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Predicting the impact of urban expansion on green space area in Kota Bharu, Kelantan, Malaysia

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Abstract: The changes in area of urban green space landscape in Kota Bharu, Kelantan may have consequences on habitat biodiversity and well-being of urban populations. The continuous land-use changes, lack of information database and empirical evidences in existing land-use planning may have impacts on green space and the socio-ecological functions that they provide. In order to understand the spatial changes and functions of green space, prediction modelling is urgently needed to quantify changes in the expansion of built-up areas and its effects on the green space. The spatial effect of green space is influenced by the historical spatial changes, implementation of the previous master planning efforts and uncontrolled urban expansion. This study is designed to provide an integrated approach for predicting landscape changes for the green area in order to provide the initial guideline for sustainable planning and management of green space.

Keywords: urban expansion, green space area, Kota Bharu

INTRODUCTION

Kota Bharu, Kelantan is the administrative, commercial and financial centre followed by Kubang Kerian a centre of the institution and Pengkalan Chepa as an industrial centre. To achieve economic viability in the business, industry, tourism and agriculture sectors have been strengthened to increase the Kota Bharu as the regional trade centre. The population in Kota Bharu in 2016 was about 1.45 million people which increased by 12% from 2010 that has been encouraged by urban development. The private sector is also involved in promoting physical development in Kota Bharu through housing projects. As a consequence, urban green space has come under increasing pressure during the urbanization process and this negatively affects the ecosystem services, cultural associations, psychological well-being and the health of urban dwellers (Hambali *et al.*, 2019; Nor and Abdullah, 2019).

The conversion of green spaces into the built-up areas has become one of the major reasons for habitat destruction world-wide (Nor *et al.*, 2018) and therefore, if some of this green space can be retained, protected or reclaimed, then it becomes important to monitor and understand the changes in spatial complexity of an urban ecosystem as rapid urban expansion occurs. As the landscape becomes urbanised, the resulting fragmentation affects landscape structure and decreases the landscape connectivity (Appalasamy *et al.*, 2018; Nor and Abdullah, 2019). Consequently, green spaces become isolated by a matrix composed of buildings and streets, limiting the distribution and the connectivity of green space patches.

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This study used the combination of Land Change Modeller (LCM) and Markov Chain modelling, incorporating GIS data and remote sensing satellite imagery. the applicability of integrated LCM-Markov Chain models to predict the observed spatial patterns and changes of urban expansion and green space. The LCM is less complex, faster and a more understandable process when compared to the most modelling techniques (Eastman, 2006; Triantakonstantis *et al.*, 2015). The quantity of change is modelled through a Markov Chain temporal analysis for the LULC types, and the process relies on the historical transitions and past changes, as there is evidence that urban land use depends on the historical development process of each city (Nor *et al.*, 2017).

MATERIALS AND METHODS

Study area

Kota Bharu is the capital of Kelantan and is chosen as the case study. It is located in the north of Kelantan with an area of 39,939 ha, which is 2.62% of the total area of the state and is administered by the Kota Bharu Municipal Council (Figure 1).

Figure 1: Location of Kota Bharu, Kelantan, Malaysia

Methodological Framework

In this study, land-use or land-cover (LULC) was modelled using the Land Change Modeler (LCM) software package (Eastman, 2006; available as ArcGIS 10.2 extension, http://www.clarklabs.org) to derive the simulation maps. The landscape modelling procedures involved the modelling of potential change using LULC maps of 1988 and 2003 to simulate the year 2017(15 years interval). The models enable the comparison of the actual map for 2015 with the results from the predicted model to verify future simulations.

Data Acquisition and Processing

Land-use or land-cover maps of 1988, 2003 and 2017 were derived from image processing using Erdas Imagine 2014. The LULC was reclassified into four types i) built-up area, ii) green space iii) agriculture areas and iv) water bodies. The maps used to predict green space area of Kota Bharu in 2030. These datasets were converted to vector and raster grid file formats for simulation and spatial analysis. Ground thruthing was conducted to collect data on the variable factors such as population and residential data, water bodies, roads, agriculture areas and built-up areas by using survey and Global Positioning System (GPS).

