Landscape analysis of urban growth patterns in Seremban, Malaysia, using spatio-temporal data

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Abstract. Urban growth is one of the major issues that have played a significant role in destroying the ecosystem in recent years. Landscape analysis is an important technique widely used to evaluate urban growth patterns. In this study, four land-use maps from 1984, 1990, 2000, and 2010 have been used to analyze an urban landscape. The values of a built-up area were initially computed using a geographic information system environment based on the spatial gradient approach. Mathematical matrices were then used to determine the amount of change in urban patches in each direction. Results of the number of patches, landscape shape index, aggregation index, and total edges confirmed that the urban patches in Seremban, Malaysia, have become more dispersed from 2000 to 2010. The urban patches have also become more continuous, especially in the north-western part of Seremban as a result of the urban development in the Nilai District. These results indicate the necessity to create new policies in the city to protect the sustainability of the land use of Seremban.

1. Introduction

Urban growth is a global issue that leads planners and decision makers to be concerned about its future effects on the ecosystem [1]. This complex issue includes large-scale changes in the land cover and use at the local and regional levels [2-4]. Geographic information systems (GISs) and remote sensing (RS) have been used in recent years for several applications, including the detection of land-use changes [5]. Land-use maps extracted from satellite images refer to the significant data commonly used in urban studies [6, 7]. The number of land-use classes in each map is determined on the basis of image resolution. An increase in satellite image resolution should correspond to an increase in the number of land-use classes in each map [8].

Spatio-temporal data, such as satellite images and land-use maps, are widely used to identify urban growth patterns using landscape analysis [3] as they provide a strong visualization of phenomena in different periods. They can also provide a statistical representation to analyze, measure, and identify urban growth in specific areas [9]. Landscape analysis is a powerful technique used to quantify urban dynamics spatially and temporally [3]. Landscape metrics are extensively used to explain the structures of urban built-up areas [10] and to describe the interrelationship of intra- and inter-land uses and the driving forces of urban growth [11, 12].

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In this study, the gradient approach has been used to understand the urban growth trends in Seremban, the capital of the Negeri Sembilan State, Malaysia, in consideration of the temporal land-use maps in the periods of 1984, 1990, 2000, and 2010. This study has mainly aimed to quantify urban dynamics using temporal RS data through landscape analysis.

2. Methodology

2.1. Study area

Seremban City is the largest district in the Negeri Sembilan State. The study area is located between longitudes of 101° 45' 0" E and 102° 6' 0" E and latitudes of 3° 0' 0" N and 2° 30' 0" N). The city occupies a total land area of approximately 935.78 km^2. Seremban City is composed of the districts of Seremban, Setul, Labu, Rasah, Ampangan, Rantau, Pantai, and Lenggeng (Fig. 1). This city is located approximately 20 km from Putrajaya, which is the national capital of Malaysia, and approximately 67 km from Kuala Lumpur, the economic center of Malaysia.

