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Urban tree biomass estimation in Universiti Putra Malaysia (UPM) campus

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ABSTRACT

Biomass is a renewable energy source refers to living and recently dead biological materials that can reduce green house effect and clean surroundings. To estimate tree biomass individually from imagery, it is necessary to clarify the relationship between attributes of stand structure obtained by field measurement and remote sensing image.This study was carried out to estimate tree biomass in Universiti Putra Malaysia (UPM) campus. Five plots were established (40 m x 40 m) and all trees with diameters at breast high (dbh) more than 30 cm , tree height and canopy size were measured. Each trees biomass were calculated by non-destructive method. Results show that tree volume is ranged from 1.75 m^3 to 24.73 m^3, wood density is ranged from 0.99 t/m^3 to 14.10 t/m^3. The overall wood densities for five plots (30 trees) are 23.35 t/m^3. Meanwhile the biomass estimated is 7,644 t/ha. Study demonstrate strong correlations ($p < 0.05$) between field measurement and IKONOS tree canopy estimates ($r^2 = 0.95$). The results obtained from the analysis are encouraging especially canopy measurement where it can be incorporated to the existing mensuration models. Estimating tree biomass through satellite images are recommended because remote sensing through image processing has potential to estimate biomass in large area.

Introduction

Trees are a valuable natural property that is necessary to our life. It is hard to imagine our life in urban areas without trees. All trees are important especially trees in and near urban area because it not only provide beauty side seeing, visual joy, but also influence directly or indirectly urban environment through their physical characteristic. For example, tree influence urban environment conditions and energy fluxes and also influence the air quality to urban communities. Trees also provide biomass. The potential role of biomass energy acquired a new dimension when it was suggested that planting large areas of new forest could slow the increase in atmospheric carbon dioxide by removing carbon dioxide from the atmosphere. In forestry, trees play a key role to global climate change, since they are both sources and sinks of carbon dioxide emissions. Trees act as a sink for CO2 by fixing carbon during photosynthesis and storing excess carbon as biomass. According to Hamilton (2002) estimating biomass is useful for evaluating the sources of carbon that result from converting a forest to cleared land, or vice versa. Forests exchange large quantities of CO2 with the atmosphere and make an important contribution to the global biogeochemical cycling of carbon.

Since an ancient time biomass is being used as a source of primary energy all over the world. The use of biomass to produce energy is only one form of renewable energy that can be utilized to reduce the impact of energy production and use on the global environment, in contrast to fossil fuels. As with any energy rears limitation on the use and applicability source there are limitation on the use and applicability of biomass and it must compete not only with fossil fuels but with other renewable energy sources such as wind, solar and wave power (McKendry, 2002). Meanwhile Bames and Spur (1998) stated that biomass is the dry mass of living organisms and dead organic matter contained in a defined area, usually one square meter or a hectare ($gm^{-2}/kg\ ha^{-1}$). In some instances, biomass is reported in its C or energy equivalent ($g\ Cm^{-2}/cal\ m^{-1}$), a necessary tool for understand the function of C (energy) within ecosystem. According to Young (1977), biomass studies can be carried out in conjunction with volume if vast amount of information of forest stand is required. The percentages of bole biomass increase with increasing age, site index and stand density.

Relatively total bole production is increase to the stand density and absolute stand density although the size of individual tree decreases with high absolute and relative density (Satoo and Madgwick ,1992). In fact, biomass is an important variable in forest properties. There were various method has been carried out in estimating biomass such as biomass for individual tree, for plantation and for other forest component. Therefore the estimating biomass density of woody formations is essential to be carried out from collected tree inventory data. The study for estimating urban tree biomass is requires to safeguarding life and provide crucial information about trees and environmental quality. Thus, the objective of this study is to estimate tree biomass from collected tree inventory data in Universiti Putra Malaysia (UPM) campus.

Materials and Methods

Study Site, Data Collection and Analyses

The study area is located in the state of Selangor, the most urbanized state in Malaysia. Geographically, the study area is within latitudes 3°26' N to 3°31'N and longitudes 101°18' E to 02°33'E. Specifically, the study area is inside the Universiti Putra Malaysia campus. The UPM's average annual temperature is between 23°C to 33°C. Humidity usually exceeds 80 percent. The annual rainfall is approximately 1900 mm. The months from December till February are considered as wet season, whereas January, June and August are months of the driest period in the study area.

