

Simulating and monitoring future land-use trends using CA-Markov and LCM models

Maher M Aburas^{1,2*}, Sabrina H Abdullah³, Mohammad F Ramli³, Zulfa H Ash'aari³ and Mohd Sanusi S Ahamad¹

¹ School of Civil Engineering, Engineering Campus, Universiti Sains Malaysia, 14300 Nibong Tebal, Penang, Malaysia

² The High Institution for Engineering Vocations Almajori, Benghazi, Libya

³ Faculty of Environmental Studies, University Putra Malaysia, 43400 Malaysia

boras222@yahoo.com

Abstract. Simulating and monitoring future land-use trends is one of the major challenges for researchers, decision makers, and local authorities in terms of data, methods, and models that should be used to create a realistic and sustainable land-use planning process. This study aims to use spatio-temporal data and models to generate realistic simulation and assessment of future land-use trends in Seremban, Malaysia. For this purpose, four land-use maps of 1984, 1990, 2000, and 2010 were used. The CA-Markov model was used to simulate future land-use change of 2020 and 2030 in Seremban. After that, a Land Change Modeler (LCM) was used to assess and monitor future land-use patterns. The results confirm that the agriculture area will be affected by urban uses in the next decade in Seremban. This increase in urban uses is due to the impact of the steady increase in economic and demographic development. These results indicate the necessity to create new policies in the city to protect the sustainability of land uses in Seremban.

1. Introduction

Change detection techniques for evaluating urban growth and land-use changes are commonly implemented via satellite images or land-use maps that have the same spatial resolution and using GIS and RS tools and software [1, 2]. Several urban change detection techniques have been used in previous studies such as NDVI, LCM, and CA-Markov. However, researchers have yet to agree on the best method for land-use change detection because of errors in environmental and sensor factors, as well as image resolution [3]. Therefore, identifying the suitable method for simulate and monitor land-use change is the main challenge in urban studies.

Land-use and land cover change related to urban movement are considered a result of the relationship between human activities and land resources. Therefore, it is expected that the demand for land will increase in line with the world's population increase. In addition, whenever the demands for land increase, the area of urban lands will also increase. Moreover, whenever the area of urban lands increases, the impact of urban areas on land-use and land cover will also be increased. Eventually, whenever land-use and land cover are affected by urban areas, the sustainability of the ecosystem will be affected [4-6]. This study aims to simulate and monitor land-use using CA-Markov and LCM models.



2. Materials and Method

2.1. Study area

Seremban City is the largest district in the Negeri Sembilan State. The study area is located between longitudes of $101^{\circ} 45' 0''$ E and $102^{\circ} 6' 0''$ E and latitudes of $3^{\circ} 0' 0''$ N and $2^{\circ} 30' 0''$ N. The city occupies a total land area of approximately 935.78 km². Seremban City is composed of the districts of Seremban, Setul, Labu, Rasah, Ampangan, Rantau, Pantai, and Lenggeng (Figure 1).

