URBANIZATION AND ITS INFLUENCES ON THE SUBURBAN LAND USE CHANGES IN BANGKOK METROPOLITAN REGION, THAILAND

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ABSTRACT: The recent urbanization process in emerging countries is entirely different from the process seen in developed countries. In Asia's emerging countries, urbanization occurs along with fast population growth that follows rapid economic development, and industries and population are centralized into large cities. One typical example of this centralization is seen in the Bangkok Metropolitan Region. In this study, the latest high resolution satellite remote sensing images, as well as the existing GIS data, were integrated to generate temporal (1994, 2000, and 2009) land use/cover maps which could be used to understand the recent expansion of urban areas and the spatial changes in land use of the suburbs (suburban farmlands). Those are also used to analyze land use with a landscape ecological patch analysis, and to explain land use changes from traditional agricultural farmlands to urban areas due to the sprawling phenomenon, which indicates chaotic urban expansion. The result shows that the urban built-up area has been increasing between 1994, 2000, and 2009 at 16.5%, 28.2%, and 35.4%, respectively. On the contrary, the proportion of agricultural land use continuously decreased from 71.4%, to 56.1%, and 43.3%, respectively. Its spatial distribution is typical sprawl into the suburban traditional farmlands, and the extremely mixed urban and agricultural landscapes are created in the urban fringe areas.

1. Introduction

The changes in land use of a large metropolitan area result in agricultural land becoming urban land in the suburban areas in response to the increased demand for land with urban functions (Kikuchi et al., 2001). These land use changes differ according to country. In Asia's many countries, the population in rural areas flows into the urban area in a search for jobs and cash income in response to the economic disparity between these areas. The end result is disordered expansion of the urban area (the sprawling phenomenon).

The Bangkok Metropolitan Region is composed of the Bangkok Metropolitan Administration and five surrounding provinces (changwats), and it functions as the center of economic growth in the Kingdom of Thailand. Since the 1980s, the population has decreased in the central area of the Bangkok Metropolitan Administration, and has rapidly and continuously increased in the suburban areas. The Chao Phraya River delta, in which the Bangkok Metropolitan Region is located, was historically a grain-producing region, and was extensively developed with traditional paddy fields. Urban sprawl into these areas has led to the recognition that this expansion will have adverse effects on the environment and ecology of these farmlands in the future. However, no data are yet available to provide a full understanding of these effects. This makes actual urban and regional planning difficult to apply to these farmlands.

Changes in land use reflect changes in the natural, social, economic, and cultural environments of a region. Therefore, understanding land use changes is important for explaining the characteristics and environmental issues of the region. In this study, the latest high-resolution satellite images and the existing Geographic Information System (GIS) data were integrated to generate map information for the Bangkok Metropolitan Region that could be used to understand the recent expansion of its urban areas and the geo-spatial changes in land use of its suburban agricultural area. The goals of the study were to provide a quantitative investigation of the area and density, to analyze land use by a landscape ecological method of patch analysis, to clarify land use changes from traditional farmlands to urban areas due to the sprawling phenomenon that indicates chaotic urban expansion, and to elucidate the characteristics of the present urbanization and the spatial arrangement of suburban agriculture.

2. Materials and Methods
2.1 Study Area

As shown on Figure 1, the Bangkok Metropolitan Region is composed of six districts: the Bangkok Metropolitan Administration and five adjoining changwats: Nontaburi, Pathum Thani, Nakhon Pathom, Samut Sakhon, and Samut Prakan. (The changwat is an administrative unit; Thailand has a total of 76 changwats.) The Bangkok Metropolitan Administration has an area of 1,565 km2, and the Bangkok Metropolitan Region is 7,760km2. This is far larger than the area of the 23 Special Districts of Tokyo (621 km2) and the Tokyo Metropolitan Region (3,600 km2).
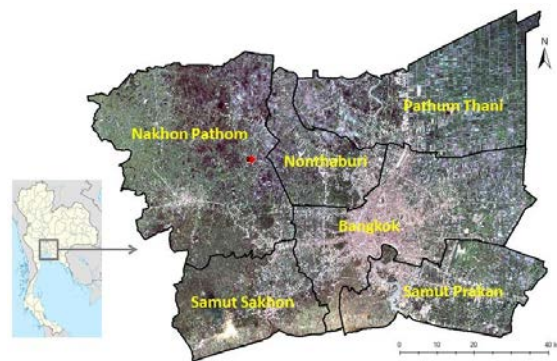