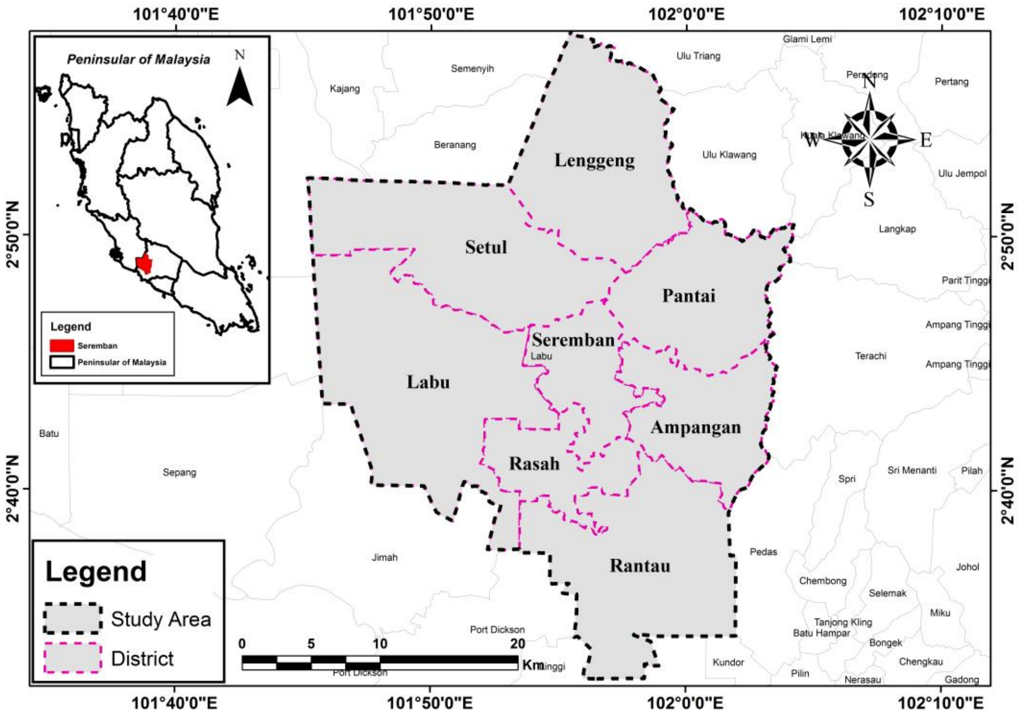

Figure 1. Location of the study area.

2.2. Materials and method

This study utilized certified land-use maps from the Department of Agriculture of Malaysia from 1984, 1990, 2000, and 2010. These land-use maps were extracted from Spot 2, 4, and 5 images. 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 accuracy assessment values reached the acceptable values of the kappa index, and thus the image classification was acceptable. According to the Anderson scheme, the acceptable kappa index value for the accuracy assessment is more than 0.85 [8].

The accuracy assessment method was applied to the land-use maps of 2000 and 2010 to ensure that the classification accuracy of the land-use maps generated by the Malaysian Department of Agriculture reached acceptable values. This study assumed that if the values of the overall accuracy and kappa coefficient of the land-use maps of 2000 and 2010 were acceptable, then all the land use maps used in this study would also be acceptable. High-resolution Google maps were used to conduct the accuracy assessment of the 2000 and 2010 maps. Random samples of each class were used on the basis of the distribution and density of each class in the study area. This method was easily conducted by using the create random point tool in the ArcGIS 10.2 software. The sample number of each class was identified on the basis of the stratified random sample. The minimum number of samples of each class should be 50, except for water, which could be less [13]. This study randomly selected 340 points for verification. Fifty-five errors were identified. The total accuracy values of the land-use maps of 2000 and 2010 were 92% and 91%, respectively. The kappa coefficients of the land-use maps of 2000 and 2010 were 0.90 and 0.89, respectively. Thus, the classification of the land-use maps met the study requirements.
The land-use maps were reclassified into two types of land use; namely, built-up and non-built-up areas, to comply with the general objective of this study. The built-up areas included residential, commercial, services, industrial, transportation, communications, utilities, mixed urban or built-up land, and other urban or built-up land. The non-built-up areas included other types of land use, such as water bodies, agricultural lands, forests, and open areas. All categories of built-up areas were combined according to the Anderson scheme. The main reason for classifying land-use maps to be built-up and non-built-up area classes was that all of the types of spatial analysis in this study were applied to the built-up area to evaluate and measure the urban growth patterns in Seremban [3, 4, 9, 14]. The spatial analysis applied to the category of built-up area is explained as follows.
Built-up area analysis based on the gradient approach: The study area was divided into four zones based on spatial directions. Each zone was further divided into concentric circles of incrementing radii of 3 km from the central business district (*CBD*) to understand the process of changes based on spatial directions and the gradient from the center to the edge. Each direction was divided into nine concentric circles from the *CBD* to explain the urban dynamics at the local level (Fig. 2). This approach can help planners and decision makers determine the causal factors of urban growth, and it can also help in visualizing the forms of urban expansion by using multiple landscape matrices (Table 1). All landscape matrices were employed by using the Fragstats software. All the built-up areas in each direction and circle were clipped and converted into the ASCII format in ArcGIS 10.2 to use them in the Fragstats environment.

