Carbon Reserve Estimation of Trees in the City Greenery Open Spaces (GOS) in East Jakarta Municipality Using Landsat Imagery

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ABSTRACT

At the end of this decade, the earth's temperature raised up to 0.6 °C. The main factor that is considered as the driver of global warming is the increasing of green house gas concentration in the atmosphere, i.e carbon dioxide (CO_2), methane (CH_4) and Nitrogen oxide (N_2O). During the last decade CO_2 emission increased twice from 1400 million ton/year to 2900 million ton/year. Some researches showed that CO_2 concentration in atmosphere in 1998 is about 330 ppm at an the incremental rate of 1.5 ppm per year (Brown et al, 1996), and in all probability to keep increasing year by year.
Based on all the problems mentioned above, this research was conducted to estimate the carbon reserve of stands of trees in Greenery Open Spaces at East Jakarta Municipality using Landsat satellite temporal imagery over a few years. The best model concluded that $Y = 43{,}448E + 11G^{-3,69}MIRI^{-2,28}$ (R^2 = 42.8%). The total area of East Jakarta Municipality is about 18,689.64 hectares with a carbon reserve above ground soil for 1986 is about 184.975 ton/hectare (LANDSAT MSS imagery 1986), 1992 which is about 165.050 ton/hectare (LANDSAT 5 imagery 1992). The data in 2001 is about 181.805 ton/hectare (LANDSAT 7 SLCOff imagery 2001) and 2005 is about 183.710 ton/hectare (LANDSAT 7 ETM+ imagery).

Keywords: Carbon, GOS, LANDSAT, Model

1. INTRODUCTION

Climate global change triggered by the increasing of temperature is now becoming the main issue worldwide. During the last century temperature was growing up at about 0.6 °C. The main factor concerned as a global warming trigger is the increasing of greenhouse gas concentration, i.e. carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). During the last decade the emission of carbon dioxide increased twice from 1,400 million ton/year become 2,900 million ton/year.

In the year 1998 the concentration of atmospheric carbon dioxide was 360 ppm with tha increasing rate of 1,5 ppm/year (Brown *et al*, 1996). Highly increasing of this concentration is affected by human activities, especially by land use change and the using of fosil oil for transportation, generating of electric energy and industrial activities. Accumulatively the fosil oil usage and the land use change from forest to other usage has contributed up to half of the carbon dioxide emission to atmosphere, but the real impact has a ration of 3:1. Fosil oil burning activities have the meaning that carbon dioxide kept in the body of trees far before released again to atmosphere.

The impact of land use conversion reveals that carbon preserved in the form of biomass (in for of peat) is releasing to atmosphere through burning or organic compound decomposition. Carbon storage from a landscape is also could be conversed through timber production, eventhough rate of carbon release depends on timber usage. During 1990-1999 land use is to be presummed to accomodate carbon dioxide emission at 1,7 Gt/year (Watson et al., 2000).

In accordance with global cliate change induced by human activities (anthropogenic), the Rio de Jeinero Conference 1992 identified that the carbon dioxide emission to atmosphere is the main issue of global climate change needed to be concerned. This is why that we need to formulate the United Nations Framework Convention on Climate Change (UNFCCC) in order to manage cooperation framework between goverments.

Development of technology by human which is applicated to increase life quality and comfortness not only give positive impact but also negative impact. One of the negative impacts triggered by human activities is environmental pollution.

The importance environment pollution in urban area is air pollution. The pollution source would be coming from vehicle, industry and household. This pollution might decrease human health. This is why we need an effort to prefent from and reduce the negative impacts.

One sollution to overcome problems of air pollution is to estimate carbon storage by trees on the ground. Vegetation and trees in urban area and urban franges in the form of garden, park, green line, and urban forest could function as urban lungs. Even, vegetation and trees can serve oxigen which is needed by people and reduce the air pollution concentration (Grey and deneke, 1978).

The purpose of this research are (1) to estimate carbon storage within green open space(GOS), (2) to find for the best model for estimation of carbon storage within green open space, and (3) to perform recommendation the quantity of green open space which is potential as a carbon storage. To complete this reseach we have taken an area of study at East Jakarta Municipallity.

