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研究課題名（和文）Measuring pattern and process of urban sprawl in South and Southeast Asian developing cities.

研究課題名（英文）Measuring pattern and process of urban sprawl in South and Southeast Asian developing cities.

研究代表者

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研究成果の概要（和文）：隣接する行政区域への都市部の拡大は、意思決定プロセスの地方分権と関係している。 大都市の状況を理解するためにさらなる研究は必要がある。 主要都市部は過去10年間に郊外の中心部よりも急速に成長していた。 この調査では、主要都市部が低密度郊外部よりも農地で拡大していることが示されている。これは、安価な土地の利用可能性と土地利用計画 の欠如による可能性があります。
この研究では、いくつかの都市拡大パターンが特定された。 最初のパターンは、農村部と道路沿いの都市開発です。 2つ目は周辺地域への侵入による主要都市部の拡大である。 第3の観察は、都市の郊外にある都市パッチの複雑さです。

研究成果の概要（英文）：The expansion of urban areas into adjoining administrative areas has a relationship with decentralization of decision-making process. Further studies need to understand the situation in larger cities. The main urban areas were growing faster than the suburban centers during last decade. This study also shows that the main urban area is expanding in agricultural lands than in low-density suburban areas. This may be due to the availability cheap land and the lack of control measures.
Several urban expansion patterns were identified in this research. The first pattern is the small urban patches in rural areas and along roads. The second one is the expansion of main urban area by encroaching into the surrounding area. The third process was infill growth. The third observation is the complexity of urban patches in the outskirts of the city.

研究分野： 都市地域計画

キーワード： urban expansion　southeast asia

１．Background

Cities are contributing to a large share of national output of many countries in Asian region. Cities provide economics of scale and agglomeration, allow many goods and services to be produced and traded more efficiently making them the engines of national development. Migration into cities has increased the net productivity of the economy by directing labour to locations were greater contribution to the economy is possible.

One aspect that is not fully understood is urban growth pattern and urban growth process in those cities. The outward expansion of settlements in those cities follow organic growth pattern. While outward growth is more prominent, there are other attributes of urban growth. The rapid growth process also changes the organization of the city activities themselves in the form of shifting activity centres, changing urban densities and changing accessibility conditions. Therefore studying rapid urbanization need to measure spatial configuration of the city at point in time and the process of change in spatial structure over time. Urban sprawl research provides a theoretical base for measuring urban expansion process. Therefore measuring urbanization across time and across the region with multiple measurements is vital to understand the urbanization pattern and process of rapidly growing Asian cites.

２．The Objective

In the field of urban design sprawl and scattered growth is conceded as un-aesthetic. At the same time, these new developments are popular among people who are looking for an urban lifestyle in the periphery. These new growth areas provide affordable housing opportunities.

The economic and environmental disbenefits of sprawl are obvious in short and long term in the form of infrastructure cost, conversion of valuable agricultural lands and deterioration of environmentally sensitive areas. Decentralization of activates from the central core to the urban periphery is fundamental to sprawl. Therefore sprawl is commonly linked with the suburbanization of economic activities. In growing cities, this is connected with job creation in the form of industrial areas in the periphery. The other phenomenon that is unique to rapidly growing cities is the variability of infrastructure availability in sprawled areas and spontaneous nature of growth.

There are numerous studies about sprawl in Northern American and European cities. These studies area trying to understand the sprawl under the topics of growth; social and aesthetic attributes (Calthorpe, 2001), decentralization (Galstera, 2001), accessibility (Hasse, 2004), density characteristics (Lang, 2003) fragmentation; loss of open space; and dynamics. Some studies are trying to measure the physical growth of sprawl quantitatively using multiple measurements (Torrens, 2008). And there few studies about Asian context as well (Murakami, 2005) who studied sprawl in small scale areas. (McGee, 1995) explained urban expansion process as a new growth type in urban periphery of Asian cities and explained that it has a mixture of urban and rural features. There are several studies that try to understand this growth process from the demographic and social point of view as well. There is a lack of studies that try to measure urban growth process and measure those patterns quantitatively and try to understand the dynamics across different scales and against different time periods. The objectives of the study area. Measure urban expansion process to understand temporal process of expansion.

1. Understand how urbanization across the city
2. Understand spatial process of the urbanization

３．Method and data

This report is using the Yogyakarta City of Indonesia as case study to demonstrate findings of this research project. Yogyakarta City is the main urban center in Yogyakarta Special Region of DIY Province and a hub of Javanese art and culture The city has outgrown its urban boundaries and speeding into neighbouring regions in recent decades. Large peri-urban areas speeding to adjoining Sleman and Bantul with population more than 1 million.

