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▶ Article ◀

Measuring Spatial Patterns of the Suburbanization Process
大都市近郊地域の都市化現象の空間分析

—A Case Study of Bekasi District, Indonesia—
—インドネシア共和国ブカシ県の事例—

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I. Introduction

The suburbs of the main cities in Indonesia have special characteristics because of their high population growth and economic activities. Jakarta had a population of 7.3 million in 1993. Its population growth rate between 1981 and 1993 was 2.3% per year, down from the 3.4% growth experienced between 1969 and 1981. This decline was because Jakarta's suburbs absorbed a disproportionate share of the city's growth. Between 1981 and 1993, suburban population growth continued at 4.3% per year, with a very significant impact on land use.

Jabotabek (the Jakarta Metropolitan Region) is the largest urban agglomeration in Indonesia. It is comprised of the following administrative regions : the Special Capital Region of Jakarta (Jakarta City), the Districts (*kabupaten*), and Municipalities (*kotamadya*) of Bogor, Tangerang, and Bekasi (see Note 1).

Recent studies on Asian urbanization have stressed that the continuing outward expansion of the largest metropolitan regions has eroded the longstanding distinction between rural and urban areas[1,2,3]. This trend has been driven by economic expansion and has resulted in extended areas of mixed land use on city peripheries. McGee[2] argues that there is a distinctively Asian variation of the usual pattern of suburbanization (see Note 2). He calls it a *desakota* region, derived from the Indonesian words for village (*desa*) and city (*kota*). A *desakota* region is a complex entity. It encompasses both the city itself, with typical urban land use, and associated compact and densely settled outlying areas that are closely enmeshed with the urban economy. Rural economics and lifestyles become submerged under the expansion of urban economic activity and culture, but do not disappear altogether[1]. This idea of *desakota* seeks to identify characteristic regions of Asia that are neither urban nor rural, but combine some of the features of both types of region into a continuously changing symbiotic relationship. McGee[2,4] describes *desakota* regions as previously agricultural areas with an intense mix of settlement and economic activity, comprising agriculture, industry, housing development, and other land use.

Many scholars have explained the spatial expansion of various major cities around the world theoretically, including Jakarta, but most have focused on socio-economic structure. A spatial review of suburbanization is needed to better understand and describe spatial expansion. Despite the many studies that describe the suburbanization of Jakarta, there is still no appropriate or practical spatial analysis tool to use to determine whether the processes of urbanization and suburbanization are leading to concentration or deconcentration.

In this study, practical tools and methods are applied to describe the spatial population distribution and changes in land use patterns that are associated with the suburbanization process. The study employs several quantitative spatial descriptions of suburbs in an extended metropolis, using a case study of Bekasi District, one of Jakarta's suburbs.

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Key words : 1) suburbanization, 2) spatial analysis, 3) spatial dispersion, 4) land use mixture,
5) spatial autocorrelation

Figure 1 Study area

Table 1 General description of the Bekasi District and its comparison with Jakarta City

		1969/70 (1975)	1981	1993	growth (%/year) 1969-81	1981-93
Bekasi	Number of desa*	94	161	234	4.7	3.0
	Number of kecamatan*	13	14	22	0.6	3.8
	Total Area (km²)***	1,442.7	1,235.6	1,348.8	-0.9	0.3
	Population (1000)*	794	1,170	2,160	3.3	5.2
	Population density*	551	904	1,601	4.2	4.9
	GDRP (Rp billion)*	500[1]	961	2,941	11.5	9.8
	GDRP/capita (Rp1000)*	630.1[1]	820.8	1,363.1	4.5	4.3
	GDRP/km² (Rp mill)*	346.9[1]	741.8	2,182.7	13.5	9.4
	Urban land ratio(%)***	10.3	11.2	14.2	0.70	2.00
	Rice field land ratio(%)	58.7	62.6	55.8	0.53	-0.95
Jakarta	Number of desa**	220	236	261	0.6	0.8
	Number of kecamatan**	27	30	43	0.9	3.0
	Total Area (km²)***	587.6	657.4	661.3	0.9	0.0
	Population (1000)**	4,107	5,789	7,395	2.9	2.1
	Population density**	6,990	8,805	11,183	1.9	2.0
	GDRP (Rp billion)**	5,931	23,273	50,999	10.8	8.0
	GDRP/capita (Rp1000)**	1,444.1	3,502.2	6,896.5	7.7	5.8
	GDRP/km² (Rp mill)**	10,094.2	30,838.2	77,120.2	9.8	7.9
	Urban land ratio(%)***	31.[illegible]	57.4	82.0	5.16	2.02
	Rice field land ratio(%)**	29.5[2]	18.4[3]	6.9	-3.86	-7.27

Note : All GDRP data is based on a 1993 constant price ; [1] 1975 data, [2] 1968 data and [3] 1980 data

Data sources :

* Central Bureau of Statistics (several years), Statistical Year Book of Bekasi

** Central Bureau of Statistics (several years), Statistical Year Book of Jakarta

*** Measured from land use maps :

BPN (National Land Agency), Land Use Map of Jakarta City (1970, 1993)

Bakosurtanal (National Coordination Agency for Mapping and Surveys), 1 : 25,000 scale Land Use Map, (1981, 1982)

II. A brief description of Jakarta City, and of Bekasi District and its suburbanization

Jakarta City is characterized by the presence of a market dualism between highly 'modern' areas and vast areas of low-income neighborhoods or urban *kampung*[5] (see Note 3). The Jakarta *kampung* are inhabited mainly by rural migrants, who are mostly absorbed by the informal sectors or the margins of the formal sectors of the local economy[6]. There has been a process of systematic demolition of *kampung* in Jakarta for many years, particularly in the central part of the city, forcing many of the former inhabitants to move to other areas. Most of the lower-classes have moved only short distances (intra-city migration), whereas the middle- and upper-classes have tended to escape from the *kampung* areas to more distant and less populated areas. Only the middle- and upper-classes can afford such a move, especially when it is to the suburbs[6] and they become commuters as a consequence. The poor are prevented from moving into the suburbs by the high cost of suburban housing because of legally required minimum standards for structure size, lot size and building methods[7]. Consequently, the outward migration of the middle- and upper-classes dominated the process of suburbanization in the Jakarta Metropolitan Area.