Figure 1   Study Area

2.2 Data used for analysis

One of the characteristics of this study is the application of high resolution spatial information used for analysis of land cover and land use. The Land Development Department of Thailand is responsible for land use mapping, and has been collecting digital land use data that can be used for GIS. This study analyzed a land use map (32 categories) created by visually interpreting Landsat ETM images obtained by the Department in 2000, and a land use map (32 categories) created by visually interpreting the ortho-rectified aerial photographs taken in 2003. Since the latter land use map was created based on the extremely high resolution ortho-rectified aerial photographs, detailed land use polygons were drawn, and the classification accuracy was evaluated as high. However, more than seven years had passed since its production, and the land use in the Bangkok Metropolitan Region had rapidly changed during the ensuing period. Therefore, the information in this land use map was already out of date. Therefore, ALOS Avnir-2 images (10 m spatial resolution) obtained on December 17, 2008, and November 21, 2009, and Prism images (2.5 m spatial resolution) obtained on the same dates were pansharpened to update the interpretation of the 2003 land use map.

The urban expansion process and land cover changes before 2000 were investigated by image classification of Landsat TM image (30 m spatial resolution) obtained on October 25, 1994 rectified using the ALOS pansharpened images. This created a temporal dataset that allowed analysis of the changes in land use and land cover over a 15 year period; i.e., between 1994, 2000, and 2009.

2.3 Analytical methods

A current land use map for 2009 was prepared by temporally updating a 2003 land use map produced by the Land Development Department by visual interpretation of ALOS pansharpened images. This updating work took about 128 hours, and resulted in a present land use map with a very high accuracy. Image classification for the 1994 land cover map was performed using Landsat TM images and the iterative self-organizing data analysis technique (ISODATA), which is unsupervised classification. This produced a land cover map with four categories.

Since the latest land use map in 2009 was produced by visual interpretation of high-resolution images, its accuracy was extremely high. Therefore, this map could be used for the landscape ecological method of patch analysis. Quantification of landscape patterns of urban and agricultural land uses was attempted using spatial pattern analysis software, FRAGSTATS, which is a computer software program developed at Oregon State University for computation of a wide variety of landscape metrics for categorical map patterns (Kevin M. & Barbara.M. 1994).

3.   Results and Discussion
3.1 Land cover changes during 1994, 2000, and 2009

Figure 2 shows temporal land cover classification maps over the past 15 years. The proportion of urban land use steadily increased between 1994, 2000, and 2009, at 16.5%, 28.2%, 35.4%, respectively (see Figure 3). After 2000,
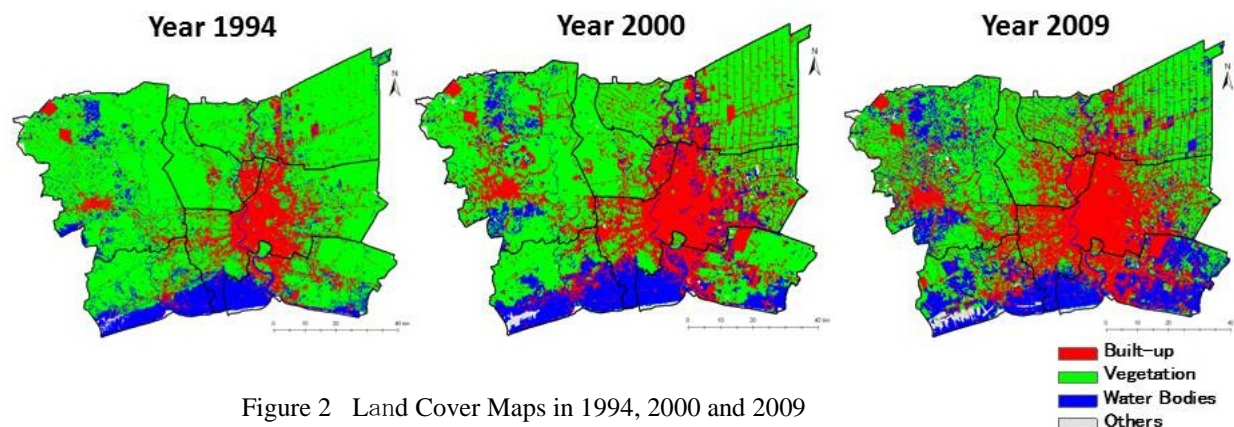