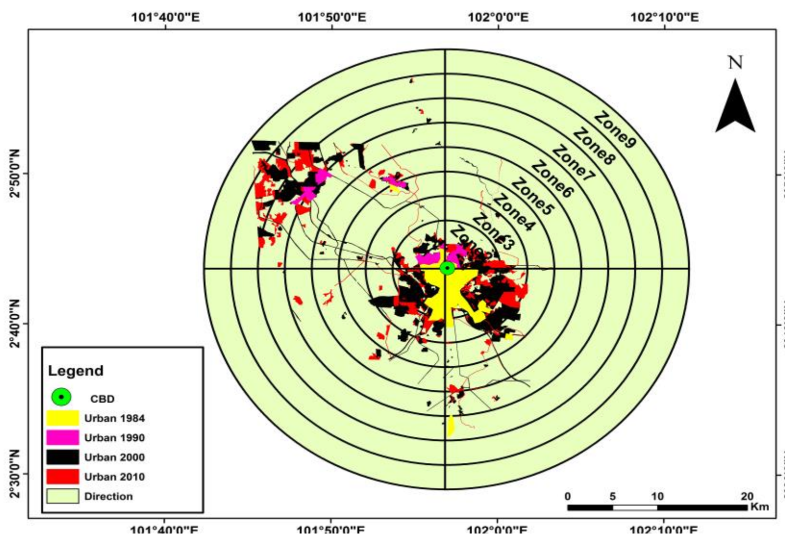

Figure 2. Diagram of the approach used to evaluate urban growth in Seremban according to gradient analysis.

Table 1. Landscape metrics used to analyze the status of the overall urban dynamics.

Landscape metrics	Equation	Description
Number of patches (*NP*)	$N = n_i$	Range $NP \geq 1$ *NP* = number of patches of the corresponding patch category. n_i = number of patches of a particular category.
Landscape Shape Index (*LSI*)	$LSI = e_i / min\ e_i$	*LSI* > 1, without limit e_i = total length of edge of class *i* in terms of the number of cell surfaces. $min\ e_i$= minimum total length of edge of class *i* in terms of the number of cell surfaces.
Aggregation Index (*AI*)	$AI = \left[\frac{g_{ii}}{max_{g_{ii}}}\right](100)$	1≤*AI*≤100 g_{ii} = number of like adjacencies (joins) among pixels of patch type (class) *i* according to the single count method. $max_{g_{ii}}$ = maximum number of like adjacencies (joins) among pixels of patch type class *i* according to the single count method.
Total Edge (*TE*)	$TE = \sum_{k}^{m} = 1e_{ik,}$	$e_{ik,}$ total length (*m*) of edge in landscape involving patch type (class) *i*; it includes landscape boundary and background segments involving patch type *i*.

3. Results and discussion

3.1. Landscape analysis

3.1.1. Number of urban patches(NP)
NP refers to the level of fragmentation of built-up areas [9]. Figure 3 shows the direction and gradient wise number of built-up patches during the different time periods. A major increase in the *NP* from 1984 to 2010 in all zones and in all gradients indicates that the landscape became more fragmented after 1990. The *NP* values decreased near the *CBD*; this decrease explains the process of aggregation of the built-up patches. The northwestern (NW) and southwestern directions illustrate a major increase. A significant increase occurred in built-up patches in most gradients, especially along the edges of the NW direction. The occurrence of urban sprawl is indicated.

