CHARACTERIZING THE URBAN GROWTH FROM 1975 TO 2003 OF HANOI CITY USING REMOTE SENSING AND A SPATIAL METRIC

by:

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ABSTRACT

This study explores an approach of combining remote sensing and a spatial metric to characterize land use change in Hanoi, Vietnam. The work is based on the land cover information of 4 different times derived from Landsat and ASTER data from 1975 to 2003. This study adopted the spatial metrics; the percentage of like adjacency (PLADJ), which calculates the number of like adjacencies involving the focal class, divided by the focal number of cell adjacencies involving the focal class, multiplied by 100 to convert to a percentage. The result successfully showed proportions of the fragmented and the aggregated areas in urbanization for each development time. During the rapid urbanization periods in 1975 – 1984 and 1984 – 1992, a large proportion of the interior non developed and aggregated non developed was converted to developed landscape, whereas fragmented non developed to developed markedly happened in 2001 – 2003. The study provided intuitive description and separation of three urbanization patterns such as infill, expansion, and outlying. Quantitative assessment revealed that the proportion of the expansion and infill steadily increased, whereas the proportion of the outlying decreased in past 30 years. The combined approach using remote sensing and a spatial metric is an effective method to improve understanding of urbanization patterns and to provide visualization of spatial – temporal change due to urbanization.

Keywords: land cover change, Landsat, ASTER, spatial metric

INTRODUCTION

Remote sensing provides great potential of acquiring data to detect land use change and urban growth in an appropriate spatial scale. Spatial metrics (landscape metrics) are a useful tool to quantity urban structures and to detect urbanization patterns from geospatial data. This study explores an approach of combining remote sensing and a spatial to characterize land use change in Hanoi, Vietnam. Recently, economic development in Hanoi city has resulted in the urbanization occurring at an unprecedented rate. This led rapid increase in population of the city from 1.4 million people in 1975 to 3.3 million in 2006. The highly concentrated residence consequently caused the uncontrollable land cover change. Therefore, an advanced land management method is required for city planners to catch up with the rapid land cover change due to urbanization. The urban area results which derived by integrating classification, VSW index (Hai and Yamaguchi, 2006) and NIR band can visually show change of objectives in the land surface. Thus, monitoring urban change using remote sensing provides city planners and decision – makers with information on the current state of development and the nature of change in a timely and cost – effective manner. However, a major problem of using remote sensing is its limits of spatial resolution that sometimes can not resolve the heterogeneity of the urban environment, mixture of build – up areas, transportation lines, park, bare soil, and water bodies. Therefore, those results by remote sensing can only show distribution of urbanized areas, Nevertheless, few studies have focuser on the integration of remote sensing data into urban planning and management applications.

The objective of this study is to investigate potential of combining remote sensing and a spatial metric to investigate the structure and change of urban areas. This study adopted one of the spatial metrics; the percentage of like adjacency (PLADJ) to detect proportions of landscape fragmentation for urban areas. Spatial metrics can be used to objectively quantity the spatial structure and pattern from a thematic map. Spatial metrics can offer improved description and representation of heterogeneous urban areas and can provide a link between the physical landscape structure and urban from (Martin, 2003). The results of this study will the useful to quantitatively characterize the spatial structure and pattern of urban areas.

STUDY AREA AND DATA SOURCE

Study Area

Hanoi is located in the center of the Red River Delta. The city area covers approximately 921 km^2 and the population is approximately3.3 million (2006). The study area is 450 km^2 including the city center of Hanoi and has a population density of approximately 5.300 people/ km^2.

At present, Hanoi has seven inner – city districts, namely, Hoan Kiem, Ba Dinh, Hai Ba Trung, Dong Da, Tay Ho, Thanh Xuan and Cau Giay, and the five sub urban districts of Tu Liem, Thanh Tri, Dong Anh, Soc Son and Gia Lam. The urban population growth and rapid economic development are vital driving forces behind urbanization, and directly impact the land use change in on the outskirts of Hanoi city.

Data Source

Multi spectral and multi temporal satellite data were obtained, ASTER images from the Earth Remote Sensing Data Analysis Center (ERDAS) and Landsat images as from the Tropical Rain Forest Information Center, Michigan State University, U.S.A (Table 1). Cloud cover was less than 10% in these images. The visible and NIR bands were used for data processing.