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Several materials had been used such as; IKONOS image (spatial resolution 1 meter)-for image interpretation and digital canopy measurement, global positioning system-to locate the location of plots areas, digital camera-for taking tree's pictures, measuring tape-to measure the canopy size, tree caliper- to measure tree diameter at breast height (DBH), clinometers-to measure tree height. Five plots were selected based on general urban forest species. The plots size were 40 m by 40 m and all trees with diameters at breast high (dbh) more than 30 cm , tree height and crown size were measured (Figure 1). Plot no.1 is located in Bukit Ekspo, plot no. 2 at the Faculty of Forestry, plot no. 3 is at the Faculty of Engineering. Meanwhile plot no. 4 is located at the College Sultan Alaeddin Suleiman Shah and lastly plot no. 5 is at fruit plantation just behind the College Chancellor.

Figure 1: A location of sample plots in UPM campus view by IKONOS imagery.

Each trees biomass were calculated by non-destructive method. Estimation of tree biomass was derived from known formula by Reyes et al.,(1992) and Sandra(1997). The formulas used are as follow:

Standing tree volume$_{30}$ (STV_{30})

Standing tree volume (m^3) = Tree basal area (m^2) x Tree height / 3 = $(DBH/200)^2$ x 3.142 x Ht / 3

Standing total Volume (m^3/ ha) = Sum of plot tree volume (m^3) / Plot area (ha)

The tree basal area and tree volume have to be calculated in order to calculate the standing total volume of each plot.

Wood Density Estimation

Sufficient wood density data of forest species to do such calculations are not always available. In these situations it is best to estimate a weighted mean wood density based on known species, using an arithmetic mean for tree species (Table 1). Since the mean of wood density for Asia region is 0.57, meaning that 1 m^3 of the area accommodate 0.57 ton of wood density. So Y = 0.57 * m^3.

Biomass Expansion Factor (BEF)

Biomass expansion factor is defined as the ratio of total aboveground oven-dry biomass density of trees with a minimum diameter at breast height of 10 cm or more to the oven-dry biomass density of the inventoried volume. Such ratios have been calculated from inventory sources for many forest types growing in moist to seasonally dry climates. Sufficient data were included in these inventory sources to independently calculate aboveground biomass density and biomass of the inventoried volume (Sandra et al., 1989). Analysis of these data shows that BEFs are significantly related to the corresponding biomass of the inventoried volume according to the following equations) Brown and Lugo, 1992):

BEF = Exp {3.213 - 0.506*Ln (BV)}

For BV < 190 t/ha 1.74

Where: BV = biomass of inventoried volume in t/ha, calculated as the product of STV/ha (m^3/ha) and wood density (t/m^3)

Volume Expansion Factor (VEF)

In an attempt to unify data on inventoried volume measured to a minimum diameter greater than 10 cm, volume expansion factors (VEF) were applied. After 10 cm, a common minimum diameter for inventoried volumes ranges between 25-30 cm. Data from inventories that reported volumes to minimum diameters in this range were combined into one data set to obtain sufficient number of studies for analysis. The VEF is defined here as the ratio of inventoried volume for all trees with a minimum diameter of 10 cm and above (STV_{10}) to inventoried volume for all trees with a minimum diameter of 25-30 cm and above (STV_{30}). The uncertainty in extrapolating inventoried volume based on a minimum diameter of larger than 30 cm to inventoried volume to a minimum diameter of 10 cm is likely to be large and is not suggested. Volume expansion factors based on these inventories ranged from about 1.1 to 2.5, and they were related to the STV_{30} as follows:

VEF = Exp {1.300 - 0.209*Ln (STV_{30})}

For STV_{30} < 250 m^3/ha = 1.13

Tree Canopy Measurement

The formula for the tree canopy measurement (average spreading) is obtained by measuring the maximum of canopy distance (MaxCD) and minimum of canopy distance (MinCD) for each tree canopy and averaging it. The way of measurement is shown in Figure 2. Tree canopy areas are calculated by using the following equation:

$CA = \pi r^2$

Where CA = canopy surface area (m^2)

r = (longest spread + shortest spread) / 2 (m)

