A CASE STUDY ON THE RELATION BETWEEN URBAN GROWTH AND CITY PLANNING USING REMOTE SENSING AND SPATIAL METRICS

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ABSTRACT

Urbanization is occurring in unprecedented rates, whereas information of land use planning and management are not always updated to catch up with urban change. In order to monitor urban change, an understanding about the change patterns of urban areas over times is getting very important. The objective of this study is to explore an approach of combining remote sensing and spatial metrics to investigate the relation between urban growth and city planning policy. The study areas are four cities such as: Hanoi (Vietnam), Nagoya (Japan), and Shanghai (China), and Connecticut State (U.S.A). Input data used Landsat and ASTER data taken in these four cities from 1975 to 2003. Firstly, this study developed a program based on a spatial metric of PLADJ to make urban growth maps. Secondly, FRAGSTATS was utilized to evaluate value of urban composition. The result showed that the urban core of Nagoya city spread out to suburb over times. At the end of 90's decade, urbanization of this city began slowdown. The characteristic of urbanization of Shanghai city was high urban density, and satellite towns around central city were established to absorb potential development to those satellite cities. Furthermore, Connecticut shows a spread development of the urban area and the high concentration of settlement in the suburb. In contrast, Hanoi city showed the fragmented growth, and rapid expansion of new urban areas along newly constructed roads and highways. This trend led a negative impact to disorder the configuration of Hanoi city areas in unusual shape. The combined approach of remote sensing and spatial metrics is powerful, and provides valuable information to the local city planners for better understanding the impacts of urban planning policy to urban development.

Index Terms— *urban change, spatial metric, Hanoi, urban planning*

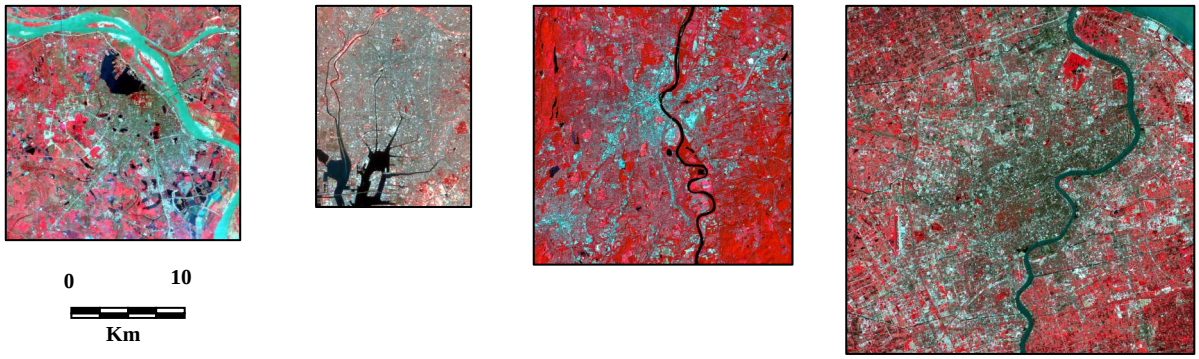
1. INTRODUCTION

This study explores an approach by using remote sensing data and spatial metrics to represent and characterize the urban growth of Hanoi (Vietnam), Nagoya (Japan), Shanghai (China), and Connecticut State (U.S.A) from 1975 to 2003. Spatial metrics (landscape metrics) were used to objectively quantify 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 form (Martin et al., 2003). The urbanization patterns of Hanoi in 30 years was analyzed and compared to them of Nagoya, Shanghai, and Connecticut for same periods. Knowledge of urban planning which derived from this study will be valuable information to offer a land use plan for the local makers. Furthermore, it will help the officials have better understanding about urban dynamics, and thus catalyze urban growth better directing future growth.

2. STUDY AREAS AND DATA SOURCE

The study areas are central parts of Hanoi, Nagoya, Shanghai and Connecticut. Fifteen multi-spectral and multi-temporal satellite images of these four cities from 1975 to 2003 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. Cloud cover was less than 10% in these images. The visible and NIR bands were used for data processing. The study areas are presented in the same scale in Figure 1.



