URBAN GROWTH PATTERN IDENTIFICATION: A CASE STUDY IN SIEM REAP, CAMBODIA

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ABSTRACT

The main purpose of this paper is to identify the pattern of urban growth from 1993 to 2011 in Siem reap town, Cambodia. Land use and land cover maps were generated from Landsat TM imageries from different years in order to extract the information related to urban sprawl. The settlement pattern theory, geographic pattern analysis and visualisation interpretation were used to detect the pattern of urban growth in Siem Reap. Result shows that from 1993 to 2011 the urban area grew significantly, about 102.51%. The development of core settlement areas in Siem Reap revealed to be concentrated along main roads and along the river in the past and still keeping the same trend in the present. The current pattern of urban settlement in Siem Reap was classified as clustered and linear, following the roads network.

1 INTRODUCTION

Urbanization is the process of changing from rural to urban areas. It is one of the most important human activities, which creates enormous impact on the environment at local, regional, and global scale. The extent of urbanization and its growth have driven the change in land use and land cover pattern. The land use and land cover pattern may have adverse impacts on natural resource and socio-economic. Economic and cultural globalization forces are observed as the dominant influence on urban change [3]. Urbanization takes place either in radial direction around a well-established city or linearly along the highways. This dispersed development along highways, or surrounding the existing urban built up area or in rural countryside is often named as urban sprawl [13]. Urban sprawl is defined as the scattering of new development on isolated areas, separated from other areas by vacant land [9]. The expanding urban sprawls come from “rural push” and “urban pull” [14]. People migrate from rural to urban area in order to find better opportunities. Because of the economic stagnation, and poverty in the rural areas, people have been forced to move to urban areas in order to improve their living conditions. Urban areas have been classified as places attracting people because many facilities, infrastructures, and services are provided. It is the centre of business, economic, education, commercial, industry, and a huge source of income [14]. Communities live and work in towns and cities; if society changes, urban form also changes and growths. Meanwhile, monitoring approaches and real-time mapping using Geographic Information System (GIS) and Remote Sensing (RS) integration are useful techniques to identify urban growth pattern and its rate. A model for urban growth pattern identification is proposed and a case study in Siem Reap, Cambodia is explored.

2 IDENTIFICATION OF URBAN SPRAWL PATTERN

Urbanization occurs when cities grow at the cost of their surrounding countryside, suburbanization and ex-urbanization when the inner ring or commuter belt grows at the expense of the urban core [14]. Urbanization takes place either in radial direction around a well-established city or linearly along the highways. This dispersed development along highways, or surrounding the city and in rural countryside is often referred as urban sprawl [13]. Urban form is a "pattern", representing the spatial characteristic of the urban area at a certain time. Urban form is also a "process", indicating the spatial change over time. The pattern is the outcome of the process. Both pattern and process are closely linked to several factors, such as social, economic, or cultural [10]. A settlement which considers buildings as clusters around a particular point, controlled by the natural factors including flat area, rivers and its intersections, and mountains is called clustered settlement pattern. This pattern starts with a small number of household and expands to large size of household with time. A settlement which is opposite to clustered settlement pattern is called dispersed settlement pattern. Dispersed pattern is considered mainly for farm land which is away from household. This settlement is mainly for the community center such as temple, market, and school, and also depends on the size of these areas. The mix between the cluster and dispersed settlements is called random settlement. This settlement starts with cluster system. Some people need to be isolated after the settlement expands, and settle down away from village. Finally, linear settlement is a pattern that follows a line along the road or river, and mostly occurs in the flat area. Ronghua et al. (2008) developed their research on mining the urban sprawl pattern, a case study on Sunan, China [11]. Their paper focused on the evolution of an urbanized area by means of complementary approaches, especially different fractal and autocorrelation measures. They employed the spatial autocorrelation Global Moran I and Sprawl intensity index to identify the urban sprawl pattern in Sunan, China. The research denoted that Sunan's urban cluster are becoming more and more homogenous and compact and are growing along the transportation axes. Saravanan et al. (2010) introduced visualization approach with the help of city model-Monocentric to identify the urban sprawl pattern in Maduarai region, India [12]. His paper demonstrated urban expansion of Maduarai, and identified the temporal and spatial development by using multi-temporal RS images and GIS technique. The pattern of sprawl was described using visual interpretation techniques. The result showed that the pattern of urban sprawl of Maduarai is identified as linear along the major roads. Michael (2009) conducted his research on measurement the urban sprawl pattern in Lokoja, Nigeria [1]. His study used the GIS approaches and the application of Shannon's entropy theory to measure the behaviour of sprawl. The measurement of entropy is derived based on the two location factors, distance from roads and distance from the town center to reveal and capture spatial patterns of urban sprawl. The results showed that Lokoja is experienced grow along the major highways. The total entropy value of the town indicated a value -1, which is an indication of the occurrence of sprawl. Huiping et al., (2005) proposed the study on developing urban growth prediction from spatial indicators based on multi-temporal images [8]. An integrated of remote sensing and GIS technique were applied to detect the spatial distribution of land use and spatio-temporal pattern over the years. Moreover, multivariate model was adopted to determine the relationship between urban expansion and factors related to growth. Finally, land use/land cover pattern was integrated with multivariate spatial model to estimate the spatial distribution of future urban expansion.

