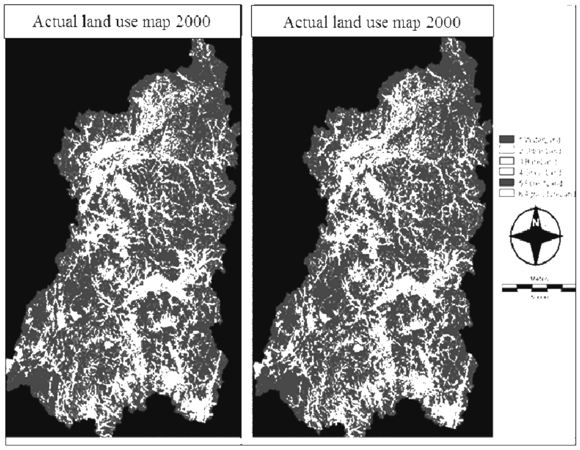

Figure 4.4. Actual and forecasted land use map of 2000

CA_Markov model combines both the concept of a CA filter and Markov change procedure. After running Markov, CA_Markov was use the transition areas table and the conditional probability images to predict land use change over the period specified in Markov change analysis. In this study, using known land use maps for two different time periods for the Nakdong river basin of 1980 and 1990 for calibration and land use map of 2000 for validation. The land use changes analysis scenario to forecast land use change with four periods slice of 2000, 2030, 2050 and 2080, they are used with number of time to project that were specified in Markov chain analysis.

Moreover, the result of factors weight are also determined and the weights and a consistency ratio (CR) was calculated to identify inconsistencies and develop the best fit weights in the complete pairwise comparison matrix. In addition, the result of the suitability map was also obtained by using the MCE and the suitability map has a range from 0-255 is given in Figure 3.3. Based on this criterion for agreement and the success of the model for forecasted land use 2000 with values above 0.82 indicate a good agreement between the actual and forecasted maps. After calibrating the model and assessing its validity, model CA_Markov take time run, the forecasting was carried out that results of future land use maps are forecasted with the years as 2030, 2050 and 2080 as well as land use of 2000 as shown in Figure 4.5

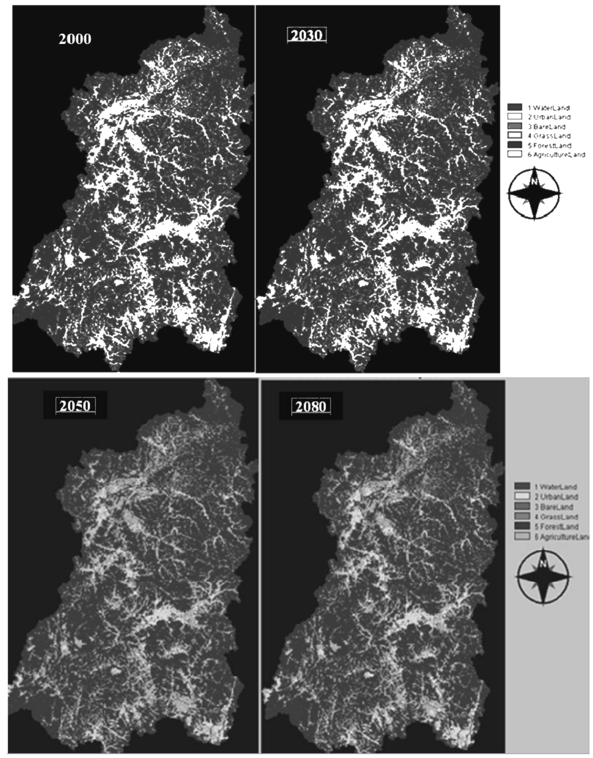

Figure 4.5. The land use maps in the future of 2000, 2030, 2050, and 2080

4.3. Results of land use change

According to the land use types areas data obtained from observation in last decades from 1980-1990 the urban land is intensive increased from 0.33% in 1990 to 1.44% in 2000, and light increasing of forest land of 69.73% to 71,02%, while the agriculture reduced from 28.46% in year 1990 to 25.99% in year 2000. The large change of land types area can be caused by the combination of rapid growth coupled with industrial and urban development. Results of study are given Table 4.4 and Figure 4.6 that showed results of land use types change in the future, a much clearly of two land use types as urbanland and agricultureland change trend can be indicated when comparison the forecasted land use map 2030, 2050 and 2080 with the basic land use map of 2000. The results of the simulation indicate that there will be a significant urban land area use changes in the future in Nakdong basin from 1.44% in 2000 to 5.59% in 2080. In contrast, the agriculture area is decreased from 25.99% in 2000 down 21.26% in 2080. Others land use types are changed insignificantly. The change for land use types in the future time period the results shown in Table 4.4.

