Land Cover Change and Urban Greenery Prediction in Jabotabek by using Remote Sensing

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ABSTRACT

The tremendous growth of population and physical development in the largest urban agglomeration in Indonesia - the Jakarta Metropolitan Region, also known as Jabotabek (Jakarta, Bogor, Tanggerang, Bekasi) - has created many environmental problems, such as land use conversion, increasing urban temperature, water and air pollution, intrusion of seawater, and flooding. These problems have become more serious as the urban green space (trees, shrubs, and groundcovers) has decreased rapidly with the urbanization process. Urban green space directly benefits the urban environment through ameliorating air pollution, controlling temperature, contributing to the balance of the hydrological system, and providing space for recreation and relaxation. Because there is little hard data to support the claim of decreasing greenery in Jabotabek, it is necessary to measure the amount of urban green space. This paper describes the spatial analysis of urban green space within Jabotabek through the use of a geographical information system (GIS).

We used GIS and remote sensing to determine land cover change and predicted greenery percentage. Interpretation of Landsat data for 1972, 1983, 1990, and 1997 showed that Jabotabek has experienced rapid development and associated depletion of green open space. The proportion of green open space fell by 23% from 1972 to 1997. We found a low percentage of urban green space in the center of Jakarta but a high percentage in fringe areas. The amount of greenery is predicted by the Ratio Vegetation Index (RVI) model: predicted greenery (%) = [146.04] RVI - 134.96. We consider that our result will be useful for landscape planning to improve the environment of Jabotabek.

Key Words : Urbanization, Urban green space, Landsat, Vegetative indices, RVI model

I. INTRODUCTION

According to the United Nations, only 30% of the world's population lived in cities in 1950. This proportion increased to nearly 50% in 2000, and is projected to reach 60% in 2025 (Breuste *et al.*, 1999). The escalation of urbanization is dramatic in the developing world, where the number of urban dwellers has increased more than fourfold since 1950. This phenomenon is also evident in countries of Southeast Asia, which are the most populous among tropical countries. By the end of the 20th century, the urban population in Indonesia was increasing rapidly particularly in the largest urban

agglomeration, the Jakarta Metropolitan Region, also known as Jabotabek (Jakarta, Bogor, Tanggerang, Bekasi). In 1990, more than 75% of the Jabotabek population resided in urban areas (Central Board for Statistics, 1990). The population growth here, in the center of economic growth and national development, has led to the expansion of urbanization in Jakarta and adjacent areas.

This unprecedented escalation in the pace of urban development has significantly affected humanity's relationship with greenery and nature. It is obvious from some studies that for a long time cities have been perceived as unnatural places with no rewarding ecological features (Maurer *et al.*, 2000). Human activity has a marked impact on the development of the urban landscape. Rapid urbanization and industrialization in Jabotabek have caused serious environmental problems, including land use conversion, increasing urban temperature, water and air pollution, intrusion of sea water, flooding, and much more. Firman (1994) reported that the socioeconomic development in Jabotabek has caused serious environmental problems in the region. These problems have become serious as the urban green space (trees, shrubs, and groundcovers), which directly benefit the urban environment, has decreased rapidly with the urbanization process.

Urban green space and the related green elements of the urban environment have conventionally been associated with quality of urban life and play an important role in improving city living conditions (Mitchell, 1985; Kuchelmeister, 1993; Stiratt, 1985). Arguably, they are an integral component of urban infrastructure. Studies have shown that trees reduce summer air conditioning demand and increase the winter heating load (McPherson, 1997); reduce the effects of particulate pollution (Becket *et al.*, 1998); and enhance nature conservation, urban recreation, and nature experience in the city (Maurer *et al.*, 2000). Increasing awareness of the importance of green open space in urban areas leads to the question of whether cities and towns have enough space for more trees (Stirrat, 1985; Atwell 2000).

The study of urban green space in Jabotabek has been neglected. Comprehensive information on vegetation is very limited in many cities (Nowak *et al.*, 1996), including Jakarta. Little quantitative analysis of urban green space has been conducted, although some research has been conducted in Jabotabek for economic analysis (Firman, 1994), rural urban relationships (McGee, 1991), sustainable development (Douglass, 1998), cultural analysis (Leaf, 1996), regional planning (Prasetyo *et al.*, 1996; Rustiadi, 1999), and transportation (Sasono, 2000).