Figure 2   Land Cover Maps in 1994, 2000 and 2009

the urban area expanded beyond the Bangkok Metropolitan Administration to adjacent Nonthaburi, Pathum Thani, and Samut Prakan, resulting in full interconnection of these urban areas. In contrast, the proportion of agricultural land use between 1994, 2000, and 2009 continuously decreased from 71.4%, to 56.1%, and 43.3%, respectively.

The area of urban land use more than doubled in five suburban changwats except for the Bangkok Metropolitan Administration, in the 15 years between 1994 and 2009. In the Bangkok Metropolitan Administration, the central city area was already completely urbanized by 1994. In contrast, the eastern agricultural areas were rapidly urbanized after 1994, due primarily to the conversion of paddy fields into built-up areas.

This tendency was particularly marked in the PathumThani and Nonthaburi changwats, which showed rates of decline in the vegetated areas of 70% and 74%, respectively. The changes in the urban and rural land uses, population, and the number of households were also investigated in each of five administrative units that compose the suburbs. The rates of population growth in these two changwats were 91.24% and 50.27%, and the rates of increase in the number of households were as high as 125.48% and 178.54%, respectively (see Figure 4). These facts clearly demonstrated that rapid urbanization has occurred in suburban areas, together with increases in population and the number of households.
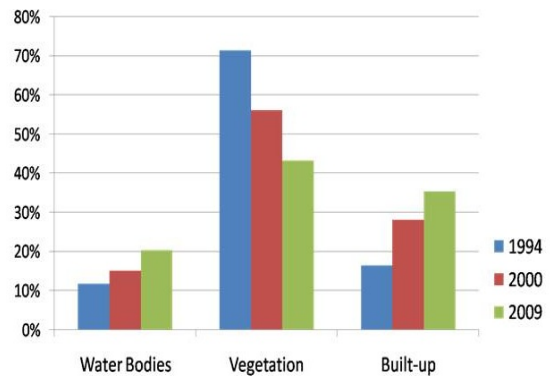
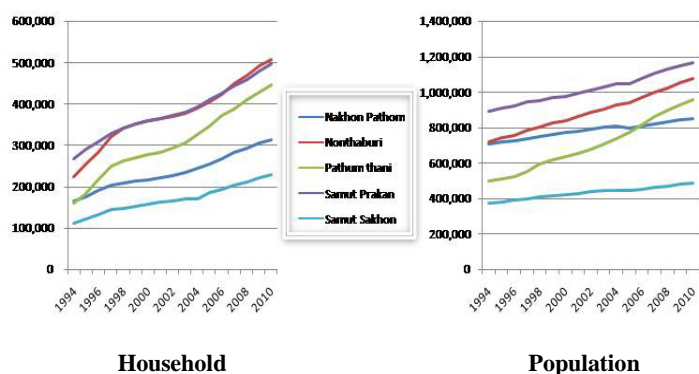Figure 3   Area Occupancy of Major Land Cover (1994-2000-2009)