The conversion of rural land to urban use in the suburbs of Jakarta is mainly by land and building development in the private sector, and can be divided into formal and informal private development[8]. Most formal development is carried out by real-estate companies. Informal private development of land takes place around existing *kampung* or urban settlements and along public roads. About 70% of the new construction in Jakarta's suburbs is developed informally by the owner's themselves.

Bekasi District, one of the administrative regions that surround Jakarta City (see Figure 1), covers an area of 1,348.8km². Fast economic and population growth due to industrial, residential, and commercial expansion has led to suburbanization. Table 1 presents information describing Bekasi District and a comparison with Jakarta City. The table describes two periods of development, namely 1969/70 to 1981/82 and 1981/82 to 1993. It contrasts the differences between the two regions, and shows how Jakarta's population and economic growth, although relatively rapid, were slower than those of Bekasi District.

Ⅲ. Variables, measurements and data

1. Basic Variables

In this study, four basic variables are used for analysis, namely : population, urban area, rice field area, and geographical position coordinates, each given in units per desa for three time periods. Population density is used as a measurement of the level of urbanization that indicates both the amount and the type of settlement in an area.

The degree of urbanization may be evaluated in various ways, e.g., socially (by population density and distribution), economically (by monetary and service agglomeration), or spatially (by land use). For example, Chaubey[9] suggests that it can be measured by the proportion of a population that lives in units of habitation that are recognized as urban. In this study, the urban land ratio is proposed as the measurement of urbanization in each village. Urban land ratio is the ratio of the area of urban land use (see Ⅲ.3 for a detailed description of land use categories) to the total area of a village. Since suburbanization is also characterized by land use, the urban land ratio could also be used as a good measurement of suburbanization[10] that directly reflects the level of suburbanization within a region. The *rice field land ratio* is the ratio of the total area of rice field to the total area of a region. The distribution of rice fields in the study area is very significant, since the area serves as one of the centers of rice production in Indonesia. To describe the relative position of each unit of data, spatial variables are applied. In this study, the UTM coordinate system is used to describe such geographical positions.

2. Measurements

Descriptions of spatial distribution patterns can be presented in several ways. Figure 2 shows the population distribution and the changes in patterns of land use, with data from 1969/70, 1981/82, and 1993 for Bekasi District. These figures vary depending on the method of data categorization used. A quantitative evaluation with appropriate parameters and measurements can provide a less ambiguous description because of its unique representation of every distribution pattern.

Geographical descriptions of areal data have usually been in the form of either one or a combination of measurements such as average position, dispersion, and orientation or arrangement[11]. Descriptions of the spatial patterns of geographical data are generally related to a combination of parameters. In this study, they are adopted to describe the population and land use distribution patterns shown in Table 2. Each geographical position in this study (X, Y) is measured as the relative position of the centroid of each *desa* (village) to the center of Jakarta City, represented by the National Monument (*Monas*)[10].

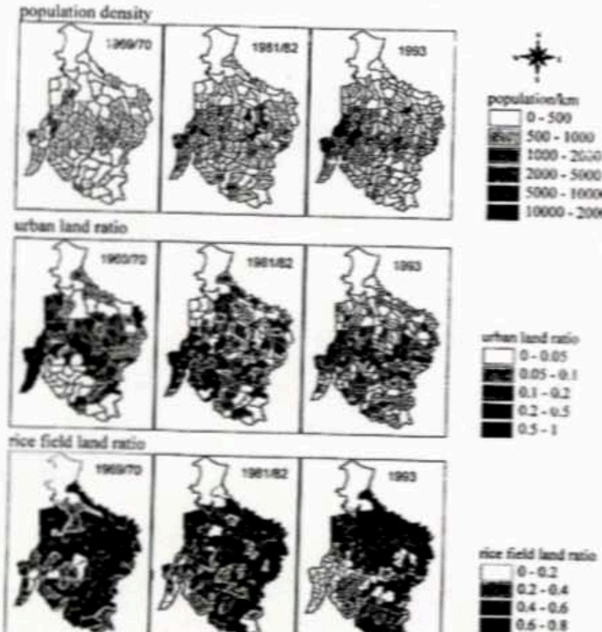

Figure 2 Spatial distribution of population, urban land ratio and rice field land ratios.

(1) Average position

The average position is a pair of spatial coordinates that provides the point presumed to be the most representative of a phenomena. In this study, two measurements of average position, namely, the median center and the spatial mean, are applied. The median center is defined as the intersection of two perpendicular lines, each of which divides the point pattern into halves. The spatial mean is obtained as an ordered pair that takes into account the position of the centroid of each region and the weight associated with the centroid[12].

(2) Orientation and dispersion

The movement of the spatial mean can indicate concentration or dispersion of suburbanization. Movement toward the city center indicates concentration, while movement away from the city center indicates dispersion. The distance between the location of one year's spatial mean and that of another year, divided by the time interval, indicates the rate of the process of concentration or dispersion.

