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SIMULATING URBAN GROWTH IN THE GEORGE TOWN CONURBATION

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ABSTRACT

Simulation of land use changes has been discussed at length, with increasing papers proposing new methods to predict urban growth. Simulating urban growth can provide a clearer view of urban expansion which gave huge impact in developing a city. This phenomenon, however, also has driven the encroachment into agricultural and forest land in order to cater urban growth expansion. Therefore, this paper aims to develop an urban growth simulation model using GIS-based CA-Markov approach, incorporated with driving forces of urban growth in the Malaysian context. Land use data based on year 2006, 2010 and 2014 of the study area were prepared in a GIS database and used to develop and validate a CA-Markov Model using Idrisi Kilimanjaro software. The findings indicated new or expanded built-up areas of 2018 are found to be located in close proximity to existing growth centers and settlements.

Keywords: CA-Markov; Geograpghic Information Sciences (GIS); Land use changes; Urbanization.

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1. INTRODUCTION

In the 19th century, United States of America and United Kingdom experienced rapid urbanization due to the revolution of agricultural and industrial activities in the late of the 18th century [1]. This phenomenon has spread throughout the world as most of the countries began to initiate agricultural and industrial activities to boost their economies. Consequently, it has attracted rural population to migrate into urban areas since most of these activities occur in the cities. Nowadays the world is witnessing an increasing number of urban population and it has been predicted that the numbers of population will keep on increasing to more than 6.3 billion in 2050 [2].

Malaysia is also experiencing a rapid urbanization and it has been classified among most urbanized countries in the East Asia [3]. Kuala Lumpur, George Town and Johor Bharu are the main regions that contribute to this phenomenon where the percentage of urban population rises from 43% (10.2 million) in 2000 to 53% (15 million) in 2010 [3]. Even though Malaysia is considered among least dense in the East Asia, the expansion of urban area is still growing in order to accommodate the demand from the increasing urban population. This will result towards the encroachment of the agricultural and forest area which can lead to other negative impacts to the environment [4].

However, rapid urbanization can also bring positive impacts to the countries such as improvement of the facilities and transportation, globalization, and quality of lifestyles if there is a proper planning in managing urbanization [5]. Federal Department of Town and Country Planning [6] has regulated three conurbations; Kuala Lumpur Conurbation, George Town Conurbation and Johor Bharu Conurbation, in order to contain and plan for the rapid urbanization generated by the cities. Still, due to the various activities occur in the conurbations, it gives a challenge situation to planners in monitoring urban growth.

Several techniques such as mathematical models, statistical models, cellular models and agent-based models have been used to model land-use change [7]. Cellular Automation-Markov (CA-Markov) model has been widely used by many researchers in predicting urban growth, which can be useful in guiding planners [8]. In addition, the latest upgrade in Geographic Information Systems (GIS) has made the integration of land-use change models been possible. The future of land use pattern can be predicted using historical spatio-temporal data that have been integrated with CA-Markov and GIS [9] [10].

Thus, this paper aim to simulate urban growth by developing a GIS-based CA Markov Model incorporated with identified driving forces in the Malaysian context especially in the George Town Conurbation. The implementation of CA-Markov and GIS allows planners and policy makers to devise regulation and guidelines in managing urban growth in the George Town Conurbation.

2. STUDY AREA AND DATA

The study was carried out in the George Town Conurbation which is located in the northwest coast of Peninsular Malaysia. Its location is between latitude 4°50’N and 5°52’N and longitude 100°10’E and 100°51’E with an area approximately 3,938 square kilometers (see Fig. 1). The George Town Conurbation was named after the George Town city indicating that the rapid urbanization produced by the city itself throughout neighboring district. Penang

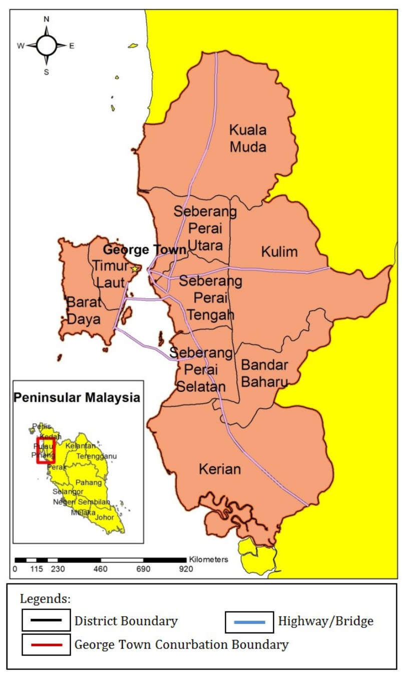

Fig.1. The Study Area (George Town Conurbation)

Source: Penang State Department of Town and Country Planning [11]

State Department of Town and Country Planning [11] has proposed that some districts of Kedah state (Kulim, Bandar Baharu, Kuala Muda) and Kerian from Perak state to be included in the George Town conurbation boundary together with all districts in Penang state. This is in line with the National Physical Plan (NPP) 2 to limit the urbanization from expanding to the outside boundary [12].