Household   **Population**

Figure 4   Population and Household between 1994 and 2010

3.2 Land use changes between 2000 and 2009

Figure 5 shows land use maps with area percentages of 19 land use categories in both 2000 and 2009. In 2000, the proportions were 36.3% for paddy fields, 28.2% for built-up areas, 14.0% for orchards, and 8.8% for aquaculture. By 2009, these areas had changed to 35.4% for built-up areas, 22.2% for paddy fields, 12.5% for the aquaculture, and 9.3% for orchards. In 2009, the proportion of built-up areas was more than one third of the total area of the Bangkok Metropolitan Region, and that of the paddy field had greatly decreased. In the region along the right bank of the Chao Phraya River in the Bangkok Metropolitan Administration (former Thonburi and Nonthaburi), a large area of former orchards was converted into built-up areas. In Nakhon Pathom, urban areas intruded into cassava-centered dry-field farming areas and showed the sprawling phenomenon where urban and rural land uses were mixed in a disordered pattern. In the other changwats, built-up areas expanded along main roads in all directions.
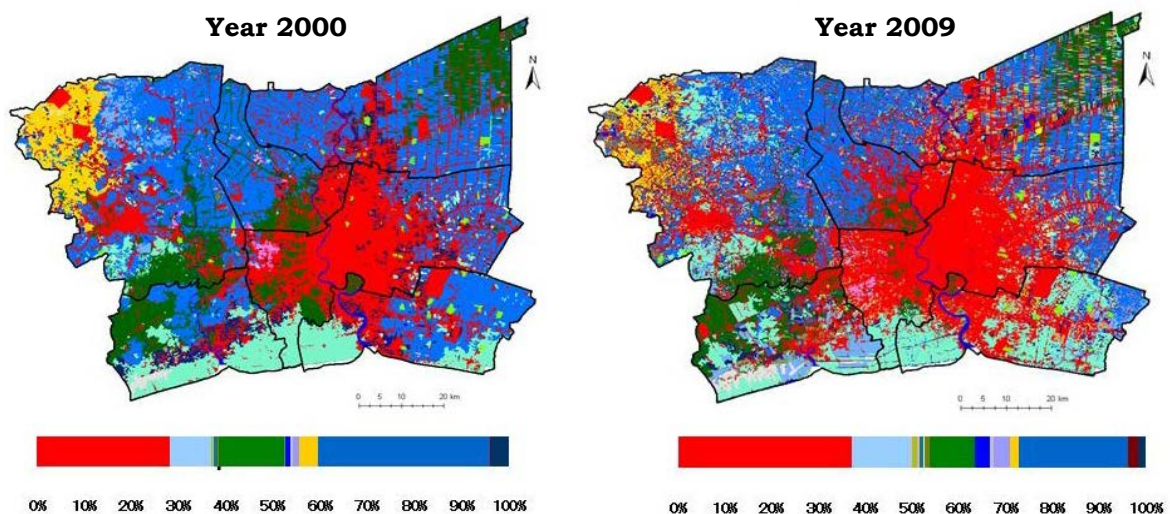
Figure 5   Detail Land Use Maps in 2000 and 2009

As shown on Figure 6, in the period between 2000 and 2009, the total of 98,949 ha of formerly rural land was converted into urban land use. A total of 44,688 ha (44.2% of the total area) was converted from paddy fields, followed by orchards (24.9%) and wetlands (13.4%). Following this type of urban expansion (i.e., urbanization showing the sprawling phenomenon), urban and rural land uses were extremely mixed in the landscapes of the urban fringes, and different land uses became competitive. Figure 7 shows the distribution of paddy fields
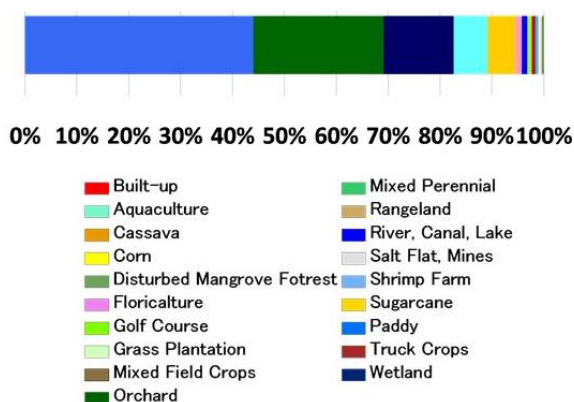

