The Prediction of Urban Growth Trends and Patterns using Spatio-temporal CA-MC Model in Seremban Basin

Rabia Ajeeb¹, Maher M Aburas², Faisal Baba³, Abdelsalam Ali⁴, Motasem Y.D. Alazaiza⁵

¹Management & Science University, 40100 Shah Alam, Selangor, Malaysia.
²The High Institute for Engineering Professions ALmajurie, Benghazi, Libya.
³The high institute for Comprehensive Vocations-Girls, Benghazi, Libya
⁴Benghazi Academy of Graduate Studies, Benghazi, Libya.
⁵Department of Civil and Environmental Engineering, College of Engineering (COE), A'Sharqiyah University (ASU), 400, Ibra, Oman.

*Email: boras222@yahoo.com

Abstract. Urban growth, a dynamic and demographic phenomenon, refers to the increased spatial value of urban areas, such as cities and towns, due to social and economic forces. Nowadays, urban lands are rapidly increasing, replacing non-urban lands such as agricultural, forest, water, rural, and open lands. In this study, a CA-Markov model was utilized to predict the growth of urban lands and their spatial trends in Seremban, Malaysia. The performance of the CA-Markov model was also assessed. The Markov chain model was applied to produce the quantitative values of transition probabilities for urban and non-urban lands. Subsequently, the CA model was used to predict the dynamic spatial trends of land changes. The change in urban and non-urban land use from 1984 to 2010 was modeled using the CA-Markov model for calibration purposes and to compute optimal CA transition rules as well as to predict future urban growth. In the accuracy assessment process, the CA-Markov model was validated using a Kappa coefficient. The overall accuracy of the Kappa index statistics was 83%, which indicates the excellent performance of the model proposed in this study. Finally, based on the CA transition rules and the transition area matrix produced from the calibration process using the Markov Chain model, future urban growth in Seremban for 2020 and 2030 was simulated.

Keywords: CA-Markov; Urban growth; Prediction; Simulation; Spatio-temporal.

1. Introduction

Urbanization has become one of the main environmental issues of recent times. Therefore, urban planners and decision makers are still trying to find out sustainable ways to decrease the impact on urban ecosystems [1]. Forecasting future urban growth trends has become a priority for protecting urban ecosystems and their sustainability [2]. Moreover, the various factors of urban development should be deeply studied to forecast urban trends correctly [2]. In Addition, the historical data should be taken into account to understand urban, spatial and temporal dimensions accurately [3]. Hence, the Influencing factors on the simulated process could be selected accurately by collecting effective spatial and temporal
data [4]. Spatio-temporal data and factors could be effectively used in the process of urban simulation and prediction using spatial models, techniques, and tools [5].

There are several different models currently being utilized in the field, such as dynamic statistics and machine learning. Based on recent literature reviews, the dynamic model is highly recommended to use in the simulation and prediction of future urban trends and the CA-Markov model has become one of the main dynamic models being used by most researchers in recent years in this specific field of study, this is due mainly to it’s ease of use and simplicity of implementation, as well as its expandability and the ability to add influencing variables in the simulation process. There are several different types of influencing variables that can be added, for example, statistics such as population and economic variables and dynamic variables such as elevation and slopes. Inserting these types of variables leads to results that are not only more realistic but also much more accurate [6].

In this research, Seremban Basin, Malaysia, was selected as a case study. Seremban Basin has faced extensive urban development in the recent years due to several reasons such as economic and population growth, which has led to a decrease in the green areas in the city of Seremban. In this research, CA-Markov model was selected to simulate future urban trends in Seremban Basin using ArcGIS and IDRISI Selva environment. This model is widely used in this field of study due to several reasons such as its simplicity and accuracy. To the authors’ best knowledge, no study of this kind has ever been done in this city before.

2. Materials and Method

2.1. Study area
Seremban Basin is one of the largest developed areas in the Negeri Sembilan State. Seremban town located in the Seremban River basin, which is surrounded by mountains and tropical forests (Figure 1). The KL-Seremban highway and railway, and rapid development in Putrajaya and Cyberjaya cities are driving factors for urban growth in Seremban. In addition, the KLIA International Airport is one of the main reasons behind the more recent urban growth in the city. Urban development in Seremban 2 and Nilai town in the north has led to rapid urban growth in the city. Seremban Basin occupies a total area of about 935.78 sq. This area is divided into seven major neighborhoods which include Labu, Pantai, Seremban town, Rasah, Lenggeng, Rantau, Setul as well as several smaller areas surrounding them.

2.2. Data and methods
In this research, four land-use maps, created in the years 1984, 1990, 2000, and 2010 were used to perform the simulations and predict future urban trends in Seremban (Figure 2). These land-use maps were developed at the behest of the Malaysian Dept of Agriculture (MDA). These land-use maps were derived from images of the Spot 2, Spot 4, and Spot 5 variety. The spatial resolution of used images is a 10 m spatial resolution of Spot 2, Spot 4 and 2.5 m of Spot 5. These images were then registered, enhanced, classified, and validated by the MDA Department. The Kappa values of all images are more than 0.85 which means that land-use classification that was conducted by the MDA meets the present study’s requirements. It should also be noted that the topographic map was obtained from the Dept of Surveying and Mapping in Malaysia (JUPEM), also, the Digital Elevation Model (DEM) was retrieved from the USGS website with a resolution of 30m.

