Journal of Forest Research

OPEN ACCESS Freely available online

Research Article

Urban Forest Inventory for Carbon Reduction in a University City Campus

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ABSTRACT

Performing forest inventory in the campus is one of the breakthroughs towards achieving sustainable campus. Forest inventory aided the universities in creating a holistic baseline or framework in managing, planning and monitoring the forest in the campus in pursuance of a functional urban ecosystem through sustainable practice. The inventory aims to determine the number of trees and the stocking of carbon and biomass. Accurate estimation of the forest's number of trees and biomass carbon sinks can improve the understanding of carbon cycles and help in developing sustainable forest management. The study area is identified as secondary type forest with 50.1% of the strata is 60%-80% canopy cover dominated by small stands. There is a total of 14 sampling plots inventoried and measured using 40 × 40 m square plot sampling. 41% of the three species found comprised of rubber trees (Hevea Brasiliensis). The total number of trees estimated is 97,325 trees with the average density of 21 m^2/ha and 24,146.54 Mg CO_2e aboveground biomass and carbon stocking.

Keywords: Forest inventory; Carbon stocking and biomass; Green campus; Urban forest; Sustainable campus

INTRODUCTION

Each year, as the world progresses, the number of students who further their studies at universities is increasing [1,2]. The increase in urban growth, population and social needs have caused negative impact on the environment such as pollution, climate change, human health and more. Therefore, it is important to balance out and create a harmonious relationship between social needs, economic activity and environment [3]. Realizing it is important to restore balance in the three pillars, sustainability or sustainability development was the hot topic discussed in the Earth Summit 1992, where the discussion led to the formulation of Agenda 21 and the current ongoing initiative by the United Nations; Sustainability Development Goals (SDG) that include the role of educational institutions in achieving sustainability goals. Beringer, et al. and Davis and Wolski mentioned that sustainability is an important issue for universities and universities can create a sustainable campus through the learning process approach, campus environment and management [4,5]. In addition, according to Alfieri et al. "By living and learning in an environmentally conscious community, students learn to consider the impact of their everyday decisions" [6].

In the recent decade, the idea of sustainable campus has become widely accepted and adapted, where universities are committed on creating a green campus because there are many benefits that can be achieved through it such as reduction in pollution, energy saving, waste management, water management, decrease in carbon emission and more. Due to its growth in population, size and impact towards the society and environment, universities nowadays have been regarded and conceptualized as "small cities" or urban agent [7,8]. Not only that, the attempt for universities to produce low carbon emission were initiated towards sustainability in higher education and the results from the initiative turns out to be a compelling breakthrough such as improved environmental performance. Improving campus sustainability and carbon emission can be made in different approaches as for the heterogeneous nature of a university campus in terms of land uses and activities on campus. The approaches can be in terms of education, green features in a building design, physical changes in existing building and change in behaviour of the population [9,10].

For this paper, focus will be given on the forest inventory in University of Malaya (UM) main campus towards becoming a sustainable green campus. The main aim of the forest inventory is to determine the number of trees in UM forest and estimate the stocking and biomass of the forest. Besides the main aim, type of tree species, type of forest and forest stratification in UM were determined. The results obtained from the forest inventory will help to give a better picture in determining the targets and goals for the urban forest in the campus. It can help in creating holistic forest management framework and planning, sustain and maintain

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Received: 19-May-2022, Manuscript No. JFOR-22-17303; **Editor assigned:** 24-May-2022, PreQC No. JFOR-22-17303(PQ); **Reviewed:** 07-Jun-2022, QC No. JFOR-22-17303; **Revised:** 16-Jun-2022, Manuscript No. JFOR-22-17303(R); **Published:** 24-Jun-2022, DOI: 10.35248/2168-9776.22.11.327.

Citation: Yusoff SYM, Md Dali M, Hassan N (2022) Urban Forest Inventory for Carbon Reduction in a University City Campus. J For Res. 11:327.

forest contribution by continuous monitoring the state of the urban forest, maintain adequate stocking and canopy cover, better decision-making in establishing baselines from which future targets and goals can be determined, and able to model the ecosystem services and economic value of the campus forest.

In Malaysia, forest is defined as land spanning more than 0.5 ha with trees higher than 5 m and a canopy cover of more than 10% or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use FRA [11]. Major forest types in Malaysia are lowland dipterocarp, hill dipterocarp, upper hill dipterocarp, montane, ericaceous, and peat swamp and mangrove forests. In addition, there also smaller areas of freshwater swamp forest, heath forest, forest on limestone and forest on quartz ridges. Currently there are about 5.89 million ha of forest occur in Peninsular Malaysia, which covers about 44.7% of its land area. Out of this, 4.92 million ha falls under Permanent Reserved Forest (PRF), 0.58 million ha is Totally Protected Area (TPA) and the remaining 0.39 million ha belongs to state/alienated land. PRF can be further classified into four major types of forest which are inland, peat swamp, mangrove forests, and plantation forest which have extents of 4.39, 0.24, 0.10, and 0.19 million ha, respectively [12]. Malaysia's forest contains 3,212 million metric tons of carbon in living forest biomass. Between 1990 and 2010, Malaysia has lost forest cover at an average of 96,000 ha or 0.43% per year; where it comes to a total of 8.6% (1,920,000 ha).

