1 <Title>

2 Trends in urbanization and patterns of land use in the Asian mega-cities Jakarta, Bangkok, and

3 Metro Manila

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1   **<Abstract>**

2   Asian mega-cities have experienced rapid population growth and continue to grow. Urbanization in

3   those areas is proceeding differently from the patterns of city growth experienced in Western

4   countries. Understanding the characteristics of Asian urbanization will be indispensable for the

5   establishment of a local landscape planning system. In this study, we used the Clark linear

6   exponential model and the Newling quadratic exponential model to compare the spatial distribution

7   of population densities in three Southeast Asian mega-cities: Jakarta, Bangkok, and Metro Manila.

8   We analyzed land use patterns in each of the three cities by examining the mixture of urban and

9   agricultural land use. The Clark and Newling models showed that the three cities were at different

10   stages of urbanization. Jakarta had entered the suburbanization stage, Metro Manila was still at an

11   early stage of urbanization, and Bangkok was at an intermediate stage between Jakarta and Metro

12   Manila. Analysis of spatial patterns revealed areas of mixed land use within and around the city

13   region in the three cities and that these areas of mixed land use would shift outward as urbanization

14   proceeds. These findings indicate that planning concepts need to respect the vernacular landscape of

15   each Asian mega-cities as well as its stage of urbanization.

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17   <Key words>

18   Population growth, land use mixture, Asian mega-cities

19

1. Introduction

In Asian mega-cities, the peripheral zones have been pushed by urbanization much beyond their previous extents and have spilled over into the rural villages or towns surrounding the cities. The growth has been rapid over the past several decades, causing rural-to-urban conversion of large areas surrounding the cities, uncontrolled development of the urban regions, housing shortages, and expansion of squatter settlements. Urbanization and growth of metropolitan regions in Asia, while showing some of the characteristics of Western urbanization, also exhibit features unique to Asian countries. Several studies have pointed out land use mixture as a major feature of Asian urbanization. McGee (1991) indicated that rapid urban growth created a chaotic mixture of urban and rural land use, and that such mixture resulted in serious environmental problems and a lack of adequate urban infrastructure. In order to establish a local landscape planning system, an understanding of these features of Asian urbanization is strongly needed.

In this paper we firstly discuss the trends in urbanization in Jakarta (Indonesia), Bangkok (Thailand), and Metro Manila (the Philippines) using Clark's linear exponential model (1951) and Newling's quadratic exponential model (1969). Secondly, we examine the characteristics of the land use patterns and the complexity of land use for each of the cities.

2. Study Areas and Materials

2.1. Jakarta

DKI (Daerah Khusus Ibukota) Jakarta, or Jakarta city, is the capital city of Indonesia. Jakarta consists of five municipalities and lies in the lowland on the north coast of the western part of Java

1   Island (Fig. 1). The city occupies an area of 640 km^2, or 0.03% of the national land area. Jakarta has

2   a flat terrain, and the land gradually rises from 5 to 50 m above mean sea level.

3   The 1970, 1980, 1990, and 1998 population data for each subdistrict (kecamatan) of Jakarta

4   were obtained from the Bureau of Statistics (BPS DKI Jakarta Provinces, Indonesia). The

5   kecamatan digital administrative boundaries used in this study were those defined by the National

6   Land Bureau (BPN), Jakarta. Land use datasets created from the 1990 land use map (scale 1:25 000)

7   were obtained from the BPN.

8   **2.2. Bangkok**

9   Bangkok, the capital city of Thailand, occupies an area of 1568 km^2, or 0.30% of the national

10 land area. Bangkok is situated on the Chao Phraya delta plain (Fig. 1), with an elevation of about 1.5

11 m above mean sea level.

12   The 1970, 1980, 1990, and 1998 population data for each ward (khet) of Bangkok were

13 obtained from the National Statistical Office. The khet digital administrative boundaries used in this

14 study were those defined by the Japan International Cooperation Agency (JICA), Japan. The 1995

15 digital land use map was obtained from JICA.

16 **2.3. Metro Manila**

17   Metro Manila is the capital of the Philippines, and consists of eight contiguous cities,

18 including Manila City, and nine other municipalities, covering an area of approximately 638 km^2, or

19 0.20% of the national land area. Metro Manila is located in the lowlands of southwestern Luzon

20 Island and is situated on the eastern coast of Manila Bay at the mouth of the Pasig River (Fig. 1).

21   Population data for 1970, 1980, 1990, and 1995 for each city of Metro Manila were obtained

22 from the National Statistical Coordination Board, the Philippines. The city administrative

1 boundaries defined by the National Mapping and Resource Information Authority, the Philippines,

2 were digitized and used. The 1995 land use map was obtained from the same agency.