The standard distance is the square root of the average squared distance from the center, meaning that it measures the dispersion of the data around the data's center. Dispersion refers to the proximity of the groups to the center. However, dispersion is often greater in one direction than another, and the standard distance is unable to reflect this phenomenon because it is a single value. A more precise measure of dispersion is Lefever's standard deviational ellipse[13], which reflects not only the conditions of dispersion, but also the orientation. The orientation can be determined as the maximum (longest) axis of Lefever's standard deviational ellipse that is angled from the X-axis.

Table 2 List of spatial pattern measurements and formulate

	Measurement		Formulate
Average location	1. median center	Xm Ym	$Xm=\frac{1}{2}(X_{max}+X_{min}),\ Ym=\frac{1}{2}(Y_{max}+Y_{min})$
	2. spatial mean[1,2]	$\overline{Xw}$, $\overline{Yw}$	$\overline{Xw}=(1/\sum_i^n wi)\sum_i^n wiXi,\ \overline{Yw}=(1/\sum_i^n wi)\sum_i^n wiYi$
Orientation and dispersion	1. spatial mean movement[3]	Vw, α_{wT1T2}	$Vw=\frac{1}{T2-T1}\sqrt{(\overline{XwT2}-\overline{XwT1})^2+(\overline{YwT2}-\overline{YwT1})^2}$, $\tan\alpha_{wT1T2}=(\overline{YwT2}-\overline{YwT1})/(\overline{XwT2}-\overline{XwT1})$
	2. spatial standard distance[4]	Sw_x Sw_y Dw	$Sw_x=\{(1/\sum_i^n wi)\sum_i^n wi(Xi-Xc)^2\}^{1/2}\quad Sw_y=\{(1/\sum_i^n wi)\sum_i^n wi(Yi-Yc)^2\}^{1/2}$, $Dw=\sqrt{Sw_x^2+Sw_y^2}$
	3. standard deviational ellipse[5]	θ_m	$\tan\theta_m=\frac{1}{2B}(-A\pm\sqrt{A^2+4B^2})$, where $A=\sum w_iX_i'^2-\sum w_iY_i'^2,\ B=\sum w_iX_i'Y_i'$
	4. relative entropy of dispersion	Hw	$Hw=-\left(\frac{1}{\log n}\right)\left(\sum_i^n p(wi)\log p(wi)-\sum_i^n p(wi)\log\frac{n.Ai}{A}\right)$
Land use mixture	1. mixture index[6]	C_w	$C=\frac{4}{A}\sum_i^n Ai(\lvert 0.5-\sigma_i\rvert-0.5)(\lvert 0.5-\tau_i\rvert-0.5)$
	2. relative entropy of mixture[7]	H_m	$H_m=-\frac{1}{\log 2}\sum_i^n\frac{u_i+r_i}{A_i}\left(\frac{u_i}{u_i+r_i}\log\frac{u_i}{u_i+r_i}+\frac{r_i}{u_i+r_i}\log\frac{r_i}{u_i+r_i}\right)$
Spatial auto-correlation	1. Moran's I index[8]	I_n	$I=\frac{n}{\sum\sum d_{ij}}\frac{\sum\sum d_{ij}(Z_i-\overline{Z})(Z_j-\overline{Z})}{\sum(Z_i-\overline{Z})^2}$
	2. Geary's index	C_n	$C=\frac{n-1}{2\sum\sum d_{ij}}\frac{\sum\sum d_{ij}(Z_i-Z_j)^2}{\sum(Z_i-\overline{Z})^2}$

[1] (X_i, Y_i) is the geographical position of the center (centroid) of area i
[2] W_i: weight (population P, Urban area U and rice field, r)
[3] $\alpha=0°$ or $360°$: east; $\alpha=90°$: north; $\alpha=180°$: west; $\alpha=270°$: south
[4] (X_c, Y_c): position of the center (Jakarta's main road exit point or spatial mean), (SW_x, SW_y): spatial standard distance for X and Y axis, and Dw is spatial standard distance
[5] (X_i', Y_i') is a relative geographical position to the spatial mean or Jakarta's main road exit point
[6] σ_i and τ_i are the urban land ratio and rice field land ratio of unit area i;
[7] u_i: urban area and r_i: rice field area of unit area i
[8] Z_i is variable of population, urban land ratio, or rice field land ratio of unit area i, where $\overline{Z}$ is average. Z_j is the variable of an adjacent unit area of i; d_{ij} is the weight for the relation between polygon (area) i and j

Both the standard distance and the standard deviational ellipse are measurements that refer to a single center. When there is more than one center, an entropy method is more appropriate for concentration or dispersion measurements. Shannon's entropy is a measure of discrete probability distribution[14]. It is often termed the amount of uncertainty in a set of probabilities. Its value is the average value expected for information contained in a single message to confirm the occurrence of one of a defined set of events[15]. However, many scholars have offered much broader interpretations such as a measure of dividedness[16], and of the degree of spatial dispersion or spatial concentration[15,17]. In this study, an entropy formula appropriate for regions of unequal size is used to determine the diversity value.

(3) Land use mixture

In order to identify *desakota* regions as complex entities, a measurement of the mixture of land use is proposed. The mixture of land use in a *desakota* identifies the degree to which the rural economy and way of life has been submerged beneath an urban economy and culture. From a geographical viewpoint, this mixture in a *desakota* region can be shown by the mixture of agricultural and urban land uses. A new formulation is proposed as a measure of this mixture. A specific entropy formulation is also employed to describe this mixture.

(4) Spatial autocorrelation

There is spatial autocorrelation whenever a variable exhibits a regular pattern over space, in which its value at one set of sites depends on the values of the same variable at other sites[18]. Like entropy, spatial autocorrelation can be interpreted to indicate concentration or dispersion without referring to any single center. There are a number of ways to calculate spatial autocorrelation. Moran's I and Geary's c are the most popular measurements for continuous variables[18].