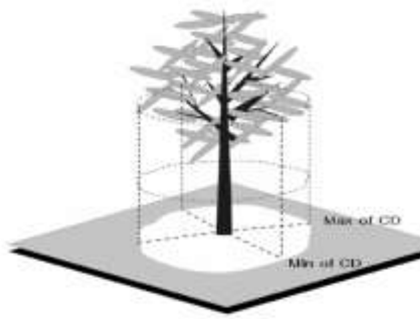

Figure 2: Tree canopy measurement *(Source: Changok, 2007).*

Canopy estimate through IKONOS imagery was carried out by using the 1 m by 1 m grid method and multiply with number of grid the tree crown accommodate. The calculated canopy areas from ground measurements and image method were regressed to determine the relationship of both data.

Results and Discussion

Tree Volume and Wood Density

By using the formula tree volume and wood density of each plot were calculated and the results as shown in Table 2. Tree volume and wood density for plot 1 is 24.73 m^3 and 14.10 t/ m^3, which is the highest among the other plots. This is because at plot 1, Bukit Ekspo consist an oldest and biggest tree diameter at breast height of *Pterocarpus indicus* species. The lowest tree volume and wood density was plot no. 2 which only 1.75 m^3 and 0.99 t/ m^3. The plot is located at Faculty of Forestry and the area only has a few trees with diameter breast height above 30 cm. The total tree volume and wood density calculated is 40.97 m^3 and 23.35 ton for one m^3.

Estimated Biomass

Table 3 shows the estimated biomass of standing trees for each plot. The different in total number of trees and diameter size are reflected the different of total biomass. Besides being influenced by the number of trees and trees diameter size, wood density also play the role in influence the estimated biomass. The total estimated biomass is 7644 ton for one hectare.

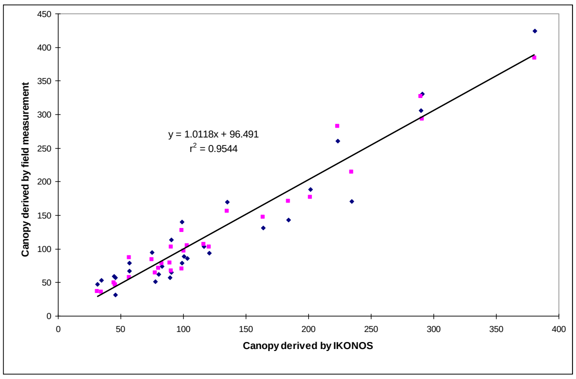

Figure 3: Linear regression fit line of comparison of canopy cover derived from field measurement and IKONOS

Conclusions

Based on the study the tree volume estimates for each plot is 24.73, 1.75, 2.61, 5.27 and 6.61 m^3 respectively. The overall tree volume is 40.97 m^3. Meanwhile the wood density estimated of each plots based on the formula and arithmetic mean is 14.10, 0.99, 1.49, 3.00 and 3.77 ton per one m^3. The overall total wood density estimated was 23.35 ton per one m^3. The tree biomass for each plot is 6305, 149, 217, 434 and 539 ton for one hectare. Therefore for five plots the total tree biomass estimated was 7644 ton for one hectare. The correlation of canopy area measurement between ground data and image method was positive where the regression model is y=1.018x + 96.491 r^2 = 0.95, p=0.05). The good correlation gained from regression model showed that image method for estimates canopy cover is consider acceptable where it can predict Y perfectly. The results obtained from the analysis are encouraging especially crown measurement that can be incorporated to the existing mensuration models. Estimating tree biomass through satellite images is recommended because remote sensing through image processing has a potential to estimate biomass in large area.

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Table 1: The arithmetic mean and most common wood density values (t/m^3 or g/cm^3) for tropical tree species by region

Tropical region	No. of species	Mean	Common range
Africa	282	0.58	0.50-0.79
America	470	0.60	0.50-0.69
Asia	428	0.57	0.40-0.69

(Source: Reyes et al. 1992)

Table 2: Tree volume and wood density for each plot

Plot no.	Tree volume (m^3)	Wood density(t/m^3)
1	24.73	14.10
2	1.75	0.99
3	2.61	1.49
4	5.27	3.00
5	6.61	3.77
Total	40.97	23.35

Table 3: Estimated biomass for each plot

Plot	Standing trees biomass (t/ha)
1	6305
2	149
3	217
4	434
5	539
Total	7644