3

4 **3. Trends in urbanization in the three cities**

5 **3.1 Population growth and spatial extension trends**

6   The historical record shows that the innermost zone of each city was the most populous and

7 that it was, as it continues to be, the center of maximum socioeconomic activity. This zone became

8 a magnet for people from outside the metropolitan area (Cadwaller, 1991; Morill, 1992). The

9 urbanization process of the innermost zone helped to expand the urban areas and increase the

10 diversity of land use on the fringes of the metropolitan areas. Expansion of urban areas to the fringes

11 of the city also influenced the distribution of population density (Befort et al., 1988).

12   In order to examine the distribution of population density, the average population density

13 (persons/ha) was plotted as a function of distance from the city center by ERDAS software for each

14 of the three cities (Fig. 2). The center point of each city was the National Monument (Monas) for

15 Jakarta, the Grand Palace for Bangkok, and Elmita for Metro Manila.

16   Fig. 2 reveals that Jakarta and Bangkok have had a similar trend of decreasing population

17 density in the center of the city since 1970. Analysis of the data for Jakarta for 1970, 1980, 1990,

18 and 1998 shows a trend of a progressive decline in population density in the center of the city, from

19 198 persons/ha in 1970 to 153 persons/ha in 1998. Bangkok has a similar trend, from 222 persons/ha

20 in 1970 to 155 persons/ha in 1998. However, Metro Manila has a different trend. In Metro Manila,

21 the population density rises continuously through 1980, declines in 1990, and rises again in 1995.

Spatial analysis over the range of 0 to 5 km from the city center suggests that each city has a specific trend. Jakarta shows drastically decreasing population density with time. The most populous area in 1970 (0.5 km from the city center) shows a rapid decline from 300 persons/ha in 1970 to 169 persons/ha in 1998. Bangkok has a variable condition. The populous area 2.2 km from the city center shows a rapid increase from 202 persons/ha in 1970 to 278 persons/ha in 1980 and a rapid decline to 183 persons/ha in 1998. In Metro Manila, the population density increases continuously over the period from 1970 to 1995.

In the range of 5 to 15 km from the city center, Jakarta shows a rapidly increasing population density at 7 km (from 63 persons/ha in 1970 to 156 persons/ha in 1998), and a more gradual increase in population density at distances greater than 7 km. In Metro Manila, the population density increased over the period from 1970 to 1995. Bangkok shows a trend of increasing population density only during 1970 to 1990, followed by a decreasing trend from 1990 to 1998.

On the fringes of the urban areas (15–25 km), all three cities show similar trends of increasing population density. Especially, Metro Manila shows a rapid increasing population density at distances greater than 18 km.

3.2. Clark and Newling models

Since Clark (1951) published his classic study on urban population densities, a number of studies have focused on modeling and analyzing urban population densities. The Clark model, which provides a negative exponential distribution of population density, can be described as

$$\underline{D}(\underline{r}) = \underline{D}_0\, \mathrm{e}^{-br},$$

1   where $\underline{D}_0$ is the population density in the center of the city, $\underline{D}(\underline{r})$ is the population density at distance

2    $\underline{r}$, $\underline{r}$ is the distance from the center of the city, and $\underline{b}$ is a measure of the rate of change of the

3   logarithm of the population density.

4   Berry et al. (1963) and Newling (1966) conducted theoretical and empirical studies to

5   confirm the feasibility of this function. Tanner (1961) and Sherratt (1960) respectively proposed a

6   revised population density model. Later, Newling (1969) introduced a more accepted and

7   generalized function:

8    $$\underline{D}(\underline{r}) = \underline{D}_0\,e^{(\underline{br}-\underline{cr}^2)},$$

9   Or,

10   $$\ln \underline{D}(r) = \ln \underline{D}_0 + (\underline{br} - \underline{cr}^2)$$

11   $$= \ln \underline{D}_0 - \underline{c}(\underline{r}\text{-}\underline{b}/2\underline{c})^2 + \underline{b}^2/4\underline{c}$$

12   where $\underline{D}(\underline{r})$, $\underline{D}_0$, and $\underline{r}$ have the same definitions as in the Clark model. The parameter $\underline{b}$ is the

13   instantaneous rate of change of population density with distance from the center of the city, and $\underline{c}$ is

14   an approximation of the quadratic exponential parameter. In the Newling model, for positive values

15   of $\underline{c}$, the most populous area is predicted to appear at the distance $\underline{b}/2\underline{c}$.

16   The Clark model explains, as a function of time, how both the city center and areas away

17   from the city show net population density gains. This model fits the early stages of urbanization in

18   metropolitan areas. The next stage of urbanization (suburbanization) is described by the Newling

19   model, which explains the shift of the most populous area from the city center to areas away from

20   the city center. In this case, the city center shows a net loss of population density, while areas away

21   from the city center show net population density gains.