Table 4.4. The land use in Nakdong basin

Land use	Water (%)	Urban (%)	Bare (%)	Grass (%)	Forest (%)	Agriculture (%)
2000	1.09	1.44	0.35	0.11	71.02	25.99
2030	1.12	3.42	0.40	0.15	71.09	23.82
2050	1.15	4.25	0.47	0.16	71.12	22.85
2080	1.20	5.59	0.38	0.19	71.38	21.26

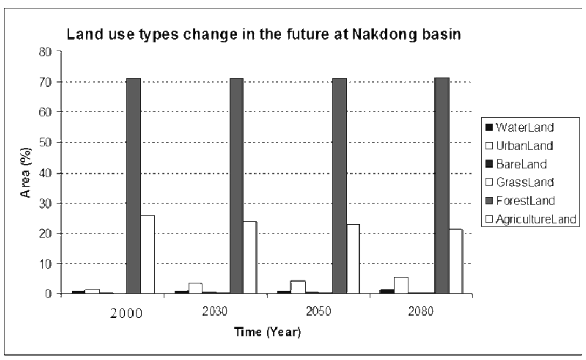

Figure 4.6. Land use types change in the future in entire of Nakdong basin

In conclusion, the result of forecasted land use change in future were revealed a large changes of land use types that are particular as significantly increase on urban area, while agriculture area was considerable decrease in basin. Thus, if in study area that there are no constrains of regulations, or policy in land use management strategies in the future where trend of urban growth would have a considerable impact on the surrounding agriculture area particularly on arable farming land cover. It can be a considerable impact on the watershed land use management in the future in study area.

5. CONCLUSIONS

Land-use change is a widespread, accelerating, and significant process. Land-use change is driven by human actions, and, in many cases, it also drives changes that impact humans. Modeling these changes is critical for formulating effective environmental policies and management strategies. Therefore, the main objective of study is to forecast and assess the land use change in the Nakdong river basin. The land use change in the future were forecasted for years of 2030, 2050, 2080 by combination using the CA and Markov models, and assessed change of land use in this basin. Based on results of this study can answer policy questions, policy makers as well as to policy making land use in basin. There is a necessity to consider long-term adaptation and mitigation strategies for land use management in the future in study area.

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Tóm tắt:

ỨNG DỤNG MÔ HÌNH CELLULAR AUTOMATON MARKOV ĐỂ DỰ BÁO VÀ ĐÁNH GIÁ BIẾN ĐỔI SỬ DỤNG ĐẤT TRONG LƯU VỰC SÔNG NAKDONG, HÀN QUỐC

Nghiên cứu dự báo và đánh giá biến đổi sử dụng đất trong tương lai không chỉ có vai trò quan trọng trong đánh giá các thay đổi của sử dụng đất mà còn có ý nghĩa lớn lao trong công tác quản lý và sử dụng tài nguyên đất, tài nguyên nước trong lưu vực một cách hiệu quả. Vì thế, mục tiêu chính của nghiên cứu này là nghiên cứu dự báo và đánh giá biến đổi sử dụng đất trong lưu vực sông Nakdong bằng việc ứng dụng mô hình Automaton và Markov. Kết quả dự báo của biến đổi sử dụng đất cũng cho thấy rằng, sự biến đổi sử dụng đất một cách đáng kể chủ yếu vào hai loại đất, cụ thể là đất đô thị trong lưu vực tăng từ 1.44% (2000) lên 5.59% (2080), trong khi diện tích đất nông nghiệp giảm đáng kể từ 25.99% (2000) giảm xuống 21.26% (2080). Sự biến đổi sử dụng đất tại các giai đoạn khác cũng được dự báo với sự thay đổi với sự tăng của đất đô thị là 3.42% (2030), 4.25% (2050), trong khi diện tích đất nông nghiệp giảm là 23.82% (2030), 22.85% (2050). Các loại đất còn lại có sự thay đổi nhưng không đáng kể. Kết quả của nghiên cứu đã chỉ ra biến đổi sử dụng đất trong lưu vực đây thực sự là điều cần thiết nên được xem xét để các nhà quản lý, quy hoạch có kế hoạch, thích ứng cũng như giảm thiểu những tác động trong quản lý sử dụng đất thời gian tới trong lưu vực nghiên cứu.

Các từ khóa: Mô hình biến đổi sử dụng đất, lưu vực sông Nakdong, chuỗi Markov.

BBT nhận bài: 30/11/2015

Phản biện xong: 09/12/2015