Urban growth process in Yogyakarta City has influenced by several significant transformations in administrative structure and infrastructure development. In 1999 and 2004 Indonesia changed its centralized administrative structure into highly decentralized system. That created an environment for less central planning in regional planning related matters. While the expanding peri-urban areas are growing outwards, the city core also expanding its densely built areas in the periphery.

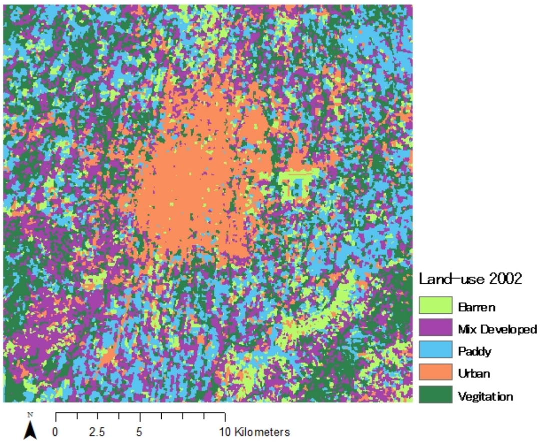

Figure 2. Land-use in Yogyakarta 2002

Spatial metrics (landscape metrics) are used in this study to describe detect and quantify characteristics of landscape objectively and to reveal properties of ecosystems in landscape ecology. Angel et al. (Angel, 2007) have defined five attributes of growth that can understand urban expansion such as urban extent, density, suburbanization, contiguity, and compactness. Torrens (Torrens, 2008) argued that sprawl must be measured in multiple scales. Urban sprawl studies that try to define the threshold of sprawl has recommended entropy method as a method of measuring sprawl (Bhatta 2010).

This study examines the characteristics of urban expansion relatively by measuring attributes of urbanization both spatially and temporally. The measurements for spatial characteristics were carried out in two stages. First, the previously classified land-use data was used to understand the land-use conversion for the period between 2002 and 2013. This research tries to measure the changes in urbanization patterns chronologically for the whole city and try to understand the trends in growth patterns by measuring five attributes of growth urban extent, scatter growth, suburbanization, and contiguity of urbanization process. These attributes were measured using spatial matrices and spatial measurements of built up area for all three periods. Declining average population density is an attribute of sprawl behaviour in many large cities.

Urbanization was measured at two scales. First, the urbanization of the whole city was measured using total urbanization for each period, Patch Density (PD), the proportion of urban footprint, COHESION and class level Contiguity matrices. Patch density (PD) measured the scattered growth of the urbanization pattern, which quantifies the number of urban patches per unit area (100ha). COHESION metrics and the proportion of urban footprint measure the suburbanization process. The value of the COHESION reaches 0 as the proportion of the landscape comprised of the focal class decreases and become increasingly subdivided and less physically connected. The Contiguity metrics measure the spatial connectedness of urban patches. Instead of population densities, this study used the density of the built-up area. This will allow measuring the scatter growth process.

And in the second stage of this study, the characteristics of urbanization was measured using a transect across the city. These measurements were taken for all three periods. Five spatial metrics were used in this analysis. Patch characteristics of the blocks were measured using patch density (PD), the number of patches in the landscape (N) and total landscape area (A). Patch density gives the number of patches per 100ha. Landscape shape index (LSI) was measured to evaluate aggregation or clumsiness of urban patches in the block. Perimeter-Area Fractal Dimension (PAFRAC) measured the shape complexity or urban patches. Patch level COHESION was calculated to measure connectedness of corresponding patches.

Calculation of spatial matrices was performed using public domain software FRACSTAT version 3.3. This software was developed and available from 1995 and was developed continuously. FRAGSTAT provide large range of matrices patch level, class level, and landscape level measurements. matrices used in this study were selected specifically to measure attributes of urbanization.

Data used for the study was prepared for three time periods. Three clouds free Landsat Thematic Mapper data sets from 1997, 2002 and 2013 with 30m resolutions were used to extract urban areas and land-use data.

4. Results

The urban land-use changes detected from land-use classification indicate a high proportion of land-use conversion from vegetation land to urban activities. This phenomenon is due to the gap filling growth pattern that converts existing green areas between 2002 urban patches. A Large extent of vegetation land that was visible in southeast hillsides and fragmented vegetation land in Northeast does not show extensive urbanization during 2002 to 2013 period.

Cropland consists of paddy land both Irrigated and barren and other irrigated land visible in classification image. Croplands are showing resistant to the high-density urbanization during this period. Particularly crop lands in the South of the city remained unchanged during this period. Eastern and North croplands are observed become high-density urban areas compared to other regions Table 1.