METHODE, RESULT, AND DISCUSE

Image Classification

Input data had different spatial resolutions and coordinate systems. SO that

Table 1. Satellite Data Used in this Study

Satellite Images	Time	Resolution (m)
Landsat MSS	1975/12/29	80
Landsat MSS	1984/08/05	80
Landsat TM	1992/10/21	30
ASTER	2001/12/01	15
Landsat ETM+	2003/10/13	30

they were converted to a standard resolution and map coordinate system. Re-sampling and geo-referencing were performed to rectify the Landsat satellite images to the Universal Transverse Mercator coordinate system corresponding to the 15 m spatial resolution of the ASTER VNIR data.

The maximum – likelihood classification method used to generate surface cover maps of the center of Hanoi. The land surface was classified into the nine classes; such as: water, bright vegetation, dark vegetation, marsh, urban, road, fallow, wet land, and sand. In order to reduce the effects of pixel to the results, this study applied approach that developed by Hai and Yamaguchi (2006) by integrating classification results, VSW index and NIR band. The final results showed the maps of urban areas from 1975 to 2003 (see Figure 1). Urban areas could the easily extracted from satellite data, and the results made it possible to visualize the expansion of Hanoi City for the period from 1975 to 2003. Since the north of city is bounded by the Red River, Hanoi has expanded primarily to the west and south to date. Also, new developments have recently been initiated on the east side of the Red River. A general characteristic of urbanization patterns is that urbanization occurs primarily in response to the construction of new buildings along transportation lines, which then subsequently expand.

However it is necessary to provide decision makers knowledge of spatial arrangements of urban land cover structure (pattern shapes) that are used to characterize urban land use (Haack, 1997). Combination of remote sensing and spatial metrics can provide more spatially consistent and detailed information on urban structure and

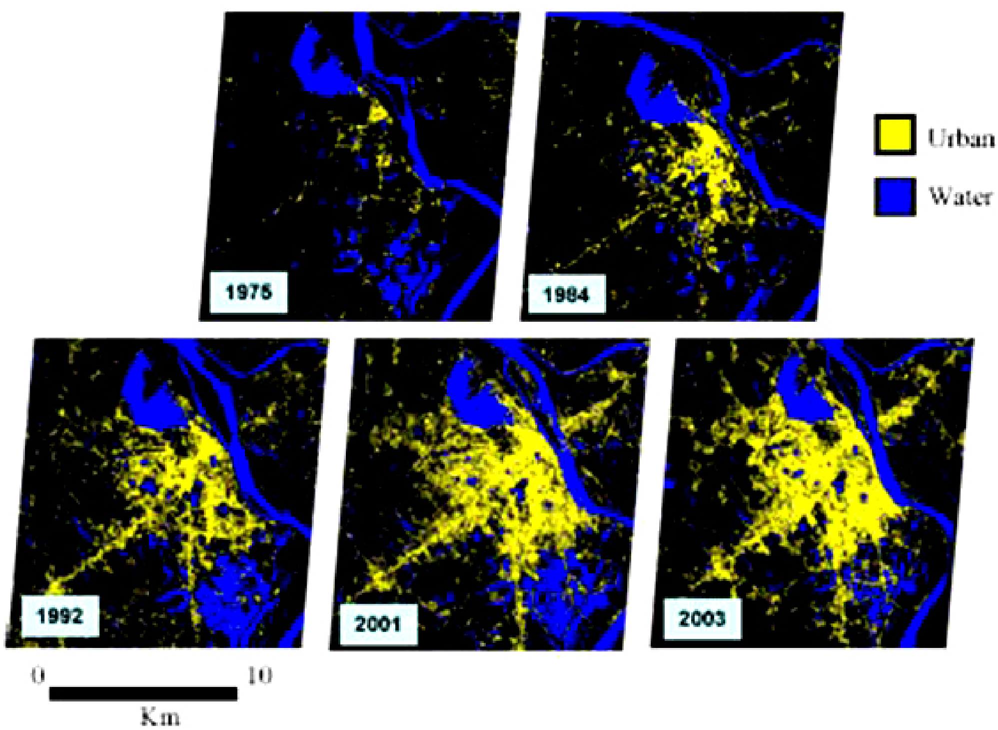


Figure 1. Urban Areas

change than either of these approaches used independently (Martin, 2003). In this study, we investigate a potential of combining remote sensing and a spatial metric to quantify spatial urban patterns