Hanoi, Vietnam Population: 3.2 million | **Nagoya, Japan** 2.3 million | **Connecticut, U.S.A** 3.5 million | **Shanghai, China** 18 million

Figure 1. Study areas

(Population number is complied from Wikipedia)

3. METHODOLOGY

3.1. Urban area mapping

All the satellite images were rectified to a 15 m spatial resolution and adopted geographic coordination systems of Hanoi, Nagoya, Shanghai, and Connecticut respectively. We applied the maximum-likelihood classification method to generate land surface cover maps of urban area. The land surface was classified into the 3 main classes such as water, non-urban and urban. In order to reduce the effects of mixel to the results, this study applied an approach that developed by Hai and Yamaguchi (2008) by integrating classification result, VSW index and NIR band.

3.2. Spatial metrics

Spatial metrics are known under the name of landscape metrics, and commonly used to detect the homogeneous areas of natural landscapes. This study developed a program based on a spatial metric of PLADJ formula to establish pattern maps of urbanization. PLADJ can provide urban growth maps.The percentage of like adjacency (PLADJ) was developed by Gardner and O'Neill (1988) (equation 1):

$$PLADJ = \frac{\sum_{i=1}^{m} g_{ii}}{\sum_{i=1}^{m}\sum_{k=1}^{m} g_{ik}} * 100 \qquad (1)$$

g_{ii}: number of like adjacencies between pixels of patch type i

g_{ik}: number of adjacencies between pixels of patch types: i and

A 5x5 pixel moving window was chosen to compute percentage of fragmentation of the urban areas. PLADJ equals 0 when a maximum disaggregated pattern happens in urban

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). This study adopted three urban growth patterns; infill, expansion and outlying, which were used to describe and map urban sprawl (Wilson et al., 2003). Result of PLADJ (Figure 2) provided visual urban change maps. Moreover, they are effective for us to have better understanding how urbanization occurs in the past and present. However, information derived from urban change map does not stand out the forces that drive urbanization in some certain degree. In order to have better analysis about urban dynamic of these three cities, this study needs more parameters to link between the urban spatial structures with urban composition.

The public domain statistical package FRAGSTATS (McGarigal et al., 2002) was applied as secondary method to characterize urbanization of three cities. FRAGSTATS, a software program, provides a large variety of metrics. We used six spatial metrics in this program for quantifying urban transition parameters. The class area (CA) measures total area of urban growth. The number of patches (NP) quantifies number of individual urban patches. The edge density (ED) measures the total edge of urban boundary. The largest patch index (LPI) describes the percentage urban land in the largest urban blob. The mean nearest neighbor (MNN) measures the open space between urbanized areas. The more MNN value shows urban patches far on each other. The fractal dimension (AWMPFD) describes fragmentation of urban patches. If the urban areas are more fragmented, AWMPFD shows a higher value (Martin et al, 2003). The spatial metrics were computed individually for each urban and for every year with the results in Figure 2.

4. DISCUSSION AND CONCLUSION

Due to the constant inflow of people from other parts of the country, the size of population in Shanghai keeps growing. This city became one of the biggest cities in China with the population over 17 million in 2004. Since 1978, the Chinese government started doing the reform policy, Shanghai witnessed significant urban change. Because of influence by British urban planning theory, satellite towns have been planned from 1979 to 1989. The goal was to guide the central city absorbing the development potential to those satellite towns (Haixiao, 2000). From Figure 2, we can visualize expansion of the urban area and the driving forces of urban change in Shanghai over 30 years. The urban area was triple than that of 1979, which is indicated by an increase in class area (CA). This was illustrated by increase of the number of urban patches (NP) and the urban boundary (ED). The government restricted expansion of existing urban area, and encouraged to develop satellite towns around urban cores. From 1989 to 2001, urbanization was complexly shaped and fragmented in the new urbanized areas. New urbanized areas those expanded from satellite towns got closer with urban cores which related to a peak of the largest patch index (LPI). Peaking of the fractal dimension (AWMPFD) in 2001 correlated with fragmented development in open spaces between urbanized areas.