3. The Data

Land use data and other socio-economic data for Bekasi District were collected for three separate years (1969/70, 1981/82 and 1993). The scale of the 1969/70 land use maps is 1 : 50,000, whereas the maps for 1981/82 and 1993 are on a scale of 1 : 25,000. The boundaries of the *desa* on all of the maps were digitized and analyzed using GIS software. In this study, the BPN (National Land Agency) and *Bakosurtanal* (National Coordination Agency for Mapping and Surveys) land use categorizations are applied[10]. The land use categories that fall under the heading 'urban' in this study are *kampung*, other settlements (real-estate), buildings, industries, storage, and cemeteries.

Ⅳ. Results and discussion

Spatial analysis shows that the spatial distribution of the population and land use in the study area have changed systematically (see Table 3). Visualization of the distribution of the three years' data is shown in Figures 3, 4 and 5. Figure 3 shows the changes in the spatial mean for population and land use distribution, while Figure 4 shows the deviational ellipse of population and land use distribution referring to two centers ; the spatial mean and the exit point of Jakarta's main road. Figure 5 shows the mixture of urban land use and rice field measured by two indices.

According to spatial pattern analysis, statistical information and the results of many previous studies, three stages can be identified in the development of suburbanization. These stages were determined by (1) the characteristics of the spatial distribution patterns of the population and of urban and rice field areas ; (2) the trend of in- and out-migration between Jakarta and its suburbs ; and (3) comparison of population and economic growth rates between Jakarta and

Table 3 Results of spatial population and land uses distribution measurements

	Measurement		Unit	1969/70	1981/82	1993
Average location	1 median center (Xm, Ym)		-	(27.7, -6.0)		
	2 spatial mean	pop ($\overline{Xp}$, $\overline{Yp}$)	km	(30.1, -7.3)	(28.2, -7.7)	(25.6, -7.9)
		UL ($\overline{Xu}$, $\overline{Yu}$)	km	(28.6, -7.1)	(26.7, -9.0)	(29.2, -8.4)
		RF ($\overline{Xr}$, $\overline{Yr}$)	km	(33.9, -6.6)	(33.4, -5.6)	(33.5, -5.4)
Orientation and dispersion	1 spatial mean movement	pop. Vp, α_p	km/yr. degree	0.16, 191.1°		0.21, 184.4°
		UL. Vu, α_u	km/yr. degree	0.22, 225.0°		0.21, 13.5°
		RF. Vr, α_r	km/yr. degree	0.09, 116.6°		0.02, 243.4°
	2 standard distance from JMREP	pop (Sp_x, Sp_y), Dp	km	(17.6, 13.4), 22.1	(16.2, 13.1), 20.8	(14.2, 12.3), 18.8
		UL (Su_x, Su_y), Du	km	(17.0, 12.8), 21.3	(15.2, 14.2), 20.8	(16.8, 13.1), 21.3
		RF (Sr_x, Sr_y), Dr	km	(19.4, 14.0), 23.9	(20.5, 13.5), 24.5	(19.7, 14.2), 24.3
	from spatial mean	pop (Sp'_x, Sp'_y), Dp'	km	(10.2, 10.1), 14.4	(10.6, 20.4), 23.0	(10.2, 8.0), 13.0
		UL (Su'_x, Su'_y), Du'	km	(11.1, 9.5), 14.6	(10.5, 9.3), 14.0	(10.1, 8.6), 13.3
		RF (Sr'_x, Sr'_y), Dr'	km	(9.7, 11.5), 15.0	(10.6, 11.5), 15.6	(8.6, 12.5), 15.2
	3 standard dev. ellipse from spatial mean	pop. Xmax. (θ)	km. degree	13.7, 41.3°	12.9, -68.0°	11.7, 13.7°
		Xmin. (θ)	km. degree	10.1, -48.7°	4.3, 22.0°	1.9, -76.3°
		UL. Xmax. (θ)	km. degree	17.3, 17.0°	2.3, 85.7°	13.3, -81.0°
		Xmin. (θ)	km. degree	1.8, -73.0°	14.2, -4.3°	5.2, 9.0°
	from JMREP	pop. Xmax. (θ)	km. degree	22.1, -30.7°	20.7, 57.1°	16.1, 53.6°
		Xmin. (θ)	km. degree	10.3, 59.3°	11.4, -32.9°	15.9, -36.4°
		UL. Xmax. (θ)	km. degree	21.2, -49.7°	19.8, -40.4°	19.3, -33.5°
		Xmin. (θ)	km. degree	8.8, 40.3°	3.3, 49.6°	16.7, 56.5°
	4. relative entropy of dispersion	pop Hp^*	-	0.9632	0.9625	0.9055
		UL Hu^*	-	0.9089	0.9240	0.9314
		RF Hr^*	-	0.9628	0.9143	0.9681
Land use mixture	1 mixture index	Cur^*	-	0.1017	0.1298	0.1046
	2 rel. entropy of mixture	Hur^*	-	0.3643	0.4070	0.3729
Spatial auto-correlation	1 Moran's I index	Pop. I_p	-	0.2516	0.3436	0.6152
		UL. I_u	-	0.5091	0.3164	0.4453
		RF. I_r	-	0.4666	0.3591	0.6497
	2 Geary's c index	Pop. C_p	-	0.6707	0.7520	0.3717
		UL. C_u	-	0.4970	0.7586	0.5883
		RF. C_r	-	0.5425	0.5895	0.3285

* The location of the *Monas* (0,0) is located at 06°49'32"E and 06°10'30"S or 702163mT and 9317088mU.
** JMREP : Jakarta's main road exit point ; pop : population ; UR : urban land ; and RF : rice field