During the last 25 years, remotely sensed data have been used extensively to monitor environmental change, to map land cover, and to monitor urban expansion (Kawamura *et al.*, 1998; Jim, 2000; Baban and Yusof, 2001). Remote sensing technologies have also been used to measure urban green space (Nowak, 1993). This paper describes the results of a quantitative analysis of green open space by using satellite data and aerial photographs of Jabotabek.

II. METHODS

1. Study Area and Data Sources

Jabotabek comprises 7 areas within 3 provinces. The first province is Jakarta (Daerah Khusus Ibukota). The second is West Java Province, consisting of the municipalities of Bogor and Bekasi, and the districts of Bogor and Bekasi. The third is Banten Province, which before 2001 used to be a region of West Java Province, and comprises

the municipality of Tanggerang and district of Tanggerang. This metropolitan region, covering an area of about 6752 km^2, is the largest urban agglomeration in Indonesia. The study area is situated along the northern coast and mountainous western part of Java. The altitude varies from 0 to 3000 m. Three types of landform exist: the northern lowlands of the coastal plain along Jakarta Bay, the central plateau, and the southern uplands and mountainous areas.

Landsat MSS image data for 1972 and 1983 and Landsat TM data for 1990 and 1997 (Table 1) were sourced from the Tropical Rain Forest Information Center (Michigan, USA), a NASA's Federation of Earth Science Information Partners. Land use maps for 1990 (scale 1:25,000), used for geometric correction of the images, and aerial photographs for 1993 (1:50,000) were obtained from the National Coordination Agency for Surveys and Mapping (Bakosurtanal), Jakarta, Indonesia. GIS data set was sourced from National Land Bureau (BPN), Jakarta, Indonesia.

Table 1. Composition of Landsat data for Jabotabek areas

Type and year	Path	Row	Acquisition
MSS, 1972	131	64	1 Oct 1972
	131	65	1 Oct 1972
MSS, 1983	122	64	14 Jul 1983
	122	65	14 Jul 1983
TM, 1991	122	64	25 May 1991
	122	65	25 May 1991
TM, 1997	122	64	12 Jul 1997
	122	65	28 Jul 1997

2. Quantitative Analysis of Land Cover Change and Prediction of Urban Green Space

Our main objective was to study temporal change and spatial distribution of land cover within Jabotabek. We carried out the study in 2 stages using GIS and remote sensing software packages (ERDAS 8.3). First, we analyzed land cover change from remote sensing data. Second, we predicted spatial distribution of urban green space within Jabotabek.

1) Land Cover Change urban green space within Jabotabek.

We studied temporal change in land use within Jabotabek by using Landsat MSS and TM data. Several studies have shown the utility of such data in land use surveys (Baban & Yusof, 2001; JI, 2001).

First, we geometrically corrected the images by using the Bakosurtanal land use map and a GIS vector data set from National Land Bureau (BPN), Jakarta, Indonesia. Geometric correction is used to correct geometric distortion and is achieved by establishing the relationship between the image coordinate system and the geographic coordinate system using calibration data from the sensor, measured position and attitude, ground control points, and so on (JARS, 1975).

Next, we joined 2 overlapping Landsat scenes of Jabotabek to create a single image for each date. Then we interpreted the images and classified land cover, using unsupervised analysis.

2) Greenery Prediction

To predict urban green space, we overlaid the remote sensing information on aerial photographs of selected areas of Jabotabek. First, we interpreted aerial photographs of 7 selected areas to work out the green cover percentage of each. The selected areas, from north to south, were Monas, in the center of Jakarta city; Cawang, representing the central business district; Depok, on the fringe of Jakarta, as a residential and settlement area; Bogor, Tanggerang, and Bekasi, satellite cities of Jakarta with agricultural activity; and Cisarua, which is

covered with paddy fields and forests.

We used a stereoscope for image interpretation. Stereoscopy allows the interprer to distinguish trees, groundcover, and hard-paved areas such as buildings, houses, and roads. The greenery was marked on dot tracing paper sourced from Japan Forest Technical Association, Tokyo, Japan.