The CA–Markov model has been utilized in the simulation and prediction of future urban growth in Seremban which can be seen in the methodology of the CA-Markov model presented in Figure 3. The four main steps outlined below have been applied in the CA–Markov chain modeling using ArcGIS 10.3 and IDRISI Selva software:
Figure 1. The location of the area that was studied.
Figure 2. Land-use maps of Seremban River Basin (a) 1984, (b) 1990, (c) 2000, and (d) 2010.

1. The urban and non-urban maps are prepared and loaded into the ArcGIS 10.3 software. Four maps of land-use generated in 1984, 1990, 2000, and 2010 were reclassified to suit the objective of predicting urban growth in Seremban. All these maps were converted from vector to raster format. After that, the raster maps were converted to the ASCII file format using conversion tools in the ArcGIS environment. Then, the ASCII files were reclassified and converted to raster format in the IDRISI Selva environment, so they can be used in the prediction of future urban growth.

2. Urban and non-urban land use transition probability matrix and transition rules utilizing the Markov chain model are identified. Based on the previous land class state, the future urban growth change was modeled, i.e., the transition probabilities among urban and non-urban maps from 1990–2000 were applied to predict the changes in 2010 and to calibrate and validate the model. Meanwhile,
urban and non-urban maps of 2000 and 2010 were utilized to predict future urban growth in 2020. Additionally, land maps of 2010 and 2020 were used to predict future urban growth in 2030. The transformation rules and the change probability of different land use layers into other layers is provided by the transition probability matrices while the quantity of land change (i.e., urban or non-urban lands) into another land layer in the predicted future is reflected by the transition area matrices.

3. The AC filter is determined; the standard 7×7, 5×5 and 3×3 contiguity kernels were designated as the neighborhoods in this study, so as to identify appropriate contiguity filters to predict urban growth. In the end, the contiguity filter 5×5 was selected; this means that each cell center is enveloped by a matrix space of 5×5 cellular kernels to reflect the cellular changes in a significant way.

4. The number of iterations and starting point of time for the CA are determined. The CA–Markov model was applied, utilizing various iteration numbers starting from 1 to 200 iterations in order to identify the appropriate iteration number. This study found that the iteration numbers all have different performances; which means that this study can use certain iteration numbers in making prediction of the future.

Here the year 1990 and the year 2000 were taken as the initial starting points to carry out the process of calibration and validation utilizing the Kappa index, while the year 2000 and the year 2010 were used as starting points to the prediction of future urban growth in 2020. Finally, the year 2010 and the year 2020 were used as starting points to predict future urban growth in 2030.

**Figure 3.** The methodology of the CA–Markov model.
3. Results and Discussion

3.1. The change in both the urban and the non-urban areas

The findings of changing urban and non-urban areas are presented in Table 1 and Figure 4 where the changes of these specific areas between 1984 and 2010 are shown. From the analysis of these results, the behavior, patterns, and speed of land use changes can be better understood. The significance of these findings is as follows; (i) these results would be very useful as a scientific basis for planners and decision makers when creating future urban policies; (ii) and will be effective in achieving urban growth sustainability. The results confirm that a major increase in urban growth has occurred in the time period between 1990-2000, which equates to 58 km² of urban area, due to growth in the population and the economy (Figure 5).

Table 1. The changes in urban-growth shown in sq.km.

|         | Urban Area | Non-urban area |
|---------|------------|----------------|
| 1984    | 34.00      | 917.87         |
| 1990    | 39.00      | 912.87         |
| 2000    | 97.00      | 854.87         |
| 2010    | 126.00     | 825.87         |
| Annual growth rate (1984 –1990) | 2.3% | -0.09 % |
| Annual growth rate (1990 –2000) | 9.54% | -0.65 % |
| Annual growth rate (2000 –2010) | 2.65% | -0.34 % |
| Total change sq.km | + 92 | -92 |

Figure 4. Urban growth in The Seremban River Basin from the year 1984 to the year 2010.
3.2. **The transition probability matrix**

The transition probability matrix, as presented in Table 2 was calculated using the Markov chain model. This matrix can be used to assert the future potential percentages of change in urban as well as non-urban land uses in the years 1990-2000, the years 2000–2010, and the years 2010–2020. In addition to that, it can be noted from further analysis of the results in Table 2, that the probability of future transition of non-urban to what can be considered urban areas from 1990 to 2000 is at 25% while from 2000 to 2010 that same transition probability dropped to 21%. The explanation for this decline is that the urbanization process in Seremban has decreased between 2000 and 2010 in comparison to 1990 and 2000, which has seen a lot of urban development operations particularly in Seremban and in Malaysia generally [7].

