(5) Green Coverage Ratio

Urban greenery, which creates comfortable shaded space along the streets and within individual house lots, is an important characteristic of tropical cities. It also plays a role as a carbon sink, which is proportional to the green coverage (canopy). According to IPCC (2002), 2.9Ton-C / hectare of canopy / year is the default value for an urban area in a temperate Zone*). Field surveys can easily quantify the trees (kinds and size, that are related to the stock of carbon) in the districts, but it is more difficult to measure the canopy area. However, recent multi-band satellite images with high resolution (1m by IKONOS, 0.6m by Quick Bird) now permit measurement of the green coverage ratio. It is still difficult to distinguish the canopy of high trees from other greenery like bushes, agricultural fields, or open grass-covered space.

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

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

a. Land Use Classification

At first we separated the greenery from other land use (roof, water etc.) by applying NDVI**), 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 a wider area in the image to obtain the teacher data.

**) Normalized Difference Vegetation Index

NDVI = (Band4 – Band3) / (Band4 + Band3) where Band 4: Infra Red, Band 3: Red

b. Analysis of Teacher Data

The spectrum of each category C1-C6 was statistically calculated as shown in Table 21.

Table 21: Statistic of each Category of Greenery

Category	Average (standard deviation)			
	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)

c. Judgement of Each Dot in the Target Area

Each pixel that had been identified as greenery within the target area was classified into the six categories (C1-C6) through maximum likelihood estimation. A pixel identified as C1 or C2 was deemed to be the canopy of trees. A total of 5,771 pixels were classified as C1 or C2from among the total of 52,028 pixels that formed the target area. Therefore, 11.1% of the total area was classified as canopy of trees. This is much larger than the open space on the site, which has been decreased by the expansion of occupied houses, as identified by a field survey performed in 2005 by RCHS. That means that trees on the very limited open space spread their canopies over the roofs, creating shade and absorbing CO_2,even in the densely inhabited area.

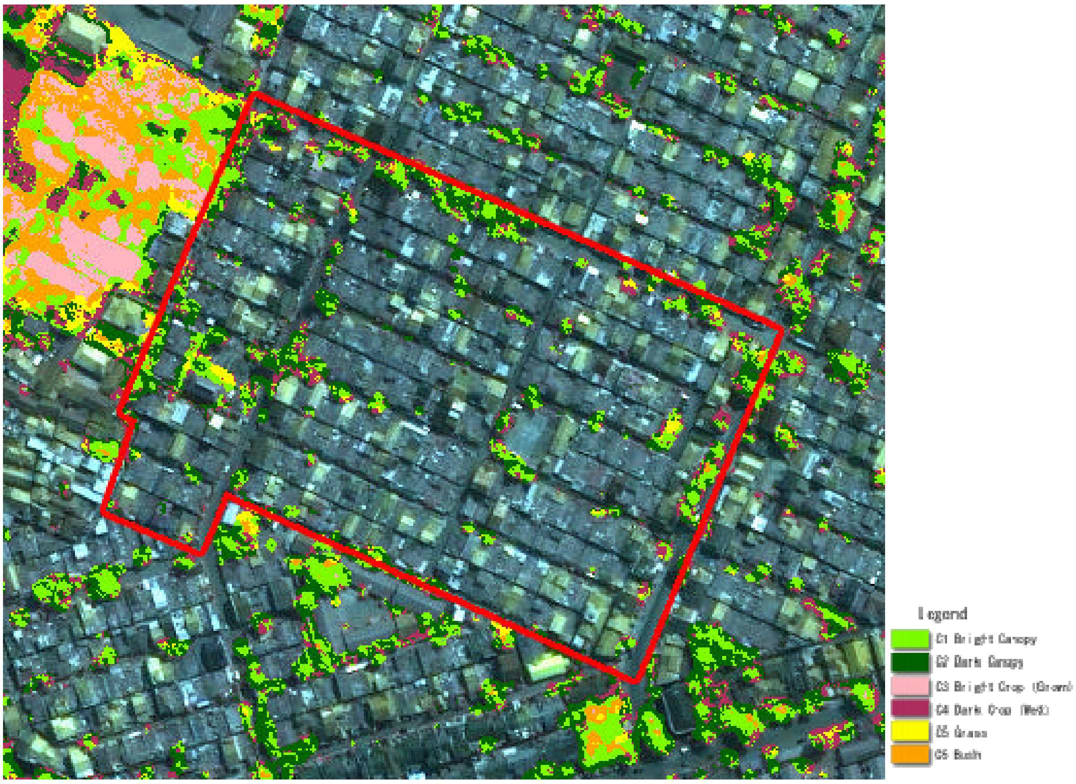

Fig.9: Identification of 6 Categories of Greenery in the Target Area (Bandung -Sarijadi)