Hanoi witnessed a big change after approving Renovation (Doi Moi) policy. The economic liberalization and the opening up to global capital marked the most recent phase of city development in Hanoi. Its first phase was characterized by a sharp increase of in unregulated building activity (Smith and Scarpaci, 2000). The CA showed an expansion of Hanoi urban areas from nearly 1000 ha to more than 6000 ha in 30 years (Figure 2). In 1975, the lowest largest patch index (LPI) and lowest number of urban patches (NP) reflected that Hanoi has a small urban core urban center. The urban patches (NP) slightly increased by 1984, in concert with an increase in the fractal dimension (AWMPFD). This trend illustrated

Hanoi's urban starts diffusing sprawl development. From 1984 to 1992, the area of the city expanded enormously. In the 1990's the expansion became manifest mainly uncontrolled suburbanization processes along newly constructed road and highways. The development of urbanized areas along highways in between 1984 and 1992 and consequently contributes to disorder the urban shape getting along the transportation system towards the south of the city. Outlying growth developed quickly beyond the urban core, as is evidenced by increasing the urban largest patch index (LPI) and the decreasing mean nearest neighbor (MNN). This period marked a most diffuse urban sprawl of Hanoi city over times, this trend indicated by increase of all indexes, especially fractal dimension (AWMPFD) peaked by 2001. In order to control the rapid urbanization of the city, a master plan for the urban area of Hanoi was first adopted in 1993. This plan concentrated in preserving and renovated the existing developed area in the central city, especially the Ancient Quarter. Moreover, high buildings are not supposed to be constructed in the city center anymore but will instead be built in new urban areas in the periphery of Hanoi (Michael, 2004). This plan new living areas in the suburb with a well-equipped infrastructure, consequently attracts people moving to live in the suburb. This trend contributed to decrease the urban growth of Hanoi since 2001.

Connecticut is an urbanizing state, which was dominated by "Urban sprawl" (Wilson et al., 2002). We can see the urban sprawl of this state from 1979 to 1989 (Figure 2). People are more dispersed and no longer residing in centralized cities. The rapid expansion of the city is illustrated by an increase of number of urban patch (NP). In 1989, the city's boundary became much bigger than that in 1979, whereas the distance of urban patches got closer in each other. An increase in edge density (ED) and a decrease in mean nearest neighbor distance (MNN) manifested for this trend. Due to the urban sprawl, the urban area expanded further to the south and consequently resulted in longer travel time for commuters. When citizens adopted automobile society, they can live in areas where separated from existing developed areas. Accidentally, this trend led to an increase in outlying pattern in the surburb areas. Connecticut shows the most outlying development in compared to other three Asian cities. Moreover, houses in America are built in a large size and consumed a lot of land, which is considered as a cause of rapid expansion of the urban areas.

In contrast with the rapid urbanization of Shanghai, Hanoi, and Connecticut, the urbanization of Nagoya city showed a moderate development over times. The development of cities in Japan strictly bases on two types of urban planning zones as urbanization promotion zone and urbanization control zone, which derived from "Policy on the Preparation, Development or Preservation of Urbanization Promotion Zones and Urbanization Zones" (Miyazawa, 1978). This is expected to control suburban sprawl and land use confusion and also to enhance the ordered development of urban areas (Saizen, 2006). The urban area could only develop in the decided urbanization promotion zone. This urban planning explains why urban transition parameter of Nagoya has a smooth change over time (Figure 2). From 1975 to 2002, a large amount of undeveloped land in the suburb of the city has been converted to urban areas. From 1975 to 1985, urban areas expanded quickly to both East and West side, this reflected by peaking of number of urban patches (NP) in concerned with a decrease of mean nearest neighbor (MNN). From 1985 to 1996, the urban area kept growing and less fragmented. This trend was confirmed by decreasing of the number of urban patches (NP) and the fractal dimension (AWMPFD). By 2002, the largest patch index (LPI) peaked while the number of patches (NP), edge density (ED) and fractal dimension (AWMPFD) declined, this trend indicated that urban growth more aggregated and close to the urban cores. In the urban change map, we can see that the urbanization spread out to the suburb, and vacant land

of Nagoya city left for future is almost used. An indication of these effects is the decreased growth of Nagoya in the future.

The combination of remote sensing and spatial metrics provides an effective method to study about urban growth. Such a method can be useful for supporting urban planning and urban management. This paper presented a detailed analysis of urban development in 30 years of Hanoi, Nagoya, Shanghai, and Connecticut. Different spatial metrics reflected specific spatial and temporal information of urban growth. The class area (CA) represented an increase of urban area, while number of patches (NP), mean nearest neighbor (MNN), fractal dimension (AWMPFD) characterize the urban fragmentation. Urbanization of these four cities occurred strongly from middle of 1980 to 1990. The comparison of Hanoi, Nagoya, Shanghai, and Connecticut provides a particular analysis about urban growth. Knowledge which I have leant from the results of this study will be useful for me to offer a future land-use plan for Hanoi city.