2. MATERIALS AND METHODS

Location and Time

The research was conducted at the street green-line and community park in East Jakarta, Indonesia. Observation and analysis was done during September 2005 up to March 2006.

Material and Tool

Materials used in this research comprised Landsat TM image, acqition of 1986, 1992, 2001 and 2005, and vector map of City of East Jakarta. While tools needed to observation comprised GPS (global positioning system), compass, DBH-meter, roll meter and digital camera. For spatial data analysis we used ERDAS *Imagine* 8.7 and Arc GIS 9.2, while for statistical analysis we used SPSS for Windows ver 11.5.

Data and Information

1. Data resulted from Landsat TM analysis
   a. Spectral number of Landsat TM, as a result from extraction of digital number within canal 1, 2, 3, 4, 5 and 7.
   b. Index number of vegetation, as a reslut from the ration of infrared canal and red canal. Some transformations should be done with this way:
      1) Ratio Vegetation Index (RVI) = NIR/Red (*Rouse et.al*, 1974).
      2) Transformed RVI (TRVI) = $\sqrt{\left(\frac{NIR}{Red}\right)}$ (*Rouse et.al*, 1974).
      3) Difference Vegetation Index (DVI) = 2.4 NIR - Red (*Richardson and Weigand*, 1977).

4) Normalized DVI (NDVI) = (NIR-Red)/(NIR+Red) (*Rouse et.al*, 1974).

5) Transformed NDVI ($TNDVI_1$) $\sqrt{\left(\left(\frac{NIR - Red}{NIR + Red}\right) + 0,5\right)}$ (*Deering et.al*, 1975).

6) Transformed NDVI($TNDVI_2$) $\left(\frac{NDVI + 0,5}{Abs(NDVI + 0,5)}\right) \times \sqrt{Abs(NDVI + 0,5)}$ (*Perry dan Lautenschlagen*, 1984).

7) Middle Infra Red Index (MIR Index) = (MIR - Red) / (MIR + Red) (*Roy dan Shirish*, 1994).

8) Average Vegetation Index (AVI) = 2,0 NIR - Red (*Ashburn*, 1978).

9) Infrared Index (II) = $\frac{NIR - MIR}{NIR + MIR}$ (*Kreiger et. al*, 1969; *Rouse et.al*, 1973).

10) Perpendicular Vegetation Index (PVI_1) = 0,647 NIR – 0,763Red – 0,02 (*Jacktion et, al*. 1980)

11) $PVI_2 = \frac{1,091 NIR - Red - 5,49}{\sqrt{1,091^2 + 1}}$ (*Perry dan Lautenschlagen*, 1984).

12) $PVI_3 = \frac{2,4 NIR - Red - 0,01}{\sqrt{2,4^2 + 1}}$ (*Perry dan Lautenschlagen*, 1984).

2. Field survei data: DBH (diameter of breath height) and height of trees, topographic data

3. Regression model:
   a. Multiple linear regression
      $Y = b_0 + b_1X_1 + b_2X_2 + ... + b_iX_j$
   b. Logaritmic model
      $Y = b_0X_{1b1}\, X_{2b2} ... X_{jbi}$
   c. Exponential model
      $Y = e^{(b0 + b1x1 + b2x2 + ... + biXj)}$

where:

Y	=	carbon storaged in trees on the ground (kg/m^2)
x1, x2 ...xj	=	spectral number (DN); j = 6 for Landsat TM
b0, b1 ... bi	=	parameter