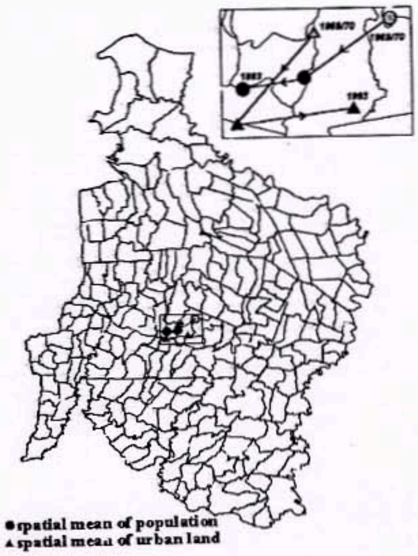

Figure 3 The movement of spatial means

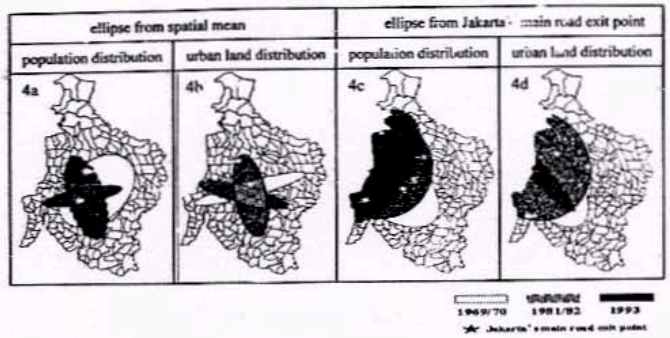

Figure 4 Deviational ellipses of population and urban land distributions reger to its spatial mean and Jakarta's main road exit point

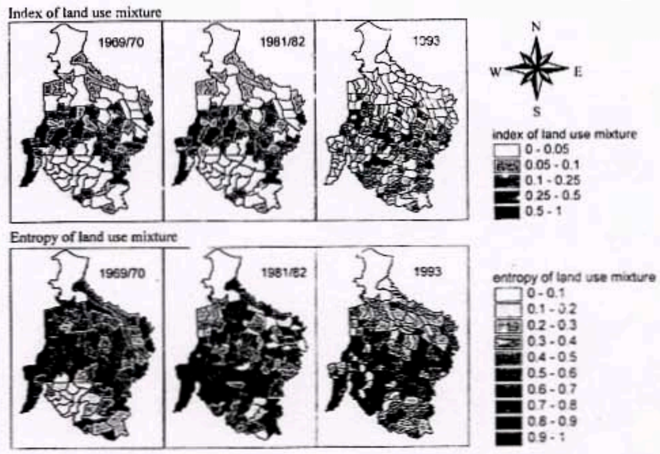

Figure 5 Spattial land use mixture between urban land and rice field measured by two indices

Bekasi District.

1. The stages of suburbanization

(1) Pre-suburbanization stage (before 1970)

The Population Census of 1930 for the city of Batavia (Jakarta City) shows that 51 % of the population of 325,978 were born elsewhere (in-migrants). The Population Census of 1971 shows that in 1970, 32.8% of total national migration was to Jakarta, of which 80% came from rural areas. Migrants were driven to leave their villages and move to the city by the expectation of a better income[19]. Indigenous inhabitants dominated the population of Bekasi District until 1970, and the study area was a typical agricultural region. Jakarta's surrounding areas, including Bekasi District, were the major origins of Jakarta's in-migrants, making the net migration of the Bekasi District negative (out-migration outpaced in-migration)[20]. At this stage, the population and economic growth rates of Jakarta were higher than those of its suburbs. The urbanization process had not yet expanded far beyond Jakarta's borders.

The population density of the study area was relatively low and the spatial distribution was relatively dispersed. The average position of the population distribution from Jakarta's center (X_p, Y_p) was farther than the average for urban land (X_u, Y_u). A relatively dispersed spatial population distribution is shown by the wide standard distance from the spatial mean (Dp), the size of the big ellipse, the small difference in length between the major and the minor axes of the ellipse from the spatial mean (see Figure 4a), and the tapering shape of the ellipse from the exit point of Jakarta's main road (see Figure 4c). Spatial interaction was relatively low, and the population's spatial autocorrelation was positive, but low (I_p and c_p).

Urban land distribution was relatively less dispersed than the distribution of population. The long ellipse is the consequence of the distribution in an urban area along the main road in a west to east direction (see Figure 4b). The spatial mean of the rice field distribution is further from Jakarta City than the population and urban land distributions (X_r and Y_r) and is relatively dispersed (Hr, I_r and c_r), although not as dispersed as the population distribution.

(2) The first stage of suburbanization (1969-1982)

Between 1970 and 1981, urban expansion spread beyond Jakarta's boundaries toward Bekasi District as the process of suburbanization developed. The population increased by almost 48% in 12 years, from about 794,000 in the year 1969/70 to about 1,170,000 in 1981/82. This high population growth (3.3% per year) outpaced Jakarta's population growth, especially during the years from 1975 to 1980. Jakarta's economic growth was 10.8% per year during this period, while growth in Bekasi District was 11.5% per year. Economic attraction made Jakarta the preferred destination of migrants; its suburbs, including the area studied, subsequently tried to be more attractive to migrants. Between 1971 and 1980, the highest population growth rates in Indonesia are found in Jakarta's suburbs, especially in Depok Administrative Municipality (12.3% per year) and Bekasi District (10.0% per year)[21].

The spatial mean and the orientation of the distribution of population moved westward (X_p, Y_p), reflecting the high population growth around Jakarta's borders. In the same year, it is evident that the population became more concentrated, since the size of the population's deviational ellipse from the spatial mean grows smaller (see Figure 4a), the entropy of concentration becomes lower (Hp) and spatial autocorrelation increases (Ip). Changes in the shape of the deviational ellipse (see Figure 4b) indicate the process of concentration towards Jakarta City.