1   The Clark and Newling models depicted the population density in the context of a

2   monocentric city, in which there existed densely populated central places. Anderson (1982) pointed

3   out the inappropriateness of the negative exponential form, such as the Clark and Newling models,

4   for multicentric cities, and concluded that the cubic spline density function could provide more

5   realistic models of urban density patterns of multicentric cities. Anderson (1985a, 1985b) and

6   Zheng (1991, 1998) conducted studies on population densities and agglomeration economics by

7   employing cubic spline functions. Those studies well demonstrate that the cubic spline function

8   allows more flexible analysis of urban population densities of multicentric cities. However, since

9   Jakarta, Bangkok and Metro Manila were considered to be monocentric cities, the Clark and

10   Newling models were used to classify the three cities in a simple way and to calculate their growth

11   trends.

12   The results of applying Clark's linear exponential model and Newling's quadratic

13   exponential model to Jakarta, Bangkok, and Metro Manila are shown in Table 1. Applying the

14   models to the data for the 1970s and 1980s indicates that although the values of the coefficient of

15   determination of the Newling model are appropriate ($\underline{R}^2 > 0.900$) for the three cities, the parameter

16   $\underline{c}$ in the Newling model has negative values, which suggests that the three cities are not properly

17   represented by the Newling model. Therefore, the spatial patterns of population density in the 1970s

18   and 1980s in the three cities are more appropriately represented by the Clark model than by the

19   Newling model.

20   During the 1990s, the three cities showed different trends of urbanization. The coefficients

21   of determination are still high but the parameter c in the Newling model is positive for Jakarta. This

22   means that the Newling model fits Jakarta of the 1990s more appropriately than the Clark model

23   does, and that Jakarta entered into the stage of suburbanization, although $\underline{b}/2\underline{c}$ still has a negative

1   value. In contrast, trends in Bangkok and Metro Manila show that the Clark model is still more

2   appropriate than the Newling model, based on the negative values of the parameter c.

3   These results from applying the Clark and Newling models suggest that only Jakarta has

4   entered the stage of suburbanization, while Bangkok and Metro Manila are still before the

5   suburbanization stage. However, the recent changes in population density in Bangkok indicate that

6   Bangkok is following right after Jakarta.

7

8   **4. Land use pattern**

9   **4.1 The complexity of spatial structure**

10   Urban–rural integration as observed in the urban fringe has been pointed out as a distinct

11   feature of Asian mega-cities (e.g., McGee, 1991; Yokohari et al., 2000). In order to comprehend the

12   features of the spatial structure of each of the three cities, we examined the complexity of land use

13   by using a GIS-based dataset relating to land use.

14   Significant spatial patterns for categorical data can be tested using the join counts method

15   (Fortin, 1999; Upton and Fingleton, 1985). The join counts method was developed by geographers

16   to assess significant spatial pattern of diseases or social behaviors (Cliff and Ord, 1981), and has

17   been broadly used to measure the degree of complexity. This method counts the joins between

18   contiguous grid cells. In the example in Fig. 3, black cells and white cells represent two different

19   categories, and the diagram shows the method of calculating joins as either BB joins (joins between

20   two black cells), WW joins (joins between two white cells) or BW joins (joins between a black cell

21   and a white cell) in a 4×4 matrix. The join counts method uses the number of BW joins as its value,

22   since this represents the frequency of contiguity between black and white. We analyzed join counts

23   between urban and agricultural land use areas. Thus, the value of join counts indicates the frequency

1 of contiguity between urbanized and agricultural areas, in other words, the degree of land use

2 mixture.

3   The join counts of land use were calculated by using GIS-based datasets for each of the three

4 cities. In the case of Jakarta, from the analysis above we expected the influences of urbanization to

5 reach beyond the boundaries of Jakarta city; therefore, the dataset was one that covered a wider

6 region (the Jabotabek region) including Jakarta city. The calculation was done for the entire

7 Jabotabek region.

8   The original GIS data were of vector type, and each metropolitan region was classified into

9 between 12 (Bangkok) and 18 (Metro Manila) classes. The data were converted to raster type, and a

10 new dataset of 50-m resolution was constructed for each city. The 12–18 classes were integrated

11 into three land use types; urbanized areas (residential areas, industrial areas, roads, etc.),

12 agricultural areas (agricultural areas, forests, fishponds, etc.), and others (sea, rivers, lakes, etc.).

13 Windows of 10×10 pixels (a 500 m $\times$ 500 m matrix) were scanned and the value of join counts

14 between urbanized areas and agricultural areas within that window was calculated, and this value

15 was assigned to the center (analyzed) pixel.

