CHARACTERIZING THE URBAN GROWTH OF HANOI, NAGOYA, AND SHANGHAI CITY USING REMOTE SENSING AND SPATIAL METRICS

Pham Minh Hai and Yasushi Yamaguchi

Graduate School of Environmental Studies, Nagoya University, Japan

ABSTRACT

The objective of this study is to explore an approach of combining remote sensing and spatial metrics to characterize the urban growth of Hanoi (Vietnam), Nagoya (Japan), and Shanghai (China). Input data is twelve scenes of Landsat and ASTER data taken in Hanoi, Nagoya, and Shanghai city 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. In contrast to development of Nagoya and Shanghai city, 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 will be useful to offer a future land-use plan for Hanoi city.

Index Terms— urban change, spatial metric, Hanoi

1. INTRODUCTION

Urbanization of Hanoi city is occurring in unprecedented rate and causing troubles in city life. An effective approach to the planning and management of Hanoi's urban area is getting important for city planners and decision-makers. 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), and Shanghai (China) 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 and Shanghai for same periods. Knowledge of urban planning which derived from urbanization of Nagoya and Shanghai city will be valuable information to offer a land use plan for Hanoi city. Furthermore, it will help local officials have better understanding about urban dynamics, and thus catalyze urban growth better directing future growth.

2. STUDY AREA AND DATA SOURCE

This study areas covered center parts of 3 cities Hanoi, Nagoya and Shanghai. Twelve multi-spectral and multi-temporal satellite data of Hanoi, Nagoya, and Shanghai city 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.

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 and Shanghai, 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 (Fig.1, Fig.2, Fig.3).

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. Recently, there has been an interest in applying spatial metrics to characterize urban fragmentation. Many kinds of spatial metrics are used to

quantify urban configurations, but for each application spatial metrics are selected and analyzed according to the context of study. In this study, we utilized spatial metrics of (O'Neill, 1988) (*) and (McGarigal, 2002) (**) to analyze the urban growth of Hanoi, Nagoya, and Shanghai city (Table 1).

Metric	Description	Range
PLADJ (*)	Measuring the degree of aggregation of a patch type	0≤PLADJ≤100
CA (**)	Measuring total growth of urban area	CA>0, no limit
NP (**)	Measuring of the extent of subdivision or fragmentation of the urban patches	NP≥1, no limit
ED (**)	Measuring of the total length of the edge of the urban boundary	ED≥ 0, no limit
LPI (**)	Describing the percentage of the total urban land represented in the largest urban blob	0<LPI≤100
MNN (**)	Measure of open space between urbanized areas	MNN>0, no limit
AWMPFD (**)	Describes the complexity and the fragmentation of a patch by a perimeter-area proportion	1≤AWMPFD≤2

Table 1. Spatial metrics used in this study

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. It is intuitive and simple in calculating by measuring only the patch dispersion (the spatial distribution of patch type of urban areas) regardless of interspersion (the intermixing of units of different objectives in the map). The percentage of like adjacency (PLADJ) was developed by Gardner and O'Neill (1988) (Fig.4):

$$PLADJ = \frac{\sum\limits_{i=1}^{m} g_{ii}}{\sum\limits_{i=1}^{m} \sum\limits_{k=1}^{m} g_{ik}} * 100$$

g_{ii}: number of like adjacencies between pixels of patch type i
g_{ik}: number of adjacencies between pixels of patch types: i and k

Fig.4. PLADJ

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). 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 (Noda and Yamaguchi,
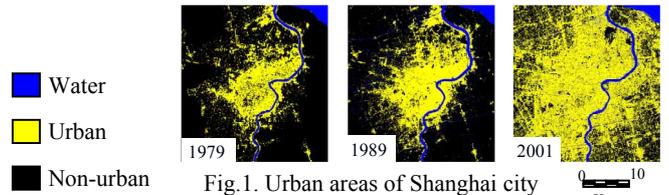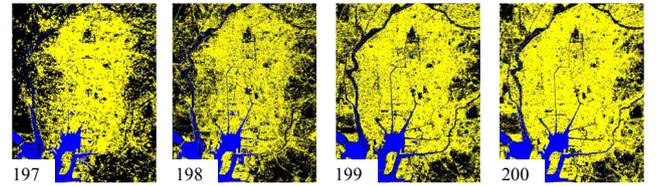

Water
Urban
Non-urban

Fig.1. Urban areas of Shanghai city

1979   1989   2001

0   10
Km

197   198   199   200

Fig.2. Urban areas of Nagoya city

0   10
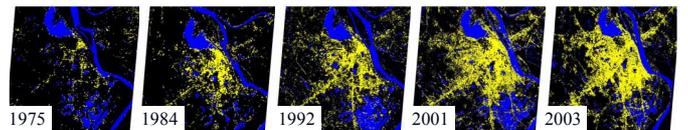Km

1975   1984   1992   2001   2003

Fig.3. Urban areas of Hanoi city

0   10
Km

2008). Conversely, if 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%.