These forests are common resources for native conservation and major income in forestry sector in Malaysia. However, those figures do not include forested areas or planted regimes within smaller landscape scales, especially in urban, settlements and campus architectures. Even though these vegetated areas are qualified as forests, they are often neglected and excluded in a larger forest management perspective. This is inevitably important when the contribution of trees to the oxygen supplies as well as stocks for carbon biomass is of concern. Realizing the importance of contribution of trees to the surrounding community, this study was therefore conducted.

The study is conducted at University of Malaya. It is located in Kuala Lumpur and well known as the best university in Malaysia. Sustainability development practice has been done by the university since a while ago. The total land area of the main campus is 367 ha. About 140 ha of forest cover was selected as the study area. The remaining areas comprise buildings, infrastructures and grasslands. The forest in UM campus is identified as secondary forest. The growth of the secondary forest was influenced by activities such as forest logging, plantation and urban development occurred around Kuala Lumpur [13]. The growth of the secondary forest in UM is related to existence of former rubber plantation in the past where abundance of unattended rubber trees can be found in the study area. Forest inventory in UM was done by using high-resolution satellite image from WorldView-2 in 2010 for sampling inventory planning and also for the forest stratification. From the image, the forest is stratified into three different strata based on the canopy cover interpreted, and a total of 14 samples was inventoried. The study area is dominated by forest which has canopy cover of 60%-80%.

All trees measuring diameter at breast height (DBH) of 5 cm and above were measured. The DBH is defined 1.3 meters above the ground, where the measurement taken. The study also used a square plot that is more suitable for tropical forest, systematic and accurate, thus able to avoid human error in acquiring the number of trees based on the strata in the study area. The estimated number of trees in the study area can be presented into two approaches; by multiplying overall average of counted number in sampling plot; and by multiplying the average number of trees within strata. The result from the later approach is more reliable for UM forest inventory. Biomass and carbon stocking were calculated by using three different allometric functions developed by Ketterings et al., Kenzo et al. and Brown for options in biomass reporting that provides most appropriate status and represent overall condition for secondary forest [14-16].

Forest inventory and management

The change in the global climate cause global warming where increase in global temperature by 1.5°C in a year is no longer impossible but an urgency that needed drastic measures to prevent it from happening IPCC [17]. The increase in population growth comes with the increase of land use for built space and decrease in green infrastructure and landscape, hence cause climate change. Therefore, environmental and ecological problems will likely arise due to the climate change, thus forest ecosystems play an important role in mitigating the impact of global warming as it is one of the major contributors of global ecosystem carbon pools [18]. Protection and rational utilization of natural resources become more and more important whereby forests are important not only as source of wood but as the means of protecting the hills. With accurate estimation of forest biomass carbon sinks, it will help in improving the understanding of carbon cycle and armed us in facing the climate change with holistic sustainable forest management policies developed from the knowledge gained [19].

The unceasing increase of carbon dioxide emission from moving vehicles fuels by fossil fuel and power automobiles, deforestation, buildings, industry development, pollution and more has cause the increase of the greenhouse gases and excessive heat in the earth's surface, thus powering the global warming and climate change. Due to the awareness to manage carbon emission, Kyoto Protocol 1997 was developed by the United Nations (UN) that aim to reduce anthropogenic greenhouse gases. According to the World Bank, and Chen and Chen, 70-80% of standard global carbon emissions are generated from economic activities and urban areas and the numbers are increasing every year [20,21]. In order to minimise the increase of carbon dioxide emission, the benefits of trees should be derived in this situation as trees have the potential and capability of carbon storage [22]. Trees acts as a sink for carbon dioxide by absorbing carbon during photosynthesis and storing carbon as biomass. During the growing period of a tree, it stores carbon, therefore, affect surrounding climate, carbon cycles, air temperature and alter the carbon emission of the surrounding area [23].