Mixed built-up lands in the classification are the peri-urban growth of the extended Yogyakarta city. The active peri-urban growth during the period of 2002 to 2013 was happening further away from the main city. The land-use change data shows 1198ha of the peri-urban area around the main urban center of Yogyakarta. Peri-urbanization is a phenomenon observed in many cities with high urban and economic growth that attracts people from rural areas. What are unique in the peri-urbanization in Yogyakarta was the extent and the rate of expansion. Peri-urban areas are not uniform in spatial structure and are diverse due to locational aspects. Development of additional facilities such as shopping areas changes the spatial characteristics of the surrounding area and become functional urban centers with time. Close observation shows that these growths are mainly extensions of existing small urban centers and a small proportion of spontaneous growth. In all cases, these growths are found along to main trunk roads.

Conversion of barren land to urban activities was relatively low. The barren land class consists of dry barren land, deforested hillsides, open grassland and golf courses. Some of the lands have urban or other economic land-use characteristics. Deforested hillsides and vacant patches in or near the main urban center are also classified into this land-use class.

Macro scale measurements show how urbanization process was progressing towards the countryside. Largest patch index (LPI) at the class level quantifies the percentage of total landscape area

Widespread land use changes prompted by rapid urbanization resulted in fundamental changes in landscape pattern in last decade. Other researchers have observed wide scale peri-urbanization in Yogyakarta region and happening further away from the main urban centers (Richard. L 2014). While peri-urbanization remains the dominant form of growth, expansion of existing urban centers is also equally visible. The growth process observable in this data shows two growth patterns between 1997 to 2002 and 2002 to 2013. No significant increase in patch density value was observed between 2002 to 2013 period. A number of patches remained constant, which point to expansion of existing canters and main urban area while urbanization increase with time.

Patch cohesion index measures the physical connectedness of the corresponding patch type. COHESION value reaches 0 if the focal class or urban patches, in this case, become increasingly scattered and less connected. From 1997 to 2013 COESION increases indicating an increase of connectedness of built up patches. The proportion of suburban area has increased between 1997 and

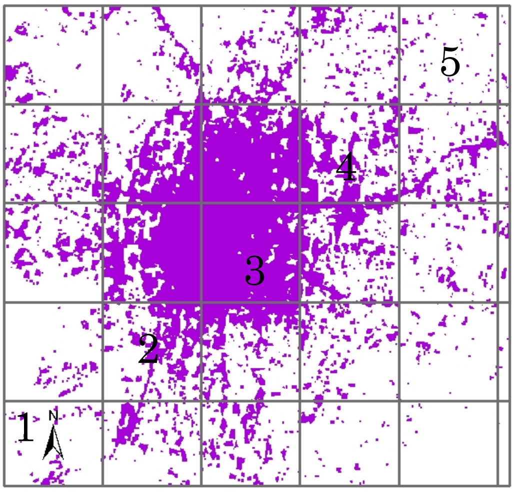

Figure 2. Blocks from 1 to 5 was used to measure urbanization characteristics.

2002. And later between 2002 and 2013 the proportion of suburbanization has decreased. This indicates that last decade has seen a significant expansion of main urban area rather than new urban areas in the periphery. This observation is similar to the relative increase of LPI value for same periods.

The observed values of COHESION indicate infill growth closer to the main urban center. Visual observation of urbanization data for three period shows the most prominent expansion of urban center is happening in the west of the city and most of the visible in early images were merged into larger urban pitchers Figure 3. Growth along the main road towards east become a strip of continues urban stretch during last decade. Growth towards west and north showing the gap-filling trend. Larger patches closer to the main urban center.

Growth in South corridor is not as prominent as other regions. Eastern growth is responding to the intercity rout and greater development services in those regions. Sothern areas are maintaining its character due to the well-irrigated agricultural lands.

Contiguity index gives connectedness of cells of a given land covers class. If the value reaches 0 then the cells are not connected. If the value reaches 1 it means that all the cells of the land cover class are connected. From 1997 to 2013 the contiguity index has decreased. This indicates a large number of suburban built up patches that are isolated and less connected. Patch Density shows the number of patches for a unit area. The value of PD has increased from 1997 to 2005. Increasing patch density and decreasing contiguity index indicates the trend of isolated leapfrog growth of small urban patches in the landscape.

The COESION value increases while contiguity index decreases show the groups of urban patches in the region.

The local characteristics of urbanization process were measured by applying several spatial metrics to blocks in Figure 5. Five spatial matrices number of patches (NP), patch density (PD), landscape shape index, PFRAC and COHESION was measured for all three data sets. Number of Patches (NP) is a simple measure of a number of urban patches in each block. Block 3 in Figure 4a to 4e corresponds with the main urban area. Block 2 and block 4 are the blocks outside the main urban area while blocks 1 and 5 are furthest from the main urban area.

Main observation of this analysis is the characteristics of urbanization along an intersect of the urban region. NP value shows that while block no 3 shows the smallest value due to being fully urbanized, highest numbers of urban patches are visible in blocks 2 and 5 for all three time periods.