3.1.2. Landscape shape index (LSI)
LSI is a simple method used to determine the aggregation and disaggregation of built-up areas [3]. Figure 4 presents lower values after 1990 at the *CBD*, thus indicating simpler shapes and more compact built-up patches. Fringes indicate increased *LSI* values. Fringes refer to complex shapes with fragmented growth, as highlighted by the *NP* in 2000 and 2010 and the development of complex patches. The zones without *LSI* values indicate no built-up area.

3.1.3. Aggregation index (AI)
AI is widely used to measure the aggregation and dispersion of built-up area patches, and it ranges from 0 to 100 [9]. Figure 5 shows the results of the *AI*. The NW zone was generally more dispersed than other directions because of new development projects, especially in the Nilai District, which considered new business areas in the NW part of Seremban [15]. The northeastern part of Seremban was less affected by urban development, and urban patches presented more aggregation near the *CBD*. By contrast, the zones near the edge were devoid of urban patches because they are considered highlands and are inappropriate for urban development[15].

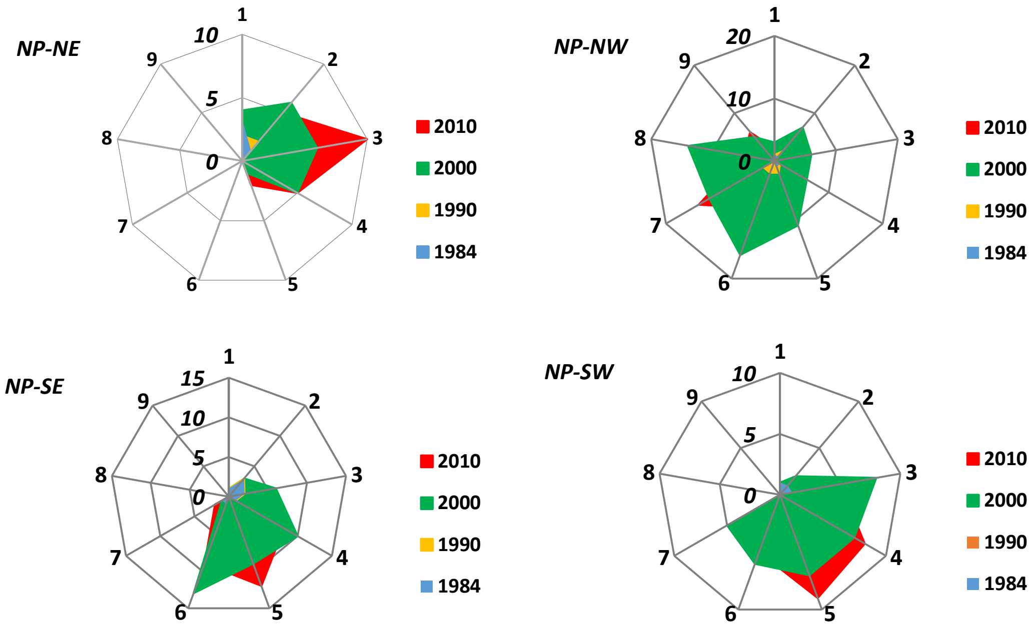

Figure 3. Number of patches metric– direction-wise/circle-wise.