More trees are needed in area where abundant carbon dioxide is released such as in urban and city areas that usually heavily populated. The type of forest that usually found in urban cities are usually secondary type of forest. It is also known as urban forest. Rapid urbanization and industrial development caused the formation of secondary forest especially in developing urban centres due to the anthropogenic pressure and population migration to urban centres [24]. Although secondary forest is closer to human territory and act as carbon reservoir, primary forest is still the best option in managing carbon cycle in an ecosystem compare to secondary forest. A large healthy tree in cities is estimated to remove as much as 60 to 70 times the quantity of air pollution

compared to new planting [25]. Failure to provide the optimum condition necessary for trees to grow and mature in city area will affect the full ecological and aesthetic potential of trees in the city [26,27]. Hence, the amount of carbon sequenced and absorbed is greater with primary forest compared to secondary forest as the trees' growing condition and environment are usually disturbed by the rapid development of the city.

Urban forest usually designed and managed to be ecologically, socially and economically sustainable [28]. Despite knowing the benefits of urban trees towards environmental, human health and aesthetic benefits, it still faces threats from the rapid urban development population growth such as disease, unsatisfactory soil conditions, vandalism, pollution, and increase in land use. Trees have it hard to survive especially in the harsh urban environment.

Without forest inventory, forest management would not be sustainable and benefits to people and environment but with forest inventory, a proper management of the forest can ensure a functional urban ecosystem including improved public health, cleaner air, cool local air temperatures, and filter and retain storm water management, sequester carbon and aesthetic value for the community [29-33]. In order to maximize these environmental services, it requires decision-making that is grounded by up-to-date inventory of the forest's trees [27]. Initiative to implement green infrastructure within urban and cities such as tree planting campaign can help in mitigating the environmental effect of urbanization [34]. Lottrup in his study mentioned that people living and working near to green outdoor environment help in reducing stress and healthier [35].

Forest inventory is one of such tools and by using the correct sampling technique, less error can be done and avoided. Usually, vital information obtained from forest inventory that is very useful for forest management are growing conditions, volume of trees, stock resources, resource planning, annual growth and net worth statement, forest composition and topography, wildlife population, tourism potentials, hydrology, species, carbon sequestration and the non-timber forest products assessment (NTFP) [36]. Hush et al. in his study mentioned forest inventory as a procedure to obtained information on the quantity and quality of the forest resource and other characteristics of the trees in the forest while they grow [37]. Correct and effective sampling technique is the most important data that need to be collected in forest inventory to establish a proper and holistic forest management. Sampling design can be classified into two groups: probability and non-probability sampling. Both sampling groups apply statistical sampling theory and obtained unbiased estimates of the sampling errors. In short, the benefit sampling is such time and money efficiency, less labour, and more ease and accurate measurements. With good and reliable data from forest inventory, better forest management can be done in order to produce excellent goods and services from the forest. According to Adekunle, there are four ingredients for the recipes of effective sampling techniques for forest management [38]. The first ingredient is to use accurate statistical and computational tools to analyse data collected during forest inventory. The second ingredient is acquiring well experienced and knowledge personnel to monitor and exercise during the data collection and processing. The third ingredient is to be well equipped in terms of equipment, logistics, facilities, etc. during data collection and processing. The last ingredient is to have proper storage and retrieval systems of the information and data gathered for reporting purposes.

Sustainable forest management (SFM) addresses great challenge to match the increasing demand of growing human population while maintaining the ecological function of the forest ecosystems [39]. It also helps in addressing forest degradation and deforestation while increasing direct benefit to people and the environment. The results obtained from forest inventory play an important role in providing data for planning, monitoring, evolution, research, growth and holistic framework of a forest. Since the past decades, sustainable forest management has become a global highlight due to the increase in overexploitation of the forest and causing climate change that effect mankind [40,41]. SFM is difficult to define and there is no universally agreed-on definition [42].

Globally, forest management related policies are reported being executed on 97 % of global forest area. Due to the increase in forest management, the numbers of countries with national forest inventories have increased over the past 10 years from 48 to 112 countries [39]. In 2010, the percentage of the forest with management plans globally increases dramatically by 70% since 1950s. Many countries in the world are competing with each other to achieve sustainable forest management by reporting data that suggest they are moving towards sustainable management goals [43]. Thus, a sound forest inventory is a vital tool in gathering information to manage forests and its resources towards sustainable ecosystems of the environment and mankind [44-46].

MATERIALS AND METHODS

Study area

The University of Malaya (UM) is a public research university located in Kuala Lumpur, Malaysia. UM can be considered as "city" due to its strategic location and the land size. The total land area of the campus is 367 ha, where UM's green covers 140 ha of the total area (exclude grassland). The forest covers area selected from this study covered 38% of total land use area in University of Malaya. There are 577 numbers of buildings containing 14 faculties, 13 hostels and 6 administrative premises. As to 2019, the total population of UM is 2,344 academic staff, 3,526 non-academic staff and 24,463 students enrolled (international and local).

