Analysis of Satellite Images for Measureing Urban Green Coverage Ratio and Land Shape in Bandung and Cirebon

- As Basis for Planning Future Urban Form Regarding Climate Change-

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INTRODUCTION

A study on "Supporting Strategies for Urban Development and Housing Construction in Developing Countries regarding Global Climate Change" was undertaken by National Institute for Land and Infrastructure Management, Ministry of Land, Infrastructure and Transport, Japan, cooperated by Research Institute for Human Settlements, Ministry of Public-works, Indonesia, between 2004-2006 fiscal years, funded by Ministry of Environment, Japan. Two sites were chosen for case studies for planning and designing future form of houses and housing complex in Bandung and Cirebon cities, regarding lower CO_2 emission in the long run. This paper describes the analysis of satellite images to obtain indicators of the existing districts as basis for the planning and designing the future.

1. Green Coverage Ratio

Urban greenery is an important characteristic of tropical cities, which creates the comfortable shades along the streets and within individual house lots. It also plays the role of carbon sink, which is proportional to the green coverate (canopy). According to IPCC (2002), 2.9Ton-C / hectare of canopy / year is the default value for urban area in Temperate Zone[1). Through field surveys, it is possible to count up the trees (kinds and size, that is related the stock of carbon) in the districts, but difficult to measure the area of canopy. However, recent multi-band satellite image with high resolution (1m by IKONOS, 0.6m by Quick Bird) provide possibilities to measure the green coverage ratio. The difficulty lies in the identification of canopy of high trees from other greenery like bush, agricultural fields or open space covered with grass.

We tried the measurement in "Sarijadi" housing complex in Bandung city, where we made field survey to estimate the current CO_2 emission and also planned and designed alternative forms of human settlements for future. We used IKONOS Pansharpen data (4 band) taken in May 6,2001, 03:13 GMT (Fig.1), with resolution of 1.0m.

(1) Land Use Classification

At first we separated the greenery from other land use (roof, water etc.) by applying NDVI[2), and classified the greenery into 6 categories: <C1>Bright Tree <C2>Dark Tree <C3>Bright Crop <C4>Dark Crop <C5>Grass <C6>Bush, and chose 56 obvious cases from wider area in the image, to obtain the teacher data.

(2) Analysis of Teacher Data

The spectrum of each category C1-C6 was statistically calculated as shown in Table 1.

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Table 1 Statistic of each category of greenery

	Average (standard deviation)			
Category	Band 1 (blue)	Band 2 (green)	Band 3 (red)	Band 4 (ultra red)
C1 Bright Tree	346.5(25.0)	358.2(37.6)	251.0(43.0)	541.7(94.8)
C2 Dark Tree	319.7(23.7)	316.8(34.1)	204.7(36.5)	382.0(76.3)
C3 Bright Crop	347.5(13.4)	371.3(20.7)	258.9(23.5)	682.2(39.4)
C4 Dark Crop	325.8(12.1)	332.7(17.1)	233.1(18.0)	389.0(58.6)
C5 Grass	364.6(11.8)	404.9(20.2)	302.5(24.1)	634.8(62.6)
C6 Bush	346.5(25.0)	358.2(37.6)	251.0(43.0)	541.7(94.8)

The value of each band: 0-2047 (11 bit)

(3) Judgement of each dot in the target area

We judged each pixel that was identified as greenery within the target area through maximum likelihood estimation, into the six categories (C1-C6), and identified C1 and C2 as canopy of trees. The numbers of pixels that were classified as C1 or C2 was 5771, while the total pixels of the target area was 52,028. Therefore, 11.1% of the total area was classified as canopy of trees. This is quite larger than the open space of the site, which has decreased after the extension of houses after inhabitation, as identified through field survey undertaken in 2005 by PUSKIM. That means, trees on the very limited open space spreads the canopy over the roofs, creating shades and absorbing CO_2 even in the densely inhabited area.