As the population increased, the amount of urban land use also increased to fulfill housing demands. Therefore, the urban land use distribution becomes somewhat similar to the distribution of population, located closer to Jakarta City. The average position moves in a similar direction to that of the average position of the distribution of population, but moves at a higher rate than the population. Concentration measurements assuming a single center (standard distance and deviational ellipse) show that urban land use distribution has become more concentrated since 1969. On the other hand, other measurements of concentration/dispersion that do not assume a single concentration center (the entropy of dispersion and spatial autocorrelation indices), show an opposite pattern. These results indicate mixed patterns of urban land concentration/dispersion during this period.

During this suburbanization, the government intensified programs to increase rice production by improving the irrigation systems and other infrastructures needed to develop one of the prime rice-producing centers in the country. This increased the area of rice field from about 55% to 63% of the total study area. However, the average position of rice field distribution showed relatively no change. Due to the significant increase in both urban areas and rice field, the land use mixture reached a peak.

(3) The second stage of suburbanization (between 1981 and 1993)

The period between 1981 and 1993 was characterized by significant increases in population and urban land ratios, and by a decrease in the amount of rice field through conversion to urban and other uses. Demand for housing was no longer the dominant feature in the expansion of urban land. The study area had become one of the main areas for industry and for the development of less dense single-family houses (real-estate-type settlements). The proportion of industrial workers increased due to the influx of migrant workers, while a number of farmers sold their land and left for more remote areas, especially the Karawang District[22,23,24]. During this period, the population and economic growth of Bekasi District outpaced those of Jakarta (Table 1). The population growth increased to about 5.2% per year, while that of Jakarta decreased from 2.9% to 2.1% per year. According to the 1990 statistics for Jakarta City, and in spite of relatively high population growth, the amount of out-migration outpaced the amount of in-migration. According to the 1990-1995 BPS survey[21], this gap between out-migration and in-migration for Jakarta City widened. In the period 1990-1995, out-migration exceeded 823,000 (9.0% of Jakarta's population), while in-migration was 594,000 (6.5%). Throughout this period, the population growth for Jakarta City was 2.1% per year, down from the 3.1% growth experienced in the previous decade[23]. Despite steady overall growth in the population of Jakarta City, Central Jakarta District experienced negative growth (-1.4%) in the period 1980 to 1990, while the population of Jakarta City's other districts continued to increase. The decrease in population in the center of Jakarta indicates a process of out-migration[6].

The movement of the average position of the population to the southwest toward Jakarta between 1981 and 1993 was simply a continuation of the trend seen in the previous period, but at a faster rate. This movement is a strong indication of the population concentration pattern. Several parameters hint at this concentration, namely, a smaller relative entropy of concentration, a stronger spatial autocorrelation, smaller standard distances, and a smaller standard deviational ellipse from the spatial mean (see Figure 4a). In-migration was a significant factor in Bekasi District's population growth. Most of these in-migrants came from Jakarta City, looking for better and cheaper housing, while they still worked in Jakarta City[24]. Another study estimated that about 50% to 62% of the local labor force in Bekasi District was commuting over the district boundary[25]. These trends indicate that the process of population distribution was a direct continuation of Jakarta's outward population expansion, whereas the process of expansion of urban land use was not.

The urban land distribution moves away from Jakarta City because of the development of new industrial estates and less dense single-family housing. Urban land use became concentrated in several new local centers away from Jakarta. As the standard deviation grows smaller, the relative entropy of concentration becomes larger, and spatial autocorrelation becomes stronger. This indicates that the expansion of urban land use in the study area did not originate solely from increasing population, but was also due to industrial activity and to the rapid development of new single-family housing. The study area had become one of the prime locations for new industrial activity. Furthermore, many new areas of spacious real-estate-type housing have never become populous areas because of the domination of single-family houses, and because many are exclusive residential areas for the middle- and upper-classes. Additionally, many houses remain unoccupied, having been purchased not for occupation, but as low-risk investments or even for speculative purposes as land prices continued to increase[22]. Henderson, *et al.*[26] explained the increase in the concentration of manufacturing in Jakarta's suburbs and called this process

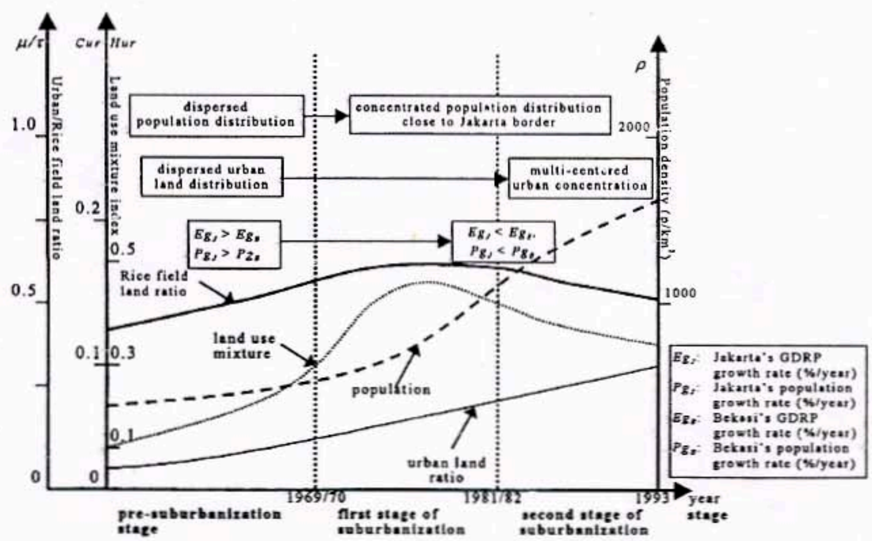

Figure 6 Suburbanization stages of Bekasi District.

the "suburbanization of industry".