The George Town Conurbation is a metropolitan area where the population is expected to exceed 3 million by 2020 [13]. It is selected as the study area because of the rapid development occurs in the city, especially in the industrial, manufacturing, trade, commerce and service sectors [14]. Its situation which is strategically located in the northern region of Peninsular Malaysia can easily establish relationships and cooperation both in regional countries and bordering regions. It has also experienced a significant land use change driven by the spillover of Penang development. This has caused many farmers to give up farming activities and in order to participate in service and industrial sectors offered by surrounding development [14].

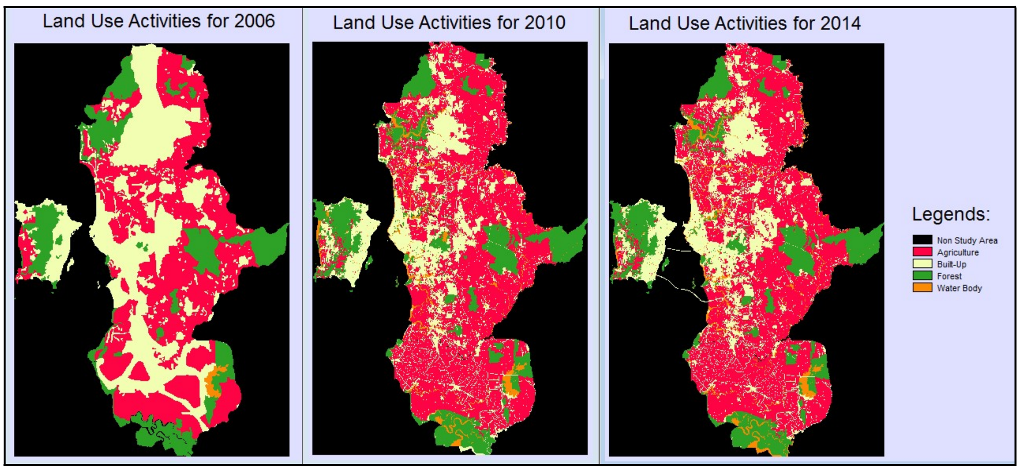

Fig.2. Land Use Datasets

The study relies on datasets obtained from PSDTCP, Northern Zone Project of DTCP, and Geoportal of DTCP. They include land use data for 2006, 2010, and 2014 (see Fig. 2), road network and administrative boundary. The driving forces that influence the urban growth were gathered and analyzed from an online survey distributed to planners from DTCP, academicians, researchers of public universities in Malaysia, private urban modelers and developers, and literature review [5].

3. METHODOLOGY

The George Town Conurbation is represented as a lattice of two dimensional rectangular grid of square cells with 100 meter resolution. The study then classifies land use activities into four categories: Agriculture, Built-Up, Forest, and Water Body. The prediction process will use the proposed model (see Fig. 3) two times, namely as Process 1 and Process 2.