3 RESEARCH METHODOLOGY

This study used GIS and Remote sensing integrated approach for detecting the land use/land cover especially urban growth pattern from 1993 to 2011. Spatial autocorrelation Global Moran I, visualisation interpretation, and pattern of settlement theory are used to identify the urban sprawl in Siem Reap. The flowchart of research methodology is described as follow in figure 1.

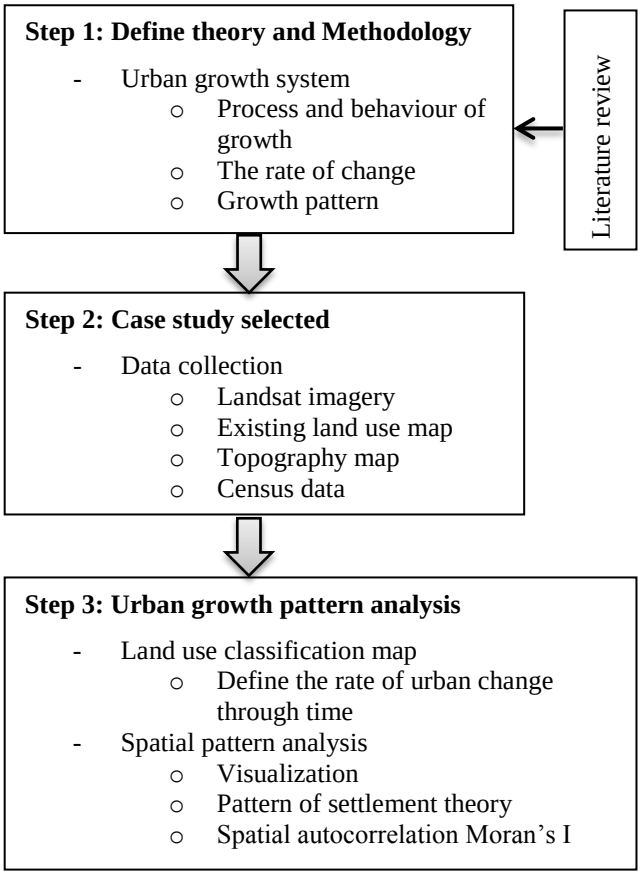

Fig. 1 Research methodology framework

Satellite images were acquired from Landsat TM 1993 to 2011 to process the land use classification map. The detection of urban area change in Siem Reap was achieved generating land use maps in order to identify the pattern of urban sprawl. The urban sprawl and the direction of growth of Siem Reap town can be explained with the help of pattern of settlement theory, visualize interpretation, and spatial autocorrelation Global Moran I.