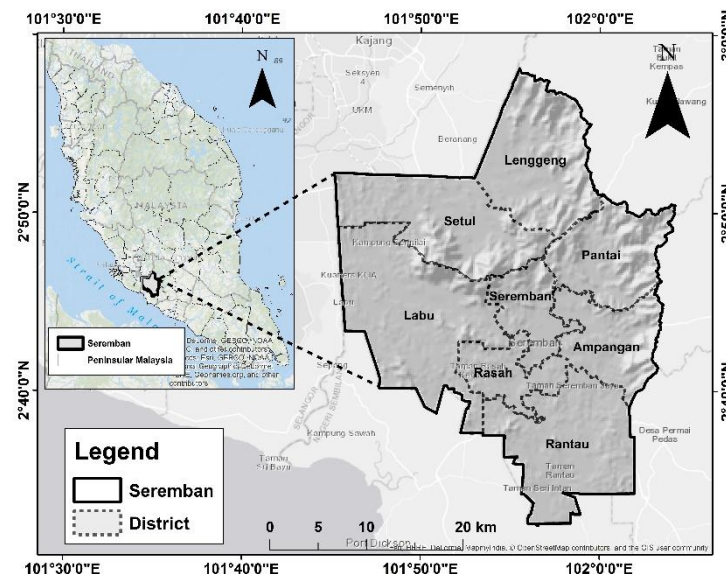


Figure 1. Location of the study area

2.2. Data Collection

This study utilized certified land-use maps from the Department of Agriculture of Malaysia from 1984, 1990, 2000, and 2010 (Figure 2). All spot images were registered and geo-corrected using ground control points through the Global Positioning System (GPS). Image-enhancement techniques were used to classify all the images with accuracy. The supervised classification method was used to classify all clipped images to extract land-use categories. Field data were collected using GPS to assess the classification accuracy by comparing the classified images with the GPS points from the field for each type of land use. The Kappa coefficient values were 0.83, 0.85, 0.90 and 0.88, respectively. High resolution Google imagery were used to validate the classification of land-use maps.

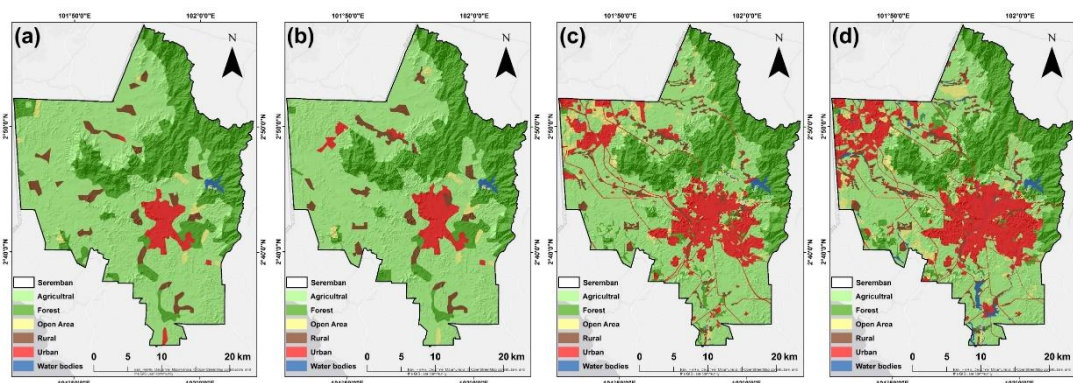


Figure 2. Land-use maps: (a) 1984 (b) 1990 (c) 2000 (d) 2010 (Source: DOA)

2.3. CA-Markov and LCM models

The CA-Markov model has been applied to simulate and predict future land-use change in Seremban as shown in the stepwise of the CA-Markov model presented in Figure 3. The reliability of land-use modeling techniques can be improved and developed by combining two or more prediction techniques to integrate the advantages of these models [7]. It could be argued that the CA-Markov model has been used recently in order to predict dynamic spatial issues such as urban growth and future land use change [8]. In addition, the integration of CA and Markov chain models is considered appropriate for spatial modeling of urban growth because it capitalizes on the advantages of the Markov chain in urban quantitative change prediction, and the dynamic explicit spatial simulation strength of the CA model [7].

LCM is widely used for ecological sustainability. This model was integrated with IDRISI Selva software. It is also available as an extension in the ArcGIS software. This extension is commonly used for addressing the pressing problem of accelerated land conversion [9]. Therefore, LCM was used in this study to measure the urban transformation in Seremban from 1984 to 2030 using land-use maps that were generated by DOA. The LCM model was applied to monitor future land-use change in Seremban as shown in the stepwise of the LCM model presented in Figure 3.

The spatial importance of the District of Seremban lies in its location, which is approximately 67 km from Kuala Lumpur, the economic centre of Malaysia and 20 km from Putrajaya, the administrative capital of Malaysia. It is adjacent to the State of Selangor, considered to be the largest State in Peninsular Malaysia. This significant spatial dimension of Seremban makes it a promising future incubator for urban development in Peninsular Malaysia.