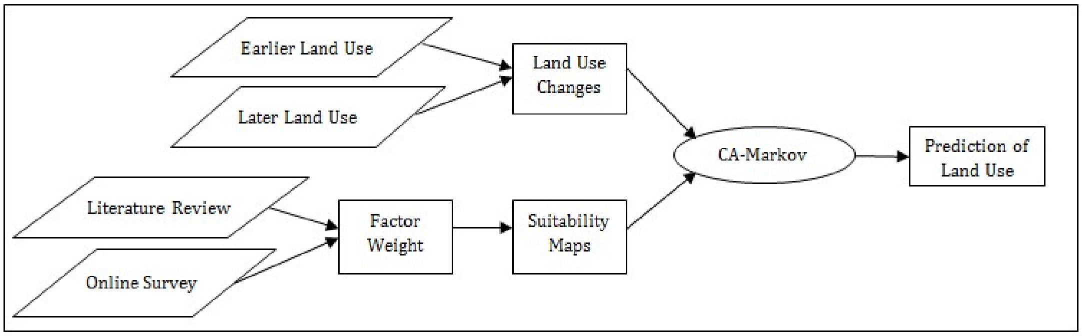

Fig.3. The Proposed Model

Process 1 is purposed to access the accuracy of the factor weight in predicting future land use pattern. The factor weight is derived from a literature review and an online survey conducted in previous study done for the George Town Conurbation [5]. Land use 2006 and land use 2010 will then use to obtain land use changes for the input in CA-Markov model together with the suitability maps obtained from the factor weight. The final output of the Process 1 will be the prediction of land use pattern for the year 2014. This output will be accessed its accuracy based on the land use 2014 dataset. Process 2 will undergo the same steps as Process 1 using land use 2010 and land use 2014 for obtaining land use changes. This land use change will be the input in CA-Markov model. The accuracy for the predicted land use of the year 2018 is expected to be in the range of accuracy done in Process 1 as they are using the same factor weight.

CA-Markov analyses the possible changes of cell states, $S=\left(s_1,s_2,...,s_n;n\in N\right)$ with a calculated probability within a given time frame [15]. Cell state represents land use activity at a specific time frame and a specific location. The calculated probability (or transition probability) is derived from the initial state value of all cells, $P_{a,b}$ (see Eq. 1). Transition matrix which contains an array of transition probability either change or unchange value $\left(s_a,s_b\right)$.

$$^{t}P_{a,b,i,j}=P\left\{X_t=s_b\left|X_{t-1}=s_a\right.\right\} \qquad \text{(Eq. 1)}$$

where ${}^{t}P_{a,b,i,j}$ represent transition probability of a cell state at a specific location i, j with a specific time frame t. The transition probability, suitability index, and neighborhood index then used to derived a transition rule (see Eq. 2).

$$ {}^{t}S_{i,j} = \sum_{m=1}^{M} \left({}^{t}x_{i,j} \cdot w_m \cdot c_m \right) \qquad \text{(Eq. 2)} $$

where ${}^{t}S_{i,j}$ = suitability index for cell i, j at time t;

${}^{t}X_{i,j}$ = score of criterian m at cell i, j at time t;

w_m = weight for criterian m;

c_m = Boolean value of constraint.

According to [16], lattice, cell state, neighborhood, and transition rules are four fundamental elements need to figure out before using Cellular Automata (CA).

$$ {}^{t}LU_{i,j} = \begin{cases} 1\text{=Agriculture} \\ 2\text{=Built-Up} \\ 3\text{=Forest} \\ 4\text{=Water Body} \end{cases} \qquad \text{(Eq. 3)} $$

Here, lattice represents the George Town Conurbation region, cell state represents land use activity, and transition rules represent the behavior of central cell based on the interaction to their respective neighborhood cells. Each cell states are represented land use activities as shown in Eq. 3.

This study then used CA-Markov provided by IDRISI Kilimanjaro to perform the analysis using Eq. 4 below. Assessment is then carried out using land use data 2010 and 2014 to verify the accuracy of the prediction land use pattern.

$$ {}^{t+1}LU_{i,j} = f\left[\left({}^{t}LU_{i,j} \right) \cdot \left({}^{t}S_{i,j} \right) \cdot \left({}^{t}P_{a,b,i,j} \right) \cdot \left({}^{t}N_{i,j} \right) \right] \qquad \text{(Eq. 4)} $$

where ${}^{t+1}LU_{i,j}$ = the potential of cell i, j to change at time $t+1$;

$^{t}LU_{i,j}$ = cell state at time t;

$^{t}S_{i,j}$ = suitability index for cell i, j at time t;

$^{t}P_{a,b,i,j}$ = probability of cell i, j to change from state a to b at time t;

$^{t}N_{i,j}$ = neighborhood index of cell i, j.

4. RESULT AND DISCUSSION

Table 1. Transition Matrix 2006-2010 (left) and 2010-2014 (right)

Given : Probability of changing to :

	Cl. 1	Cl. 2	Cl. 3	Cl. 4
Class 1 :	0.6740	0.1933	0.0797	0.0529
Class 2 :	0.5317	0.3700	0.0652	0.0331
Class 3 :	0.2288	0.0789	0.6318	0.0605
Class 4 :	0.0532	0.0289	0.2111	0.7069

Given : Probability of changing to :

	Cl. 1	Cl. 2	Cl. 3	Cl. 4
Class 1 :	0.8193	0.1435	0.0104	0.0268
Class 2 :	0.1235	0.7814	0.0395	0.0556
Class 3 :	0.0462	0.0918	0.8224	0.0397
Class 4 :	0.1066	0.1403	0.0743	0.6788

Note:
Class 1/C1: Agriculture Class 2/C2: Built-Up Class 3/C3: Forest Class 4/C4: Water Body

Table 1 are the probabilities of original cell state to change into another state. The percentage of forest to change into built-up are 7 per cent (transition matrix 2006-2010) and 9 per cent (transition matrix 2010-2014), while the percentage of agriculture to change into built-up are 19 per cent (transition matrix 2006-2010) and 14 per cent (transition matrix 2010-2014).