Because a number of rice fields were converted to other uses, especially urban, the land use mixture between urban and rice field decreases. The expansion of industrial activity and real estate development in Bekasi District has decreased the spatial mixture of urban activities with rice farming activity.

2. General trend of spatial pattern changes

Based on the spatial analysis results above, statistical data and the general theory on urbanization process[27,28], the general trend of the development of suburbanization process in Bekasi District can be described in contiguous curves. Figure 6 shows a general description of the stages of suburbanization in Bekasi District. Like the common urbanization level curve[27], the population growth of Bekasi District follows an S-shaped curve, building up very slowly and then expanding very quickly before slowing down or even reversing slightly. The urban land ratio curve shows a similar shape, after a time lag behind the population growth curve. On the other hand, the rice field land ratio and land use mixture curves are bell-shaped. The peak of the curve of the rice field land ratio is reached earlier, and is followed by the land use mixture curve. The land use mixture reaches a peak when the population and urban land use are expanding quickly.

The pre-suburbanization stage of Bekasi District was characterized by a dispersed population of relatively low density and a low level of both urban and rice field land ratios. Bekasi District was a typical region, where traditional rural and agricultural activities predominated. The population and economic growth rates of Bekasi District lagged far behind those of Jakarta. Since 1969, the development of rice production has played an important role in the regional economy. Bekasi District and other northern coastal areas of Java became the most rapidly developed agricultural regions as policies to develop agriculture were implemented through various programs intended to improve food crop production. Because of these programs to increase rice production, both the total area of rice field and the proportion of rice fields irrigated increased. Meanwhile, as the suburbanization process continued, the expansion of Jakarta beyond its boundaries toward Bekasi District began. The increases in both rice field and urban land ratios indicate their impact on the increase of the level of land use mixture in Bekasi District. This phenomenon characterized the first stage of suburbanization in Bekasi District. The second stage of suburbanization was characterized mainly by : (1) the continuance of population agglomeration in areas closest to Jakarta City, (2) the emergence of new, local, and less-dense urban concentration in several areas relatively distant from Jakarta, (3) a decrease in rice field land ratios, due to a shift toward urban activity, and (4) a decrease in the mixture of land use between urban land and rice fields.

V. Concluding Remarks

This study described changes in the spatial distribution of population and in land use patterns in Jakarta's suburb, Bekasi District. Three stages of suburbanization in Bekasi District were identified by spatial analysis. The statistical information revealed that the urban development of Bekasi District was mostly as a result of out-migration from Jakarta, first by the expansion of *kampung*-type housing in the area closest to Jakarta's boundaries, and then through the development of real-estate-type housing and industry.

The quantitative spatial measurements used in this study were able to show how fast, how far, how disperse, how complex, and in which direction changes occurred. These quantitative measurements were able to provide more objective, less ambiguous results, and to contribute to a better understanding of these suburban phenomena. This method can therefore be the basis of an effective approach to further spatial analysis studies in various areas.

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Notes

1. Indonesia is administratively divided into 27 provinces. A province is subdivided into several districts. There are three types of districts : *kabupaten* (district), *kodya* (municipality), and *kota administratif* (administrative municipality). A district is subdivided into several *kecamatans* (subdistricts), and a kecamatan consists of several *desas or kelurahans* (villages)

2. Urbanization refers to the population increase in cities or towns through migration from rural areas because of social and economic changes[28]. Suburbanization is defined as the creation of residential areas, and to some extent industry, at the edge of the city[28,29].
3. *Kampung* in Indonesian literally means village. It is broadly used in reference to any unregulated and popular settlement.

Ⅰ　緒論

インドネシア最大の都市圏域であるJabotabek地域は，ジャカルタ市及びボゴール，タンゲラン，ブカシの各県（市部及び郡部）からなり，急激な人口増加及び経済成長の下で，ジャカルタ市の肥大化とそれに伴う周辺域の都市化が顕著な地域として様々な地域問題を抱えるに至っている。こうした大都市及びその周辺域の都市化現象を説明するための理論的研究は多いが，これを空間的パターンの問題として捉え，実用的かつ適切な空間的指標を利用して定量的に評価した研究はこれまでのところみあたらない。本研究は，Jabotabek地域の中でとくにジャカルタ市の郊外地域として都市化進展の著しいブカシ県を対象として，人口増加及び土地利用変化を分析するための空間分析指標を提示し，いくつかの分析を試みたものである。

Ⅱ　ブカシ県の概要とその都市化進行過程

ブカシ県（面積1,348.8㎢）はジャカルタ市の東部に隣接する地域（図１）で，ジャカルタ市の発展の影響を大きく受け，様々な地域問題の緩衝ゾーンとして機能している。本地域は，インドネシアの他の大都市及びその周辺域に比較して経済成長が急激で土地利用も複雑に錯綜し，これらに関するデータ整備状況も良好なことから調査対象地域として選定された。本研究では，ブカシ県の３カ年（1969/70年，1981/82年，1993年）の土地利用及び他の社会経済データを収集し，分析に供した。

表１は，ブカシ県及びジャカルタ市の２期間（1969－81年，1981－93年）における地域発展を表す諸指標を整理したもので，ジャカルタ市の人口及び経済成長が鈍化し，それに比べて郊外地域の成長が急展開している様子が読みとれる。