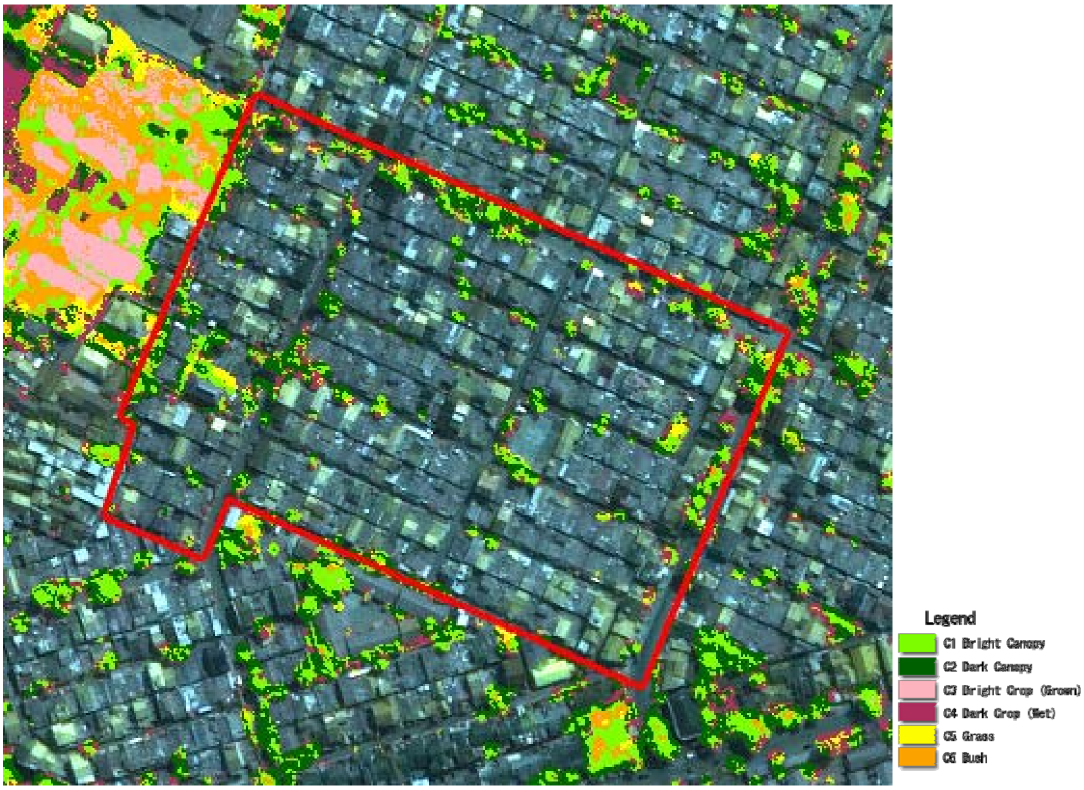


Fig. 1 Identification of 6 catgegories of greenery in the target area (Bandung-Sarijadi)

(4) Comparison with the result from visual identification

In order to check and evaluate the accuracy of the classification, we also tried visual classification by an operator. This method considers not only the color, but also texture of each land use, and needs more skills and man-power. This method identified 5,176 pixels (9.9%) as canopy of trees. The result is not far different from classification of each dot. We also tried to judge the teacher data used for determination of parameters. The result is shown in table 2. For example 8.3% of the teacher of C1 is misjudged as C3 and 5.4% of the teacher of C4 is misjudged as C2. The similarity of spectrum of different categories implies the cause of errors.

Table 2 Errors of classification as for the teacher data

(%)

		Teacher						
		Other	C1 Bright Canopy	C2 Dark Canopy	C3 Bright Crop (Grown)	C4 Dark Crop (Wet)	C5 Grass	C6 Bush
Maximum Likelihood Classification	Other	55.4%	0.0%	0.1%	0.0%	0.1%	0.0%	0.0%
	C1 Bright Canopy	10.4%	63.6%	13.0%	2.0%	5.4%	2.9%	5.3%
	C2 Dark Canopy	13.2%	14.4%	72.8%	0.0%	4.0%	0.7%	0.1%
	C3 Bright Crop (Grown)	1.1%	8.3%	0.0%	83.8%	0.0%	6.1%	17.3%
	C4 Dark Crop (Wet)	11.2%	2.9%	10.5%	0.0%	89.4%	1.5%	0.3%
	C5 Grass	6.3%	2.7%	0.6%	4.4%	0.1%	77.9%	3.4%
	C6 Bush	2.3%	8.2%	3.0%	9.8%	1.1%	10.8%	73.8%
Total		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