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

Result of PLADJ 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. Some simple metrics shown in Table 1 are widely applied to measure the composition in the urban area. The class area (CA) measures total area of urban

Urban growth maps by PLADJ
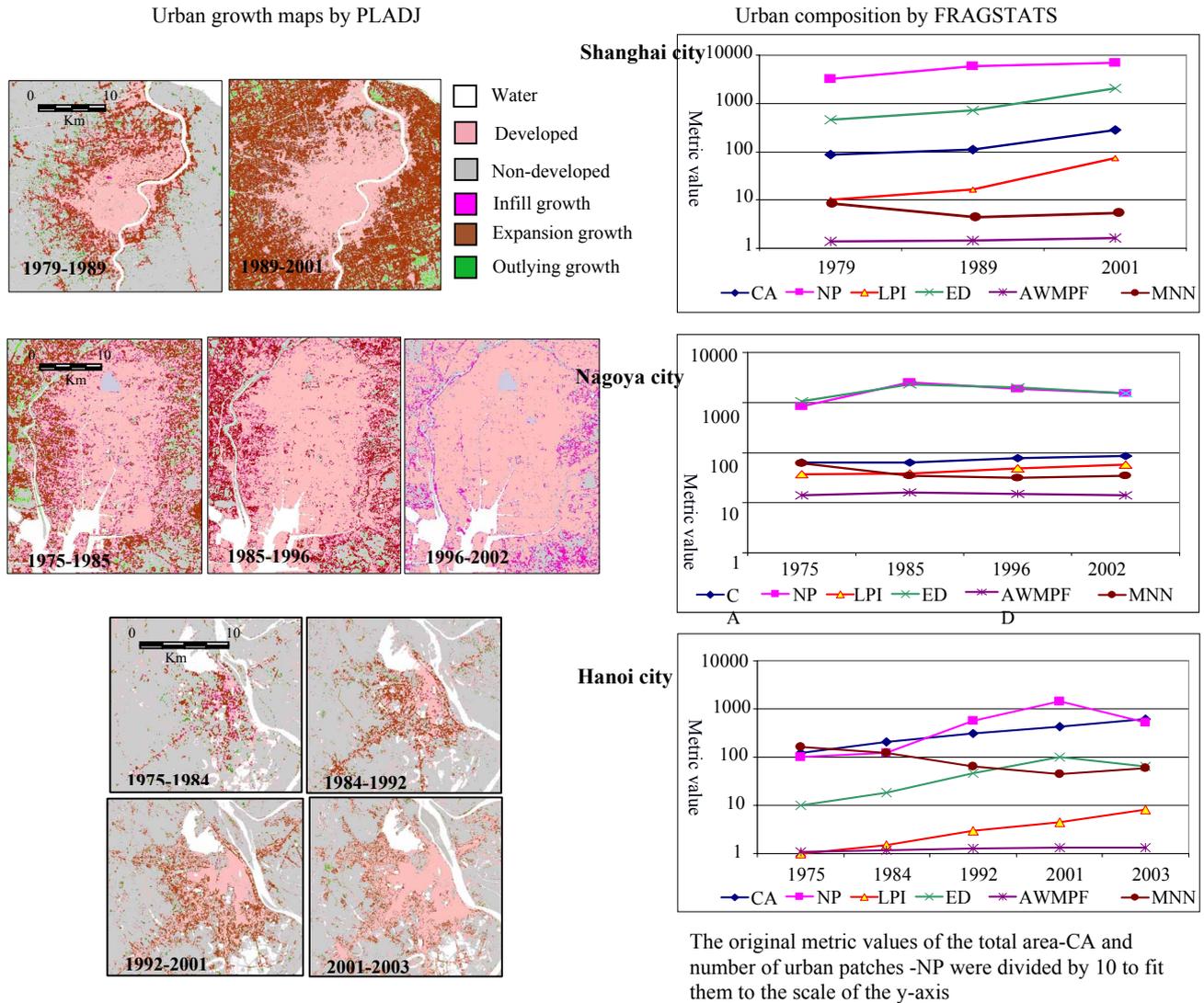
Urban composition by FRAGSTATS

Fig.5. Urban growth maps and urban composition

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 Fig.5.