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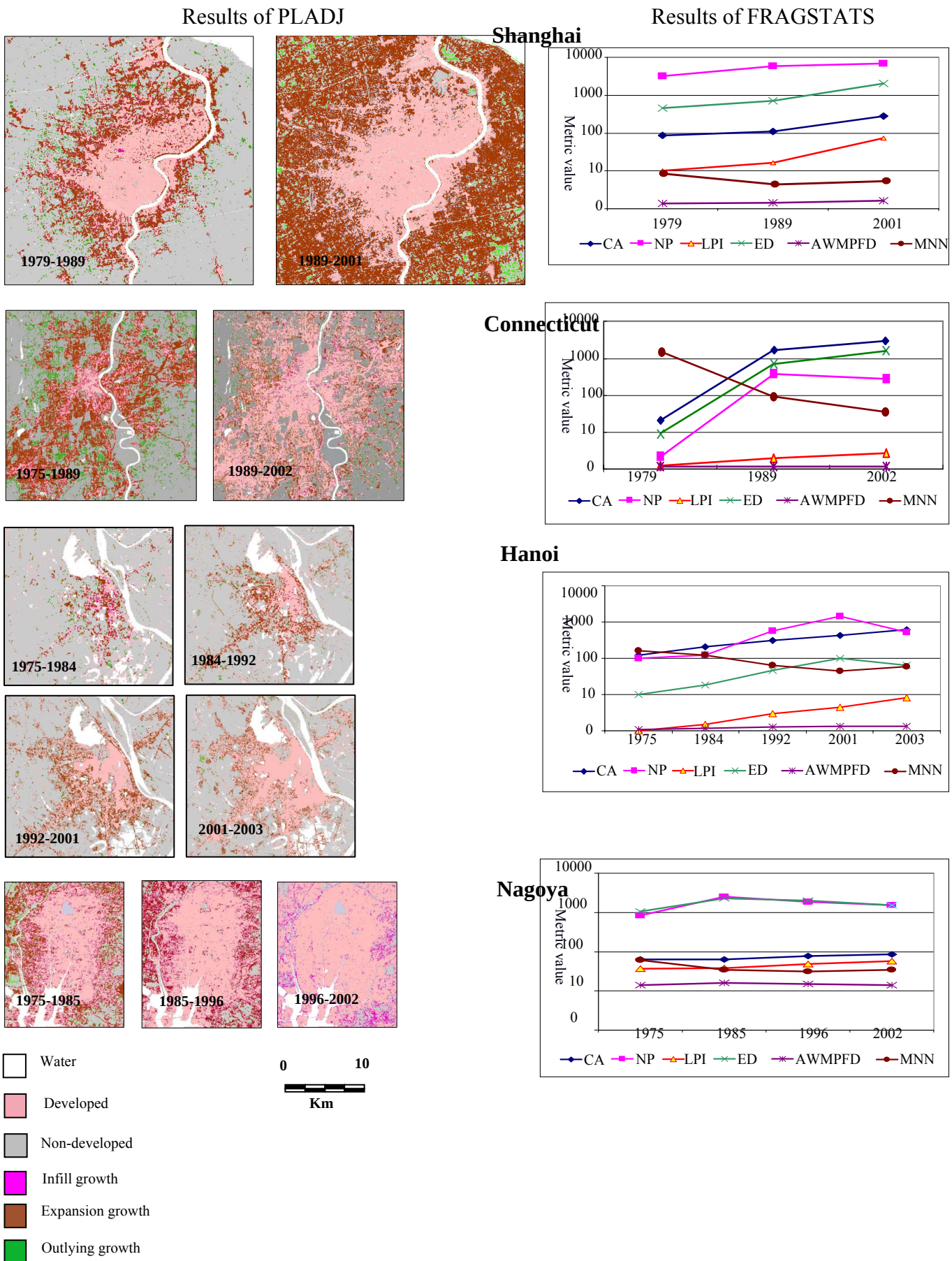

Figure 2. Results of PLADJ and FRAGSTATS