Figure 6 Land Cover change to Built-up Area
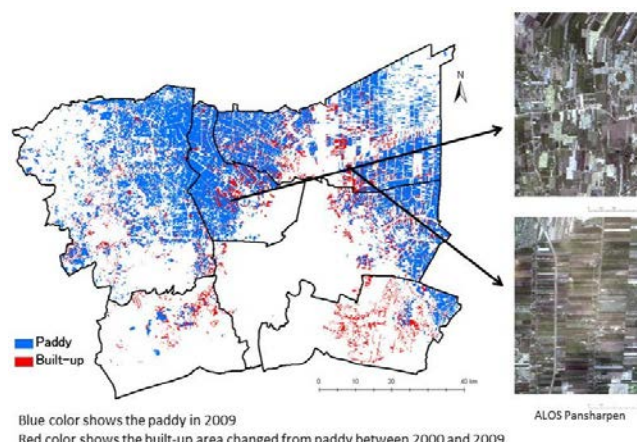
between 2000 and 2009

Figure 7   Paddy Field Distribution in 2009

converted into urban land use in the period between 2000 and 2009. The traditional rural landscapes with paddy fields in Nonthaburi, Pathum Thani, and the eastern Bangkok Metropolitan Administration were built up with many factories and apartments, resulting in the rapid expansion of landscapes in the suburbs, in which cities and agricultural villages were mixed (see Figure 8). The majority of these development projects were carried out by private developers. To enlarge the development scale, private developers obtained large development areas in the suburbs while unused areas remained in the region near the city center. Consequently, the evident sprawling phenomenon occurred in traditional rural areas at specific distances from the city center. The main reason for this urban-rural mixture was the land tenure system of Thailand, which dictates that landowners in agricultural villages in the suburbs of large cities can convert rural land use into urban land use at any time they so desire.

Figure 8   Mixed Landscape of Urban and Agriculture

3.3 Spatial characteristics of land use patches

The process of rapid mega-urbanization in Asia's emerging/developing countries, because of the disorderly development of residential areas and industrial parks in suburban farmlands, leads to splitting and fragmentation of traditional agricultural land use and results in land use changes. In suburban areas, strong artificial influences have been exerted and patch-like landscapes consisting of various small-scale land uses now appear. Investigation of the present distribution characteristics of each land use requires the utilization of landscape metrics, such as shape, proximity, and contagion metrics, as indices for each patch, in addition to measuring the area of each land use. In this study, landscape coefficients that indicate proximity, connection, diversity, and mixture degree of land use patches were analyzed for the present situation of landscapes. FRAGSTATS can investigate landscape indices at three levels (patch, class, and landscape levels). Each land use patch, land use category, and a certain spatial unity can be analyzed at the patch, class, and landscape levels, respectively. In the present study, built-up areas and paddy fields were analyzed at the class level, and six changwats in the Bangkok Metropolitan Region were analyzed at the landscape level.

The number of patches and the patch density (per 100 ha) were obtained as the most simple indicators. The number of patches in built-up areas was the largest in Nakhon Pathom,followed by Pathum Thani. The number of patches was the smallest in Nonthaburi. The patch density (per 100 ha) was also the largest in Nakhon Pathom, and had a large value in Pathum Thani (see Table 1). This fact tells us that the built-up areas were clearly dispersed. The proximity index differentiates a large aggregation of patches from the sparse state of patches, and a larger value

indicates a smaller distance between patches. For built-up areas, the value of the proximity index was extremely large in Bangkok, followed by Pathum Thani and Samut Prakan. Its value was extremely small in Samut Sakhon, where the built-up area was small. This index indicates the progress of urbanization; namely, following the Bangkok Metropolitan Administration, a continuous distribution of built-up areas was indicated in Pathum Thani and Samut Prakan, which are the closest to Bangkok. In the case of paddy fields, the value of the proximity index was extremely large in Nonthaburi, indicating that paddy fields were connected to each other in this changwat. In contrast, the value of the proximity index was low in Bangkok and Samut Sakhon, indicating that paddy fields were fragmented by other land uses and were individually isolated. The connectance index, one of landscape indices, denotes the degree of connection of patches. The value of this index is the largest when all patches within a certain distance are connected to each other, where a larger value indicates higher connection. The value of this index was extremely large in Bangkok, indicating that built-up areas were connected to each other in this city. The value of this index was extremely small in Nakhon Pathom, indicating that built-up areas were fragmented and dispersed in this changwat. Nonthaburi, Samut Sakhon, and Samut Prakan exhibited intermediate values of this index. The connection of paddy field patches was low in Pathum Thani and Nakhon Pathom, and it was high in Samut Prakan and Nonthaburi.