The main campus is located in Lembah Pantai. The campus spans over two municipalities' planning jurisdiction; the Kuala Lumpur City Hall (DBKL) and Petaling Jaya City (MBPJ). University of Malaya is bordered by more developed urban areas such as Taman Bukit Damansara and Bukit Kiara on the North, Phileo Damansara Trade Center on the west, while Bangsar on the East. The campus has a good accessibility to Sprint Highway on the North, the Federal Highway and Dato' Abu Bakar Road on the South and University Road on the West. These make University of Malaya a major node and gateway for most people around Petaling Jaya and Kuala Lumpur.

Data

In additional to some basic information that was acquired from the management of UM, a high-resolution satellite image over the campus area was used as ancillary information. This image was acquired from WorldView-2 satellite in panchromatic mode, with spatial resolution of 0.5 m. The image was captured on 2nd June 2010. It was used for sampling inventory planning and also for the forest stratification.

Forest stratification

The survey was conducted employing stratified random sampling. Intact forest in UM Campus was stratified into three strata, based on the canopy cover interpreted from the satellite image, namely (i) canopy cover <60%, (ii) canopy cover 60-80% and, (iii) canopy cover >80%. The fourth stratum was fragmented forest, classified based on condition where the forests are isolated by other land covers.

Sampling strategy

The sampling plots were laid randomly on ground in the forests according the strata. The number of sampling plots was determined based on the extent of each stratum. A total of 14 sampling plots were inventoried, which correspond to the total forest extent of 140 ha. The sampling technique applied was stratified random sampling with 10% sampling intensity. All trees measuring diameter at breast height (DBH) of 5 cm and above were taken into measurement. The DBH is defined as 1.3 m above the ground, where the measurement is taken. Height of the trees we also observed and species were identified whichever recognized.

Sampling plot layout

Different studies use different size, shape and dimension of sampling plots, depending on the objectives. This study used a square plot measuring 40 × 40 m. A total of 14 sampling plots were inventoried made up a total area of 2.24 ha, corresponding to representing 14 ha of 10% sampling intensity. This size was identified as ideal for tropical forest, which is sufficient to represent the condition of a forest in 1 ha (100 × 100 m). The plot was divided into four quarters, in which each measuring 20 × 20 m. The cross section of all quarters was used as the plot centre, where the geographic location was recorded. It was conducted in such a way to make sure that the inventory work is carried out systematically, to avoid double counting of trees and also to minimize human errors in the field. The layout of the plot is depicted in Figure 1.

Stands physical variables

In additional the information on the number of trees in the study area, it is also important to understand the other stand variables so that the forest resources being assessed is well described. The stands variables that were included in this study are:

(i) Basal area/Stands density

(ii) Stand volume

(iii) Biomass

Basal area was calculated to measure the density of standing trees in the study area. It is simply the area (normally in m^2) of base or stump of the standing trees, used to measure the growth rate and productivity of a forest. It is calculated by using the following formula

$$\text{Basal area, BA } (m^2) = \pi (DBH/100/2)^2 \quad (1)$$

Volume in a stand or plot is important for forests quantification and management. Stand volume at a nominated age is related to the site quality, and the total at any time is important for an estimate of wood and biomass resource in a forest. The stand volume that was calculated for this study considers the total volume of a standing tree including bole stem, trunk and branches. The calculation was based on the followings:

$$\text{Volume, V (m3)} = -0.331 + 6.694 (DBH/100)2 \quad (2)$$

Biomass is another important forest variable, which measures the mass of living materials in a standing tree. According to the early investigation, it was found that the forest in the study area is consisting of secondary forest. It was also notably that the forest comprises unattended rubber plantation, where the production of rubber operated in the study area a few years ago. Therefore, the selection of allometric functions to estimate aboveground biomass of the trees was based on the forest types. In this study, only aboveground part of biomass was taken into consideration. Table 1 summarizes the allometric functions that were used in the study.

RESULTS AND DISCUSSION

Forest stratification mapping

Forest classification was carried on the satellite image and was found that the total forested area (based on definition) in UM Campus was about 108 ha. Although there are individual landscape trees standing in the campus area, they are not considered in this study. Further classification needs to be carried out to determine the number of this kind of trees and it can be done by using similar or the same satellite image. From the image interpretation and vectorisation of the forest cover in the study area, it was found that the study area is dominated by forest which has canopy cover of 60%-80%. Table 2 summarizes the extent of forest strata in the study area. Based on these extents, the number sampling plots were determined. Figure 2 shows strata of forests while Figure 3 indicates locations of sampling plot distributed in the entire study area.

Sampling plot summary

A total of 14 sampling plots were inventoried from 18th to 23rd November 2013. A team consisted of 5 field workers were involved in the survey work. Table 3 lists the properties of all plots that were sampled in the inventory.