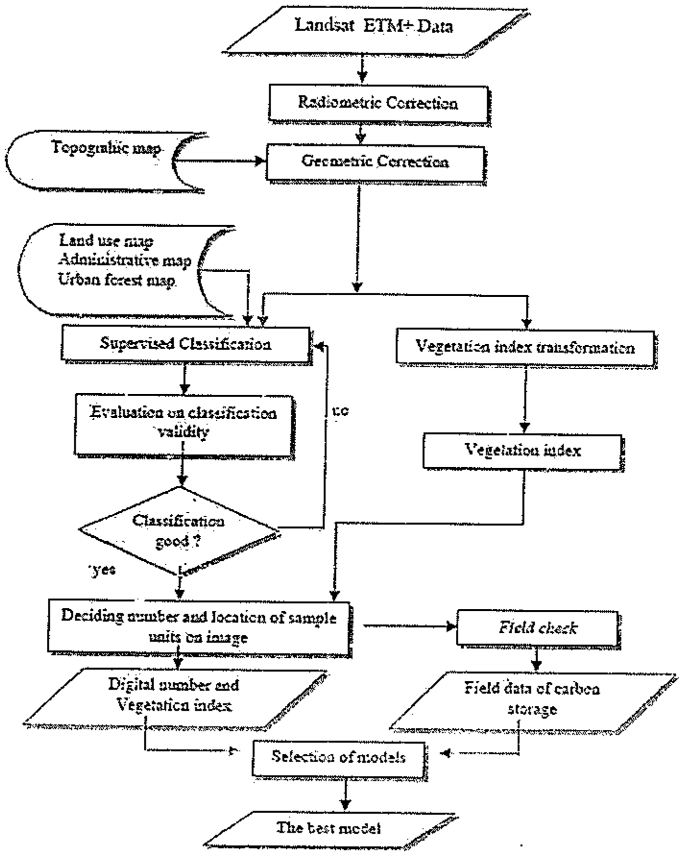

Figure 1. Flow diagram to perform model

3. RESULTS AND DISCUSSIONS

3.1. Spectral analysis to indentify green open space (GOS)

Spectral analysis of GOS was applied to community park and road-trees located in area of East Jakarta Municipality, which is distributed in 10 districts (kecamatan). Vegetation index for this area was very clear, so that it is very confinience to analyze carbon storage.

Selection of the best canal combination in order to give more information bagi identification of green open space (GOS) dengan nilai OIF (Optimum Index Factor). Canal combination which was analyzed comprises cannal combination RGB542 / Natural Colour Composite (TM), RGB 432/ Standard False Colour Composite (TM), RGB 453/ False Colour Composite (TM). Result of the canal combination and OIF number calculation are presented in Figure 2 and Figure 3.

