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Automated Hazard Rating Assessment of Roadside Trees Using MUTIS ver 1.0

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ABSTRACT

Despite providing benefits in the forms of green landscape, human health, storm water management, carbon storage, etc., roadside trees are also potentially hazardous to their surroundings. Hence, there is a need to determine hazardous severity of these trees. Hazard rating assessment in the context of urban trees is the evaluation of the hazard by trees and how likely they are to fail as well as how severe in terms of damages that they could cause to their surroundings. In this study, roadside trees hazard rating was assessed automatically using a customized ArcMapTM and Visual Basic for Applications (VBA), known as Malaysian Urban Trees Information System (MUTIS), developed by Faculty of Forestry, Universiti Putra Malaysia (UPM). The study determined the accuracy of MUTIS in generating hazard rating assessment. The study area covered parts of UPM's academic zone. Results depicted that out of 909 trees assessed, 99.8% (907 trees) were categorized as 'Medium' hazard, while no trees had 'Low', 'High', and 'Severe' hazard rating. In this study, MUTIS assessment achieved 93.75% accuracy. Upon deriving hazard rating assessment, abatement activities were subsequently prescribed, in which the activities were mainly tree pruning with specified direction and intensity. This study indicated that MUTIS ver 1.0 can be an alternative tool to determine hazard rating of roadside tree.

Keywords: Tree hazard rating assessment, GIS, urban trees, MUTIS

INTRODUCTION

Roadside trees provide benefits such as rainfall interception and tempered release into surface waters, reduced air pollution through leaf uptake of pollutants, positive effects on the psychological health of people, etc. (Hauer & Johnson, 1992).

However, they are bound to be hazardous to their surroundings. Hazardous trees are trees that have structural defects in their roots, stem, or branches, which may cause the trees or parts of the trees to fail, where such failures may cause property damages or personal injury (Joseph, 1992).

Hazard rating assessment or tree risk inspection in the context of urban forest or roadside trees is the evaluation of the hazard of trees and how likely they are to fail, as well as how severe in terms of damages that they could cause to their surroundings. The purpose of tree risk inspections is to identify defective trees in target areas, assess the severity of the defects, and recommend corrective actions before tree failure occurs. Tree risk ratings can assist communities in quantifying the level of risks posed to public safety and in prioritizing the implementation of corrective actions (Albers, 1993).

The word hazard, for both lay-people and professionals, denote that some thresholds of risk have been surpassed. Hazard also conveys the immediacy of structural failure as determined by a tree professional. The hazard concept demands a completed evaluation and assessment of risk, which reaches a management threshold, where the situation cannot be allowed to continue. This requires an evaluation that is based on spatial information for better visualization and data management.

Geographic information system (GIS) software is therefore a logical choice for storing and manipulating urban tree resource data. In particular, GIS provides a logical foundation for any data collection, analysis and planning initiative related to a community's urban and community forest. GIS programmes such as ArcGIS and ArcPad are powerful and important tools to consider, whether looking at the overall urban forest, or managing individual trees growing along streets or in parks. Whether looking at the urban forest from a broad scale or more closely examining individual trees, GIS provides a strong backbone to any useable system (David et al., 2003). Hence, the best solution is to acquire a comprehensive urban forest management system that integrates relational database with GIS and decision support system.

MUTIS ver 1.0 (Malaysian Urban Trees Information System) is a programme jointly designed by the certified arborists from International Society of Arboriculture (ISA) and GIS specialists from the Faculty of Forestry, Universiti Putra Malaysia (UPM). The programme was established to assist tree technicians in their daily-routine management activities of the urban forest. It is a comprehensive urban tree inventory and urban tree management system that provides decision support system in determining hazard risks and suggesting abatement for subsequent actions as well generating conforming reporting (Alias, 2009).

The objectives of this study are:

i. to determine the hazard rating of roadside trees; and,

ii. to determine the efficiency of MUTIS in evaluating hazard risks of roadside trees.

METHODOLOGY

Study Area

The study was conducted at Universiti Putra

Malaysia (UPM), Serdang, which covers about 105.22 ha that encompasses parts of the academic area. These area was divided into four zones; A, B, C and D, as shown in Fig.1 below.

Methods

This study utilized the QuickBird satellite image of UPM, which has spatial resolution of 0.6 m as the base map. Digital vector layer of UPM's boundary was acquired from UPM's University Agriculture

Park office to demarcate its boundary on the satellite image. Roadside trees were digitized using ArcMapTM to produce a tree vector layer and each tree was given identification number and tagged on the ground. Tree inventory and hazard assessment form were prepared to assist in ground data collection. The ground data collection consisted of two parts: i) hazard assessment and (ii) tree inventory. Hazard assessment parameters were filled in the form according to the International Society of Arboriculture (ISA). ISA form format was based on the handbook "A Photographic Guide to the Evaluation of Hazard Trees in Urban Areas" (Matheny & Clark, 1994). Ground activities include collecting basic tree information such as height, tree performance, GPS location,etc. Ground data were keyed into MUTIS to calculate hazard rating. The overall activity flowchart is shown in Fig.2.

Fig.1: Study area at UPM which was divided into 4 zones A,B,C, and D

In this study, hazard rating was derived from three components: (a) Failure Potential (FP), (b) Size of Parts (SOP) and (c) Target Rating (TR). Component FP has three sub modules: (i) site conditions, (ii) tree defects and (iii) tree health. In the sub-modules, there were attributes for each parameter. These attributes were given scoring based on the status, magnitude or severity of each parameter. The accumulated scores of each sub modules were summed up to compute failure potential. The conclusive formula of hazard rating is as follows:

Hazard rating (HR) = Failure potential (FP) + Size of parts (SOP) + Target rating (TR)

The explanations for FP, SOP and TR given by Matheny and Clark (1994) are as follows:

Failure Potential (FP)

Failure potential identifies the most likely failure and rates the likelihood that the structural defect(s) will result in a failure within the inspection period. Examples of the ratings are:

1. low: defects are minor (e.g. dieback of twigs, small wounds with good wound wood development)
2. medium: defects are present and obvious (e.g. cavity encompassing 10 – 25% of the circumference of the trunk, codominant stems without included bark)
3. high: numerous and/or significant defects present (e.g. cavity encompassing 30 – 50% of the circumference of the trunk, multiple pruning wounds with decay along a branch)
4. severe: defects are very severe (e.g., heart rot decay fungi along the main stem, cavity encompassing more than 50% of the circumference of the trunk)

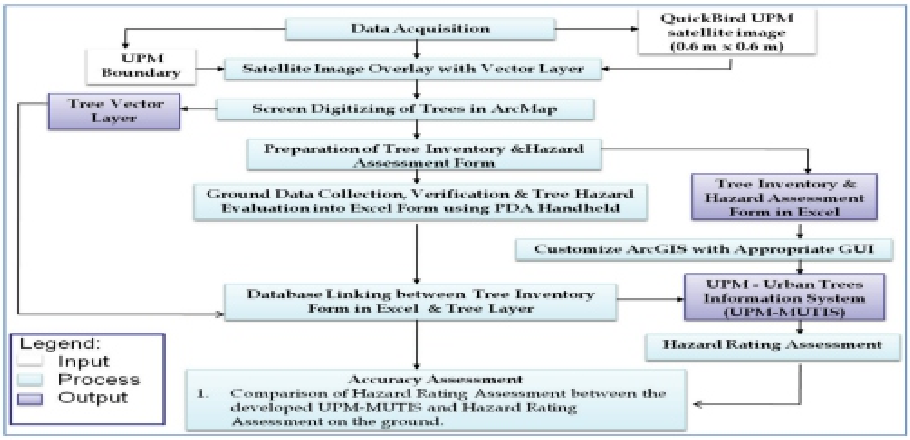

Fig.2: A flowchart showing the overall activities carried out in this study

Size of Part (SOP)

Size of defective part rates the size of the parts that most likely to fail within the inspection period. The larger the part that fails, the greater the potential for damages. Therefore, the size of the failure affects the hazard potential. Examples of the ratings are:

1. most likely failure less than 15 cm in diameter
2. most likely failures, 15 – 45 cm in diameter
3. most likely failures, 45 – 75 cm in diameter
4. most likely failures greater than 75 cm in diameter

Target Rating (TR)

Target rating rates the use and occupancy of the area that would be struck by the defective part. Examples of the ratings are:

1. occasional use (e.g. jogging or cycle trail)
2. intermittent use (e.g. picnic area, day-use parking)
3. frequent use (e.g. seasonal camping area, storage facilities)

4. constant uses, structures (e.g. year round use for a number of hours each day, residences)

The points in each category are added to obtain the overall hazard rating:

HR was categorized into four levels of summation, based on the cumulative scores for each component, as follows: (i) low, (ii) medium, (iii) high, and (iv) severe. Details of the HR levels are shown in Table 1 below.

Accuracy assessment of the MUTIS system was carried out by using a sample of 32 trees. Eight trees were selected from each zone. Accuracy percentage was calculated using the following formula:

Accuracy percentage (%) =

number of correct trees/ 32 x 100

TABLE 1
Description of Hazard Rating levels

Level	Scores	Classified	Remarks
1	3-4	Low	A tree presents with no or minimal risk assessment or associated risks
2	5-7	Medium	A tree presents with known risk assessments, or as yet undetermined associated risks
3	8-10	High	A tree "at risk" of catastrophic failure or with a significant target profile potentially leading to great injury and harm. A "tree at risk" has potential for becoming a hazard tree.
4	11-12	Severe	A tree that has a major structural fault that could lead to catastrophic loss and it has an identifiable target (people or property).

RESULTS AND DISCUSSION

From the study, it was found that there were 36 species of roadside trees. The most dominant was samanea saman with 149 trees (16.4%), followed by tamarindus indica with 124 trees (13.6%).

Analysis from MUTIS depicted that out of 909 trees assessed, 99.8% (907 trees) were categorized as 'Medium' hazard rating and no trees with 'Low', 'High' and 'Severe' hazard ratings. This was due to most trees were roadside which had Hazard Rating value of '3'. Table 2 shows the hazard rating of trees according to zones.

From Table 2, there were 832 trees and 75 trees which had hazard rating of 6 and 7, respectively. Zone B had the highest number of trees with hazard rating of 7 (medium). Ground observation revealed that all these trees are roystonea regia species which has high SOP factor. Two trees were without any hazard rating as they were removed by the authorities. Table 3 shows the results of hazard rating of trees according to species.