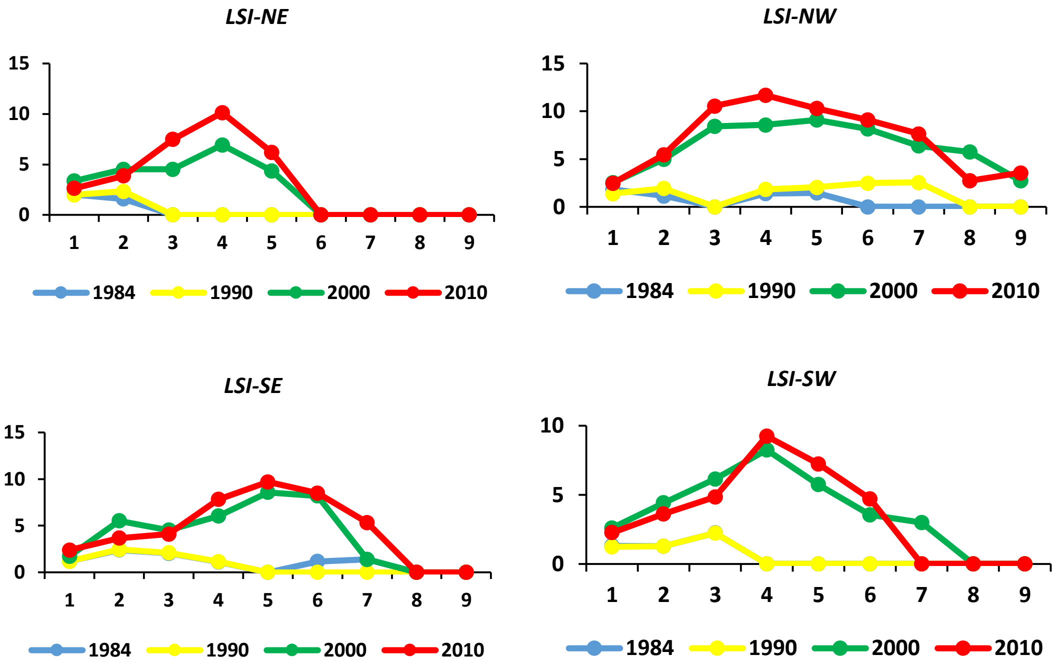

Figure 4. Landscape shape index– direction-wise/circle-wise.

3.1.4. Total edge (TE)
TE is the absolute measure of the total length (perimeter) of the built-up areas of a particular patch in a landscape in meters. Large values of *TE* indicate large, continuous urban patches. *TE* values are greater than or equal to zero. Figure 6 illustrates that in 1984 and 1990, the edges were smaller, and thus the urban patches were discontinuous because the landscape was fragmented. In 2000 and 2010, the results of the *TE* show larger edges. These results indicate that urban patches were ubiquitous and continuous

in 2000 and 2010. The *TE* findings imply continuous urban growth and the breadth of its area in most zones of Seremban.