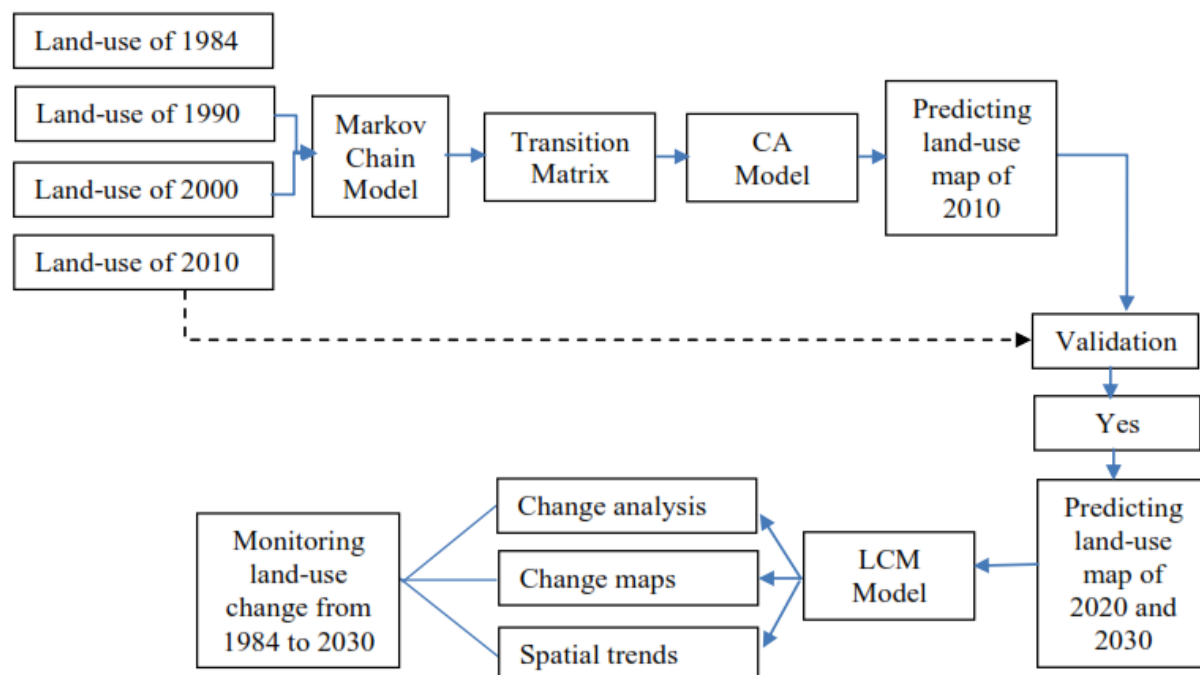


Figure 3. Stepwise of the CA-Markov and LCM models

3. Results and Discussion

The Markov chain model was used to calculate the transition probabilities matrix, as presented in (Table 1). In addition, future potential percentages of change in land use in the time periods of 1990–2000, and 2000–2010 are also ascertained using the transition probabilities matrix. The Markov chain analysis identifies the frequency of use of earlier and later land-use maps along with the specified date (Mishra et al., 2014). How much land-cover categories would be expected to transition from the later

date to the predicted according to projection of the transition probabilities into the future is observed and a transition probabilities matrix generated (Table 1).

Table 1. Stepwise of the CA-Markov and LCM models

		Agriculture	Forest	Rural	Open area	Urban	Water
1990 - 2000	Agriculture	0.6394	0.0545	0.0681	0.0372	0.1987	0.0021
	Forest	0.1693	0.7081	0.0263	0.0028	0.0914	0.0021
	Rural	0.6359	0.0344	0.0769	0.0871	0.1531	0.0126
	Open area	0.4277	0.0553	0.0175	0.2948	0.2038	0.0008
	Urban	0.2345	0.0162	0.0120	0.0336	0.7021	0.0016
	Water	0.0300	0.0300	0.0300	0.0300	0.0300	0.8500
2000 - 2010	Agriculture	0.6884	0.0637	0.0821	0.0213	0.1378	0.0066
	Forest	0.0501	0.7831	0.0228	0.0101	0.0634	0.0705
	Rural	0.3257	0.0197	0.2123	0.0372	0.3946	0.0105
	Open area	0.1534	0.0105	0.0026	0.6710	0.1503	0.0122
	Urban	0.1447	0.0253	0.0387	0.0142	0.7701	0.0069
	Water	0.0418	0.0015	0.0894	0.0350	0.1313	0.7010