Factors or driving forces that influence urban development and their respective weightings derived from the previous study are shown in the following Table 2.

Table 2. Factors with Respective Weighting Value

Factors	**Weight**
Distance to public amenities e.g. school, university, etc.	0.1122
Distance to workplace	0.1141
Proximity to area that support new and growing business	0.0977
Distance to health centre e.g. public hospital, public clinic, etc.	0.0950
Distance to main road or highway	0.0906
Distance to commercial or industrial area	0.0977
Proximity to parks and natural features	0.0977
Distance to city centre	0.0879
Cheap housing price	0.1123
Population density or neighbourhood	0.0948
Consistency Ratio	*0.0040*

From the criteria derived from factor weight, then will be used to generate suitability maps as shown in Fig. 4. Prediction of land use pattern for the year 2014 will be simulated using 2010 dataset (Fig. 2), transition matrix (Table 1) and suitability maps (Fig. 4). The predicted land use pattern will be assessed its accuracy based on the land use 2014 dataset as shown in Fig. 5.

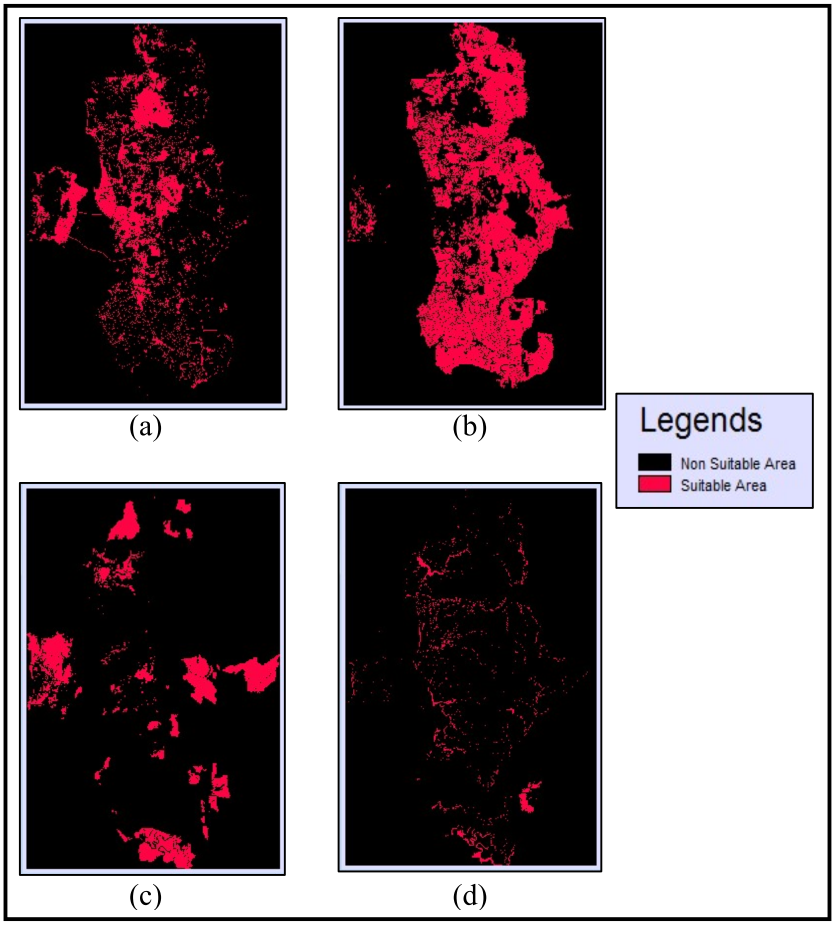

Fig.4. Suitability Maps

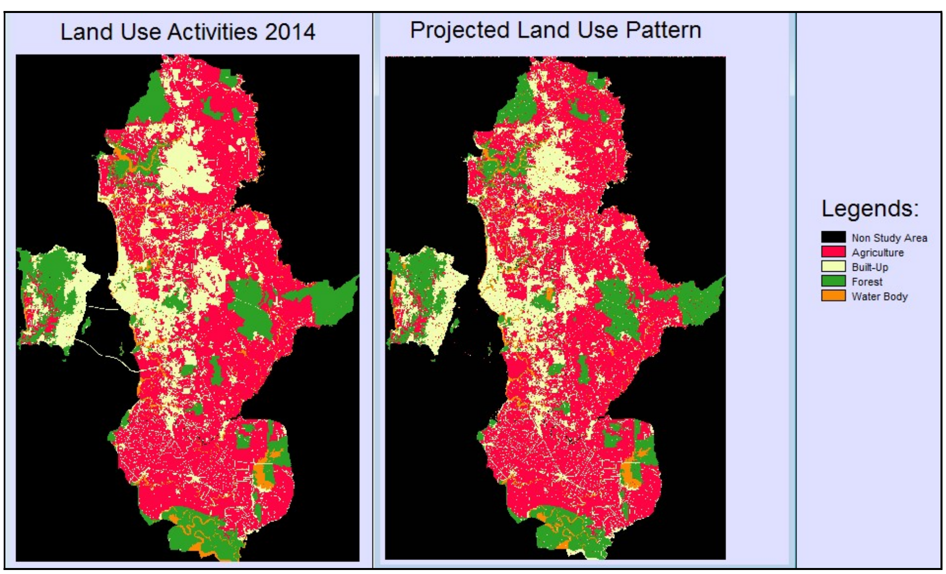

Fig.5. Predicted of Land Use Pattern

Table 3. Accuracy Assessment

Accuracy Assessment

Category	KIA
Agriculture	0.8790
Built-Up	0.8259
Forest	0.9193
Water Body	0.7120
Overall Kappa =	*0.8620*

Based on the Table 3, the accuracy of predicted land use pattern is approximately 86 percent, which reflecting the projected site are the same land use activities with the land use dataset. From this assessment, the next projection of land use pattern of the year 2018 using land use 2014 dataset is expected to have the same value of accuracy. The following is predicted land use pattern of the year 2018.