d. Comparison with the Results of Visual Identification

In order to check and evaluate the accuracy of the classification, we also had an operator try to perform a visual classification. This method, which considers not only the color, but also the texture of each land use, requires greater skill and man-power. This method identified 5,176 pixels (9.9%) as the canopy of trees. The result is quite similar to that obtained by classifying each dot. We also tried to judge the teacher data used to determine the parameters. The result is shown in table 22. 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 the spectra of the different categories is probably the cause of the errors.

Table 22: Errors of Classification of the Teacher Data

(%)

		Teacher						
		Other	C1 Bright Canopy	C2 Dark Canopy	C3 Bright Crop (Grown)	C4 Dark Crop (Wet)	C5 Grass	C6 Bush
Maximum Likelyhood 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%

(6) Land Shape

Land shape is another indicator important in the consideration of climate change. Considering the impact of sea level rise, the detailed contour or altitude of an area is an important factor in planning for the future. On hilltops, slopes eliminate transportation modes . At first, we tried to obtain the contour from a digital map from BAKOSURTANAL, however it was too rough for district planning (12.5m pitch of contour lines, or 50m mesh of DEM).

Direct measurement performed for this kind of study (not an actual urban development) is also quite disturbing to the inhabitants. Fortunately, satellite images obtained from the ALOS-PRISM sensor provide images from with three different camera angles, namely front view, straight view and back view, all available in the library images.

Analysis of normal stereo air-photos is one established photogrametry technology. Since the 1990s pattern-matching of one stereo pair is performed automatically by computers. However, working on stereoscopic satellite images is a somewhat new field developed since ALOS-PRISM data became available in 2006. The most important feature of the PRISM sensor is its ability to shift the scanning angle forward (+23.8 degree) and backward (-23.8 degree). That means that one point on the earth is portrayed from three different angles (positions of satellites), enabling three pairs for stereoscopic viewing (front-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 an image of Cirebon city taken in 2006/07/04, and an 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".

a. Control Points and Tie Points

In order to identify the coordinates, 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 obtaining their altitudes from the 90m mesh DEM data from SRTM (Shuttle Radar Topography Mission, with mesh by 90m).

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

Table 23: 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

b. 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 in the least error at each dot.

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

Table 24: 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 7.5m mesh DEM of, and re-arranged it to 10m mesh for convenient usage.