Table 2. The amount of changes in urban growth observed here in sq.km.

| Date       | Type   | Urban    | Non-urban |
|------------|--------|----------|-----------|
| 1984-1990  | Urban  | 0.6530   | 0.3470    |
|            | Non-urban | 0.2553   | 0.7447    |
| 1990-2000  | Urban  | 0.7699   | 0.2301    |
|            | Non-urban | 0.2164   | 0.7836    |
| 2000-2010  | Urban  | 0.6653   | 0.3347    |
|            | Non-urban | 0.2912   | 0.7088    |

3.3. **The transition probability matrices**

In order to confirm the accuracy of future urban and non-urban land use predictions in 2010, the CA-Markov model was used. The 1990 and 2000 maps were used to predict land-use state in 2010. After that, the actual 2010 land-use map was analyzed and compared to the predicted 2010 land-use map to ensure model reliability (Figure 6). This study used different iteration numbers (i.e., the appropriate iteration numbers) in order to measureably obtain the best performance for the CA-Markov model.

**Figure 5.** Urban growth in The Seremban River Basin from the year 1984 to the year 2010.
Figure 6. Observed and simulated urban growth of 2010: (a) Observed; and (b) Simulated.

To perform an accuracy evaluation of the used model, the projected urban and non-urban map of 2010 was compared with the actual map of 2010 using the Kappa index statistic to measure its validity in terms of both quantity and location [8]. Figure 7 illustrates the variation in the Kappa coefficient with various iteration numbers from 1 to 200. From Figure 7, it can be observed that, when predicting urban and non-urban areas of 2010, the CA-Markov model performed best at 40 and 60 iterations. High values of the Kappa coefficient were also achieved; (i) Kappa standard index of 0.83; (ii) Kappa location index of 0.86; (iii) and Kappa no index of 0.83.

Figure 7. The values of the Kappa index vs. the number of iterations.
After performing our accuracy evaluation of the model we can clearly see a large match between the actual and the simulated urban and non-urban land-use maps. Due to the validation phase, the optimal rules of transition for this model were calculated using the suitable iteration numbers (i.e., 40 and 60). After that, these iteration numbers were then utilized in the prediction of land use in the years 2020 and 2030. The future urban and non-urban land-use maps of the year 2020 and the year 2030 were calculated by utilizing the actual map of 2010 and projected map of 2020, respectively based on the successful model validation. By using the 2010 and 2020 urban and non-urban land uses as base maps and the potential transition maps and transition area matrices of the years 2002–2010 and the years 2010-2020 as well as the future of urban growth patterns can be predicted, as presented in Figures 8 and 9.

Figure 8. Maps of Urban Growth that were predicted in Seremban River Basin: (a) 2020; (b) 2030.

Figure 9. The quantities of both the previous and the predicted urban and non-urban areas in sq.km.
4. Conclusion
From these results the effectiveness of the CA-Markov chain model in modeling urban growth can clearly be seen, something is does especially well in developing countries with their varied urban environments. But it is essential that we apply the forces behind the urban growth in the predictive processes of the CA-Markov chain model so that we may obtain a much deeper understanding of the change in urban growth patterns. That is why we believe that the CA-Markov chain model and other models such as the Analytic Hierarchy Process (AHP), Frequency ratio (FR), and logistic regression (LR) models should be combined so that its capability may be further improved.

References:
[1] Bihamta, N., Soffianian, A., Fakheran, S., & Gholamalifard, M. (2014). Using the SLEUTH Urban Growth Model to Simulate Future Urban Expansion of the Isfahan Metropolitan Area, Iran. Journal of the Indian Society of Remote Sensing, 1-8.
[2] Barredo, J. I., Kasanko, M., McCormick, N., & Lavalle, C. (2003). Modelling dynamic spatial processes: simulation of urban future scenarios through cellular automata. Landscape and Urban Planning, 64(3), 145-160.
[3] Sudhira, H., Ramachandra, T., & Jagadish, K. (2004). Urban sprawl: metrics, dynamics and modelling using GIS. International Journal of Applied Earth Observation and Geoinformation, 5(1), 29-39.
[4] Pijanowski, B. C., Brown, D. G., Shellito, B. A., & Manik, G. A. (2002). Using neural networks and GIS to forecast land use changes: a land transformation model. Computers, Environment and Urban Systems, 26(6), 553-575.
[5] Punia, M., & Singh, L. (2012). Entropy approach for assessment of urban growth: a case study of Jaipur, India. Journal of the Indian Society of Remote Sensing, 40(2), 231-244.
[6] Aburas, Maher Milad, et al. "Improving the capability of an integrated CA-Markov model to simulate spatio-temporal urban growth trends using an Analytical Hierarchy Process and Frequency Ratio." International Journal of Applied Earth Observation and Geoinformation 59 (2017): 65-78.
[7] Economic Planning Unit, M. (2013). Economic History of Malaysia. Economic Planning Unit, Malaysia, 4,5.