Table 3 depicts that there were only three species with hazard rating of 7, in which the highest was roystonea regia(67 trees), followed by samanea saman (6 trees) and callerya atropurpurea (2 trees). Meanwhile, Table 4 shows a comparison of hazard ratings that were generated through MUTIS system and manual rating from ground evaluation.This comparison can determine the accuracy assessment of hazard rating by MUTIS by applying the following formula:

Accuracy assessment
= (Number of trees with correct hazard rating/Total number of sampled trees) X 100

Hence, the accuracy assessment for this study = (30/32)*100%
= 93.75%

CONCLUSION

The tree hazard assessment process has provided a useful tool and information for evaluating and planning of roadside trees. The GIS platform of MUTIS ver 1.0 provides a better visualization of hazardous trees distribution. This study concluded that 99.8% of the roadside trees at the academic

TABLE 2
Results of hazard rating of trees according to zones

Hazard Rating	Low				Medium			High		Severe	None*	Total
Zone	3	4	5	6	7	8	9	10	11	12		
A	0	0	0	167	6	0	0	0	0	0	0	173
B	0	0	0	65	67	0	0	0	0	0	0	132
C	0	0	0	257	1	0	0	0	0	0	0	258
D	0	0	0	343	1	0	0	0	0	0	2	346
Total	0	0	0	832	75	0	0	0	0	0	2	909

*Trees removed by the authority after been tagged.

TABLE 3
Results of hazard rating of trees according to species

Hazard Rating / Species Name	3	4	5	6	7	8	9	10	11	12	None*
Azadirachta excelsa	0	0	0	8	0	0	0	0	0	0	0
Borassus flabellifer	0	0	0	1	0	0	0	0	0	0	0
Callerya atropurpurea	0	0	0	62	2	0	0	0	0	0	0
Callistemon citrinus	0	0	0	15	0	0	0	0	0	0	0
Calophyllum inophyllum	0	0	0	36	0	0	0	0	0	0	0
Caryota mitis	0	0	0	1	0	0	0	0	0	0	0
Casuarina equisetifolia	0	0	0	6	0	0	0	0	0	0	0
Casuarina nobilis	0	0	0	34	0	0	0	0	0	0	0
Cinnamomum iners	0	0	0	4	0	0	0	0	0	0	0
Cinnamomum verum	0	0	0	33	0	0	0	0	0	0	0
Cocos nucifera	0	0	0	40	0	0	0	0	0	0	0
Cynometra ramiflora	0	0	0	4	0	0	0	0	0	0	0
Fagraea fragrans	0	0	0	9	0	0	0	0	0	0	0
Filicium decipiens	0	0	0	5	0	0	0	0	0	0	0
Firmiana malayana	0	0	0	7	0	0	0	0	0	0	0
Hopea odorata	0	0	0	2	0	0	0	0	0	0	0
Hura crepitans	0	0	0	20	0	0	0	0	0	0	0
Juniperus chinensis	0	0	0	4	0	0	0	0	0	0	0
Licuala grandis	0	0	0	1	0	0	0	0	0	0	0
Livistona chinensis	0	0	0	25	0	0	0	0	0	0	0
Melalueca alternifolia	0	0	0	8	0	0	0	0	0	0	0
Mesua ferrea	0	0	0	93	0	0	0	0	0	0	0
Mimusops elengi	0	0	0	21	0	0	0	0	0	0	0
Peltophorum pterocarpum	0	0	0	8	0	0	0	0	0	0	0
Pinus caribaea	0	0	0	4	0	0	0	0	0	0	0
Polyalthia longifolia 'Temple Pillar'	0	0	0	13	0	0	0	0	0	0	0
Pongamia pinnata	0	0	0	14	0	0	0	0	0	0	0
Pterocarpus indicus	0	0	0	1	0	0	0	0	0	0	0
Ptychosperma macarthurii	0	0	0	1	0	0	0	0	0	0	0
Roystonea regia	0	0	0	61	67	0	0	0	0	0	0
Samanea saman	0	0	0	143	6	0	0	0	0	0	0
Swietenia macrophylla	0	0	0	1	0	0	0	0	0	0	0
Syzygium jambos	0	0	0	4	0	0	0	0	0	0	0
Tamarindus indica	0	0	0	122	0	0	0	0	0	0	2
Veitchia merillii	0	0	0	21	0	0	0	0	0	0	0
Total	0	0	0	832	75	0	0	0	0	0	2

*Trees removed by the authority after been tagged.

TABLE 4
Comparison of hazard level between MUTIS and ground evaluation

No	Tag_No	MUTIS	Ground Evaluation	No	Tag_No	MUTIS	Ground Evaluation
1	A0054	medium	medium	17	A0914	medium	medium
2	A0294	medium	medium	18	A0930	medium	medium
3	A0322	medium	medium	19	A0947	medium	medium
4	A0452	medium	medium	20	A0962	medium	medium
5	A0461	medium	medium	21	A0974	medium	medium
6	A0531	medium	medium	22	A0983	medium	medium
7	A0594	medium	high	23	A0993	medium	medium
8	A0610	medium	medium	24	A1008	medium	medium
9	A0615	medium	medium	25	A1011	medium	medium
10	A0672	medium	medium	26	A1019	medium	medium
11	A0696	medium	medium	27	A1026	medium	medium
12	A0734	medium	medium	28	E0004	medium	medium
13	A0760	medium	medium	29	E0029	medium	medium
14	A0816	medium	medium	30	E0033	medium	medium
15	A0875	medium	medium	31	E0036	medium	medium
16	A0880	medium	medium	32	E0039	medium	medium
16	A0897	medium	high				

area of UPM are safe, where the trees are classified as imposing medium hazard. Hazard rating assessment by MUTIS ver 1.0 is 93.75% as accurate compared with manual assessment. Based on the high accuracy assessment achieved by MUTIS ver 1.0, it can be recommended as a potentially suitable tool for accurate hazard rating evaluation of roadside trees.

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Species Diversity, Dominance and Management of Shorea lumutensis-Stand at Pangkor Island, Perak, Malaysia

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ABSTRACT

High Conservation Value Forest (HCVF) stand of Shorea lumutensis, one of the endemicdipterocarps in Peninsular Malaysia, was established in Pangkor Island, Perak, Malaysia to conserve the species. The study was carried out at the HCVF stand to identify species dominance and social behaviour of S. lumutensis for future ex-situ rehabilitation effort. A total of six (6) sample plots (in the size of 50 x 50m each) were prepared. The richness, heterogeneity and evenness analyses by the principle component analysis were carried out on five canopy layers such as emergent or super tree (ST), dominant (T1), co-dominant and suppressed (T2), shrub (S) and herb (H). The H-layer showed higher richness for Plot 1 (P1), P2 and P3, with 69.141, 65.178 and 83.135, respectively, and a high level of heterogeneity. Meanwhile, the ST-layer recorded the lowest values for richness, evenness and heterogeneity. No single species dominates the S, T2 and T1 layers. The S layer in P3 and P5 is dominated by Diospyros subrhomboidea and Aporosa frutescens, respectively, while Fordia unifoliata, Vatica pauciflora, Teijsmanniodendron coriaceum are dominant in P6. On the other hand, the T1 layer (Plot 3) is dominated by Shorea maxwelliana, Vatica pauciflora and Hopea latifolia. Only two individuals of S. lumutensis are found in the T1-ST layers of all plots, showing the lesser dominance of the species. Hence, it is suggested that bigger HCVF area is needed to protect the species.

Keywords: Diversity, endemic species, Shorea lumutensis, HCVF

INTRODUCTION

Every forest has some biological, environmental and social values, and the values may include rare species, special recreational sites or resources harvested by the local residents, of which can be considered as highly invaluable for them to be conserved. In the beginning, High Conservation Value Forest (HCVF) concept was developed by the Forest Stewardship Council (FSC) for utilization in forest management certification and published in 1999. Globally, HCVF is defined by FSC as a forest of outstanding and critical importance due to its high environmental, socio-economic, biodiversity or landscape values (Jennings et al., 2003). In the Malaysian context, any forest containing endemic species as identified by Forest Research Institute Malaysia, Malaysian Nature Society, Sarawak Forest Corporation, Forestry Departments (Peninsular Malaysia, Sarawak and Sabah) and published literature, particularly in high concentrations or highly restricted distribution, can be considered as HCVF (WWF-

Malaysia, 2009). Under Principle 9 of the FSC certification, forest managers are required to identify any High Conservation Values (HCVs), which occur within their individual forest management units to manage and to maintain them or to enhance the values identified, as well as to monitor the success of this management (Jennings et al., 2003).

Endemic species are ones that are confined to a particular geographic area. When this area is restricted, then a species has particular importance for conservation. This is because restricted range increases the vulnerability of species to further loss of habitat (Jennings et al., 2003).

In Southeast Asia, family Dipterocarpaceae, which hosts a huge array of biodiversity, is comprised of 155 species (Ashton, 1982), and Peninsular Malaysia is a home of those species, of which thirty (30) species are endemic to Peninsular Malaysia, with 12 being considered as rare (Boshier, 2011). One of the rarest and endemic dipterocarps in Peninsular Malaysia is Shorea lumutensis, which has been assigned as critically endangered (IUCN criteria: CR A1cd, C2a) due to suspected population reduction of at least 80% over the last 10 years and the population estimated to number less than 250 mature individuals (Boshier, 2011; IUCN, 2004). In HCVF, one of the key elements is endemic species conservation. Therefore, the objective of this research was to identify species dominance and the social behaviour of the S. lumutensis within the HCVF stand for future conservation and ex-situ rehabilitation efforts.