2. Land Shape

Land shape is also an important indicator for considering the climate change. From viewpoint of the impact of Sea Level Rise, the detailed contour or altitude ot the area is an important condition for planning future. In the area on the hilltop, slopes will eliminate the mode for transportation. At first, we tried to get the contour from digital map from BAKOSURTANAL, however it was too rough for the district planning level (12.5m pitch of contour line, or 50m mesh of DEM).

Direct measurement was also quite disturving the inhabitants for this kind of study (not an actual urban development). Fortunately, satellite image obtained from ALOS-PRISM sensor are provided with three different angle of cameras, namely, front view, straight view and back view, and that are provided in the library images.

Analysis of normal stereo air-photo is a kind of established technology of photogrametry. Since 1990's pattern-matching between one stereo pair is undertaken automatically by computers. However, working on stereoscopic satellite image is rather a new trial, since ALOS-PRISM data came to be available in 2006. The most important feature of the PRISM sensor is the ability to swift the scanning angle foward (+23.8 degree) and backward (-23.8 degree). That means that one point on the earth is portraited from three different angles (positions of satellite), enabling three pairs for stereo scopic view (fromt-straight, straight-back, front-back). The altitude of the orbit is 691.65km. We analyzed the monochrome (single band) images with level of processing IB2R (geo reference) , provided in the form of Geo-TIFF format. We used the image of Cirebon city taken in 2006/07/04, and image of Bandung city taken in 2006/08/07.

We used "Leica Photogrammetry Suite 9.1" software for the analysis, using the function (sensor model) of "Generic Pushbroom".

(1) Control points and Tie points

In order to identify the coordinate, we chose the control points randomly from the straight image and identified the x and y coordinates obtained from the attribute data of the image, while obtained the altitude of them from the 90m mesh DEM data from SRTM[3)].

We also automatically selected tie points from the images that are needed for image matching(Table 3).

Table 3 Number of control points and tie points

Area	Number of control points	Number of tie points	Total
Bandung	24	19	43
Cirebon	25	23	48

(2) Image Matching

DEM was obtained through image matching between each pair from three images, and we chose the altitude data from one of three pairs that resulted the least error at each dot.

The important three parameters for this matching are <a> the area for searching <b> the windows size for matching, and <c> lower threshold of corelation coefficient. Through several trials, we came to the conclusion that the following parameters gave the best result (Table 4).

Table 4 Optimal parameters for matching

Area	Area for searching (pixels)		Size of matching window (pixels)		Lower limit of coefficient
	X	Y	X	Y	
Bandung	31	3	3	3	0.5
Cirebon	11	3	7	7	0.5

At first, we obtained the DEM of 7.5m mesh, and re-arranged it to 10m mesh for convenient usage.