Geographic pattern analysis is very important tool to understand geographical phenomenons. Statistical analysis has been used to identify spatial pattern. Spatial autocorrelation statistic has been applied to detect the pattern of urban area through time. Spatial autocorrelation statistic measures and analyses the degree of dependency among observation in a geographical space. Global Moran I [2, 4], a measure of spatial autocorrelation, which is used to measures spatial autocorrelation based not only on feature locations or attribute values by itself but on both feature locations and feature values simultaneously. Given a set of features and an associated attribute, it calssifies the pattern as clustered, dispersed, or random. The tool calculates index value I ranging from +1 to -1

respectively showing clustering and dispersion, as well as a Z value showing the significance of I. The Moran's I statistic is given in Equation (1) below.

$$I = \frac{n \sum_{i=1}^{n} \sum_{j=1}^{n} \omega_{i,j} z_i z_j}{S_0 \sum_{i=1}^{n} z_i^2} \quad (1)$$

Where:

Z_i : the deviation of an attribute for feature *i*

$\omega_{i,j}$: the spatial weight between feature *i* and *j*

n : the total number of features

S_0 : the aggregate of the spatial weights which is computed as shown in Equation (2)

$$S_o = \sum_{i=1}^{n} \sum_{j=1}^{n} \omega_{i,j} \quad (2)$$

The Z_I -score for the statistic is computed in Equation (3)

$$Z_I = \frac{I - E[I]}{\sqrt{V[I]}} \quad (3)$$

Where:

$$E[I] = \frac{-1}{(n-1)} \quad (4)$$

$$Var[I] = E[I^2] - E[I]^2 \quad (5)$$

After the Spatial Autocorrelation (Global Moran's I) tool has computed the Index value, it computes the Expected Index value. The Expected and Observed Index values are then compared. Given the number of features in the dataset and the variance for the data values overall, the tool computes a z-score and p-value indicating whether this difference is statistically significant or not. Index values cannot be interpreted directly; they can only be interpreted within the context of the null hypothesis. In the case of the Spatial Autocorrelation tool, the null hypothesis states, "there is no spatial clustering of the values". When the Z score is large (or small) enough to such that it falls outside of the desired significance, the null hypothesis can be rejected. When the null hypothesis is rejected, the next step is to inspect the value of the Moran's I Index. If the value is greater than 0, the set of features exhibits a clustered pattern. If the value is less than 0, the set of features exhibits a dispersed pattern.

4 A CASE STUDY IN SIEM REAP

The study area is located between 13°12' N to 13°29' N latitudes and 103°44' E to 103° 56' E longitudes as shown in figure 2. Siem Reap is situated in the North-western part of Cambodia. With a total land area of 181,035 square kilometres, the Kingdom of Cambodia is the smallest of the former Indochinese countries. It is bounded to the west of and northwest by Thailand, to the north by Laos, to the east and southeast by Vietnam, and to the south by the Gulf of Thailand. Cambodia's geographical position in extreme co-ordinates, North: 10°N/ South: 15°N/ East: 108°/ West: 103°E. The step and trend of urbanization in Cambodia have fluctuated, depending on the political regime. During the period after the independence from France (1954-1969) and in recent years (since 1990), the country has experienced fast urbanization. During the Khmer Rouge regime (1975-1979), urbanization in Cambodia completely stopped.