For the accuracy assessment of the model, the projected land-cover map of 2010 was compared with the actual map using Kappa index statistics, which measures its validity in terms of quantity and location (Figure 4). The findings of model validation confirm that the accuracy of simulation achieved meets the requirements of the study. The model validation findings indicate 0.85, 0.85, and 0.81 prediction accuracy for the Kappa value, Kappa location, and Kappa standards, respectively. Based on historical and simulated land-cover maps, it can be noted that the sustainability of agricultural lands will be affected by changes in land development processes (Figure 5).

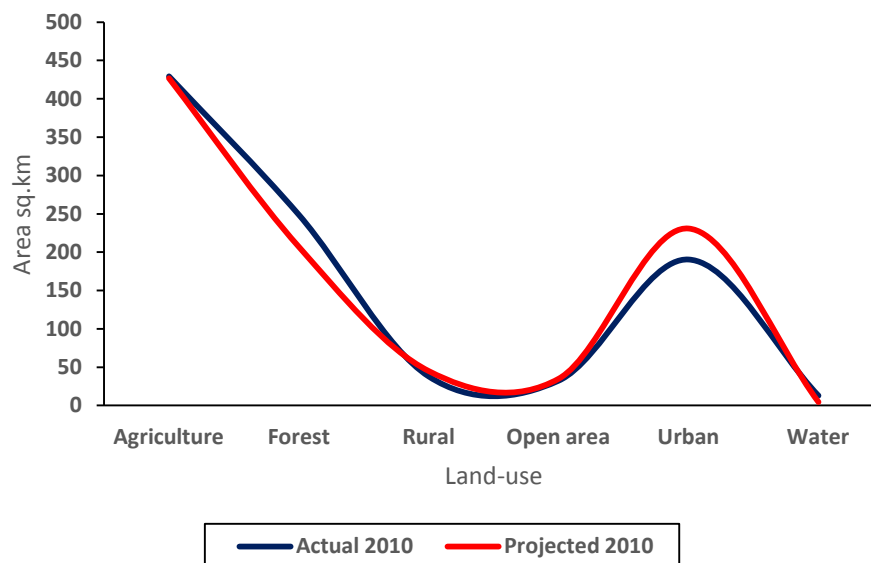


Figure 4. Observed and projected land-use map of 2010

The CA-Markov chain model predicts that agricultural lands will decrease by 369 km² and 337 km² in 2020 and 2030, respectively, compared to 603 km² in 1984. The major reason for decreasing agricultural lands in Seremban is the increase of urban areas due to rapid population and economic growth. This means that the urban growth in Seremban has a negative impact on the sustainability of agricultural lands in the area of study. The major reasons behind such a transition are that agricultural lands are located near urban development operations such as in Seremban 2, Seremban 3, and Nilai. In addition, agricultural lands are located in low elevation areas, which are suitable for urban projects [10]. On the other hand, urban areas will increase by 243 km² and 278 km² in 2020 and 2030, respectively.

Generally, the transition of all types of land use to urban areas will continue in the near future in the same directions as before (Figure 6). The future trends of land-use change in urban areas will be concentrated in the north-west, south-east, and south-east regions of Seremban, which would require city planners in Seremban to generate quick and focused plans to manage land use in these directions in order to protect the natural diversity of land cover and land use in the area.