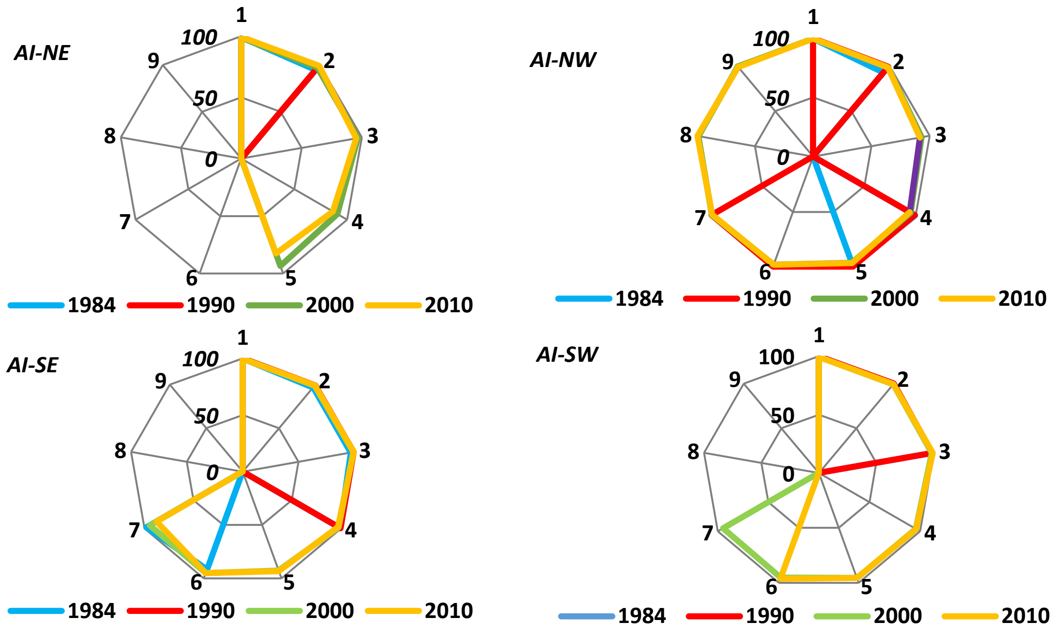

Figure 5. Aggregation Index– direction-wise/circle-wise.

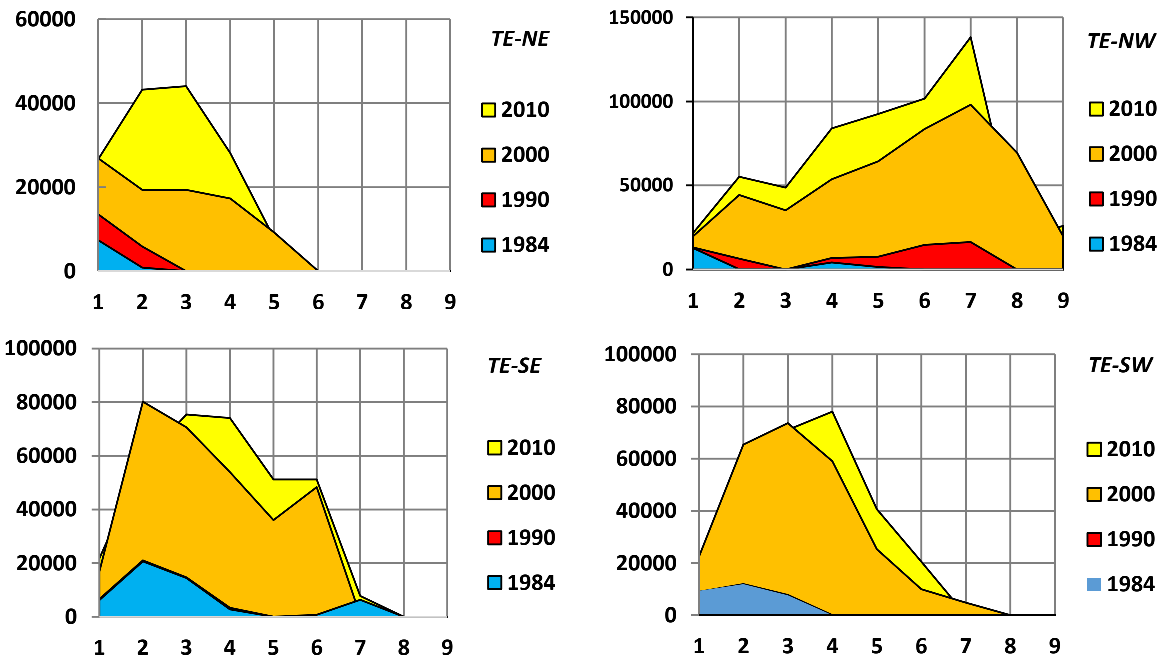

Figure 6. Total Edge metric – direction-wise/circle-wise.

4. Conclusion

Landscape analysis has recently become an important indicator used to evaluate urban growth patterns. This analysis can effectively help monitor urban dynamics and support planners and decision makers in creating sustainable urban strategies. The results of the landscape analysis confirmed that Seremban City is facing expansibility and fragmented and continuous urban patches. The results also showed that the *NW* direction of Seremban has a significant increase in built-up patches in most gradients, and this increase explains the process of urban dynamics in Seremban. This study has demonstrated the potential of *RS* and *GIS* data in providing an accurate means, supplemented with landscape analysis and gradient approach, to understand urban development trends.

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