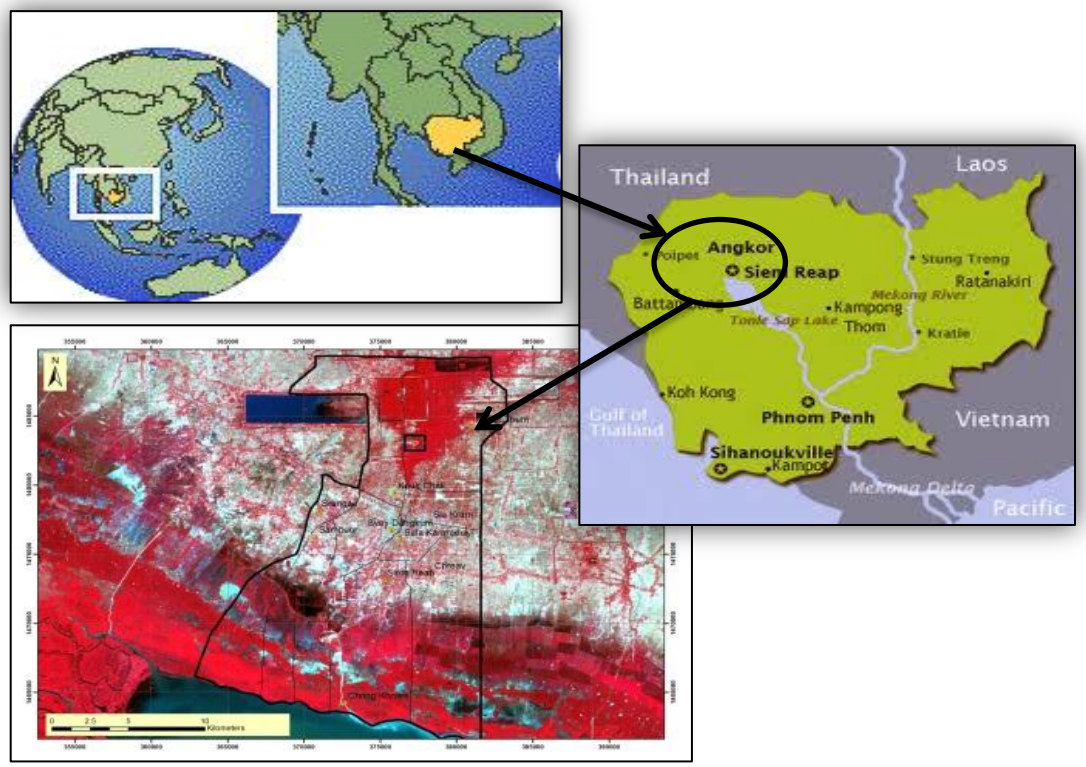

Fig. 2 Map of selected study area

Siem Reap has been selected as a case study on urban growth pattern identification because of the dramatically changed in building construction, population, and infrastructure. Today, Siem Reap is undoubtedly Cambodia's fastest growing city and serves as a small charming gateway town to the world famous heritage site of the Angkor temples. Siem Reap has transformed itself into a major tourist hub. According to national socio-economic census in 2003 from National Institute of Statistic (NIS) of Cambodia, the total population of Siem Reap district was 126,820 with a density of 365 persons per square kilometres (sq.km) [5]. However, the population increased gradually to 166,867 in 2008 with a density of 489 persons per sq.km [5, 6]. Moreover, in 2003, the number of housing was only 21,878 but in 2008, it increased gradually to 27,161 with 128 hotels, 1,174 guesthouses, and 219 restaurants in Siem Reap district [5, 6]. Furthermore, in 1993 the number of tourists visiting Siem Reap was only 118, 183 but in 2010, the number of tourists increased significantly to 2,508,289. Thus, it can be projected that the number of tourist will continuously increase [7]. Despite international influences, Siem Reap and its people have conserved much of the town's image, culture and traditions. Because it is an area of archaeological and world heritage, therefore royal government is concerned with the present situation because it may affect the characteristic of archaeological heritage sites in Siem Reap district if land use continues changing with improper plan.

5 RESULT AND DISCUSSION

5.1 Land use change detection analysis

Land use map was generated from Landsat TM data and was classified into seven classes. There are forest covers, urban built-up area, water features, agriculture, shrub land, mixed use, and temples as shown in figure 3.