MATERIALS AND METHOD

The study was conducted at High Conservation Value Forest of S. lumutensis (Balau putih) at compartments 2 and 5 of Sungai Pinang Forest Reserve, Pangkor Island, in Perak (see Fig.1). A total of six (6) phytosociological relevés or sample plots (in the size of 50 x 50m each) were randomly prepared in the both compartments in 2008 (within the 10-ha HCVF stand). The sampling technique could be simply characterized as: a) Selection of homogenous sites without gaps within the compartment; b) Creation of sample plots

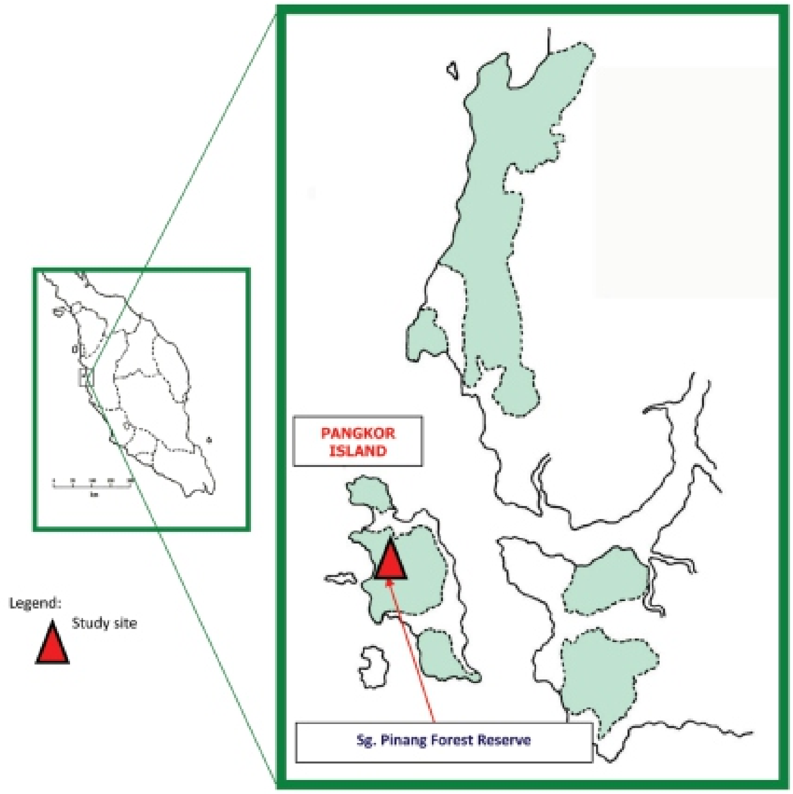

Fig.1: Location of the study site at Sungai Pinang Forest Reserve, Pangkor Island
(Adapted from Lee *et al*., 2004)

with homogenous species composition; c) Identification and record of all species found in each of the five layers: emergent or super tree (ST: above 30m in total height), dominant (T1: 15–30m), co-dominant and suppressed (T2: 8–15m), shrub (S: 2–8m) and herb (H: lower than 2m); d) Estimation of canopy coverage and sociability, and e) Identification of communities. This technique follows the phytosociological technique, which has been described by other researcher (Suzuki,2005)

The diversity analysis (richness, heterogeneity and evenness) based on five canopy layers, i.e. emergent or super tree (ST: above 30m in total height), dominant (T1: 15–30m), co-dominant and (T2: 8–15m), shrub (S: 2–8m) and herb (H: lower than 2m) was carried out by using principle component analysis (PCA).

RESULT AND DISCUSSION

Species Diversity

Species diversity usually refers to the species richness, abundance, or a combination of both, of a community (Rice & Westoby, 1982). Looking at the H-layer alone, three

TABLE 1
Species diversity on five canopy layers

Layer	Diversity Parameters	Site					
		P1	P2	P3	P4	P5	P6
H	Number Individual	120	103	134	36	7	43
	Richness	69.141	65.178	83.135	32.319	7.751	37.282
	Heterogeneity	4.014	3.970	4.292	3.429	1.946	3.568
	Evenness	0.803	0.815	0.881	0.964	1.000	0.958
S	Number Individual	22	11	74	8	25	51
	Richness	11.815	8.763	31.480	6.775	14.641	26.565
	Heterogeneity	2.237	2.020	3.124	1.667	2.393	3.016
	Evenness	0.851	0.942	0.734	0.883	0.782	0.785
T2	Number Individual	29	28	78	22	43	57
	Richness	19.542	9.806	36.480	12.742	22.613	24.613
	Heterogeneity	2.737	1.739	3.362	2.284	2.892	2.941
	Evenness	0.813	0.632	0.802	0.818	0.820	0.789
T1	Number Individual	39	13	79	21	35	54
	Richness	21.613	9.723	30.500	15.653	22.537	25.588
	Heterogeneity	2.862	2.098	2.963	2.624	2.939	2.976
	Evenness	0.833	0.906	0.645	0.919	0.859	0.785
ST	Number Individual	10	5	7	3	4	10
	Richness	6.885	3.898	5.813	3.880	4.837	8.751
	Heterogeneity	1.696	0.950	1.550	1.099	1.386	1.973
	Evenness	0.908	0.862	0.942	1.000	1.000	0.899

Note: H = Herb (lower than 2m in height), S = Shrub (2-8m), T2 = Co-dominant and Suppressed (8-15m), T1 = Dominant (15-30m), ST = Emergent (more than 30m)

plots showed high species richness, namely; Plot 3 (P3) (with the species richness value of 83.14), followed by P1 (69.14), and P2 (65.18), whereas P5 exhibited the lowest level of species richness at 7.75 (Table 1). Generally, the distribution of individuals in all the plots is relatively uniform with the evenness value of less than 0.8.

Plot 3 (P3) attained the highest value of species richness at the S-layer, with a total value of 31.48 species, followed by P6 (26.57 species), and the lowest species richness was found in P4 at 6.78 species (Table 1). The plots showed high individual distribution with heterogeneity of more than one (1) (see Table 1). Unlike the H-layer, only three plots, namely P3, P5 and P6 exhibited an evenness index of less than 0.8, of which P3 is dominated by Diospyros subrhomboide, while P5 is dominated by Aporosa frutescens, and P6 with Fordia unifoliatat, Vatica paucifloraand Teijsmanniodendron coriaceum. The existences of heterogeneity, as shown in present study (of more than 1), have strong effect on species diversity (Whitmore, 1998)

Similar to the S-layer, P3 still showed the highest species richness of 36.48 species in T2-layer. The species distribution at P3 and P6 are lower than the other plots because of species domination, where P3 is dominated by Fordia unifoliata, and P6 is dominated by Aporosa frutescens, Teijsmanniodendron coriaceum and Xanthophyllum affine. The results are in agreement with the findings of Denslow (1995) and Preston (1962), where species richness was found to be positively associated with species abundance.

The highest species richness in the T1-layer was found at P3 with 30.50 species. Meanwhile, the heterogeneity of all the plots is higher than that of the other layers (H, S, and T2), with the value of more than two (2) and it showed that the total individual at all the plots was relatively high. Shorea maxwelliana, Vatica pauciflora and Hopea latifolia dominate P3, while P6 is dominated by Swintonia floribunda. The level of evenness at P3 and P6 is lower than the other plots (<0.8), indicating lower species domination, which is in agreement with the earlier findings by Magurran (2004) and Kindt et al. (2006), whereby the level of evenness is strongly influenced by the relative frequencies of species dominance.

The species richness of the ST-layer is generally lower (3.88 to 8.75) than the other layers (7.75 to 69.14), but its evenness value is relatively high, i.e., from 0.862 to 1.00, which is comparable to the other layers. According to He and Legendre (2002), species richness decreases with the increase in species dominance. Being the highest layer (biggest diameter class),it was expected that this layer would have the least number of individuals (from 3 to 10) and also species, as shown in a typical inverse-J curve.

Domination Species Based on PCA

The spatial distribution of understorey vegetation may provide a clue to the nature, degree and duration of processes or resources that structure understorey communities and also assist in formulating hypotheses about the relevant processes (Dale, 1999). The H-layer is divided by two components; the first component consists P1, P2 and P5, whereas the second component is composed of P3, P4 and P6 (see Fig.2). Based on species similarity, the first component consists Shorea maxwelliana (5 individual/plot), Swintonia floribunda (1 individual/plot) and Xanthophyllum affine(3 individual/plot), whereas component two has Diospyros subrhomboidea (1 individual/plot), Galearia fulva (1.67 individual/plot), Garcinia forbesii (1.67 individual/plot), Gynotroches axillaris (1 individual/plot) and Lijndenia laurina (1.33 individual/plot).

Just like the H-layer, the S layer is also divided by two components; component 1 consists of P1, P2, and P5, whereas component 2 is made of P3 and P4, and P6 is located between components 1 and 2 (Fig.3). The main species in component 1 are Aporosa frutescens (5.67 individual/plot), Mesua daphnifolia (2.33 individual/plot) and Xanthophyllum affine (2.00 individual/plot), whereas Diospyros subrhomboidea(4.67 individual/plot), Fordia unifoliata(4.67 individual/plot) and Vatica pauciflora

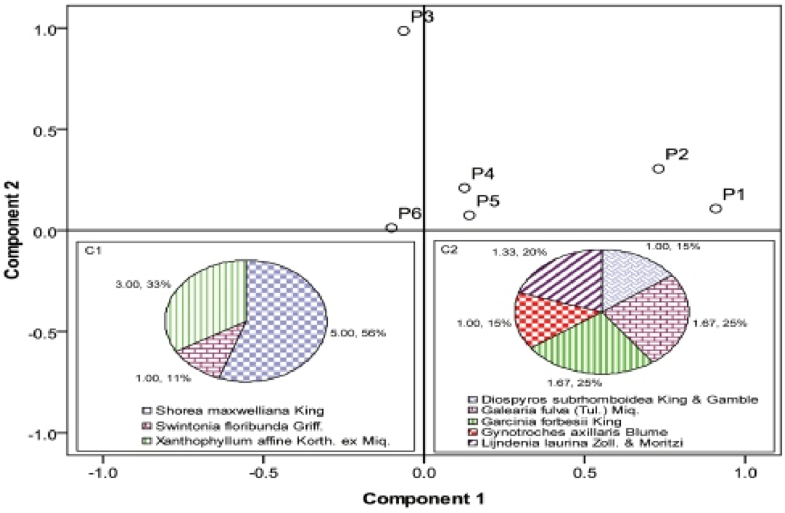

Fig.2. Species domination at the Herb (H)-layer in all plots

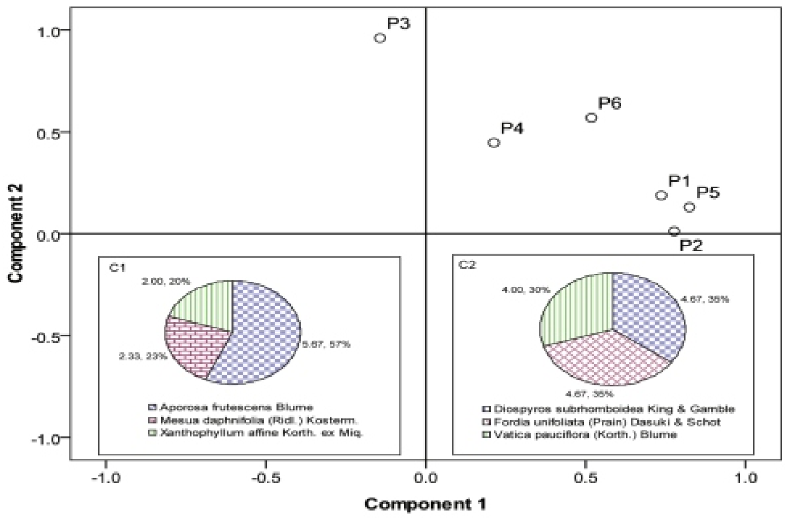

Fig.3: Species domination at the Shrub (S)-layer in all plots

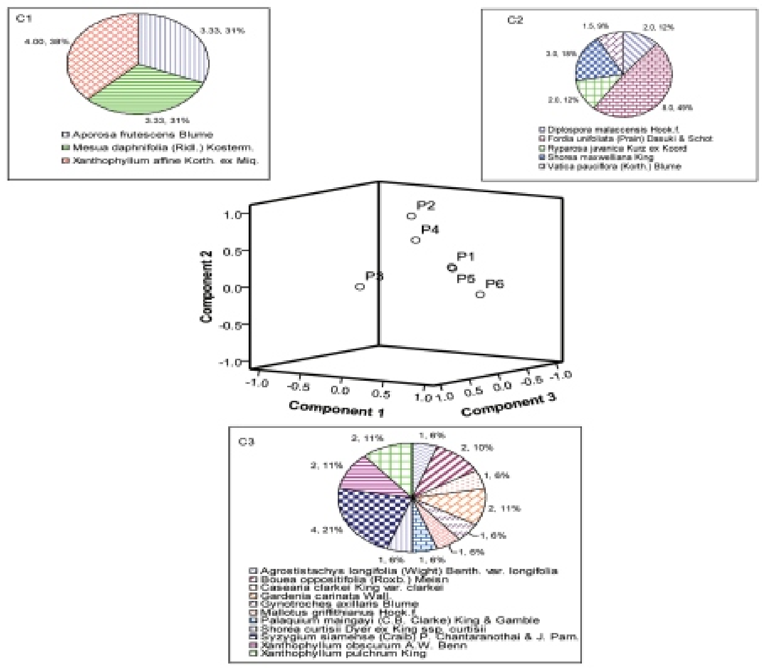

Fig.4: Species domination at the Co-dominant (T2)-layer in all plots

(4 individual/plot) are the main species of component 2.