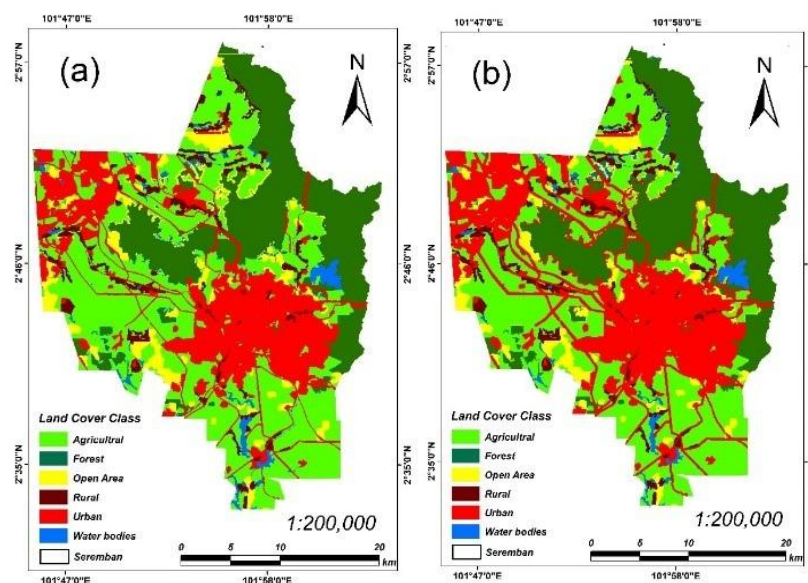


Figure 5. Predicted land-use Maps for (a) 2020; and (b) 2030

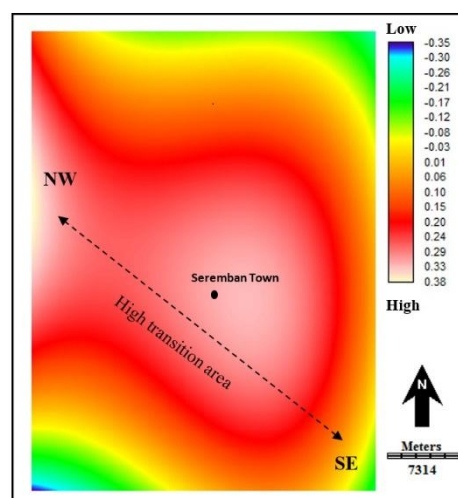


Figure 6. The transition of all categories of land use to urban area from 1984 to 2030

The trends of land transition for each type of land use to urban area show that agricultural lands will be strongly affected by the land transformation process as a result of urban development operations in Nilai, Rasah, and Seremban 2 along the KL-Seremban highway (Figure 7). Meanwhile, most transitions between forest and urban lands will occur in the eastern part of Seremban District as a result of the extension of built-up area towards Ampangan Mukim. This technique provides effective and powerful results of future trends of urban transitions and the relationship between land uses within the city.