Model Verification

Before the simulation and assessment of the future scenarios, it is necessary to evaluate the reliability of the LCM-Markov chain models and the relevant variable settings. The aim of the verification model is to test "how well do a pair of maps agree regarding the transition in each category?" (Pérez-Vega *et al.,* 2012). Based on Pontius and Millones (2008), a comparison of the agreement and disagreement between maps were adopted by using the validation module in LCM to evaluate the 2015 predicted result compared to the actual green space area. The high levels of agreement achieved allowed the simulation of future scenarios to be carried out with considerable confidence to their reliability.

Landscape change

After the LCM model was verified, a similar process was conducted to simulate green space landscape in 2035 based on the green space landscape maps in the period from 2003 and 2017 using the probability Markov chain modelling. The procedure determines how much land of each LULC types would be expected for transition in the period from 2015 to the predicted year, based on the projection of the potential future transition and the probability of change through the creation of the transition probability file. This is a matrix that records the probability of each LULC category changing into every other category (Mishra *et al.*, 2014).

RESULTS

Model Verification

The actual LULC map for 2017 was compared with the results from the simulated model. In Kota Bharu, the percentage combined agreement and persistence was 84.6%, the false negative was 8.4%, and the false positive was 6.9%. The low level of disagreement (false negative and false positive) indicated that the model and the relevant variable settings were appropriate. The accuracy of the simulated LULC results was deemed to be acceptable allowing the model to be used to simulate.

Landscape Change

The landscape change of Kota Bharu was examined based on built-up area, green space area, and water bodies. The results showed the built-up areas at Kota Bharu significantly increase in the 1988 to 2003 time period with 40% change rate. However, the change rate of built-up area at Kota Bharu decreased to 20% in the 2003 to 2017 time period. The changes in rate of built-up area is expected to continuously reduce in the 2017 to 2035 time period (Figure 2). Furthermore, Kota Bharu has experienced the highly green space area loss with 10% change rate in the 1988 to 2003 time period. In the 2003 to 2017 time period, the changing rate of green space area loss decreased to 5%. It is interesting to highlight that the green space area is predicted to expand with change rate less than 5% in the 2017 to 2035 time period (Figure 3). Besides that, water bodies in Kota Bharu has experienced rapid losses in the 1988 to 2003 time period (<5%) and 2003 to 2017 time period (27%). In the 2017 to 2035 time period, water bodies in Kota Bharu is predicted will reach 30% of loss rate. The result of statistical analysis for Land Use and Land Change (LULC) in Kota Bharu based on two periods of year show that there is significant change in LULC in the context of built-up area, green space, and water bodies in period 1 (1988-2003) (Figure 3). However, statistics show that the change in LULC is only significant for built-up area and green space and not significant for water body in the period 2 (2003-2035).