Spatial Metrics

Recently, there has been an interest in integrating remote sensing and spatial metrics to analyze spatial structure and patterns for urban growth. In this study, spatial structure can be understood as spatial distribution of individual urban areas in the thematic maps. According to Martin (2003), spatial metrics can be defined as measurements derived from the digital analysis of thematic categorical maps exhibiting spatial heterogeneity at a specific scale and resolution. Indeed, spatial metrics can be computed as patch-based indices (e.g. size, shape, edge length, patch, density, fractal dimension) or as pixel-based indices (e.g. contagion) computed for all pixels in a patch Gustafson, 1998). Patch can be defined as homogenous regions for a specific landscape property of interest, such as park or residential zone (Anderson, 1976)

We are especially interested in detecting spatial structures and quantitative change patters of urban areas due to the urbanization from 1975 to 2003, but those could not be detected directly from the result of remote sensing (see Figure 2). From late 1980s, a number of metrics were developed for a variety of applications such as quantifying total urban growth in urban

$$PLADJ = \frac{g_{ii}}{\sum_{k=1}^{m} g_{ik}} \times 100$$

g_{ii}: number of like adjacencies (joins) between pixels of patch type (class) i

g_{ik}: number of adjacencies (joins) between pixels of patch type (classes) i and k

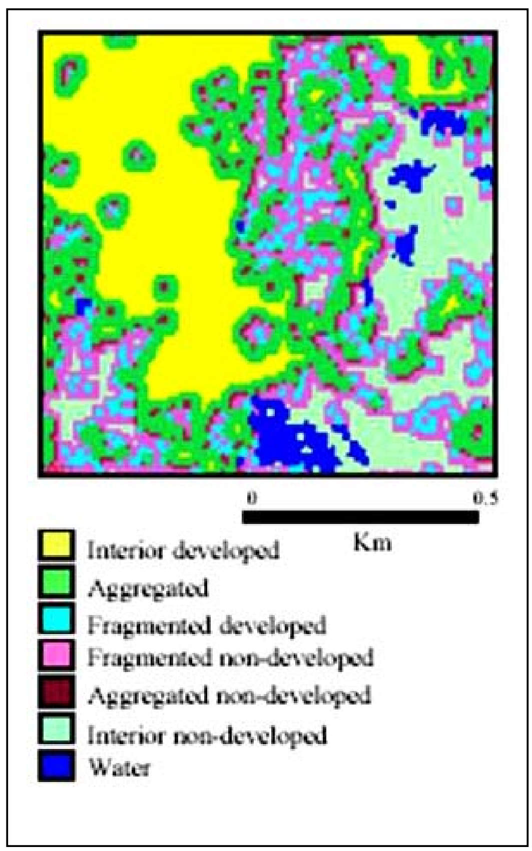


Figure 2. PLADJ Pattern in the South of Hanoi in 2003

area by the class area (CA), detecting patch fragmentation of urban area by the edge density (ED), and measuring of the spatial arrangement and landscape heterogeneity of urban land by the percentage of like adjacency (PLADJ) (Martin, 2003). This study applied PLADJ to investigate the urban growth because it is intuitive and simple in computing.

A 5 x 5 pixel moving window was chosen to compute percentage of fragmentation of the urban area. An output value is retuned to the center cell of the window. PLADJ moves randomly conditional probabilities through pixels in the moving window and equals the number of like adjacencies, divided by the total number of cell adjacencies involving in the same class and is multiplied by 100 (to convert to a percentage). Like adjacencies between four orthogonal cells were refereed, but diagonal cell were ignored (Noda, 2007).