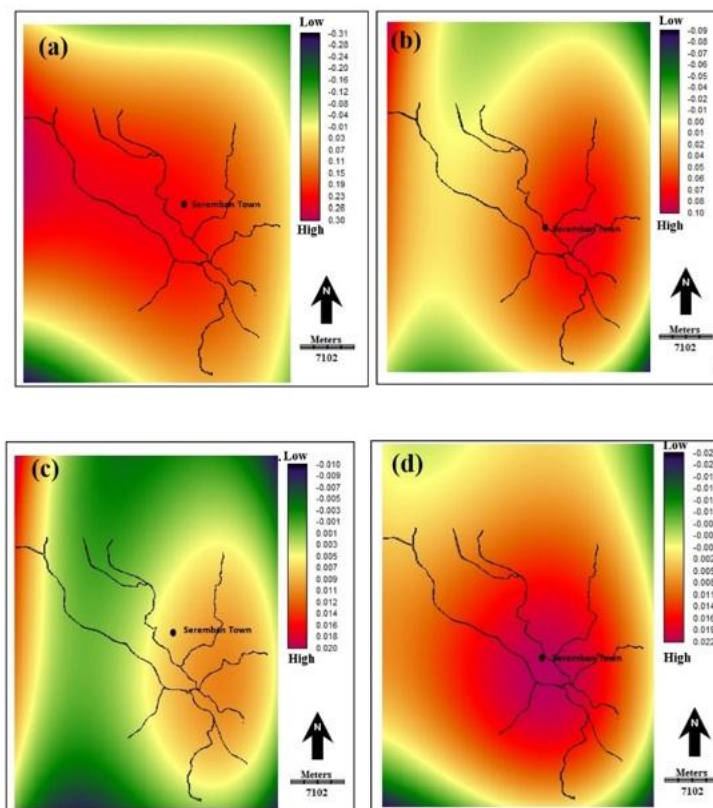


Figure 7. Future trends of urban transitions in Seremban based on each type of land use and its relationship with main roads between 1984 to 2030 (a) Agricultural to Urban (b) Forest to Urban (c) Open Area to Urban (d) Rural Land to Urban

From Figure 8, it can be concluded that agricultural lands will be negatively affected by the increase in other types of land use especially urban areas. On the other hand, a significant gain has been recorded in urban areas because of the development process in Seremban. Generally, it can be confirmed that the green lands in Seremban such as forest and agricultural lands are the significant types of land use that will lose a lot of space to other types of land use such as open and urban areas.

Figure 9 shows positive and negative contribution to net change in each type of land-use in Seremban between 1984 and 2030. The green ecosystem in Seremban will be substantially affected due to the continuity of the urban development process, which makes it imperative for local institutions to create strict policies to protect and save the local environment in the long term.

To observe and understand the effect of land-use change on green lands and the main role of urban growth, Figure 10 shows the transition of agricultural lands into other types of land use. The spatial visualisation provided by the LCM shows that the urban area is the significant type of land use that will affect agricultural lands in the next twenty years. In addition, Figure 10 shows the transition of forest lands to other types of land use between 1984 and 2030, which confirms that urban growth plays a main role in the loss of green lands in Seremban previously, currently, and in the future.