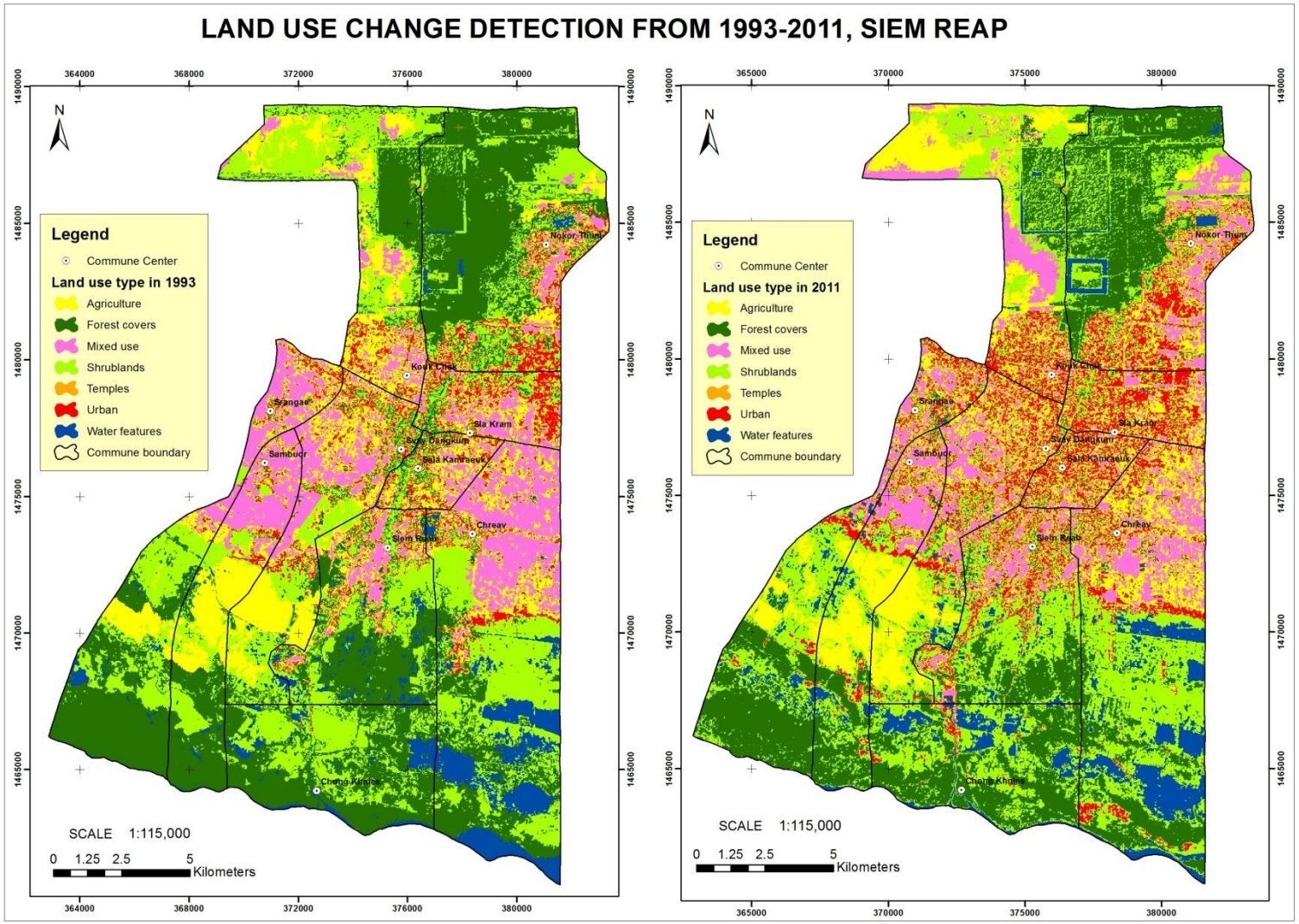

Fig. 3 Map of land use change detection from 1993 to 2011 in Siem Reap, Cambodia

Figure 4 shows that the urban area and mixed used increased significantly from 1993 to 2011 in Sla Kram commune, Sala Kamroeuk commune, Svay Dangkum commune, some part in Kouk Chak commune and in Nokor Thum commune. The percentage of change in land use from 1993 to 2011 was calculated and can be seen in Table 1 and 2.

Table 1 Land use change detection rate in Siem Reap

No.	Land use	Area ($km^{2)}$		Change in %
		1993	2011	
1.	Urban	19.65	39.80	**102.51**
2.	Agriculture	74.05	66.73	-9.81
3.	Mixed use	13.42	63.95	376.40
4.	Water	18.71	22.68	21.19
5.	Shrub land	97.14	67.30	-30.71
6.	Forest	108.20	70.71	-34.64
7.	Temples	0.13	0.13	0.00

In the period of 1993 to 2011, it is shown in table 1 that the rate of mixed use area increased dramatically while the forest area is declined significantly. In the past, charcoaling had been an important source of household income and the main resource for producing charcoal is from forest. Moreover, these declined have resulted not only from charcoaling but also from illegal logging and clearing land for agriculture. Furthermore, it is also seen that area of urban built-up land has extended from 19.65km^2 to 39.80km^2. With a yearly increasing of the number of tourist, the construction of hotels, guest houses, and other recreation areas were built to increase the offer. Urban increased significantly their area by (102.51%) due to rapid growth in population and tourist. It is the result of the eco-tourism industry boom in Siem Reap started since Angkor has been inscribed as the World UNESCO heritage in 1992.