The contagion index shows the degree of mixture of the land uses in each administrative unit at the landscape level. This index is often used for propagation and aggregation of patches, and correctly indicates fragmentation of landscapes. A small value for this index indicates that many small patches exist. A large value indicates that the landscape is composed of large aggregated patches. In this study, the value of this index was large in Bangkok and Nonthaburi, and was small in Nakhon Pathom, and similar values were exhibited in the other changwats. Overall, large land use patches predominated in the landscapes of Bangkok and Nonthaburi, and the landscape of Nakhon Pathom was composed of aggregations of many small land use patches.

Table 1　Landscape Metrics calculated by FRAGSTATS

| | Bangkok | | Nonthaburi | | Pathum Thani | | Nakhon Pathom | | Samut Prakan | | Samut Sakhon | |
	built-up	paady	built-up	paady	built-up	paady	built-up	paady	built-up	paady	built-up	paady
NP	875	677	330	233	1457	1218	5163	1627	630	121	892	43
PD	0.205	0.125	0.267	0.188	0.551	0.461	1.593	0.502	0.416	0.081	0.612	0.029
PROX	201095	914	21358	7350	34291	1625	23520	2148	32108	1281	3204	163
ENN	55	492	142	76	63	91	63	117	92	173	60	881
CONNECT	0.886	0.624	0.374	0.951	0.168	0.137	0.057	0.102	0.339	0.978	0.383	1.439
CONTAG	70.95		69.38		62.56		56.71		64.53		62.73	
SIDI	0.609		0.677		0.734		0.801		0.735		0.751	

NP:Number of Patch　　PD:Patch Density　　PROX:Rroximity Index　　ENN:Euclidean Nearest Neighbor Dista
CONNECT:Connectance Index　　CONTAG: Contagion Index　SIDI:Shannon's Diversity Index

The spatial distribution of the degree of mixture and the diversity of present land uses was investigated by constructing meshes 250m in size in the land use map for 2009, and the number of patches, the length of edges, and the number of land use categories in each mesh were measured using the spatial analysis function of ArcGIS.

As shown in Figure 9, the density distribution of patches was similar to that of the categories. The numbers of patches and of categories were extremely large in Nakhon Pathom, and were small in the Bangkok Metropolitan Administration and its suburbs. The land use in Nakhon Pathom was particularly complicated, consisting of small built-up area patches that invaded into orchards, and various patches in which orchards had been converted into other farming types.

The comprehensive results obtained by analyzing land use patches are described below. In the Bangkok Metropolitan Administration, where urbanization was saturated, built-up areas were large and the values of landscape indices indicated a continuous and aggregated spatial distribution of built-up areas. All values of the landscape indices for the Bangkok Metropolitan Administration differed substantially from those for other changwats. The Bangkok Metropolitan Administration therefore exhibited unique characteristics, and the Administration could be easily differentiated from other changwats on the maps. Nakhon Pathom exhibited contrasting values, with dispersed built-up areas in small patches that were characteristically connected to each other. In the Bangkok Metropolitan Region, the central urban area of Nakhon Pathom is located at a distance from the center of Bangkok, and its built-up areas were not completely connected to each other, indicating that cities and farm villages were heavily mixed in this changwat.
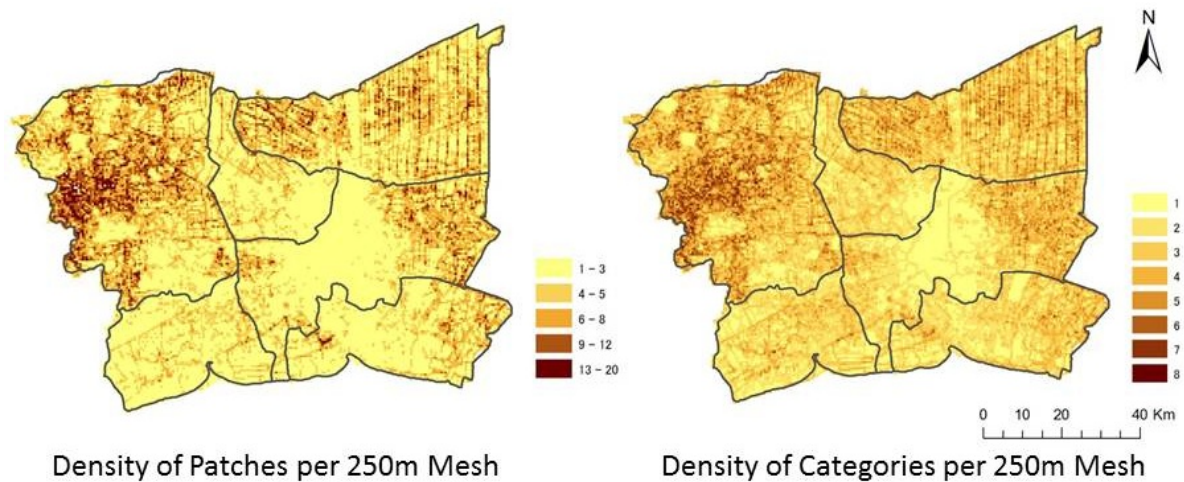
Figure 9   Land Use Patches Diversity Maps in 2009