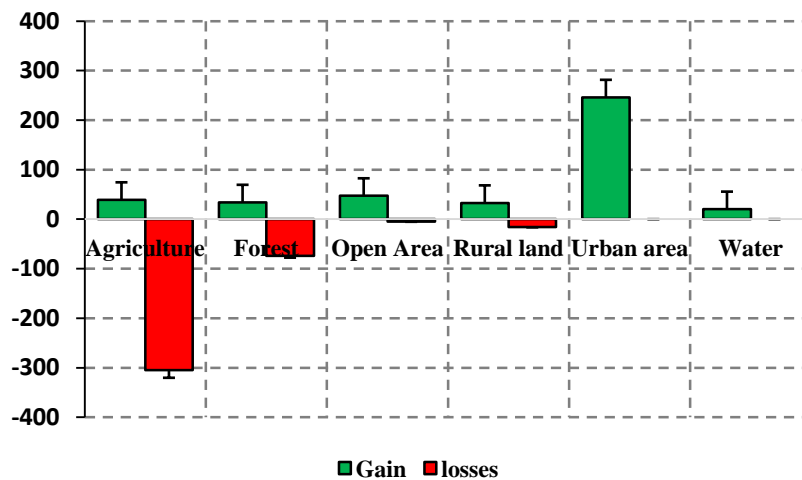


Figure 8. The gain and losses of land-use in Seremban between 1984 and 2030

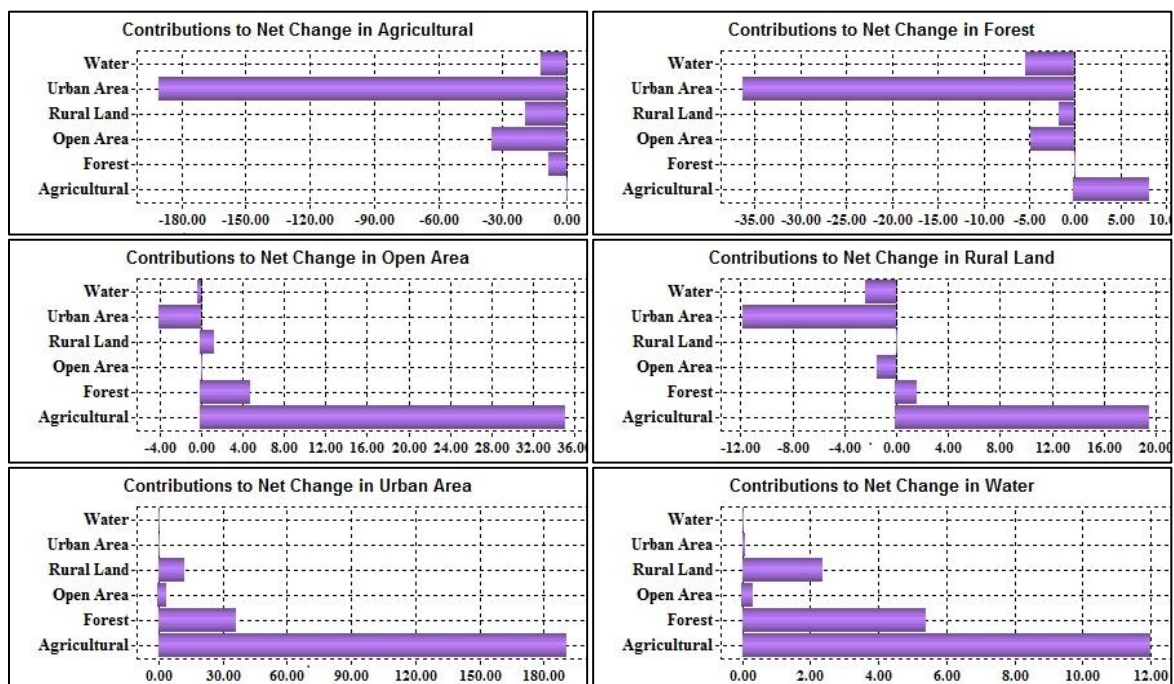


Figure 9. Positive and negative contribution to net change in each type of land-use in Seremban between 1984 and 2030

The multiple linear regression model was employed to determine whether or not strong relationships exist between population growth and household income and urban land-use. This model was also used to assess whether or not population growth and household income positively affect urban growth in Seremban. Population growth and household income were designated as independent variables because these two parameters determine the effect of socio-economic factors on urban land-use. On the contrary, the measures of urban development were designated as the parameters to be predicted and hence were denoted as dependent variables. The results derived from the linear regression model show that both population growth and household income in Seremban positively affect urban growth. If the P-value is less than the critical value, the relationship will be statistically

significant (Figure 11). The histograms show that population growth and household income have strong positive correlations with urban growth.