McGee[1]は，アジアの大都市及びその周辺域の都市化過程にはアジア型ともいえる独特のパターンが存在するとし，その地域を「desakota地域」と名付けている（インドネシア語で，desaは村，kotaは都市の意）。「desakota地域」は，都市と農村の複合体であり，農村部での都市化が進んで農村経済や農村の生活様式が薄れてはいくが，それがなくなることはない。都市文化と農村文化が共存するハイブリッド地域であり，インドネシア及び東アジア諸国の社会経済の発展過程及びそれに伴う土地利用変化の概念形成の新しい枠組みを与えるものである。このようなアジアにおける特徴ある地域の都市化過程を，実用的な指標を利用して説明することが本研究の目的である。

Ⅲ　空間的パターン分析のための指標

地域事象の空間的分布パターンを表示する方法にはいろいろある。主題図が一般によく用いられるが，データのカテゴリー化の方法によってアウトプットも変わりうる。例えば，図２はブカシ県の人口分布と土地利用を異なる３時点について表したものであるが，これらの図は人口や土地利用率をどのカテゴリーで表すかによって異なり，場合によっては異なる解釈が得られる。これに対して，適切なパラメータないし指標を利用して空間的分布パターンを評価する方法が有用である。以下では，いくつかの基本変数を用いて展開される空間的分布パターンを表す指標を提示する。

1　基本変数

地域事象の空間的分布パターンを表す指標を構築する上で基本となる変数として，(1) 人口（P）と人口密度（ρ），(2) 都市的土地利用率（σ），(3) 水田面積率（τ），(4) 地理的位置（ＵＴＭ座標）を利用する。

2　空間的分布パターンを表す指標

より定量的な人口分布及び土地利用変化を記述するための指標として，表２に示すパラメータを用いて対象地域の空間パターンの分析を行う。これらは以下に示す４群の指標に整理される。

(1)　平均位置

部分地域の地理座標の中央値（Xm，Ym）と対象重み付き平均値（Xw，Yw）によって，地

域全体の空間的平均位置（重心）を推定する。

(2) 地域発展の方向と分散度

2時点間の空間的平均位置の移動速度（Vw）とその方向角（$\alpha w_{(t_1t_2)}$）によって地域の発展状況が，また標準距離（Dw：各部分地域の平均位置からの平均距離）によって地域の分散状況が推定される。さらに，地域発展の分散程度は方向に依存することから，Lafeverの標準偏差楕円[9]の長径，短径，方向角（A，B，θm）がより適切な分散指標となる。地域全体における事象の分布程度は，Shannonの情報エントロピーを基本とした相対的分散エントロピー（Hw）を利用することによっても解釈することができる[11),13)]。

(3) 土地利用混在度

対象地域の土地利用混在度を表す指標として，混在度（C）と相対的混在エントロピー（Hw）を提示する。これらの2指標は，対象地域で重要な二つの土地利用である都市的土地利用と水田のみに着目して構築した新指標である。

(4) 空間的自己相関

人口や土地利用の部分地域間の関連性を評価するために，MoranのI指数及びGeary指数を使用する。

Ⅳ 結果及び考察

ブカシ県の3時期（1969/70年，1981/82年，1993年）について，上記指標及びGISを用いて都市化過程の空間的パターンの分析を行った結果を表3及び図3～5に示す。

1 大都市周辺域の都市化の段階

(1) 都市化進展の開始以前期（1969/70年以前）

1970年以前はブカシ県の人口は少なく，しかも分散していて，ジャカルタ市との空間的相互作用もそれほど顕著ではなかった。都市的土地利用分布は人口分布に比較して分散が小さく，西から東へ延びる幹線道路沿いに集まっている。水田の平均的位置もジャカルタ市遠方にずれ，その分散は都市的土地利用よりは大きくなっている。

(2) 都市化第1期（1969/70年～1981/82年）

ジャカルタ市の発展・拡大と共に対象地域の都市化が始まり，1981/82年の人口は1969/70年の約1.5倍に急増した。人口の重心は西へ移動し，その標準偏差楕円の形状も小さくなり，ジャカルタ市へ向かった人口集中が表されている。これに伴って都市的土地利用が増大し，その分布変化も人口と同様の動きを示した。その一方で，灌漑施設の整備により水田面積が増加した結果，都市的土地利用と農業的土地利用の混在化がピークに達した。

(3) 都市化第2期（1981/82年～1993年）

本期におけるブカシ県の人口増加及び経済成長はジャカルタ市のそれを上回り，人口密集化がジャカルタ市寄りに進む一方で，ジャカルタ周辺域での新たな工業団地の開発や核家族化に伴う住宅需要の増大により，都市的土地利用はジャカルタ市東方へ展開していった。また，ジャカルタ市からの人口移動に伴い，ブカシ県内にいくつかの小さな中心地が成長し，多極分散型の都市化の過程が展開してきた。これに伴い，水田が都市的土地利用に転換されてその面積が減少した結果，都市的土地利用と農業的土地利用の混在度が低下した。

2 空間的パターン変化の一般的傾向

図6は，対象地域の都市化過程の空間分析結果から，都市化に伴う空間的パターンの変化の傾向を整理したものである。初期のジャカルタ市の急成長，その延長としてのブカシ県への都市化の波及，それに続くブカシ県での多極型の都市化成長の過程が表される。

Ⅴ 結論

本研究は，ジャカルタ市に隣接するブカシ県の都市化に伴う人口分布及び土地利用の変化について，空間的パターンを表すいくつかの指標を用いてより定量的かつ科学的に説明することを試みたものである。これらの指標を利用して，都市化の速度，方向，範囲，分散度，複合性等がより客観的に評価でき，大都市周辺の都市化現象を的確に把握するばかりでなく，こうした地域の土地利用計画策定においても有用な地理情報を提供することができる。

Key Words：1)都市近郊地域の都市化，2)空間分析，3)空間分布，4)土地利用混在度，5)空間的自己相関

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