Table 2 Urban area change detection from 1993 to 2011

No.	Land use	1993-2011 (km^2)
1.	Forest-Urban	0.00
2.	Agriculture-Urban	6.33
3.	Mixed use-Urban	11.65
4.	Water-Urban	0.20
5.	Shrub land-Urban	1.97
6.	Temples-Urban	0.00

Table 2 shows that the most significant conversion to urban built-up area is mixed use land which is 11.65km^2. Because of the tourism industry development, some agriculture land has also been converted to urban built-up area (6.33km^2). In the southern part of Siem Reap, floating village became the most famous tourist attraction place due to the waterscape view of the Tonle Sap River and flooded forest. Thus, 0.20km^2 of surface water has been converted to urban built-up because of the population boom in that floating village.

5.2 Measurement urban growth pattern in Siem Reap

The pattern of urban sprawl and the direction of urban growth in Siem Reap town can be described using visual interpretation as shown on figure 4, pattern of settlement theory and spatial autocorrelation Global Moran I which can be seen in figure 5 and 6.

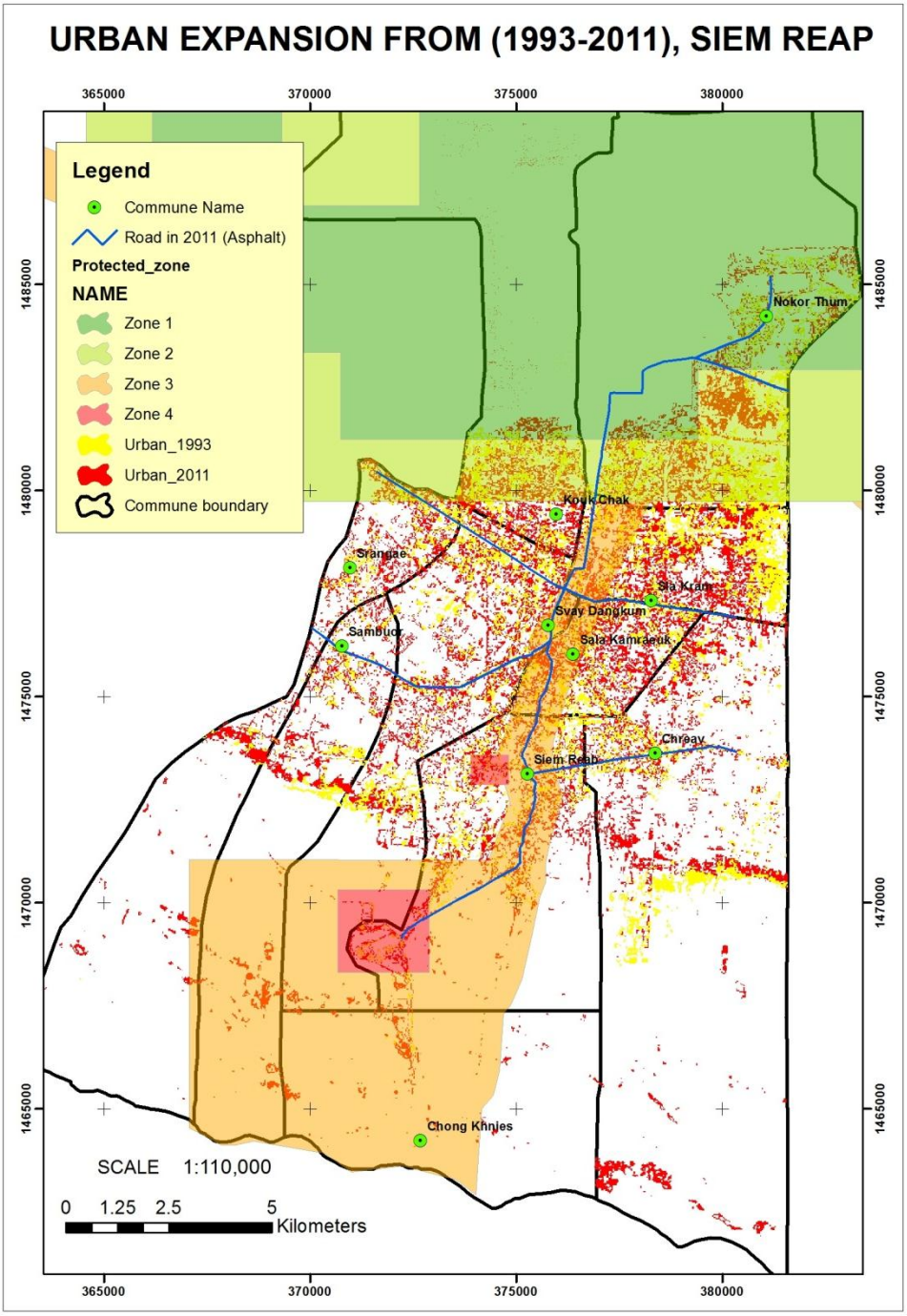

Fig. 4 Urban expansion pattern in Siem Reap from 1993 to 2011

Urban sprawl reveals eight distinct dimensions: density, continuity, concentration, clustering, centrality, nuclearity, mixed use, and proximity. Clustering is the degree to which development has been tightly bunched to minimize the amount of land in each sq.km of developable land occupied by residential or nonresidential uses [15]. As shown in