NP value also varies from year to year. Block 2 has seen a large increase in the number of urban patches from 1979 to 2002. Later from 2002 to 2013 the number of patches has decreased that of 2013. This can be due to 2 factors. One possibility is that a large number of urban patches appeared from 1997 to 2002 has expanded and merged into larger patches in 2013. The other possibility is that outward expansion of main urban are. This observation is consistent with the behaviour of COHESION value observed for the total study area in the previous section. It is possible that both outwards expansion and merging patches are happening in parallel to varying in degree in different directions.

NP value also changes in core urban area for the same period. In block 3 the NP has steadily decreased from 1997. This may due to the infill developments happening in those areas. NP value at block 5 shows that the numbers of patches are steadily increasing in these areas. The values of Patch Density closely follow the corresponding NP value. The observation of land-use changes between 2002 to 2013 shows the large extent of urbanization of vegetation land class. While most of the large green areas conversion of small vegetation lands locked within urban patches can be explained with this observation.

Landscape shape index provides a standardized measure of total edge or edge density that adjusts for the size of the landscape. LSI = 1 when the landscape consists of a single square (or almost square) patch. LSI increases without limit as landscape shape becomes more irregular and/or as the length of the edge within the landscape increases. LSI has a close relationship with NP and PD figures. In block 3 the LSI value decreases with the decrease of the number of patches. In blocks 2 and 4 the LSI value again closely follows the values of NP and PD. In 1997 there are large numbers of urban patches and they had complex shapes. Later in 2002 and from 2002 to 2013 number of patches has dropped and fewer urban patches with less complex shape were observed in 2013.

Table 1. Patch density for 1997, 2002 and 2013

Year	PD
1997	1.1158
2002	1.7264
2013	1.7296

Table 2. Urbanized are for 197, 2002 and 2013

Year	Total	% of land	LPI
1997	7832	12%	7.2433
2002	11409	18%	10.0833
2013	16932	27%	17.8341

Table 3. Proportion of suburbanization and COHESION

Year	Proportion of sub urban growth	COHESION
1997	42%	98.6729
2002	47%	98.7517
2013	34%	99.2085

Table 4. Contiguity

Year	CONTIG_MN
1997	0.7138
2013	0.7130
2003	0.6931

Patch COHESION index measures the physical connectedness of the corresponding patch type. It approaches 0 as the proportion of the landscape comprised of the focal class decreases as the patch becomes increasingly subdivided and less physically connected. The COHESION value of 1 and 5 are low due to the smaller number of patches. Blocks 2 and 4 show an increase in COHESION value. The values of 1997 and 2013 show the process of urbanization in Yogyakarta urban area. First, the NP and PD shows increase from 1997 to 2013 indication increase of urban patches in block 2 and 4. The COHESION index for both blocks 2 and 4 show increase during this period. This observation can be explained as that the new urbanization in peripheral areas is essentially a fragmented. And with the progress of urbanization, these fragmented patches are connected with each other forming larger and larger patches. These larger patches tend to have complex shapes in certain areas. Particularly in the northeastern part of the city urban patches has a complex shape than that of southeastern corner.

Local variations of urbanization in Yogyakarta city are visible in the spatial matrices output for blocks 1 to 5 (Figure 2). Urbanization in the northeastern corner is more prominent than that of southwestern corner.

This study show that main urban area is expanding faster than other parts of the urban region. The outwards expansion of the urban growth starts with small urban patches. Later these patches expand and merge into larger urban patches. These large patches may have various levels of complexity depending on the region. This fact is visible in urban extent data of 1997 to 2013 and cohesion value for the corresponding periods. The expansion of main urban area was particularly visible for the period of 2002 to 2013. During that period the proportion of urban growth was less than the urban growth before 2002.

From above observations, several urban expansion patterns can be identified. The first pattern is the immerge of small urban patches in rural areas and along roads. The second one is the expansion of main urban area by encroaching into the surrounding area. The third process was infill growth. Infill growth can be identified in the patterns of NP and PD data between 1997 and 2013. The third observation is the complexity of urban patches in the outskirts of the city.

Yogyakarta has seen several stages urbanization during past decades. First is the completion of the outer ring road and the urbanization between ring road and the main urban agglomeration. Later the decentralization of decision-making process and the growth of peri-urban areas that are expanding into adjoining administrative areas. Although the peri-urban areas are more attractive for living, the main urban agglomeration also growing steadily in last decade. The observations of this study based on land use study between 2002 and 2013 show that the main agglomeration is not necessarily growing into peripheral low-density suburbs. There more growth observed on agricultural and nonurban land uses such as vegetation areas. This may be due to the available land as well as deficiencies in land regulations and implementing them. Studying Yogyakarta will be a valuable lesson to understand other south east Asia cities those following the same path.

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５．主な発表論文等

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〔その他〕

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６．研究組織

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