The second step involved calculating the vegetation index from the 1997 Landsat image data. Vegetation indices are derived from different spectral responses from the plant canopy. Several methods have been developed to analyze greenery condition, such as the Ratio Vegetation Index (RVI), Normalized Difference Vegetation Index (NDVI), and Modified RVI (MRVI). RVI and NDVI values are created by using data of spectral bands 3 and 4, while MRVI uses data from bands 1, 2, 3 and 4:

RVI = NIR/R,

NDVI = (NIR - R) / (NIR + R),

MRVI = NIR / (NIR + R + G + B),

where TM bands 1, 2, 3, and 4 correspond to B (blue), G (green), R (red), and NIR (near infrared), respectively. The last step involved prediction of the greenery percentage. The percentage of green open space within Jabotabek was predicted by overlaying the information from the 1993 aerial photographs on the information from the vegetation indices from Landsat TM 1997 (Table 1).

III. RESULTS AND DISCUSSION

1. Land Cover Change and Urbanization

As a center of economic growth, Jakarta has been the most attractive area in Indonesia for domestic and foreign investment (Firman, 1994). Better infrastructure, access to decision makers, and a pool of skilled labor and entrepreneurs partly explain why rapid economic growth has caused Jakarta to become the most populous city in Indonesia. Urbanization in Jakarta expanded to reach the satellite cities of Bekasi in the west, Tanggerang in the east, and Bogor in the south. To cope with the rapid population increase and the expansion of urbanization, the Jabotabek area was officially declared a Metropolitan Region in 1976.

The creation of Jabotabek, with the aim of resettling citizens, potentially backfired in the form of urban sprawl on the fringe of Jakarta. Our analysis of remote sensing data showed that the proportion of built-up areas as an indicator of urbanization increased from 17% in 1972 to 22% in 1983, 25% in 1990, and 31% in 1997 (Figure 1).

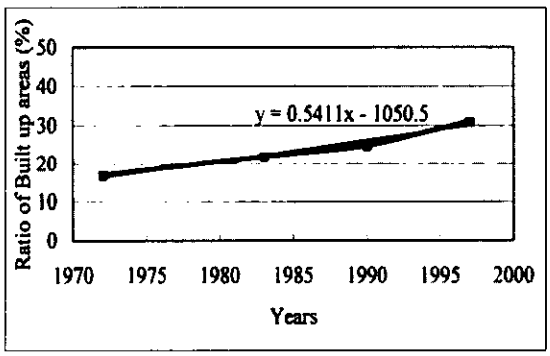

Figure 1. Proportion of built-up areas from landsat imagery in Jabotabek

Spatial analysis of urbanization in Jabotabek showed that the built-up areas expanded gradually to reach the three satellite cities. This result is supported by our previous analysis of urbanization and spatial- temporal population density in Jabotabek (Zain *et al.*, 2001), which found a decreasing population density in the center of the region, but a rapid increase outward, between 10 and 20 km from the city center (Figure 2), in the same period.

Research by Sasono (2000) also found that from the mid 1970s, the pattern of migration change

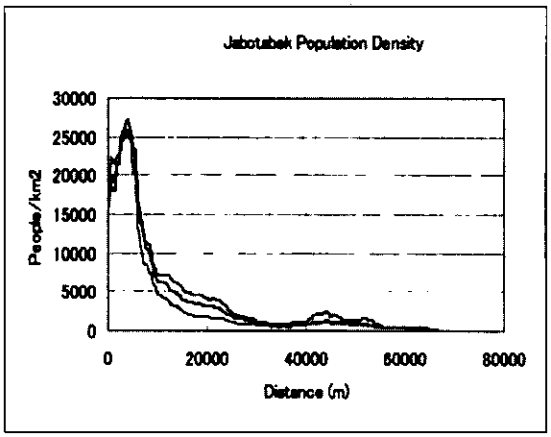

Figure 2. Population density by distance
Legend: —: 1982: —: 1990: —: 1997
Source: Zain *et al.* (2001)

and the main stream of urbanization shifted from Jakarta to the three satellite cities (Botabek areas), bolstering the population increase there (Figure 3).