In general, a sum of 2000 stands was measured in the inventory. Basic analysis indicated the forests in the study area are dominated by small stands, which have DBH ranging from 5 to 10 cm. It dominates about 43% of the total stands sampled. This is followed by stands measuring DBH from 10 to 20 cm, which consisted of about 37% of the total stands. These were made up of 80%, which means that only 20% of the remains comprised big trees measuring DBH more than 20 cm. Figure 4 illustrates the distribution of stands in the total 2.24 ha of sampling plots. Figure 5 also indicates the overall condition of stands in the sampling plots.

The status of forests in the study area can be also represented in species composition. The study found that almost half (41%) of the trees sampled comprised rubber trees (Hevea Brasiliensis). The remaining consists of mixed species, which are majority that dominating secondary forest. No dipterocarps species was found in the inventory implies that the forest is not a natural lowland dipterocarps forest. The species composition of the trees in the sampling plots is summarized in Figure 6.

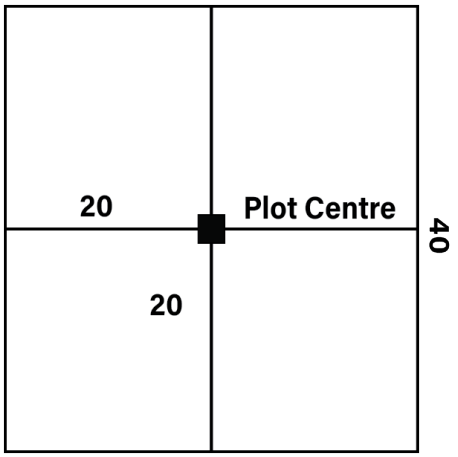

Figure 1: Layout of sampling plot.

Table 1: Allometric functions used to estimate aboveground biomass.

No.	Source	Allometric functions	Site
1	Katterings et al. (2001)	ln(Wt) = 2.59 × ln(D) - 2.75	Secondary forest, Sumatra, Indonesia
2	Kenzo et al. (2009)	Wt=0.0829 × D2.43	Secondary forest, Sarawak, Malaysia
3	Brown (1997)	Wt=exp [-2.134+2.530*ln (D)] (For diameter limit <60 cm) Wt=42.69 – 12.800* (D)+1.242* (D) ^{2} (For diameter limit 60-148 cm)	Rubber plantation, Indonesia

Note: * Where D is the diameter at breast height (DBH); Wt is the aboveground biomass of standing trees.

Table 2: Extent of forests in UM Campus according to strata.

Strata	Area (Ha)	Percentage (%)	Sampling plot (No/ID)
Canopy cover<60%	20.13	18.6	3 (7,9,10)
Canopy cover 60-80%	54.17	50.1	7 (1,2,3,4,5,6,8)
Canopy cover 80%	26.66	24.7	2 (13,14)
Fragmented Forest	7.13	6.6	2 (11,12)
Total	108.09	100	14

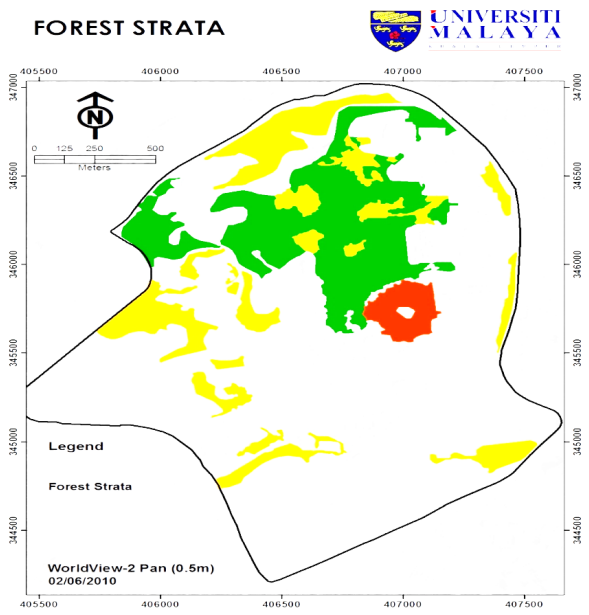

Figure 2: Strata of forests in the study area. **Note:** (▭) UM Bounsary, (▬) CANOPY 60-80%, (▬) CANOPY <60%, (▬) CANOPY >80%, (▬) FRAGMENTED FOREST.