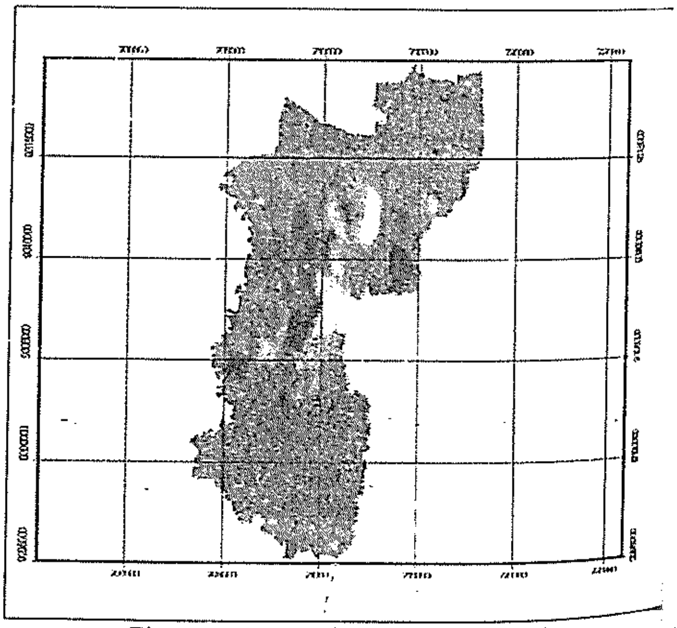

Figure 2. Composite Landsat of ETM RGB 542

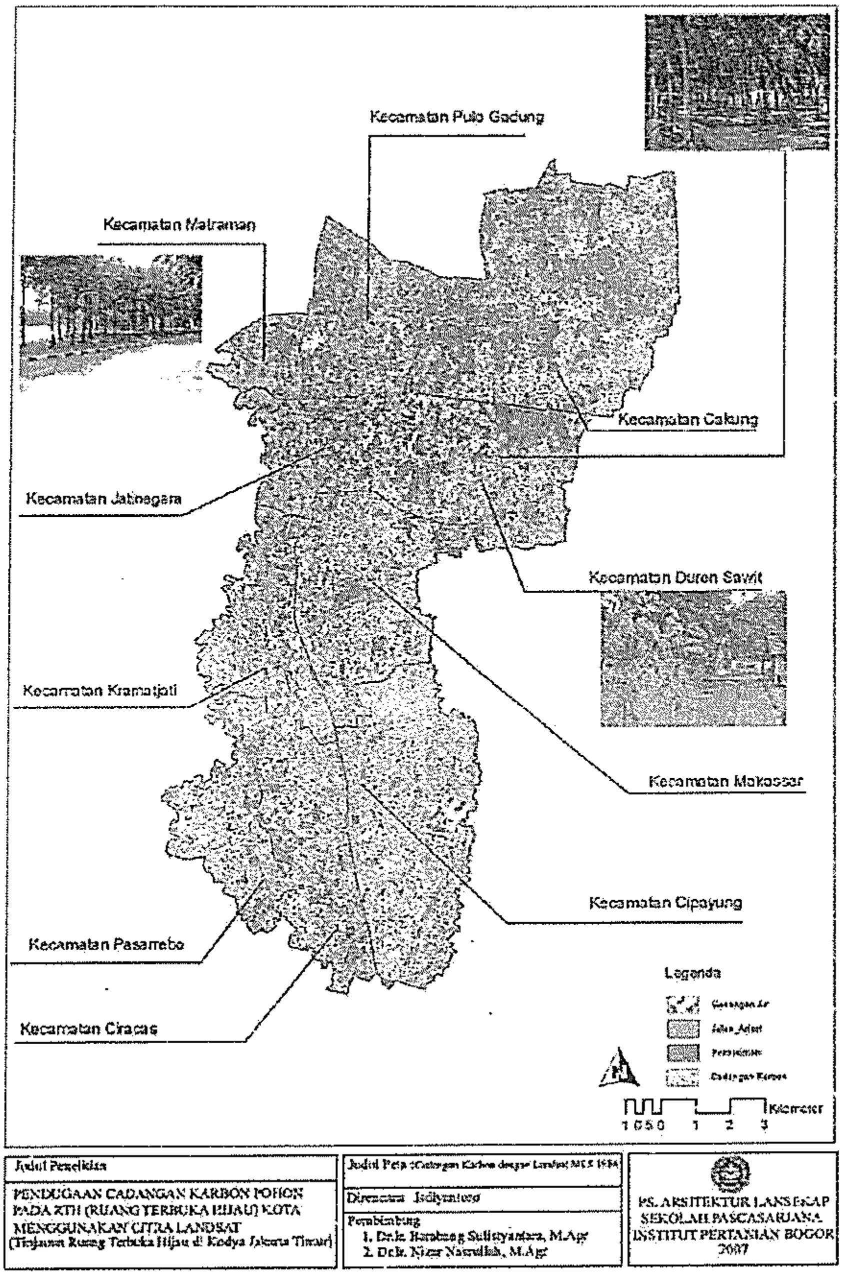

Figure 3. Carbon storage estimation map extracted from Landsat MSS

3.2. Carbon Storage Estimation Model

a. Carbon Storage Estimation Model based on Digital Number

Carbon storage estimation model for green open space (GOS) with digital number variabel was conducted with the simple model or multiple model. Number of carbon storage was estimated with alometric equation. Data of carbon storage is a result from extraction of Landsat image data. Digital number (DN) which reflects canopy cover of trees was analyzed using multiple linear regression.

Concerning multicolinearity and correlation between digital number variable and carbon storage variable, leads to perform estimation model with some combinations of digital number variable. Result of carbon storage estimation model based on digital number of green open space on the ground is decided by the number of determination coefficien (R^2), *Cp Mallow* and error mean square. The result of calculation is drawn as in Table 1.