figure 4, earlier, Siem Reap town growth was based on Angkor Temple as the central place. According to the theory, it is named as clustered pattern settlement. The development was uniform around the temples and the road networks were also established nearby. Therefore, the residential and commercial activities spread evenly in all directions; a radial pattern of urban expansion in 1993 was the result. Later the development was due to rapid population growth and due to the restriction of vertical development, construction higher than the towers of temple are not allowed; as a result horizontal expansion took place. By the existence of national restrictions, the horizontal expansion has not happened in all directions. The development in the northern part of the town is prohibited because of the preservation zone for archaeological sites. In figure 3 indicates that the urban area has grown along the road, river, and surround particular central point such as temples since 1993. In 2011, it remained the same pattern, the urban expanded along the major roads. According to the settlement pattern theory, a group of houses which settle around the transportation lines are called linear pattern. In contrast, a group of houses settle around particular point are named clustered pattern. Thus, from this theory, the urban expansion pattern in Siem Reap is linear and cluster.

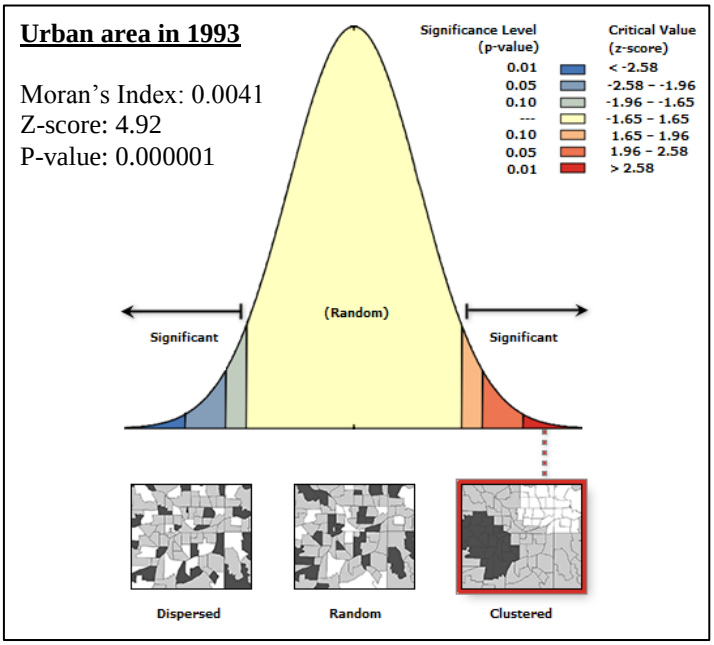

Fig. 5 Global Moran I pattern analysis for urban area distribution in 1993

Based on Moran's I statistical analysis, it is showed in figure 5 that the Moran's I Index value 0.0041, which is near to +1.0000 indicates clustering pattern. The statistically result is significant which p-value is 0.000001 ($p < 0.05$). Given the z-score of 4.92, the spatial distribution of urban pattern in 1993 is clustered (Figure 5).