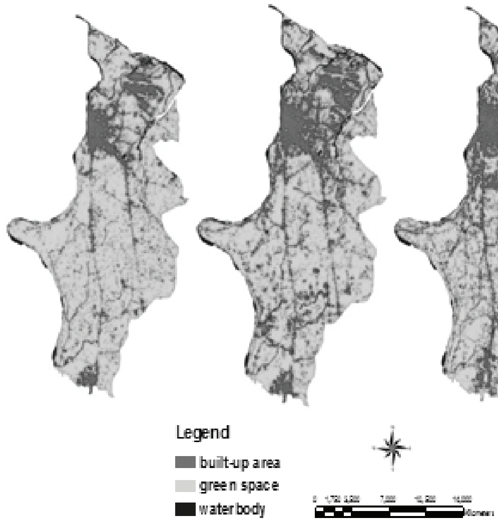

Figure 2: Land-use in Kota Bharu in 1988, 2013, 2017 and 2035

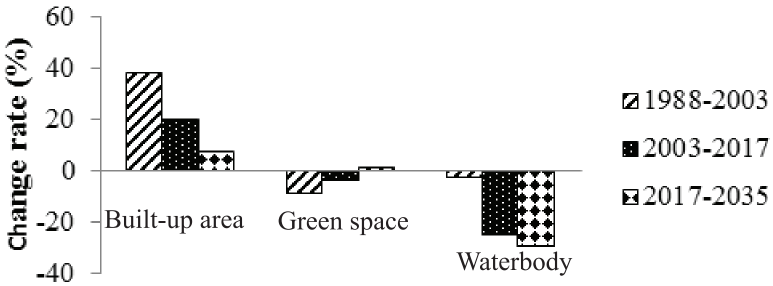

Figure 3. LULC changes over time (1988-2035)

Green space change detection

Table 1 shows the green space conversion in three different periods, 1988-2003, 2003-2017, and predicted in 2017-2035. Most of the green spaces have been converted into built-up areas as compared to water bodies. In fact, the green space area in Kota Bharu has decreased 0.1% based on the period 1988-2017. The area of green space is predicted to decrease 2.2% in the period of 2017-2035.

Table 1. Green space change detection

green space conversion	1988-2003	2003-2017	2017-2035
	%	%	%
green space to built-up area	11.10	12.91	15.11
green space to water body	1.79	0.11	0.14
green space persistence	87.10	86.97	84.74

In 1988, the percentage of built-up area, green space and water bodies in Kota Bharu were 12.66%, 82.23% and 5.11%, respectively. By 2017, Kota Bharu had substantial built-up areas (24.36%), which was also dominant LULC in the 2035 simulated model (26.10%) (Table 1). In the period 2017-2035, there would be major changes from green spaces to built-up areas in Kota Bharu with Markov Chain values of 0.2109. The Markov Chain value for the transition built-up areas to green space was 0.5492.

DISCUSSION

In this study, the 80% of agreement and persistence showed that the LCM model verification for 2015 was reliable and therefore the model is appropriate for predicting future transitions. The evidence of verification combination model used (LCM-Markov Chain model showed in the green space landscape plan map 2035 (Figure 2). The differences between the modelled spatial changes and observed in 2014 supplied evidence for successful planning interventions. The previous study shows that data generated using LCM is more accurate when the per transition susceptibilities are combined to compose an overall potential change map because neural network outputs can express the simultaneous potential change for various LULC types more adequately than the individual probabilities obtained (Pérez-Vega *et al.*, 2012). These predictive capacities allow models to be useful tools for local stakeholders involved in urban change decision making. The results from these models obtained in this study would suggest that a verified LCM-Markov Chain model is an effective tool to simulate future urban expansion.

Over the 29 year period, Kota Bharu has experienced a decrease in green space and an increase in built-up area (Figure 2). The predictions indicate a further increase in built-up area and decrease in green space by 2035(Figure 3). The results further suggest that built-up area expansion and the location of the variables affecting the model outputs are the major drivers of green space change and fragmentation. The projected Markov Chain conditional probability matrices for 2035 revealed that the growth of built-up areas in this city showed a multidirectional urban expansion growth pattern, tending to occur in areas of better road accessibility, near the green space edge, on higher elevations and steep slopes where there is a low risk of flooding. These results agree with the findings of other studies, in which the distance from main roads is linked to the degree of landscape fragmentation (Gao and Li, 2011; Aziz *et al*., 2019). The combined fragmentation and barrier effects of road networks considerably degrade landscape connectivity and ecological processes in the landscape (Fu *et al.*, 2010). Inherently, green space edge has a high probability of being fragmented and in the results from this study show that development changes tend to start from the edge of existing green space.

CONCLUSION

This study sought to simulate rapid urban expansion and green space using integrated LCM-Markov chain model. The information could be further used to study the relations between landscape green space changes and other phenomena such as carbon fixation, biodiversity, climate change and sustainable management of resources.

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