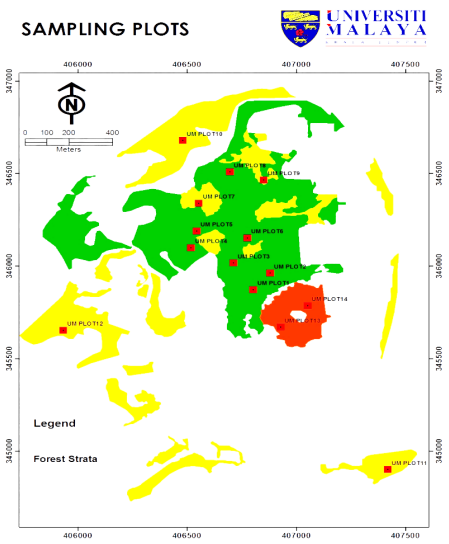

Figure 3: Location of sampling plots, corresponding to forest strata. **Note:** (▭) UM Bounsary, (▬) CANOPY 60-80%, (▬) CANOPY <60%, (▬) CANOPY >80%, (▬) FRAGMENTED FOREST.

Table 3: Properties of the sampling plot.

Plot ID	Easting	Northing	Elevation (m)	Date	Day	Time
UM PLOT1	101.65575	3.12525	84	18-Nov-13	Monday	1120
UM PLOT2	101.656444	3.126056	79	18-Nov-13	Monday	1419
UM PLOT3	101.654944	3.126556	99	18-Nov-13	Monday	1240
UM PLOT4	101.652583	3.125	94	19-Nov-13	Tuesday	1005
UM PLOT5	101.653417	3.128111	103	19-Nov-13	Tuesday	1125
UM PLOT6	101.6555	3.127778	73	19-Nov-13	Tuesday	1250
UM PLOT7	101.6535	3.129472	107	20-Nov-13	Wednesday	1330
UM PLOT8	101.654778	3.131	93	20-Nov-13	Wednesday	1215
UM PLOT9	101.656167	3.130611	78	20-Nov-13	Wednesday	1005
UM PLOT10	101.652833	3.132528	120	21-Nov-13	Thursday	1020
UM PLOT11	101.661306	3.116472	76	21-Nov-13	Thursday	1205
UM PLOT12	101.647944	3.12325	98	21-Nov-13	Thursday	1335
UM PLOT13	101.656889	3.123417	87	22-Nov-13	Friday	1155
UM PLOT14	101.658	3.124472	93	23-Nov-13	Friday	1025

Table 4: Summary of basal area and volume estimated for all sampling plots.

Plot ID	Basal Area (m^2/ha)	Volume (m^3/ha)
UM PLOT1	30.33	297.8
UM PLOT2	26.71	265.13
UM PLOT3	20.67	202.8
UM PLOT4	23.14	234.1
UM PLOT5	22.17	219.4
UM PLOT6	25.12	255.7
UM PLOT7	23.16	232
UM PLOT8	25.66	247.2
UM PLOT9	18.51	184.5
UM PLOT10	2.81	29.57
UM PLOT11	19.18	184.79
UM PLOT12	15.57	163.1
UM PLOT13	22.16	217.23
UM PLOT14	18.48	183.54
Average	20.98	208.35
UM PLOT14	UM PLOT14	UM PLOT14
UM PLOT14	UM PLOT14	UM PLOT14
UM PLOT14	UM PLOT14	UM PLOT14

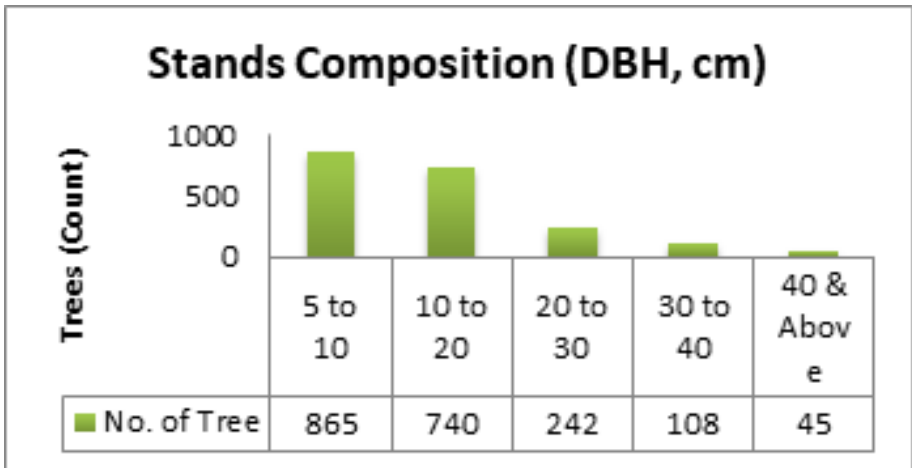

Figure 4: Distribution of stands according to the DBH classes.