There are three components at the T2-layer of component 1 (P1, P5 and P6), component 2 (P2 and P4) and component 3 (P3) (Fig.4). Component 1 consists of Aporosa frutescens (3.33 individual/plot),Mesua daphnifolia (3.33 individual/plot) and Xanthophyllum affine (4.00 individual/plot). Diplospora malaccensis (2 individual/plot), Fordia unifoliata (8.00 Individual/plot), Ryparosa javanica (2 individual/plot), Shorea maxwelliana (3 individual/plot) and Vatica pauciflora(1.50 individual/plot) are the species at component 2, whereas Agrostistachys longifolia (1 individual/Plot), Bouea oppositifolia (2 individual/plot), Casearia clarkei (1 individual/plot), Gardenia carinata (1 individual/plot), Gynotroches axillaris (1 individual/plot), Mallotus griffithianus (1 individual/plot), Palaquium maingayi (1 individual/plot), Shorea curtisii(1 individual/plot), Syzygium siamenseand Chantaranothai (4 individual/plot), Xanthophyllum obscurum (2 individual/plot) and Xanthophyllum pulchrum (2 individual/plot) belong to component 3.

The T1-layer is divided into two components, namely, component 1 (P2,P3 and P5) and component 2 (P1, P4 and P6) (see Fig.5). The species in component 1 are Hopea latifolia (4.67 individual/plot) and Shorea maxwelliana (6.33 individual/plot), whereas component 2 is made up of Artocarpus lanceifolius (1.33 individual/plot), Diospyros rufa (2.67 individual/plot), Mesua daphnifolia (2.33 individual/plot), Swintonia spicifera (3.33 individual/plot), Vatica pauciflora (3.67 individual/plot) and Xanthophyllum affine (2 individual/plot).

As it is in the T2-layer, the ST-layer consists of three components, of which component 1 comprises of P2, P3 and P5, while P1 and P4 are in component 2 and P6 belongs to component 3 (Fig.6). Hopea latifolia dominates P2, P3 and P5, with 2 individual/plot, while Shorea maxwelliana(1 individu/plot) and Vatica pauciflora (1.5 indvidu/plot) dominate in P1 and P4, respectively. Component 3 is dominated by several species, namely, Dipterocarpus grandiflorus (1 individual/plot), Hopea beccariana (1 individual/plot), Shorea curtisii (3 individual/plot), Shorea multiflora (1 individual/plot) and Swintonia spicifera (1 individual/plot).

Generally, the correlation between DBH and height of every layer showed a positive relationship; high density followed by the increase in height ® =0.86 p-value=0.00). The correlation at the S-layer is lower than the other layers; meanwhile, the r values increase (T1 and T2), and there is a decrease at the ST layer (Fig.7). The results contradict with the earlier statements which indicate that tree density is often negatively associated with mean or median tree size (Richards, 1952; Condit et al., 1994). However, according to Denslow (1995), the

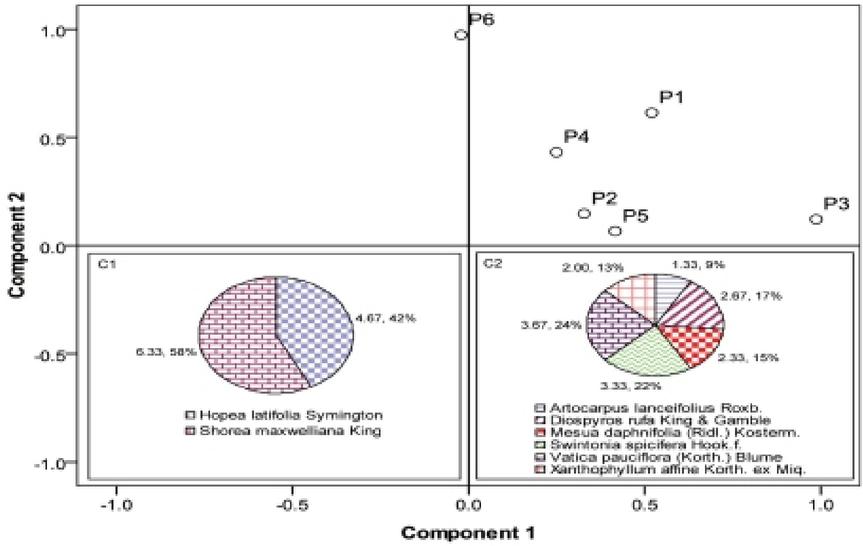

Fig.5: Species domination at the Dominant (T1)-layer in all plots

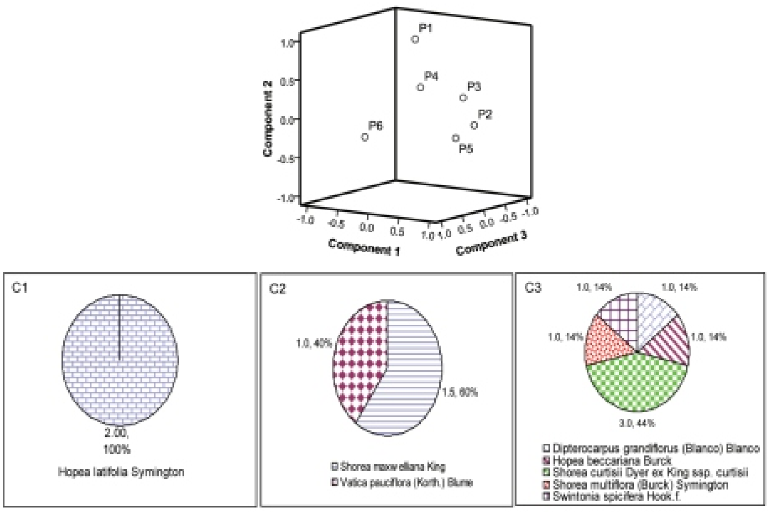

Fig.6: Species domination at the Emergent (ST)-layer in all plots

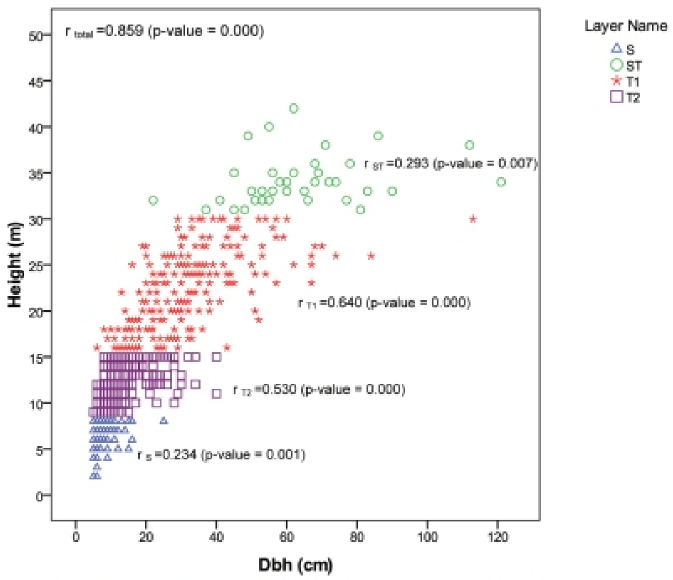

Fig.7: Relation between DBH and height at every layer level in all plots

process affecting tree size and density may also influence species diversity.

Only two (2) individuals of S. lumutensis are found in the T1 layer, while the presence of seedlings and saplings (in T2 and lower layers) is also small, reflecting a low regeneration or survival rate. Many rare plants are endangered in part because their populations are small. Small and isolated populations are inherently more vulnerable to natural catastrophes, demographic and environmental stochasticity (Holsinger, 2000; (Lee et al., 2004). In this study, the number of S. lumutensis is very alarming, with only 2 individuals in 1.5-ha plot, and this is apparently lower than the previously known population density of 4.4 trees ha1(Boshier, 2011; Lee et al., 2004). According to Boshier (2011), the rarity of S. lumutensis in Pangkor Island and its surrounding areas can be classified as locally common, but occurring in only a few places.

CONCLUSION

Conservation programmes on the Dipterocarps are on-going; for example, since 2001, the Forest Research Institute of Malaysia (FRIM) and International Plant Genetic Resources Institute (IPGRI) have been collaborating to explore the genetic diversity and to develop conservation strategies for Shorea lumutensis. The long-term goal of this project is to give scientific support to the design of new in situ conservation areas as well as to establish an ex situ conservation programme for the species.

Based on the species diversity characteristic at Pangkor HCVF, restoration and conservation efforts can be designed accordingly. In species restoration, recognizing straightforward performance from every species is an essential key. At the global scale, several schemes have been employed for identifying areas that may be particularly important for the long-term maintenance of biodiversity. As decision criteria, these schemes have variously used data on patterns of species richness, endemism, threat or taxonomic uniqueness of species, and habitat features. The specific community of the endemics must be redeveloped (i.e. through of those species) in any ex-situ rehabilitation project. Development of HCVF covering all identified endemic species should be developed into a policy in the overall forest management plan in all states, which is in line with Strategy 11 of the National Policy on Biological Diversity launched in 1998. The area, which has been designated as HCVF must be big enough to provide buffer to protect the endemics, as in the case of S. lumutensis at Sungai Pinang Forest Reserve in this study.