16   Each value is plotted in Fig. 4. A high value indicates a high degree of complexity in the

17 land-use type and that the land use is heterogeneous around that pixel (black area). A low value

18 indicates a low degree of complexity in the land-use type and that the land use is homogeneous

19 around that pixel (white area).

20 As is evident from Fig. 4, a high-value area spreads like a belt around a low-value area in Metro

21 Manila. The homogeneous land-use area, which spreads inside the belt, is considered to be highly

22 urbanized. In Jakarta, the spatial structure is similar that of Metro Manila with a belt of mixed

23 land-use surrounding the city area. However, this high-value belt spreads outside Jakarta city,

1 beginning almost at the city boundary; the entire city region of Jakarta is considered to be highly

2 urbanized.

3   In Bangkok, areas of mixed land use follow a different pattern from those in Metro Manila or

4 Jakarta. High-value areas can be seen to the east and west of the central city region and seem to

5 spread linearly, presumably along causeways. The homogeneous zone further to the east of the

6 eastern area of mixed land use is considered to be an area of predominantly agricultural or natural

7 land. The location of this area coincides with the largest one of the three green zones preserved by

8 the Metropolitan Bangkok Regulations (1982). This indicates that the policy of green zones is

9 effective in this region.

10 **4.2 Belt-transect analysis**

11   In Metro Manila, we conducted a further examination to analyze the temporal change of land

12 use mixtures. On two sets of aerial photos (taken in 1986 [1:32000] and 1996 [1:12500]) we defined

13 a 24-km × 0.9-km belt-transect, running from the city core to the south (from lat 14°22′00″N to lat

14 14°35′00″N; from long 121°00′00″E to long 121°00′30″E), an area that we considered was

15 undergoing intensive urbanization (Fig. 5). The land use within the area was identified by

16 overlaying 100 m × 100 m grids on each of the aerial photos. The land use in each grid cell was

17 classified into one of three categories; urbanized area, agricultural area, or other.

18   In both photos the most highly urbanized area was located near the center of Metro Manila,

19 an area showing urban–rural integration spread outward from the center, and a continuous rural area

20 existed in the outermost part.

21   The comparison revealed that by 1996 agricultural land shown in the 1986 transect had

22 either vanished as the densely built-up area at the center spread outward or tended to be fragmented.

1   We calculated 3×3 join counts after reclassifying the land use into the three categories. The

2   comparison of the join counts (averaged every 1.5 km) from 1986 and 1996 showed that the

3   low-join-count urbanized area spread outward, join counts in urban–rural integrated areas of

4   initially high value decreased, and join counts in rural areas with initially low values started to

5   increase (Fig. 6). This suggests the outward shift of the urban–rural integrated area, and also the

6   simultaneous spread of the urbanized area.

7

8   **5. Discussion**

9   Analysis of the distributions of population density showed that Jakarta, Bangkok, and Metro

10   Manila are at different stages of urbanization. Jakarta has entered the suburbanization stage. Metro

11   Manila is still before the suburbanization stage. Bangkok can be placed between Jakarta and Metro

12   Manila.

13   From the spatial analysis, an area of mixed land use was observed within or around the

14   metropolitan regions in each of the three cities. Such mixture occurs as urbanization proceeds.

15   Many studies report that, because of insufficient infrastructure, such as sewerage systems, serious

16   problems of competition arise between urban and agricultural land use in areas of mixed land use

17   (e.g., Kelly, 1998). Therefore, an unbalanced mixture of urban and agricultural landscape must be

18   controlled.

19   In Jakarta, a belt of mixed land use was seen outside the city region, and we considered that

20   suburbanization continued beyond the city limits. Therefore, a regional plan covering not only

21   Jakarta city but also other neighboring cities is required. In Metro Manila, the area of mixed land use

22   was observed inside the metropolitan region. In addition, the population of Metro Manila is

23   expected to continue growing. A sound land use plan must be established to control urbanization

1 and to avoid an uncontrolled mixture. In Bangkok, the areas of mixed land use spread linearly. A

2 detailed, fine-scale land use plan is required to cope with the problem of such a land use mixture.

3   Although it is known that mixtures of urban and agricultural land use may cause several

4 environmental problems, segmented patches of agricultural land that remain in the urban fringes can

5 be expected to provide many services, such as water retention capability, micro-climate control, and

6 conservation of visual quality. The establishment of a strategy for urban and agricultural land use to

7 co-exist is strongly needed for Asian mega-cities.

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1   **Figure captions**

2   Fig. 1. Location of the three cities

3   Fig. 2. Population density as a function of distance from the center of the city

4   Fig. 3. Black-and-white map and join counts

5   Fig. 4. Distribution of land use join counts

6   Fig. 5. Location of belt-transect in Metro Manila

7   Fig. 6. Spatial profile for land use join counts

8   Table 1. Results of application of the Clark and Newling models

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