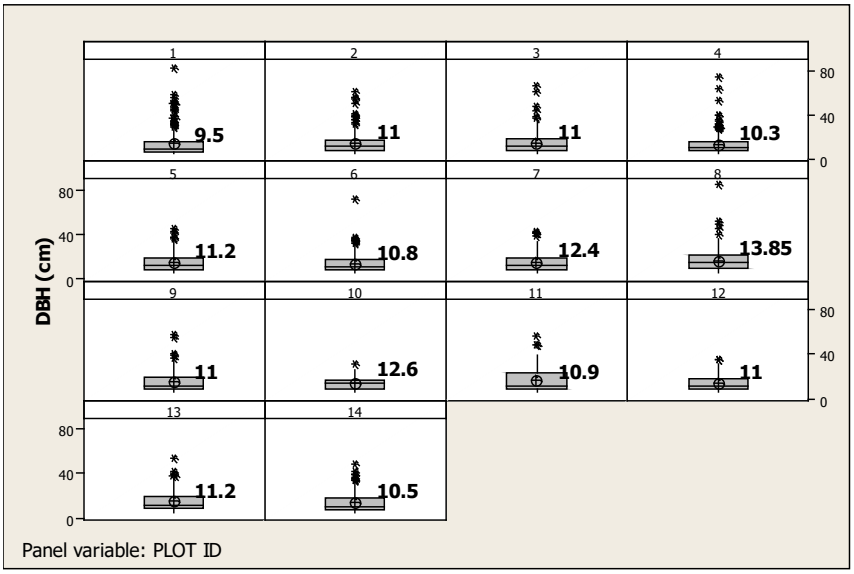

Figure 5: Distribution tree sizes in the sampling plots. The figures indicate the mean DBH of each sampling plot.

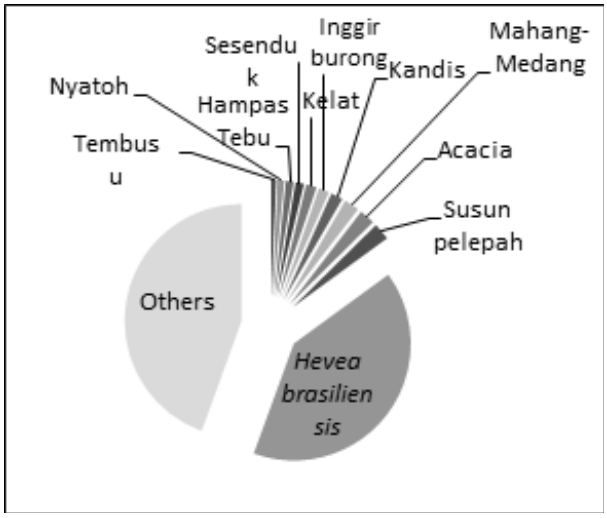

Figure 6: Composition of tree species in the sampling plots.

Basal area and volume

The basal area and volume of stands were estimated in per-hectare basis, where each plot was converted into 1-ha. Table 4 summarizes the estimated basal area and volume in all sampling plots. It was observed that the basal area is ranging from 15 to 30 m^2/ha, except for UM PLOT10 has extremely low and out of range. The average basal area was about 21 m^2/ha, indicating that the forest is in growing stages where trees are generally small with medium density. Basal area for natural dipterocarps forests usually ranges from 50-100 m^2/ha.

Number of trees

Estimation of the number of trees in the study area was conducted based on strata, rather than overall sampling plots to improve the estimation accuracy. Tables 5 and 6 describe how the number of trees was estimated for the whole study area.

The estimated number of trees in the study area can be presented into two approaches, which are (i) by multiplying overall average of counted number in sampling plots, and (ii) by multiplying the average number of trees within strata. The first approach estimated that the total number of trees was 96,524, while the second approach was 97,325. Although there is difference about 801 trees, the second approach gave more reliable estimates.

Biomass

Biomass of the forest in the study area was calculated by using three different allometric functions. Allometric function that was developed by Katterings et al. and Kenzo et al. were designated for secondary forest [14,15]. Brown allometric equation was developed for rubber trees [16]. These functions were used to produce options in reporting biomass, which are most appropriate to represent the overall status and condition of forests in the study area. There is no clear demarcating line to separate the value of biomass for each forest type but it was indicated from previous study that the average aboveground biomass for secondary forest was around 200 Mg/ha. However, it depends also on the allometric functions used to estimate biomass and physical conditions of forest. Table 7 summarises the estimates of aboveground biomass in all sampling plots of the study area [47-49]. Taking Kattering's allometric functions as the most appropriate equation, the total aboveground biomass in the study area was estimated at 13,158.88 Mg, equal to 6,579.44 Mg of carbon stock, which is equivalent to 24,146.54 Mg CO_2e.

Table 5: Counted trees in sampling plots, classified into forest strata.