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Development of Standard Volume Equations for Malaysian Timber Trees I: Dark Red and Light Red Merantis

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ABSTRACT

Volume is important in updating and projecting inventories, determining harvest level or allowable cut, scheduling the harvest unit for logging, analyzing potential alternatives stand treatments and determining site-productivity. Inherent in the preparation of a forest management plan, an annual forest working plan and a forest harvesting plan is the availability of a volume table, which is usually derived from a functional relationship using a diameter and/or a log length or tree height. Four unweighted and five weighted volume equations were fitted by the method of least squares to volume data of each of the two species groups of Dipterocarp Merantis - Dark Red Meranti (DRM) and Light Red Meranti (LRM) obtained from the mixed tropical forest of Malaysia. Furnival's Index (FI) was used as the criterion for selecting the best fit regression equation of each species group under study. The equation weighted by 1/D2H showed its superiority over other equations in both species groups. The standard volume equations selected are as follows:

DRM: V = -0.5994 + 3.1947E-04D2 + 0.0370H + 4.2054E-05D2H (FI = 0.9474)
LRM: V = 0.2059 + 1.6593E-04D2 + 8.3346E-03H + 4.8974E-05D2H (FI = 0.9434)

Where,
V is the commercial tree volume (m3 overbark), D is the reference diameter or dbh (cm) and H is the total commercial log length (m) up to the first large branch below the crown base or up to the 30cm end diameter. The standard volume equations obtained from this study were compared with the existing volume equations by FAO (1973) and Canonizado and Buenaflor (1977).

Keywords: Dark Red Meranti, Furnival's Index, Light Red Meranti, standard volume equation, weighted least squares

INTRODUCTION

The Malaysian flora, among the richest and most diverse in the world, is of great interest in view of the geographical position of the Peninsular – the southernmost land limit of the mainland of Asia. This rainforest is characterized by the dominance of the family Dipterocarpaceae, which forms the bulk of the commercially valuable timber trees in Malaysia and Southeast Asia. The forest covers the full range of timbers from Dipterocarps: Meranti to non Meranti groups to non-Dipterocarps: Light Hardwoods (LHW) to Medium Hardwoods (MHW) to Heavy Hardwoods (HHW). Commercially, the Dipterocarp species is the most valuable timber in the timber markets – nationally and internationally, and it is usually of high price, though the non-Dipterocarp species is equally preferred commercially for specific end uses.

BACKGROUND AND SCOPE

Inherent to the preparation of a forest management plan or an annual forest working plan, or an annual harvesting plan is the development of volume tables for a species concerned. A number of researchers, such as Vincent and Sandrasegaran (1965), have compiled volume tables from the stem analysis data of felled trees for seven species and six species groups occurring in the rich lowland Dipterocarp forests. Similarly, Wan Razali et al. (1989) developed a volume table for the planted Acacia mangium in Peninsular Malaysia. However, most of these lowland forests, which have given way to agriculture development and the Permanent Reserve Forests (PRFs) for timber production, are now confined mainly to the hill forests between 300m to 750m altitude above sea level (asl). The volume tables for the lowland natural forests are thought to be not applicable or less applicable to hill forests due to the different growth structures and characteristics, as well as species composition of the hill forests. A bibliography search for the development of volume equations or volume tables of indigenous and exotic species in Malaysia reveals the following:

1. Sandrasegaran (1961) developed a commercial general volume table for ShorealeprosulaMiq (Meranti tembaga);
2. Vincent and Sandrasegaran (1965) compiled 13 commercial general volume tables from the stem analysis data of felled trees for 38 species and/or species groups;
3. Sandrasegaran developed a provisional local volume table for teak (Tectonagrandis linn. F.) (1966a) and a local volume table for Tembusu (Fagraeafragrans Ridl.) (1966b);
4. Sandrasegaran also constructed a local volume table for Yemani (Gmelinaarborearoxb) (1966c), fuel wood volume table for Eucalyptus robusta (1966d), a local volume table for Eucalyptus saligna Sm. grown in Malaya (1967a), a local volume table forEucalyptus grandis (1967b), a general volume table for Pinuscaribeamor. (1968), a general volume table for Tectonagrandis Linn. f. (Teak) grown in North-West Malaya (1969), a standard volume table for Pinusmerkusii Jungh & de vriese grown in the Forest Research Institute plantations in Malaya (1970), and a general volume table for Rhizophoraapiculata BI. (syn. Rhizophoraconjugata Linn.) (Bakau minyak) in Matang Mangroves, Taiping, West Malaysia (1972);
5. Sandrasegaran (1973) discussed the statistical properties of tree volume and the use of weighted regression in the development of overbark and underbark volume tables for Gmelinaarborea Roxb (Yamane) grown in Peninsular Malaysia;
6. FAO (1973a) prepared the volume equations for the mixed Dipterocarp forests of West Malaysia during the 1stNational Forest Inventory;
7. FAO (1973b) prepared a compilation of volume tables for the mixed Dipterocarp forests of Sarawak;

8. Canonizado and Buenaflor (1977) developed tree volume functions for the SJSB dipterocarp;
9. Wan Razali M (1981) developed a general volume table for Pinuscaribaeavar. Hondurensis;
10. Wan Razali W.M. et al. (1983) constructed double entry volume table equations for some RRIM 600 series clones of Hevea Brasiliensis;
11. Afzal-ata et al. (1985) developed a local volume table for plantation Kapur (Dryobalanopsaromaticagaertn. f.) at Sungai Puteh Forest Reserve (Federal Territory);
12. Wan Razali W.M. et al. (1989) developed a volume table for planted Acacia mangium in Peninsular Malaysia;
13. Awang Noor Abd. Ghaniet al. (1999) developed a preliminary analysis in the construction of local volume tables for lowland and hill Dipterocarp forests of Pahang;
14. Suratman et al. (2004) developed prediction models for estimating the area, volume, and age of rubber (Heveabrasiliensis) plantations in Malaysia using lands at TM data;
15. Nur Hajar Zamah Shari et al. (2007) developed a volume equation for Ramin (Gonystylusbancanus) in Pekan Peat Swamp Forest, Pahang, Malaysia;
16. Awang Noor Abd. Ghani and Khamuruddin Mohd Noor (2009) developed local volume tables for inland forests, Negeri Terengganu; and
17. Nur Hajar Zamah Shari et al. (2010) also developed a local volume table for the second growth forests using standing tree measurements.

In principle, there are two basic types of volume equation: local volume equation and standard volume equation. The local volume equation is based on the single variable of interest, usually diameter at breast height (dbh). The term 'local' is used because such equation is generally restricted to the local areas. Meanwhile, the standard volume equation gives volume in terms of dbh and merchantable or total length (L) and the type of equation may be prepared for individual species or groups of species and specific localities. A volume table is usually constructed from a volume equation.

A volume table developed by the Pahang Tenggara Regional Master Plan was used to estimate commercial standing volumes of trees at Syarikat Jengka Sdn. Bhd. (SJSB) (Anon, n.d.): a timber concessionaire in Pahang, Malaysia, who managed approximately 120,000 ha of mixed tropical forests of which about 60,000 ha were hill Dipterocarp forests. For a given species and dbh class, an average log length (L) in meter and a net factor (F) - equivalent to a form factor - were determined in priori. By using a perfect cylinder formula, that is {(πD2/40,000) x L x F}, where D=dbh in cm, the volume for each tree was tabulated for the various species and dbh classes. However, the use of this formula in most cases underestimated the commercial standing volume of trees. For example, SJSB underestimated commercial standing volumes between 10 - 40% and 10 - 60%, respectively for a 4 and 5 log lengths (1 log length = 5 meter) with dbh classes between 60 - 110cm. Similar observations were also noted by another timber concession in Pahang, i.e. Lesong Forest who managed 54,000 hectares of the mixed tropical forests of which at least 75% of the areas were made up of hill Dipterocarp forests. Nonetheless, reasons for the underestimation of tree volume were not exactly known; these are more likely due to the use of a perfect cylinder formula and an average log length for a given dbh class, although a net factor was used for each species. However, the use of an average log length for a given dbh class in a local volume equation contributed to a less accurate estimation of volume. Furthermore, SJSB used one volume equation for all species. Hence, standard volume equations by species groups would be a logical remedial action to solve the problem of volume underestimation. Canonizado and Buenaflor (1977), under the SJSB-FDPM Cooperative Projects known as Integrated Studies on Forest Management and Operations, developed a set of volume equations for Dipterocarp and non-Dipterocarp hill forests. However, these volume equations were developed using the ordinary least square regression techniques and based on a small number of felled sample trees. For unknown reasons, the equations were not used by SJSB.

This study was initiated to correct the inadequacies of the volume equations derived by the Pahang Tenggara Regional Master Plan, and to have a larger sample size in addition to the use of unweighted and weighted least square regression techniques. Furthermore, Furnival's Index (Furnival, 1961) was used in selecting the most suitable volume regression model, as compared to the use of usual statistics such as coefficient of determination (R2), and adjusted R2(R2adj) and/or residual mean square error (RMSE). The development of the volume equations of tropical mixed forests demands a lot of time to attain a true representation of the population of interest (volume) and it is ften set-back by the erratic occurrence of certain individual species or species groups, diameter and height classes, as well as the availability of up-to-date analytical and statistical techniques; all of which require a continuous updating.

MATERIALS AND METHODS

Field Measurements

Data for the development of volume equations in this study were obtained through felling and measuring of trees from 29 sample locations in the production forests of SJSB. A sample location was randomly chosen yarding setup of 20-30 hectares within a forest compartment of 100-120 hectares ear-marked for timber tree felling. Two types of working crew were provided by SJSB for this study; one was the tree felling crew and the other was the tree measuring crew who worked independently of each other. The measuring crew measured all the felled trees ≥ 50cm dbh (1.3m above ground or just above the end of taper if a tree was heavily buttressed) in each sample location after felling crew felled all commercial trees. Felling crew worked ahead of the measuring crew and the former was informed that all the felled trees would be commercially extracted as usual but was not told that all the felled trees would be measured for developing volume equations. As such, the felling crew was asked to cut all the trees as commercially done, and then cut the log at the end of the merchantable bole before the logs were extracted. These instructions were necessary so that the volume equations developed would reflect the actual commercial tree volumes extracted from the forests. However, the felling crew was directed not to section the logs as they normally did if a log was too long to be hauled or extracted. The sectioning of the logs would only be done after all the necessary measurements were completed by the measuring crew.