Moran's I statistical analysis reveals in figure 5 that the Moran's I Index value 0.101, which is near to +1.0000 indicates clustering pattern. The statistically result is significant which p-value is 0.000001 ($p < 0.05$). Given the z-score of 4.91, the spatial distribution of urban pattern in 2011 is clustered (Figure 6).

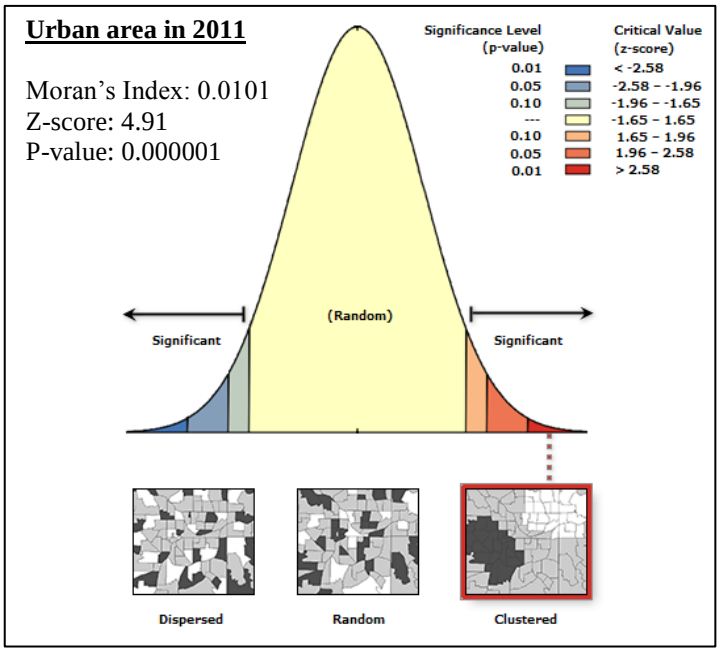

Fig. 6 Global Moran I pattern analysis for urban area distribution in 2011

6 CONCLUSION

This paper aims to characterize urban expansion in Siem Reap town and identifies the temporal and spatial development pattern by using Remote Sensing and Geographic Information System approach. Land use classification technique was used to identify the land use/ land cover change from 1993 to 2011 in Siem Reap especially urban area change. Several analyses were applied in quantifying the urban sprawl pattern. Visualisation interpretation, settlement pattern theory, and spatial autocorrelation Global Moran I were applied to detect the urban growth pattern in Siem Reap. It was found that urban area grew significantly between 1993 and 2011. Moreover, the development of core settlement areas in Siem Reap town is concentrated along the main roads and along the river since past time. Thus, there has been a tendency of linear development along the roads with a development focused on main roads. The result from visualization, theory, and Global Moran I showed that urban growth along the roads and the intersection of roads formed a linear and clustered pattern. In 1993, the urban areas located along the main roads, rivers, and some particular points. In 2011, when the new road had been constructed, the urban area still expanded along the main road. In the future, the urban area shall be extended to the east, the west, and the south direction while the north direction is prohibited. The Angkor preservation zone shall be protected from further expansion of settlement areas.

Urban sprawl generally is known as the pattern of land use exhibit without proper plan. Urban sprawl reveals eight distinct dimensions: density, continuity, concentration, clustering, centrality, nuclearity, mixed use, and proximity. Because of this characteristic, the urban sprawl is one of potential threats to sustainable development where urban planning should be taken because it implies an increase the consumption of land, water, energy, and other resources as well as of pollutants and waste. Therefore, identification and analysis of the urban growth pattern may help in effective land use planning and making decision for urban landscape planning and environmental management.

7 REFERENCES

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