4. Conclusion

In this study, temporal high resolution satellite images and GIS thematic data were integrated for geospatial analysis of the urbanization process and its influences on the suburban land use changes in the Bangkok Metropolitan Region over the past 15years. The characteristics of spatial arrangement of the present land use (2009), which were the results of urbanization, were investigated using several landscape indices.

The results obtained in this study show that expansion of urban land use in the Bangkok Metropolitan Region, indicated as a proportion, was 16.5% (1994), 28.2%(2000), and 35.4% (2009). Urbanization of the Bangkok Metropolitan Administration was already saturated by 1994. In contrast, the area of urban land use more than doubled during these 15 years in all five of the suburban changwats analyzed. This was mainly due to conversion of paddy fields into built-up areas. This trend was particularly significant in Pathum Thani and Nothaburi, and the decrease in agricultural land use was much higher in these two changwats than in the other changwats. This trend was also seen in population and the number of households; i.e., population and the number of households markedly increased in Pathum Thani and Nonthaburi in the past 15 years. In other words, rapid urbanization has progressed together with increases in population and the number of households in the northern suburbs closest to the Bangkok Metropolitan Administration.

The results obtained by analyzing present land use using landscape indices were highly consistent with results obtained by analyzing actual land use changes. In the Bangkok Metropolitan Administration, where urbanization was already saturated, landscape patterns were simple and showed continuous and aggregated spatial distribution of built-up areas. All of the values for the landscape indices for the Bangkok Metropolitan Administration were extremely different from those for the other changwats. Therefore, the Administration exhibited unique characteristics and it could be easily differentiated from the other changwats on the maps. Nakhon Pathom showed contrasting values with dispersive built-up areas, but with small patches that were characteristically connected to each other. In the Bangkok Metropolitan Region, the central urban area of Nakhon Pathom is located at a distance from the center of Bangkok, and its built-up areas were not completely connected to each other, indicating that cities and farm villages were extremely mixed in this changwat. Nothaburi and Pathum Thani, which were adjacent to the northern part of the Bangkok Metropolitan Administration, were considered to be in the intermediate stage of urbanization.

References

Kikuchi T. Yamamoto M. Sasaaki H. and Tubaki M.(2001), Sustainability and its Driving Force of Agricultural Land Use Changes in the Suburbs of Bangkok Metropolitan Region (in Japanese), Global Environment, 6(2), 227-239

Kevin M. & Barbara.M. (1994), FRAGSTATS. Spatial Pattern Analysis Program for Quantifying Landscape Structure, http://www.umass.edu/landeco/pubs/mcgarigal.marks.1995.pdf, 1-134

Turner M.G. (1990), Spatial and Temporal Landscape Pattern, Landscape Ecology, 4, 21-30