Plot ID	Strata	No. of tree
UM PLOT1	Canopy cover 60%-80%	190
UM PLOT2	Canopy cover 60%-80%	181
UM PLOT3	Canopy cover 60%-80%	129
UM PLOT4	Canopy cover 60%-80%	178
UM PLOT5	Canopy cover 60%-80%	147
UM PLOT6	Canopy cover 60%-80%	201
UM PLOT8	Canopy Cover 60%-80%	138
UM PLOT7	Canopy cover<60%	167
UM PLOT9	Canopy cover <60%	129
UM PLOT10	Canopy cover <60%	27
UM PLOT11	Fragmented Forest	103
UM PLOT12	Fragmented Forest	147
UM PLOT13	Canopy cover 80%	137
UM PLOT14	Canopy cover 80%	126
	Average/plot	143
	Average/ha	893

Table 6: Estimations of the total number of trees in the study area.

Strata	Mean no. of trees (Count/plot)	Mean no. of trees (Count/ha)	Strata area (ha)	Total trees (Count)
Canopy cover<60%	107.7	672.9	20.13	13,545.80
Canopy cover 60%-80%	166.3	1039.3	54.17	56,298.10
Canopy Cover 80%	131.5	821.9	26.66	21,911.20
Fragmented forest	125	781.3	7.13	5,570.30
Average	143	893	108.09	96,524 A
Total	-	-	108.09	97,325 B

Note: A Calculated based on overall average of sampling plots; B Calculated based on average sampling plots according to forest strata.

Table 7: Aboveground biomass estimation for all sampling plots.

PLOT ID	Biomass Katterings (Mg/ha)	Biomass Kenzo (Mg/ha)	Biomass brown (Mg/ha)
UM PLOT1	202.89	146.51	295.8
UM PLOT2	160.5	119.57	241.17
UM PLOT3	126.36	93.71	189.54

UM PLOT4	139.93	103.66	209.73
UM PLOT5	122.13	93.62	185.56
UM PLOT6	136.07	104.21	206.55
UM PLOT7	121.32	94.28	185.28
UM PLOT8	161.3	118.48	241.03
UM PLOT9	104.68	79.43	158.39
UM PLOT10	12.91	10.42	20
UM PLOT11	114.77	85.96	172.85
UM PLOT12	73	58.52	112.8
UM PLOT13	125.53	95.44	190.13
UM PLOT14	103	78.61	156.23
Average	121.74	91.6	183.22

In the initial phase of the introduction of the concept of sustainable development, it seems to bring a new mindset in the field of environment and development of the country. In the context of sustainable development, 'development' must keep pace with environmental concern on the background so that the process does not leave a negative impact on people and the environment in particular. A forest inventory should be taken seriously and accurately to improve the creation of the forest management on campus. A forest inventory is the foundation to understand the resources that the campus urban forest currently contains and tracking changes.

CONCLUSION

The study has successfully assessed the forest resources that are available in UM Campus. From the image interpretation and vectorisation of the forest cover in the study area via the satellite image, it was found that the study area is dominated by forest which has canopy cover of 60%-80%. It was found that the forests in the study area fall in the category of secondary forest where stands are in the successive growing stages. This study used a square plot measuring 40 × 40 m. A total of 14 sampling plots and 2000 stands were measured and inventoried in this study. Basic analysis indicated the forests in the study area are dominated by small stands (DBH range from 10 to 20 cm) which consisted of about 37% of the total stands. The species composition found of the tree sampled in the study comprised of 41% rubber trees (Hevea brasiliensis). The remaining consists of mixed species, which are majority that dominating secondary forest. The study estimated that the total number of trees in the study area was 97,325, with the average density of 21 m^2/ha. The average basal area density of 21 m^2/ha, indicating that the forest is in growing stages where trees are generally small with medium density and 24,146.54 $MgCO_2e$ aboveground biomass and carbon stocking was calculated by using Kattering's allometric functions as the most appropriate equation compare to the other three allometric function calculated.

Intensive sampling units with support from sufficient spatial data produced reliable estimates. This information is crucial for the reporting of forest resources that reside in an urban environment. With the new sets of data of the trees in UM obtained from the forest inventory, UM management now have the ability to easily and accurately evaluate the composition and condition of the forest, and estimate the environmental services and aesthetic values. These are the first few steps that have been taken by UM towards improving the management and governance of the urban forest on campus. There are other tremendous opportunities to grab by the university and the stakeholder by exploring and working on the data obtained from the inventory in order to maintain, sustain, monitor or even develop the forest on campus.

ACKNOWLEDGMENT

The authors would like to acknowledge the financial support provided by University Malaya Sustainability Science Cluster Flagship Grant [FL027-2012B] and the field work assistance by the staff of Forest Research Institute Malaysia (FRIM).

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