PLADJ equals 0 when a maximum disaggregated pattern happens in the current class or there are no like adjacencies. PLADJ equals 100 when the computed areas cover a single class or all adjacencies are in the same class (maximally contagious). If the result expresses the lower percentage, the higher fragmentation or large number of individual urban units will appear in the map. In order to discriminate developed and non-developed pixels (urban and water, vegetation, bare soil, agricultural land), if a center pixel of the window was originally non-developed, a positive PLADJ value was appointed to it. Conversely, id a center pixel of the window was originally developed, a negative PLADJ value was appointed to it. A PLADJ threshold was determined to identify spatial structures of urban areas. A pixel became 'fragmented' when its value was less than 70%, "aggregated" when its value ranged from 70% to 99%, and "interior" when its value equaled to 100%.

Rule of Urban Change

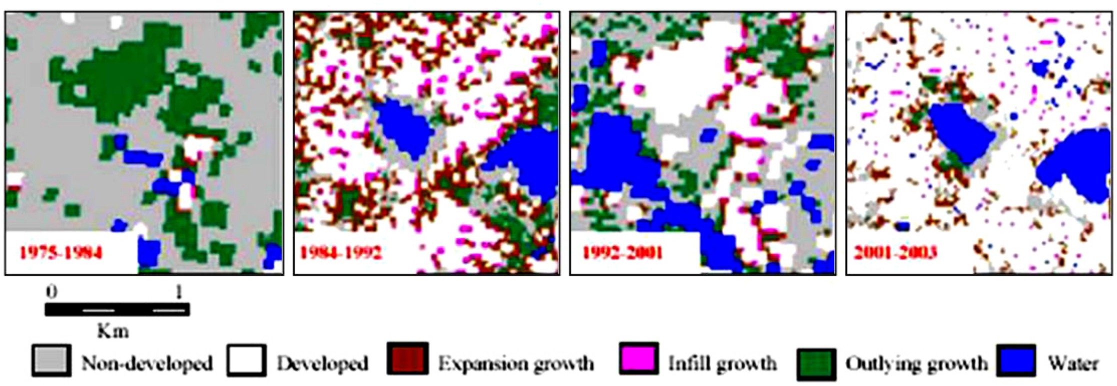
This study adopted three urban growth patterns; infill, expansion and outlying, which were used to describe and map urban sprawl (Wilson, 2003). Forman (1995) presented a regulation of landscape transformation based on those three patterns. Firstly, the infill pattern occurs when a pixel changes from fragmented non-developed, and it mostly appears inside the existing developed areas. Secondly, a pixel change from aggregated non-developed to developed is defined as the expansion pattern, and it dominates in the urban fringe. Lastly, outlying pattern appears when a pixel changes from interior non-developed to developed, and this pattern occurs at a distance from existing developed areas.

Detection of Urban Growth Patterns

Integration of remote sensing with a spatial metric (PLADJ) provided an effective method for quantifying urban growth patterns of Hanoi from 1975 to 2003. The urbanization map for the period 1975-1984 demonstrated infill and outlying growth patterns. Infill pattern occurred when a part of non-developed area in the south-west of the city center was converted to urban areas. On the other hand, outlying pattern mostly occurred in the suburb of the city, and as the result the city expanded further to the Southward. The 1984-1992 map depicted urban expansion occurring in the south, while outlying growth still developed in the westward of the city center. The 1992 - 2001 maps indicate a rapid development of urbanization, and the urban area expanded nearly double in comparison with

Figure 3. Urban Growth Pattern in Cau Giay Precinct

the previous period. Getting along with the rapid expansion, infill growth also occurred with high density in the south-west areas of the city. The east bank of the Red River also exhibited the beginnings of urbanization. The 2001-2003 marks a significant decrease of outlying growth whereas there are some evidences of expansion-type in the west of city (see Figure 3).



the remote sensing showed clearly the spatial arrangement of heterogeneity of urban areas over times. During the expansion of urban area, the number of individual urban patches increased in the undeveloped areas. The urban change was then quantified to detect the growth pattern by applying the regulation of landscape transformation. Analysis showed that expansion and outlying growth patterns regularly occurred until 2001, whereas infill growth pattern dominated from 2001 to 2003 period.

The analysis also highlighted some problems due to the spatial resolution of
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and spatial metric is an effective tool to detect and quantify urban growth. This study is a good example to exhibit decision-makers to understand urban growth dynamics and is useful to make future sustainable land use plan.

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