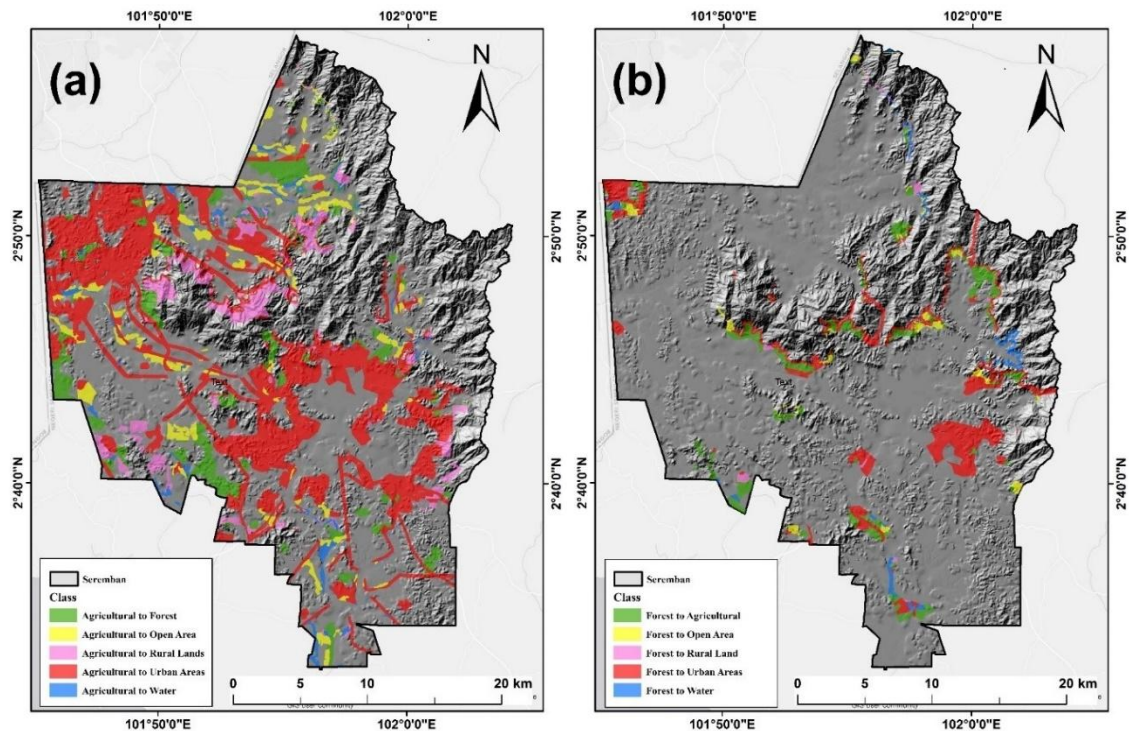


Figure 10. Transition from green lands to all categories of land use in Seremban between 1984 to 2030 (a) Transition from agricultural to all categories (b) Transition from forest to all categories.

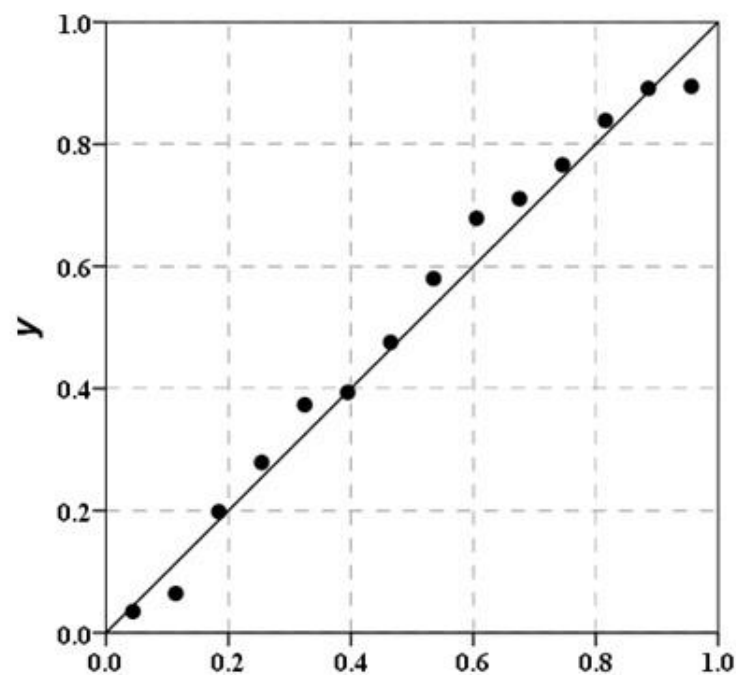


Figure 11. Summary of Linear Regression Results between Population Growth, Household Income, and Urban Growth.

4. Conclusion

This study has effectively identified, analysed, and simulated future land-use trends in Seremban from 1984 to 2030. The growth rate of built-up areas will rapidly increase in Seremban. Meanwhile, non-urban areas such as agricultural and forestlands will decrease because of the urban development process. The simulation and prediction results confirm that using, developing, and integrating spatial and quantitative methods, techniques, and models such as the techniques used in this study will help to protect and monitor the sustainability of the ecosystem in Seremban in particular and Malaysia in general. This study suggests that high-resolution images and land-use maps should be used in the future to obtain accurate results when evaluating, analysing, simulating, and predicting land-use trends. Moreover, more factors and variables such as land value and economic criteria should be included in the land suitability analysis to produce more realistic suitability maps that can help yield more accurate results of simulation and prediction of future urban growth. In addition, Geospatial technologies should be integrated with other social and economic aspects to evaluate and predict land-use trends and to obtain more realistic results.

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