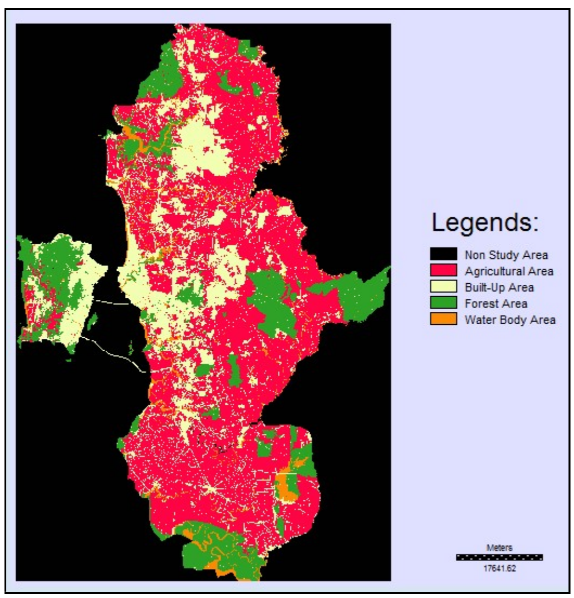

Fig.6. Prediction of Land Use Pattern 2018

Built-up area is expected to grow in the northern region of The George Town Conurbation which is at the border state between Kedah and Penang. This is probably due to the land value at that areas are cheaper than the Seberang Perai area. People are considering on staying in this area because of the availability of North-South Highway, which has shortened traveling time to Penang. In addition, the accessibility to the business centers, commercial and industrial area that grow rapidly due to the urbanization of George Town city has made this area is suitable for living. On the other hand, south area of Penang Island is expected to cover with built-up area due to the existence of the First and Second Penang Bridge that facilitated people to move from island to mainland.

5. CONCLUSION

Simulation of future land use pattern using CA-Markov model can assist urban planners and developers to manage urban development from sprawl and encroach to agricultural and forest land. Many considerations should be accounted for developing urban so that the area is contained in the identified area done by DTCP. This study has demonstrated the capability of CA-Markov model to project future development which can notify us to regulate and plan for avoiding unnecessary development that can affect the physical and environment. At the same time, necessary action can be carried out for areas that are less developed in order to disseminate development for people benefit.

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