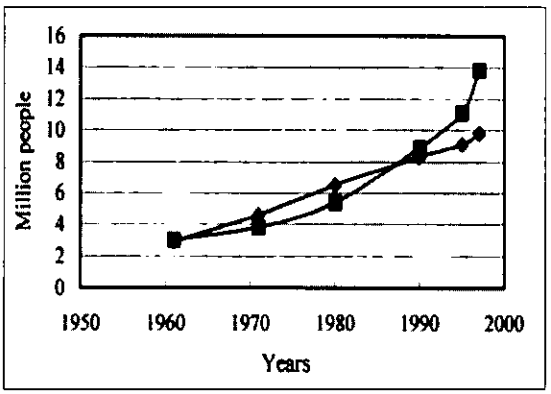

Figure 3. Population growth in Jabotabek
Legend: —◆—: Jakarta: —■—: Botabek
Source: BPS, Indonesia

Nearly to 1990, the evidence of population growth in Jabotabek showed that there were rapidly increasing of population growth in outside of Jakarta. In the other side it considered also there were slowly increasing of population growth in inner of Jakarta.

The increase in urban dwellers was followed by an

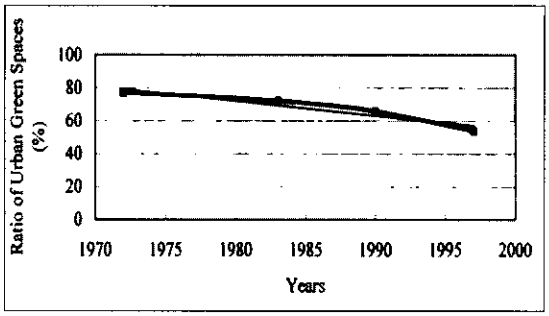

Figure 4. Proportion of urban green space from landsat imagery in Jabotabek
Y = - 0.8842x+1822.8

increasing proportion of built-up areas and a decreasing proportion of green areas in Jabotabek. The proportion of greenery decreased from 77% in 1972 to 72% in 1983, 66% in 1990, and 54% in 1997 (Figure 4).

Spatial analysis showed that the lack of greenery in Jabotabek was greatest in inner part of Jakarta and in each satellite. It also showed up on the fringes of Jakarta, especially along the highways from Jakarta to the satellite cities. Land conversion is a significant cause of loss of greenery in the center of a city. Land conversion from parks, pocket gardens, and urban forests was easy to see. Examples include the construction of gasoline stations (Tebet and Kebayoran Baru Parks, and Panglima Polim pocket garden), office buildings (Majestic Park), and a bus terminal (Blok M pocket garden).

Increasing population density on the fringes of Jakarta also caused high conversion of land for residential and other built-up purposes. The low price of land and high access to the center of trade in these areas became the determining factors for conversion. A study by Sasono (2000) considered that housing development in the three satellite cities is increasing rapidly, whereas there is almost no increase in the center of Jakarta (Figure 5).

From an ecological perspective, the high land

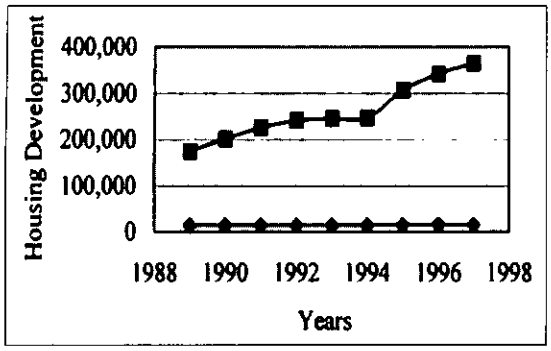

Figure 5. Cumulative number of private housing develpments in Jabotabek, 1987-1997
Legend: —◆—: Jakarta Housing; —■—: Btabek Housing
Source: Sasono, (2000)

conversion on the fringes of Jakarta is not environmentally friendly, because these areas were previously water basins and catchments with massive green open spaces.

Extrapolation of the loss of greenery from 1972 to 1997 shows that the urban green space in Jabotabek will disappear in the next 50 years. In the equation Y = - 0.8842. X + 1822.8, Y is the proportion of urban green space in Jabotabek and X is the period. Urban planners and landscape architects should be made aware of these findings. Our study shows that the pattern of built-up areas in Jabotabek is due to poor planning, is undesirable, and creates sprawl. The expansion of built-up areas should be controlled by urban zoning, and the urban green space must be conserved. The conservation of urban greenery is more important than ever as a means of mitigating air pollution and contributing to the sustainability of biodiversity (Takeuchi, 1999).