Table 1. **Carbon storage estimation models based on digital number (DN)**

Carbon storage estiation model	R^2 (%)	C_p	EMS	F_{cal}	Sig
Linear Model					
Y = 124-0,231NIR-1,30MIRI	35,0	-0,1	446,6	7.27	0,003
Y = 175-1,77G-0,923MIRI	36,1	-0,5	439,0	7,63	0,002
Y = 78+2,22B-2.86G-0,922MIRI	37,1	1,1	449,0	5.10	0,007
Quadratic Model					
$Y = 132222940{,}623MIRI^{-3,89}$	41,5	-2.0	0,721	19.86	0.000
$Y = 43{,}224E + 13B^{-3,91}MIRI^{-3,89}$	42.1	-0,2	0.741	9,80	0.001
$Y = 43{,}448E + 11G^{-3,69}MIRI^{-2,28}$	42,8	-0,5	0,731	10,11	0,001
Exponential Model					
$Y = e^{6,62-0,0535MIRI}$	41,5	-2,2	0,721	19,87	0,000
$Y = e^{7,02-0,0215R-0,0564MIRI}$	41,9	-0,4	0.743	9,72	0,001
$Y = e^{8,89-0,0609G-0,0491MIRI}$	42,5	-0,7	0,735	9,98	0,001

Table 1 shows that all calculation indicating a valid calculation because of signification less than 5%. Then, based on the determination coefficien (R^2), we choose the highest value. As a result, the carbon storage extracted from landsat spectral image is shown as in the Table 2.

Table 2. **Selected model to estimate carbon storage**

Carbon storage estimation model	R^2 (%)	C_p	KTS	F_{cal}	Sig
$Y = 43{,}448E + 11G^{-3,69}MIRI^{-2,28}$	42,8	-0,5	0,731	10,11	0,001

b. Carbon Storage Estimation Model based on Vegetation Index

Variation of estimation models based on vegetation index of Landsat image was calculated as shown in Table 3. As mentioned before, correction of models was conducted with evaluation on number of determination coefficien (R^2) and error mean square (EMS). Concerning on this values, we decided that the best equation model of carbon storage estimation based on vegetation index is shown as in the Table 4.

Table 3. **Carbon storage estimation models based on vegetation index**

Carbon storage estimation model	R^2 (%)	EMS	F_{cal}	Sig
Linear Model				
Y = -77 + 113 TNDVI	3,5	639,1	1,02	0,320
Y = 11,1 + 133 II	21,5	520,4	7,65	0,010
Y = 89,2 - 78,2 MidIR	22,0	516,5	7,92	0,009
Quadratic Model				
$Y = 27{,}113NDVI^{6,49}$	7,8	1,136	2,38	0,134
$Y = 68.033NDVI^{1,35}$	9,8	1,112	3,03	0,093
$Y = 7{,}099\ MidIR^{-3,28}$	29,0	0,875	11,44	0,002
Exonential Model				
$Y = e^{-3,6+6,90TNDVI}$	7,1	1,144	2,15	0,154
$Y = e^{1,96+6,67II}$	29,2	0,872	11,55	0,002
$Y = e^{5,9-3,95MidIR}$	30,3	0,859	12.15	0,002

Carbon storage estimation model	R^2 (%)	EMS	F_{cal}	Sig
$Y = e^{5.9-3,95MidIR}$	30,3	0,859	12,15	0,002

1. The result of this research found carbon storage estimation at greenery open space at East Jakarta as follow:
   - as Landsat MSS acquitition 1986 is 184.975 ton/ha
   - as Landsat 5 acquitition 1992 is 165 050 ton/ha
   - as Landsat 7 ETM SLCOFF acquisition 2001 is 181.805 ton/ha

- as Landsat 7 ETM acquitition 2005 is 183.710 ton/ha

2. The number of carbon storage estimation above was calculated using the best model based on digital number (DN) $Y = 43{,}448E + 11G^{-3{,}69}MIRI^{-2{,}28}$.

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