Trees felled and measured for the development of volume equations were distributed as equally as practicable throughout the sample locations. A total of 2707 trees of various species were measured from 29 locations in 7 logging compartments. These trees comprise the following:

Dipterocarp (Meranti) = 914 trees

Dipterocarp (Non-Meranti) = 809 trees

Non-Dipterocarp (LHW, = 984 trees

MHW & HHW)

Total = 2707 trees

Commercially, the family Dipterocarpaceae (or commonly called Dipterocarps) comprises tree species belonging to Dark Red Meranti (DRM), Light Red Meranti (LRM), Yellow Meranti (YM) and White Meranti (WM). All individual species of DRM, LRM, YM and WM belong to the genus Shorea. The other Dipterocarpaceae family belongs to the non-Meranti group or the genus NonShorea. The rest of the families belong to non-Dipterocarpaceae (or commonly called Non-Dipterocarps) and commercially consist of Light Hardwood (LHW), Medium Hardwood (MHW) and Heavy Hardwood (HHW).

This paper, however, deals only with the development of volume equations for Dipterocarp Meranti comprising DRM and LRM. All the felled trees were not necessarily measured due to either relatively inaccessible areas or were on steep slopes or terrains that could risk the measuring crew. Each measured tree was identified to the species level possible.

The following measurements were taken on each sample tree after it was felled:

1. Diameter outside bark (Dob) at dbh (1.3m above the ground or just above the end of taper, if a tree was heavily buttressed);

2. Diameter outside bark (Dob) at a “reference point”, if the reference point was lower than 1.3m high from the ground. The reference point was usually the point at which felling crew cut the tree;

3. Diameter outside bark (Dob) at the end of the commercial log/ merchantable log/ clear bole log where felling crew made another cut. This end was usually at the first large branch below the base of the crown or at 30 cm diameter, whichever came first;

4. Diameter outside bark (Dob) at the midpoint of the commercial log length;

5. Commercial log length from points (2) and (3) above;

6. Diameter outside bark (Dob) at the beginning point of "top" log, if any;
7. Diameter outside bark (Dob) at the midpoint of the top log, if any;
8. Top log length from the point immediately after the knot of the first branch to 30 cm diameter if the cut in (3) above was at the first large branch below the crown base, and provided that the top log was not broken or damaged or both due to felling;
9. The average diameter (if any) of the rot or hole at the end points in (2) and (3) above to indicate the extent of decay or butt- or end-rot occurrences; and
10. The extent of felling damage to the top log, recorded as either broken or split or both.

All diameters were measured to the nearest 0.1cm and length to the nearest 0.1m. A full illustration of the field measurements of a felled tree is shown in Fig.1.

Species Grouping

Although all trees ≥ 50 cm dbh in all the sample locations were felled – not all were measured for reasons indicated earlier – it was not possible to provide sufficient depth and range of data necessary to compile volume equation for individual species mainly due to erratic occurrence of certain species and limited diameter and height classes. It was decided to construct volume equations by "species groups" as sufficient numbers of the sample trees in each species group were available.How would one group the species? Would several volume equations necessary to segregate a species group, for example, by forest types and site or geographical regions? Since data for this project came from hill Dipterocarp forests (a forest type) and commercial volume was a parameter of interest, it was then decided to group the species by commercial classification currently used by Forestry Department Peninsular Malaysia (FDPM), taking into consideration the physical and biological factors of trees. This classification is shown in Table 1.

FAO (1973) concluded that tree forms within the mixed Dipterocarp forests did not show any marked affinity to species groups and could be a feature of environmental factors such as stand density.

The FAO conclusion led to the derivation of one volume equation1 to be applied to all individual species. However, my personal experiences have shown that there was a marked difference in tree form within a mixed Dipterocarp forest, and the above observation by FAO, though statistically verified, was mainly due to the small number of sample trees collected, especially for trees

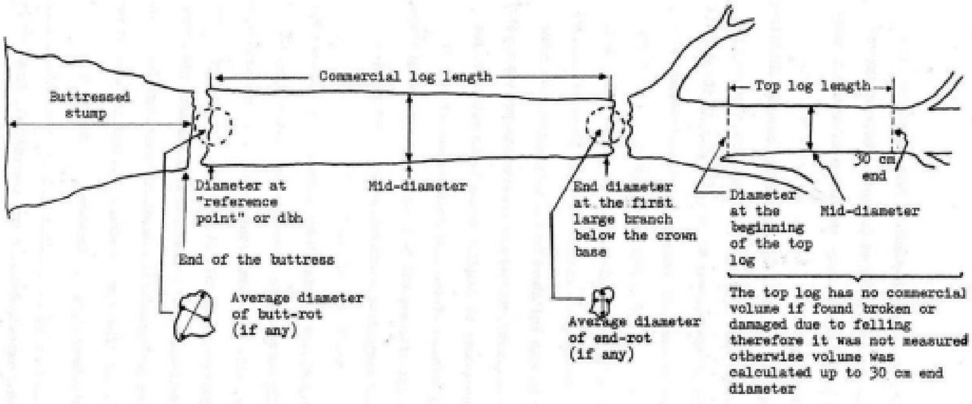

Fig. 1: Illustration of field measurements on a felled sample tree

TABLE 1
Commercial species groups used in this study

Dipterocarp Species Group	Species*
Dark Red Meranti	*Shoreacurtisii, S. platyclados, S. pauciflora, and S. singkawang.*
Light Red Meranti	*Shoreaacuminata, S. dasyphylla, S. hemsleyana, S. leprosula, S. lepidota, S. johorensis, S. ovalis, S. parvifolia, S.platycarpa, S. teysmanniana, and S. palembanica.*

*Vernacular name and its symbol, vernacular synonyms, timber and trade names and storey class can be found in Wyatt Smith, J. (1979). *Pocket Check List of Timber Trees.* Malayan Forest records No. 17, Forest Department Peninsular Malaysia, Kuala Lumpur.

with diameters >76cm, whereby a minimum of 21 trees with 3 or less commercial logs in bole (i.e. height <17.5m) to a maximum of only 51 trees with 4 commercial logs in bole (i.e. height 17.5m – 22.5m) were measured.

These observations and experiences strengthened the decision to derive one volume equation for each species group within a forest type - hill Dipterocarp forest.

Volume Calculation

The parameters on each sample tree for DRM and LRM are summarized in Tables 2a to 2b, respectively. The total overbark volume for the commercial log of each tree was the sum of two log section volumes, namely; from the dbh or reference point to the end of commercial log length and from the first large branch to the 30cm diameter limit - if the length of the latter log section was commercially extractable, otherwise, there was no volume for this log section. The volume of each log section was calculated using the Newton's formula, vis-à-vis:

$V = \{[Al + 4Am + As] / 6\} \times L$

Where

V = Volume overbark (ob), m3

Al = cross-sectional area (ob) at the bigger end of the log section (m2),

Am= cross-sectional area (ob) at the midpoint of the log section (m2),

As= cross-sectional area (ob) at the smaller end (m2), and

L = length of each log section (m).

Regression of Volume Equations

Although many methods of volume equation development are available (Chapman & Meyer, 1949; Hummel 1955), the method of least squares is the generally acceptable procedure. The popularity of the method is primarily due to its objectivity, the statistical provision for test of significance and the defining of confidence limits.

However, the need to weigh volume equations in most circumstances in order to induce or to equalize homogeneity of variance in volume along the regression line has been discussed by Wright (1964) and Cunia (1964); this being the pre-requisite before valid test of significance can be applied to the regression equation. The inclusion of weighted or transformed models into the analysis poses problems in testing the goodness-of-fit to statistically select the most appropriate model. Regression in which the same dependent variable has been subjected to different transformations or weightings cannot be compared directly for goodness-of-fit using the R2 or even adjusted R2. The regression may be biased by a transformation or weighting of the dependent variable, volume in this case.

A more suitable index for comparing a such regression equation is that of Furnival (1961); the expression of Furnival's Index is given as follows:

FI = [f ' (V)] -1 s

The geometric mean of the derivative of the dependent variable (V) of the unweighted regression is 1.0. The geometric mean of

TABLE 2a

A summary of parameters per tree (unless specified) of DRM

Parameter	No	Min	Max	Mean	Std. Deviation
Trees measured	408	-	-	-	-
Diameter at reference point (cm)	-	50.0	177.3	86.3	21.3
Total commercial log length (m)	-	7.9	35.1	21.8	6.1
Trees with broken or damaged top/ crown after first large branch[1]	340	-	-	-	-
Trees with internal rot (hole) at the base of reference point and its diameter (cm)[2]	25	18.0	76.9	35.1	15.0
Trees with internal rot (hole) at the end point of commercial log and its diameter (cm)[3]	0	-	-	-	-
Trees with reference point higher than the dbh (1.3m)[3]	332	-	-	-	-

[Note: If the internal rot (hole) at the base of reference point extended all the way to the end of the commercial log, which could easily be seen if there was, the volume of the defective wood was calculated for each commercial log as half the sum of the bigger end cross-sectional area and the cross-sectional area of the smaller end multiplied by the length of the rot, which was equal to the length of the commercial log, L. This defective volume was deducted from the commercial log volume. However, in this study, no trees of any species groups had the internal rot extended all the way from the base of the reference point to the end of the commercial log].

TABLE 2b
A summary of parameters per tree (unless specified) of LRM

Parameter	No	Min	Max	Mean	Std. Deviation
Trees measured	331	-	-	-	-
Diameter at reference point (cm)	-	52.1	138.2	80.5	17.7
Total commercial log length (m)	-	9.7	37.1	24.3	5.3
Trees with broken or damaged top/ crown after first large branch[4]	242	-	-	-	-
Trees with internal rot (hole) at the base of reference point and its diameter (cm)[5]	7	17.5	45.8	30.8	10.2
Trees with internal rot (hole) at the end point of commercial log and its diameter (cm)[3]	-	-	-	28.4	-
Trees with reference point higher than the dbh (1.3m)[6]	292	-	-	-	-

he derivatives of the dependent variable LogeV, V/D2, and V/D2H of the weighted equations are V, D2 and D2H, respectively. The equation with the smallest Furnival's Index indicates the best fit regression equation for a particular species group in this study.