2. Urban Greenery Prediction from Aerial Photographs and Landsat TM

In the previous paragraphs we have shown the decrease in urban greenery in Jabotabek. This leads to the question of what the spatial distribution of greenery there is like. We determined the correlations of the three vegetation indices (RVI, NDVI, and MRVI) with the green coverage determined from the aerial photographs to select the index that best predicted the greenery distribution of Jabotabek. On the basis of the coefficient of determination, all three models predicted the greenery well: RVI, R^2 = 0.9259; NDVI, R^2 = 0.9245; and MRVI, R^2 = 0.9191 (Figure. 6)

Y=146.4X-134.96(R^2=.9259) (Formula 1)
Y=328.4X-2.793(R^2=.9245) (Formula 1)
Y=899.46X-16.87(R^2=.9191 (Formula 1)

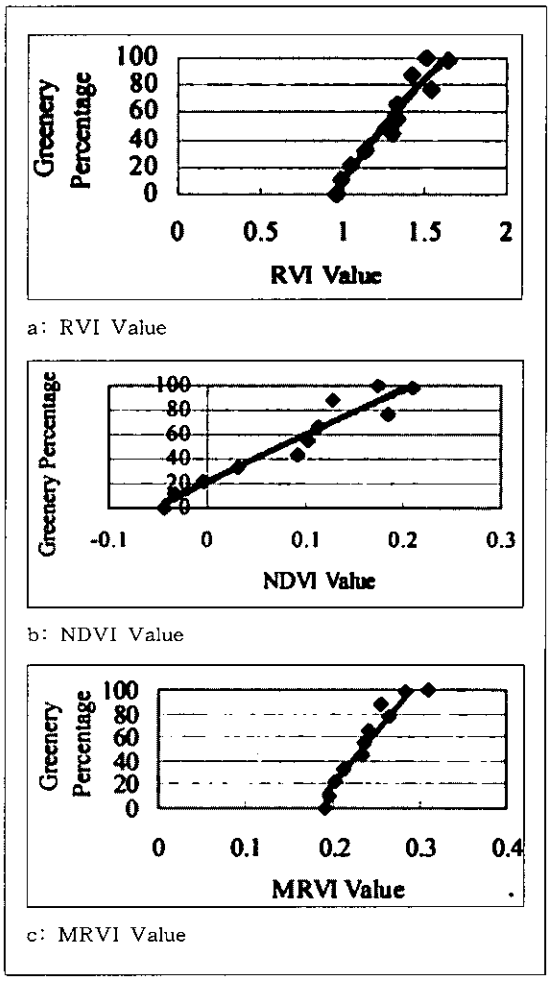

Figure 6. Prediction of Greenery Percentage By NDVI, RVI, RVIVI

We selected the RVI model, which had the highest coefficient of determination. The equation of RVI model is Y = 146.04 X - 134.96, where Y is greenery prediction (%) and X is RVI value.Spatial analysis of the application the RVI model in Jabotabek showed that the area in the range of 0 to 20 km, in which Jakarta lies, has the least greenery. This range has also the highest population density and the most built-up areas. Greenery has been almost eliminated, and from a greenery perspective the area is entering a critical phase. In the fringe of Jabotabek, where mountainous conservation areas exist, the greenery reached the highest.

IV. CONCLUSION

Analysis of land cover change in Jabotabek showed that development in Jakarta and adjacent areas caused loss of about 23% greenery in the last 25 years. The results suggest that urban green space will continue to be lost and could disappear in no more than 50 years. The RVI model was the best for urban greenery prediction in Jabotabek. The model showed substantial greenery in traditional home gardens and paddy fields in the rural areas within Jabotabek and in the mountainous conservation areas. On the other hand, the central part of Jakarta and of the three satellite cities showed lack of greenery.

Evaluation and redesign of the urban landscape in Jakarta should be started immediately. Otherwise Jakarta will be without esthetic greenery. This result could be used as a preliminary warning that urban development should not be based on economics alone.

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