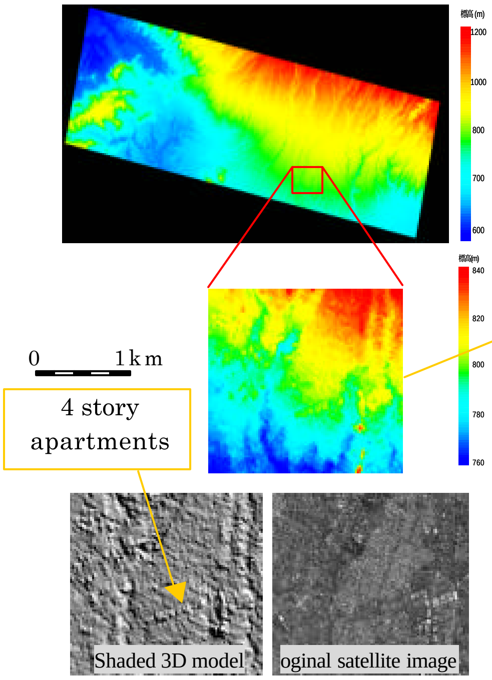

Fig.10: The DEM Data obtained for Bandung

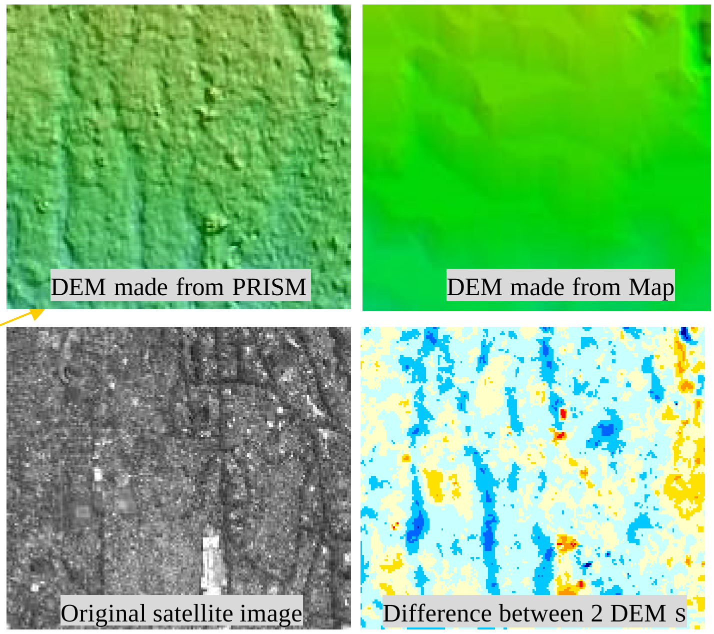

Fig.11: Comparison of DEM from PRISM & Geographical Map 1:25,000

The figure 10 shows that the land shape obtained from PRISM data is far more detailed than that obtained from the map (1:25,000) and more useful for urban planning activities (Fig. 11-12).

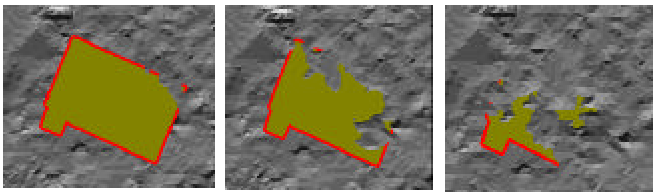

Fig.12: DEM around Target Area

Fig. 13: Photo of the Target Area

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

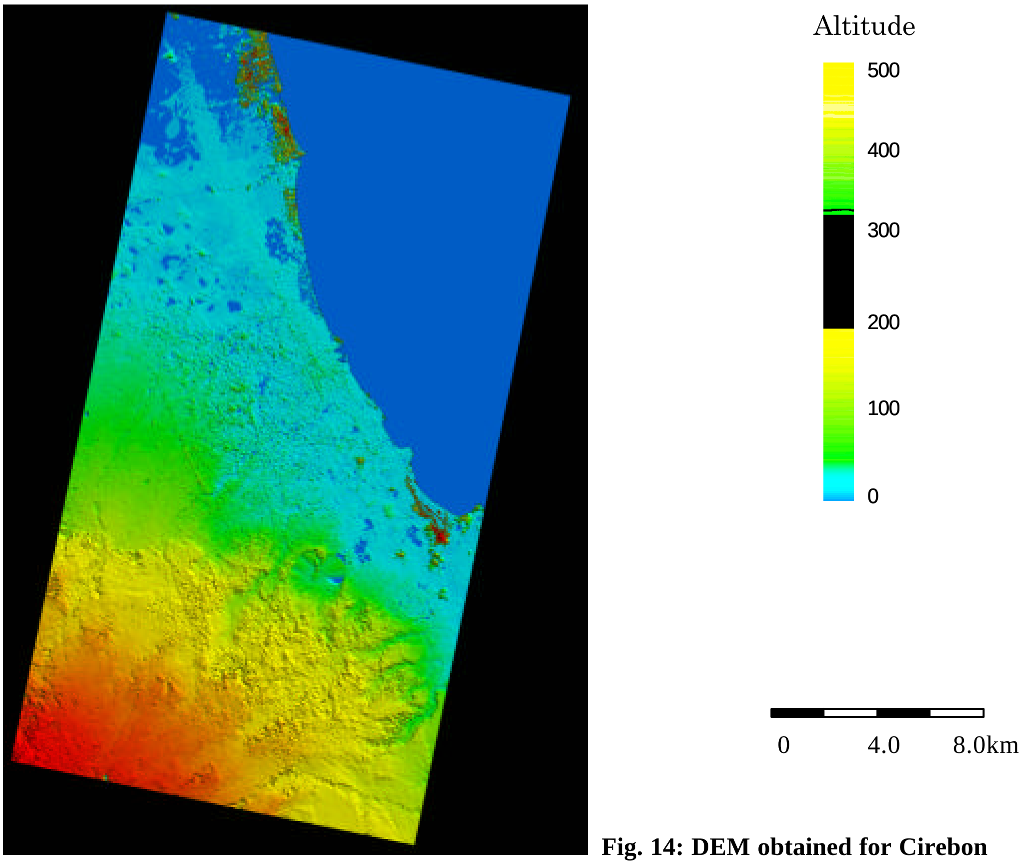

Fig. 14: DEM obtained for Cirebon

The data clarified the altitude of the target area for planning and design, and it was adequately high and free from the impact of the forecasted rise of the sea level.