With the above observation, 9 of the most commonly used regression equations or models were fitted to the raw data of trees in each species group and analyzed accordingly. The most commonly used regression models are as follows:

UNWEIGHTED EQUATIONS

1. $V = \beta 0 + \beta 1D2H + \varepsilon$
2. $V = \beta 0 + \beta 1D2 + \beta 2H + \beta 3D2H + \varepsilon$
3. $V = \beta 0 + \beta 1D2 + \beta 2\, DH + \beta 3D2H + \varepsilon$
4. $Log\, eV = \beta 0 + \beta 1Log\, eD + \beta 2Log\, eH + \varepsilon$

WEIGHTED EQUATIONS

5. $V/D2\, H = \beta 0 + \beta 1\, (1/D2H) + \varepsilon$.... Equation [1]weighted by D2H
6. $V/D2 = \beta 0 + \beta 1\, [1/D2) + \beta 2\, (H/D2) + \beta 3H + \varepsilon$ .... Equation [2]weighted by D2
7. $V/D2H = \beta 0 + \beta 1\, (1/D2H) + \beta 2\, (1/H) + \beta 3\, (1/D2) + \varepsilon$.... Equation [2]weighted by D2H
8. $V/D\, 2 = \beta\, 0 + \beta\, 1\, (1/D\, 2\,) + \beta\, 2\, (H/D) + \beta 3H + \varepsilon$.... Equation [3]weighted by D2
9. $V/D2H = \beta 0 + \beta 1(1/D2H) + \beta 2(1/H) + \beta 3(1/D) + \varepsilon$.... Equation [3]weighted by D2H

Where

V = dependent variable (commercial tree volume, m3),

D = dbh or reference diameter (cm),

H = commercial log length (m),

βi= regression coefficients, and

ε = error term.

RESULTS AND DISCUSSION

Tables 2a and 2b show various parameters measured and calculated for DRM and LRM, respectively. As mentioned earlier, the regression models and geometric means of each species group were analyzed. The results – regression coefficients, residual standard deviation from the fitted regression, the geometric mean and the FI – are shown in Tables 3a and 3b for the respective Meranti species groups.

The results showed the superiority of the weighted equation in the species group. The equation with the smallest FI was chosen as having the best fit to the data of each species group. These are as follows:

Dark Red Meranti

V/D2H = (4.2054E-05) - (0.5994(1/D2H)) + (3.1947E-04(1/H)) + (0.0370(1/D2))

.... Equation [7]

Multiplying both sides by D2H produces the final volume equation:

V = - (0.5994) + (3.1947E-04D2) + (0.0370H) + (4.2054E-05D2H)

Light Red Meranti

V/D2H = (4.8974E-05) + (0.2059(1/D2H)) + (1.6593E-04(1/H)) + (8.3346E-03(1/D2))....

Equation [7]

TABLE 3a
Commercial volume equations for Dark Red Meranti (DRM) (*Best fit Standard volume equation)

Unweighted equations		Standard deviation	R^2	Geometric mean of =		Furnival's Index
1.	$V = 0.5558 + 5.4636E\text{-}02D^2H$	1.2499	0.9562	1	1	1.2499
2.	$V = - 3.8178E\text{-}02 + 2.4194E\text{-}04D^2 + 1.1169E\text{-}02H + 4.5669E\text{-}05D^2H$	1.2088	0.9593	1	1	1.2088
3.	$V = - 0.6272 + 3.0308E\text{-}04D^2 + 8.3666E\text{-}04DH + 3.8626E\text{-}05D^2H$	1.2048	0.9596	1	1	1.2048
4.	$\text{Log}_e V = -9.0841 + 1.9823\text{Log}_e D + 0.8063\text{Log}_e H$	0.1669	0.9110	V	8.5977	1.4357
Weighted equations						
5.	$V/D^2H = 5.5369E\text{-}05 + 0.4348(1/D^2H)$	6.7333E-06	0.0707	D^2H	147844	0.9955
6.	$V/D^2 = 2.9047E\text{-}04 - 0.4153(1/D^2) + 2.8170E\text{-}02(H/D^2) + 4.3424E\text{-}05H$	1.3953E-04	0.6860	D^2	7033.14	0.9814
7.	$V/D^2H = 4.2054E\text{-}05 + 0.5994(1/D^2H) + 3.1947E\text{-}04(1/H) + 0.0370(1/D^2)$	6.4084E-06	0.1624	D^2H	147844	**0.9474***
8.	$V/D^2 = 1.8759E\text{-}04 + 0.2771(1/D^2) - 1.2135E\text{-}04(H/D) + 4.8954E\text{-}05H$	1.3975E-04	0.6851	D^2	7033.14	0.9829
9.	$V/D^2H = 4.6356E\text{-}05 + 4.4099E\text{-}02(1/D^2H) + 2.2247E\text{-}04(1/H) + 1.0053E\text{-}04(1/D)$	6.4308E-06	0.1565	D^2H	147844	0.9508

TABLE 3b
Commercial volume equations for Light Red Meranti (LRM) (*Best fit Standard volume equation)

Unweighted equations		Standard deviation	R^2	Geometric mean of =		Furnival's Index
1.	$V = 0.6559 + 5.4174E\text{-}05D^2H$	1.2452	0.9447	1	1	1.2452
2.	$V = 0.4124 + 1.9456E\text{-}04D^2 - 4.5242E\text{-}03H + 4.8406E\text{-}05D^2H$	1.2223	0.9470	1	1	1.2223
3.	$V = - 0.6640 + 1.6634E\text{-}04D^2 - 3.5342E\text{-}04DH + 5.1538E\text{-}05D^2H$	1.2217	0.9470	1	1	1.2217
4.	$\text{Log}_e V = -8.8185 + 1.9102\text{Log}_e D + 0.8316\text{Log}_e H$	0.1327	0.9273	V	8.6073	1.1423
Weighted equations						
5.	$V/D^2H = 5.4586E\text{-}05 + 0.5969(1/D^2H)$	6.5029E-06	0.1073	D^2H	146561	0.9531
6.	$V/D^2 = 2.3282E\text{-}04 + 8.5472E\text{-}02(1/D^2) + 1.2158E\text{-}02(H/D^2) + 4.6376E\text{-}05H$	1.5466E-04	0.6803	D^2	6192.74	0.9578
7.	$V/D^2H = 4.8974E\text{-}05 + 0.2059(1/D^2H) + 1.6593E\text{-}04(1/H) + 8.3346E\text{-}03(1/D^2)$	6.4372E-06	0.1306	D^2H	146561	0.9434*
8.	$V/D^2 = 2.0917E\text{-}04 - 0.2244(1/D^2) + 1.6679E\text{-}04(H/D) + 4.6293E\text{-}05H$	1.5469E-04	0.6802	D^2	6192.74	0.9579
9.	$V/D^2H = 4.9151E\text{-}05 + 0.3091(1/D^2H) + 1.4857E\text{-}04(1/H) + 9.5435E\text{-}05(1/D)$	6.4381E-06	0.1303	D^2H	146561	0.9436

Multiplying both sides byD2H produces the final volume equation:

V = (0.2059) + (1.6593E-04D2) + (8.3346E-03H) + (4.8974E-05D2H)

Comparison of Standard Volume Equations Developed Herewith with FAO 1973 and Canonizado and Buenaflor 1977 volume equations

The nature of the development of many other volume equations (e.g., FAO, 1973; Canonizado & Buenaflor, 1977), hence volume tables, for hill Dipterocarp forests makes it difficult to make a good comparison between them and the equations developed in this present study. Perhaps, some "arbitrary" comparisons can only be made between the three sets of volume table equations - FAO (1973), Canonizado and Buenaflor (1977) and the present study, whereby, some forms of regression analyses have been used, although different goodness-of-fit statistics have been used to select the best fitted equations.

The basis of comparison between the three sets of volume table equations for each species group is a range of reference diameter or dbh (mean ± standard deviation) and to use 4 and 5 log lengths (1 log length = 5 meter), which were the average for the species groups as found in the present study. The results of the comparison are shown in Table 4a and Table 4b.

TABLE 4a

A comparison of the gross volume estimates (m^3) for two species groups at various reference diameters, with 4 log length (1 log length = 5m)

Diam 5cm class	No. of 5m log	DRM			Difference (nearest 1%)		LRM			Difference (nearest 1%)	
		1973	1977	2012			1973	1977	2012		
		(3)	(4)	(5)	(5)-(3) %	(5)-(4) %	(3)	(4)	(5)	(5)-(3) %	(5)-(4) %
60	4	-	-	-	-	-	-	-	-	-	-
65	4	3.90	4.71	5.04	29%	7%	3.90	4.82	5.21	33%	8%
70	4	4.60	5.50	5.83	27%	6%	4.60	5.59	5.99	30%	7%
75	4	5.35	6.36	6.67	25%	5%	5.35	6.42	6.82	27%	6%
80	4	6.35	7.28	7.57	19%	4%	6.35	7.31	7.70	21%	5%
85	4	7.40	8.27	8.35	13%	1%	7.40	8.26	8.65	17%	5%
90	4	8.45	9.31	9.54	13%	3%	8.45	9.26	9.65	14%	4%
95	4	9.50	10.44	10.61	12%	2%	9.50	10.32	10.71	13%	4%
100	4	10.55	11.62	11.75	11%	1%	10.55	11.43	11.83	12%	4%
105	4	11.60	12.88	12.94	12%	0.5%	11.60	12.61	13.00	12%	3%
110	4	12.70	14.20	14.18	12%	-0.1%	12.70	13.84	14.23	12%	3%

Diameter for comparison is outside the mean ± standard deviation, as obtained in this study (1973 = FAO; 1977 = Canonizado and Beunaflor; 2012 = this study).

TABLE 4b
A comparison of the gross volume estimates (m³) for two species groups at various reference diameters, with 5 log length (1 log length = 5m)

Diam 5cm class	No. of 5m log	DRM			Difference (nearest 1%)		LRM			Difference (nearest 1%)	
		1973	1977	2012			1973	1977	2012		
		(3)	(4)	(5)	(5)-(3) %	(5)-(4) %	(3)	(4)	(5)	(5)-(3) %	(5)-(4) %
60	5	-	-	-	-	-	-	-	-	-	-
65	5	3.90	5.65	6.12	57%	8%	3.90	5.84	6.29	61%	8%
70	5	4.60	6.60	7.04	53%	7%	4.60	6.77	7.23	57%	7%
75	5	5.35	7.63	8.04	50%	5%	5.35	7.77	8.23	54%	6%
80	5	6.80	8.74	9.10	34%	4%	6.80	8.85	9.31	37%	5%
85	5	8.40	9.93	10.23	22%	3%	8.40	9.99	10.46	24%	5%
90	5	10.05	11.19	11.43	14%	2%	10.05	11.20	11.68	16%	4%
95	5	11.65	12.53	12.70	9%	1%	11.65	12.48	12.96	11%	4%
100	5	13.30	13.96	14.03	6%	0.5%	13.30	13.84	14.32	8%	3%
105	5	14.95	15.46	15.44	3%	0%	14.95	15.26	15.74	5%	3%
110	5	16.55	17.05	16.91	2%	-0.8%	16.55	16.75	17.24	4%	3%

Diameter for comparison is outside the mean ± standard deviation, as obtained in this study
(1973 = FAO; 1977 = Canonizado and Beunaflor; 2012 = this study)

From Tables 4a and 4b, all the species groups generally showed higher volume estimates (>1.0m3) than the volume estimates of FAO (1973), but fairly close to the volume estimates obtained by Canonizado and Buenaflor (1977). In comparison, the following generalizations can be made:

1. The volume equations in this study consistently gave higher estimates - up to 33% for diameter classes between 60 - 110cm at 4 log length and up to 61% for diameter classes 60 - 110cm at 5 log length compared with FAO (1973);
2. The volume equations in this study consistently gave higher estimates - up to 8% for diameter classes between 60 - 110cm at 4 and 5 log length compared with Canonizado and Buenaflor (1977);
3. For DRM and LRM at 4 and 5 log length with tree diameter >100cm, the difference in volume estimates between the equation developed herewith and that of FAO (1973) was up to 2m3/tree; and
4. For DRM and LRM, at 4 and 5 log length with tree diameter >75cm, the difference in the volume estimates between equation developed herewith and that of Canonizadoand Buenaflor (1977) was up to 0.5m3/tree.