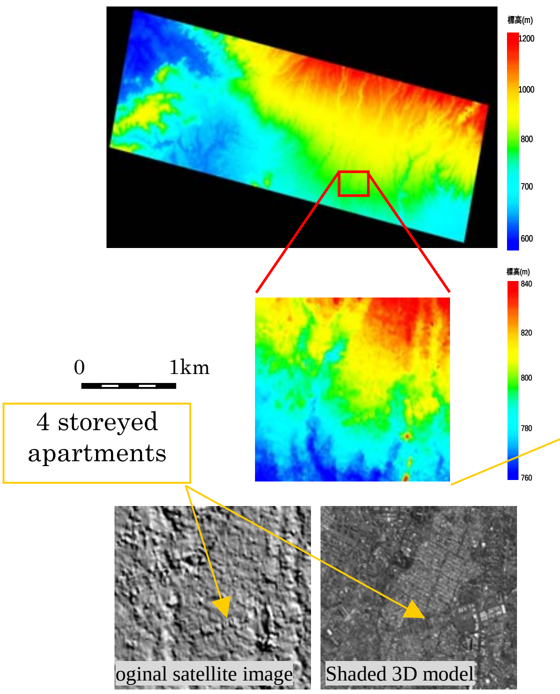


Fig. 2 The obtained DEM data for Bandung

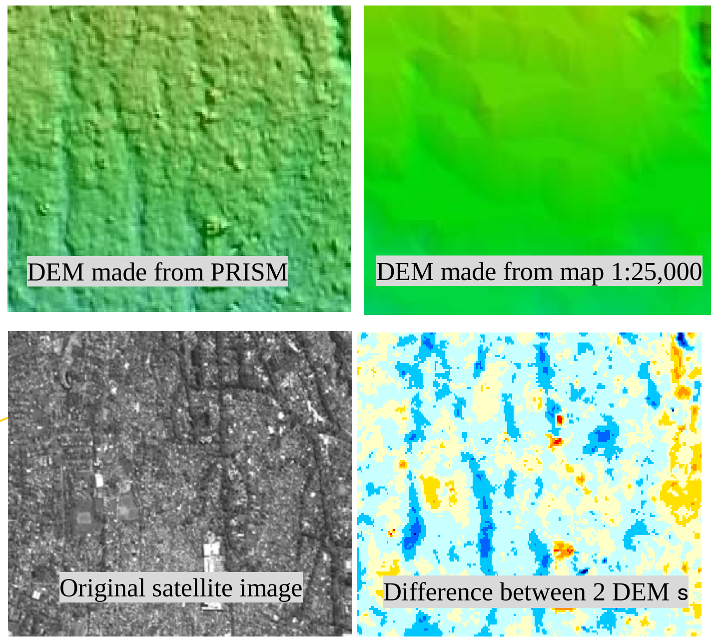


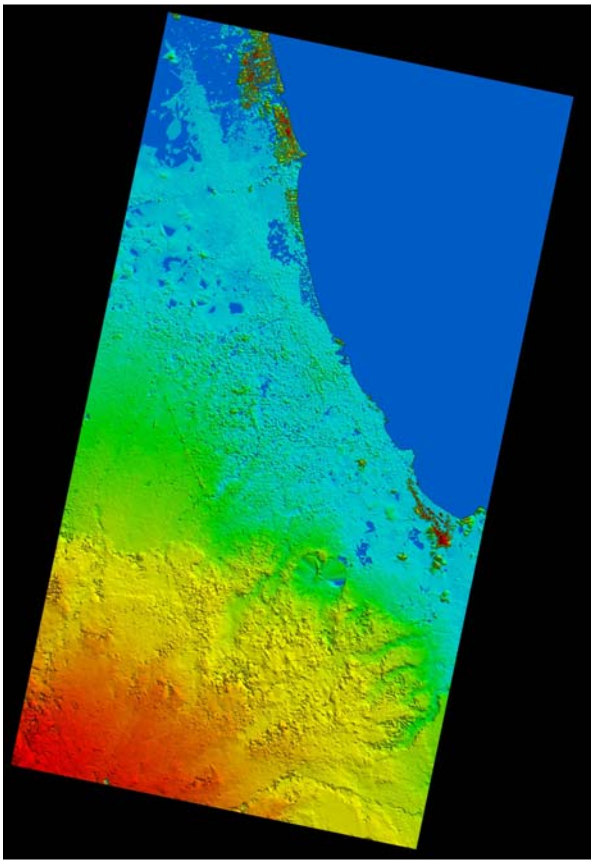
Fig. 3 Comparison of DEM from PRISM & GeographicalMap 1:25,000

The figure 3 shows that land shape obtained from PRISM data is far more detailed than that obtained from map (1:25,000) and useful for urban planning activities (Fig. 4-5).