4. DISCUSSION AND CONCLUSION

4.1. Discussion

Urbanization of Shanghai city developed rapidly. The class area (CA) in 2001 was triple than that of 1979. 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). 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.

The urbanization of Nagoya city showed a moderate development over times. A large amount of undeveloped land in the suburb of the city has been converted to urban areas from 1975 to 2002. 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 CA showed an expansion of Hanoi urban areas from nearly 1000 ha to 6000 ha in 30 years. 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, there was an increase of urbanized areas along newly constructed road and highways. As a result, 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). 1984-1992 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. The development of urbanized areas along highways in between 1984 and 1992 and the urban sprawl between 1992 and 2001 contribute to disorder the urban shape getting along the transportation system.

4.2. Conclusion

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, and Shanghai city. 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 composition. Urbanization of these three cities occurred strongly from middle of 1980 to 1990. Shanghai city expanded rapidly, this city has transferred its spatial structure form mono-center to poly-center (Haixiao, 2000). It was detected in the urban growth map by developing of satellite towns around urban core instead of infill growth inside existing urban areas. Urbanization of Nagoya city indicated moderate growth, the urban core

planned to widespread out to suburb. At the end of 90's decade, urbanization of this city occurred mainly in the remaining undeveloped land in suburban areas and began slowdown. In contrast to development of Nagoya and Shanghai city, Hanoi city showed the diffuse sprawling development and uncontrollable urban spatial structure. This is highlighted by the shape of the city expanding much to the South of the city.

The comparison of Hanoi, Nagoya, and Shanghai city provides a particular analysis about urban growth. Knowledge which I have leant from Nagoya and Shanghai city's urban plan will be useful for me to offer a future land-use plan for Hanoi city.

5. REFERENCES

[1] A. Noda and Y. Yamaguchi, "Charactering urban sprawl using remote sensing, GIS and a spatial metric for a medium sized city in Japan", *International Journal of Geoinformatics*, in press, 2008.

[2] E.H. Wilson, D.H. James, L.C. Daniel, P.P. Michacle, and C. Arnold, "Development of a geospatial model to quantify, describe and map urban growth", *Remote Sensing of Environment*, vol.86, pp.275-285, 2003.

[3] E.J. Gustafson, Quantifying landscape spatial patterns: What is state of the art?, *Ecosystem*, vol.1, pp.146-156.

[4] H. Martin, G.C. Noah, and C.C. Keith, The spatial form of urban growth: measurement, analysis and modeling, *Remote Sensing of Environment*, vol.86, pp.286-302, 2003.

[5] J.R. Anderson, *A land use and land cover classification scheme for use with remote sensing data*, U.S. Geological Survey Professional Paper, no.964, 36 pp., 1976.

[6] K. McGarigal, S.A. Cushman, M.C. Nell, and E. Ene, *FRAGSTATS: Spatial pattern analysis program for categorical maps*, URL:www.umass.edu/landeco/research/fragstats.html, 2002.

[7] P.M. Hai and Y. Yamaguchi, "Monitoring land cover change of the Hanoi city center under impacts of urbanization by using remote sensing", *International Journal of Geoinformatics*, vol.3, December, 2008.

[8] R.T.T. Forman, *Land mosaic: The Ecology of Landscapes and Regions*, Cambridge, UK, 632 pp., 1995.

[9] P. Haixiao, *Shanghai from dense Mono-center to organic poly-center urban expansion*, http://enviroscope.iges.or.jp/modules/envirolib/, 2000.

[10] R.V. O'Neil, J.R. Krummel, R.H. Gardner, G. Sugihara, B. Jackson, D.L. DeAngelis, B.T. Milne, M.G. Turner, B. Zygmunt, S.W. Christensen, V.H. Dale, and R.L. Graham, "Indies of landscape pattern", *Landscape Ecology*, vol.1, pp.162-163, 1988.