Fig.4 DEM around target area

Fig. 5 Photo of the target area

The similar analysis was also undertaken in Cirebon (Figure.6)



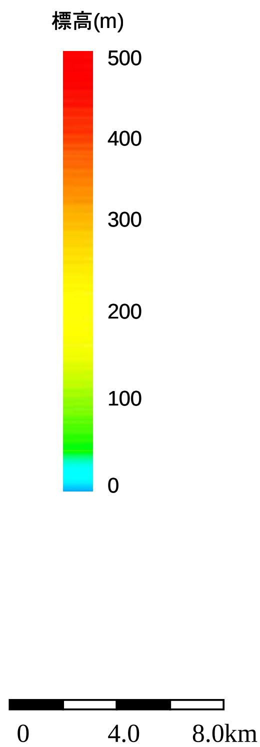


Fig. 6 DEM obtained for Cirebon

The data clarified the altitude of the target area for planning and design and that was enough high and free from the impact of forecasted sea level rising.

CONCLUSION

As final results from the study, we provided alternative future shape of district and houses, regarding the global climate change, and evaluated them in comparison to the existing houses and district. We made efforts for reducing the CO2 emission through (1) saving domestic usage of energy, (2) saving fuels through rational transportation system, (3) appropriate usage of building materials, and (4) enhancing urban greenery. Those features can be quantitatively evaluated as Emission of CO2 Tons / year / person (or sq-m) in the long run. The basic data needed for this estimation were obtained through field surveys undertaken in 2005. After architects and city planners provided several alternative future images for two sites in Bandung and Cirebon, we had a workshop inviting resource persons who are non-professionals of architectural design and city planning to evaluate them also from social-economical-cultural aspects.

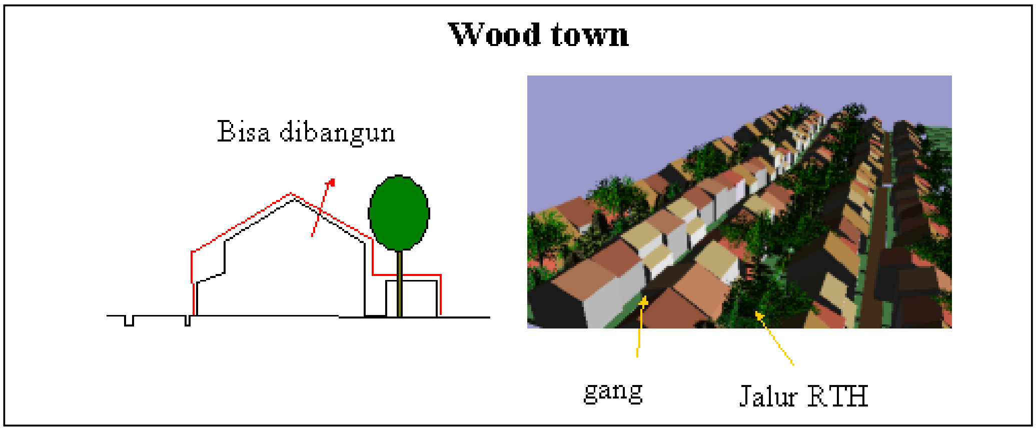


Fig. 7 Planning an alternative future, based on the obtained land shape

The target areas for this study were some 5 hectares, however, by utilizing the satellite image, we can approach to the wider area (up to full urbanized area of a large city). Especially, reminding that there are many large coastal cities in this country, detailed contour data is quite valuable, if we take the impact of sea level rising into account.

Remarks:

1) "Good Practice Guidance" by IPCC, Chapter III, (D. Nowak 2002.

2) Normalized Difference Vegetation Index
NDVI = (Band4 – Band3) / (Band4 + Band3) where Band 4 : Ultra Red, Band 3 = Red
We chose 97 as threshold, that was obtained from the distribution of all pixels.

3) STRM : Shuttle Radar Topography Mission

4) The analysis of green coverge ratio was elaborated by Ms. Kakuta, and the analysis of land shape by Mr. Nakazawa, under Asia Photo Survey Co.Ltd.