Notes on the Occurrence of Butt- and Endrots and Log Damage Due to Felling The extent of the butt- and end-rots

occurrences in commercial tree boles was small. Approximately 6% and 2% of the commercial tree boles of DRM and LRM respectively showed some forms of buttrots. No trees, except 1 out of 331 LRM trees measured, showed any sign of endrot in the commercial tree boles. No trees in any species groups studied had the rot extended all the way (i.e. from the base of the reference point to the cut point) at the first large branch below the crown base.

The percentage of trees having a reference diameter higher than dbh was high in all species groups - 81.4% in DRM and 88.2% in LRM. This showed that the Meranti trees in hill Dipterocarp forests in this area were heavily buttressed and the height of the buttressed stumps, which were left inside the forest, exceeded 1.3m.

It was noted that the incidence of the top log damage or breakage, after the first large branch due to felling, was higher in DRM (83.3%), followed by LRM (73.1%), indicating that the recovery of volume of logs after the first large branch ranged from a low of 17% of all the trees measured in DRM to a high of 27% in LRM. The recovery of sound commercial log boles, especially after this first branch, was low due to problem of breakage during felling, hence, additional handling of this portion of the logs would be required to recover the commercially available wood fibres for other purposes, such as for chips. The availability of wood fibres from branches and other parts of the stem, such as damaged top logs and high stumps left in the forest could be very substantial and thus the economics of harvesting such wood fibres should be carefully considered.

CONCLUSION

The volume equations for DRM and LRM developed in this study can be expected to give satisfactory estimates for the aggregate standing volume of a group of tree species. The problem of underestimating log volumes, for examples, by as much as 40% for a 4 log length (about 20 meters total log length) and 60% for a 5 log length (about 25 meters total log length) would have been addressed by the development of these new volume equations; more so as the volume equations were developed by species groups rather than one equation fits all, the number of sample trees measured were 739 trees for both DRM and LRM, while the range of diameters and log lengths measured were 50 - 177cm and 8 - 37m, respectively. Lastly, a more superior method of the weighted least squares to equalize the homogeneity of variance in volume, along the regression lines and validated by the Furnival's Index as statistical measure of goodness-of-fit, was used.

These equations are also expected to give accurate and satisfactory estimates of the standing volume of mixed hill Dipterocarp forests in the nearby region, but as with all volume equations a test of applicability is necessary if used outside the range of the original data and/or other conditions. With the advent of computer and given these volume equations, volume tables for DRM and LRM can easily be computed for a required range of diameters and heights for daily and routine uses of practicing foresters.

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FOOTNOTES

2 Indicates that trees have no utilizable volume after this branch and also indicates the incidence of log damage due to felling.
3 The length of the rot into the log was not measured unless the hole extended all the way to this end point, whereby its length was equal to the length of commercial log. This information was provided to the SJSB management as to indicate the extent of occurrence of the butt- or end-rot. Species were mainly S. pauciflora and S. curtesii.
4 Indicates the number of trees having buttress higher than dbh.
5 Indicates that trees have no utilizable volume after this branch and also indicates the incidence of log damage due to felling.
6 The length of the rot into the log was not measured unless the hole extended all the way to this end point, whereby its length was equal to the length of commercial log. This information was provided to the SJSB management as to indicate the extent of occurrence of the butt- or end-rot. Species were mainly S. leprosula, S. ovalis, S. parvifolia and S. lepidota.
7 Indicates the number of trees having buttress higher than dbh.

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Reproductive Patterns of Cynopterus brachyotis (Dog-Faced Fruit Bat) in Bintulu, Sarawak

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A B S T R A C T

Reproductive period is a critical phase for most living organism. However, the influence of environmental condition on the reproductive pattern of Chiroptera in Malaysia is not well studied. A study on the reproductive patterns of dog-faced fruit bat, Cynopterus brachyotis,was conducted at Universiti Putra Malaysia, Bintulu Campus, Sarawak. Bats were captured in a planted forest and mixed dipterocarp forest using mist-nets for a period of 14 months from January 2009 to February 2010. The reproductive status was determined based on morphology of the bats. Five (I-Minor testes enlargement, no epididymal distention, II Testes at or near maximal enlargement, no epididymal distention, III-Testes regressed, cauda epididymal distented, IV-Testes not regressed, cauda epididymal distented and V-No testiscular or epididymal enlargement) and four (I-Possibility pregnant, II-Lactating, III-Post-lactating and IV-Not reproductively active) categories of the reproductive status were categorized for the male and female C. brachyotis, respectively. Bats reproduce at all time of the year and the peak periods are associated with the rainy seasons. The first peak of reproduction (pregnancy and lactation) occurred in January to April 2009 and second peak in June to November 2009. The highest frequency of pregnancy and lactation female coincided with the fruit abundance. The results indicated that C. brachyotis performed a non-seasonal reproductive pattern. The findings are important in understanding the reproductive biology of bats and in protecting this ecologically important and diverse group of mammals.

Keywords: Cynopterus brachyotis, fruit bat, planted forest, reproduction

INTRODUCTION

The environmental factors are known to affect the timing of reproduction in many species of mammals including bats. In bats, the reproductive cycles are affected by photoperiod, rainfall, food abundance, and temperature (Heideman, 2000). Most bat species that have been studied to date display strong seasonality and synchrony in their reproductive cycles such that pregnancies and lactation coincide with food abundance. This increases the chances of the young to survive.

The dog-faced fruit bat, Cynopterus brachyotis (family Pteropodidae), is a common frugivorous species in Southeast Asia, and widely distributed in Malaysia. Throughout its range, this bat species occupies a variety of habitats including primary forest, disturbed forest, mangrove, cultivated areas, orchards, gardens, and urban areas (Funakoshi et al., 1997). Feeding areas and the composition of their food are largely influenced by the seasonal flowering and fruiting of trees (Kofron, 1997). The species appears to be an important seed dispersal agent due to its wide distribution and it is also important in pollination as it feeds on nectar (Funakoshi et al., 1997). Considering its dependence on plants for food and the changing environment (Funakoshi et al., 1997; Phua et al. 1989), the response of C. brachyotis to these factors and the timing of its reproduction are of interest.

Rising development in industries, urbanization, animal husbandry and agriculture has been affecting bats' population. If these man-made disturbances prevail without any perturbation, it will lead to bats' population being threatened with extinction due to habitat loss, decreasing food resources, pollution, deliberate killing and loss of genetic diversity (Meffe et al., 1994). Therefore, a better knowledge on the reproductive biology is important in the management and conservation of this diverse group of mammals. This study was carried out to investigate the synchronization of the reproductive pattern between the male and female C. brachyotis and to correlate it with the climatic and food availability factors.

MATERIALS AND METHODS

Study Site

This study was carried out in planted forest (UPM~Mitsubishi Corporation Forest Rehabilitation Research Project) (113o 03.591' E, 03o 12.691' N) and mixed dipterocarp forest (113o 04.105' E, 03o12.967' N) at Universiti Putra Malaysia Bintulu Sarawak Campus (UPMKB) from January 2009 to February 2010.

Bat Trapping

Cynopterus brachyotis were captured using mist-nets that were set along the trails at the vicinity of flowering and fruiting trees and in open areas within the forest. Mist-nets were set up from dusk to dawn and checked at 10 pm and 5 am for 16 days every month for 14 months. All adult bats were recorded and examined.

The bats' body mass (g), length of forearm (mm), sex, and their reproductive status were determined. The reproductive status was assessed based on the morphology. The reproductive status was determined following the characteristics outlined by Happold et al. (1990) and Kofron (1997). Male bats were categorized into five reproductive status (I-Minor testes enlargement, no epididymal distention, II-Testes at or near maximal enlargement, no epididymal distention, III-Testes regressed, cauda epididymal distented, IV-Testes not regressed, cauda epididymal distented and V-No testiscular or epididymal enlargement), while four reproductive status for female bats (I-Possibility pregnant, II-Lactating, III-Post-lactating and IV-Not reproductively active). Males with testes enlarged and females that were pregnant, lactating and post-lactating were classified as reproductively active individuals (Kofron, 1997). Meanwhile, post-lactating females possessed large, flaccid and dark nipples. Females lacking these characteristics were considered as non-reproductive (Duarte et al., 2010).

Monthly climatic data were obtained from Bintulu Meteorology Station, Sarawak. Opportunistic observations on flowering and fruiting trees (in campus and study area) were also recorded monthly. Statistical tests were done using analysis of variance (ANOVA) to determine the difference in body mass in different months. In addition, Pearson's correlation analysis was done to determine whether there is a correlation between the male and female bats' body mass with the climatic factors (rainfall, humidity and temperature).

RESULTS AND DISCUSSION

A total of 1,328 individual bats comprising of 679 females and 649 males were trapped during the study period. The relationships between body mass in male and female bats with rainfall, temperature and humidity over 14 months from January 2009 to February 2010 are shown in Fig.1. Fig.2 shows the male and female bats' reproductive percentages for the 14 month's period. Bats' body mass was also used as an indirect indicator of their reproductive status. The body mass of the male and female C. brachyotis fluctuated throughout the study period. The highest male bats' body mass was recorded in January 2009 (33.15 ± 6.68 g), whereby it coincided with the highest rainfall (1199.4 mm/month). Food resources are more abundant in the rainy season than in the dry season (Bumrungsri et al., 2007). The highest percentage (24.24%) of status II (testes at or near maximal enlargement, no epididymal distention) was recorded within this wet season (see Fig.2).

In Myotis myotis, fluctuation of body mass can indicate times of food abundance and scarcity (Andreas et al., 2007). During spermatogenesis of Pteropus poliocephalus, the size of the testis increases to indicate the time of reproduction (McGuckin et al., 1991). The testis size of C. brachyotis was enlarged in January 2009, February 2009, July 2009, August 2009, November 2009 and December 2009. This was synchronized with the increase of the body mass of mature males, which might be influenced by the higher food availability (Table 1). According to Tan et al. (1998), C. brachyotis preferred

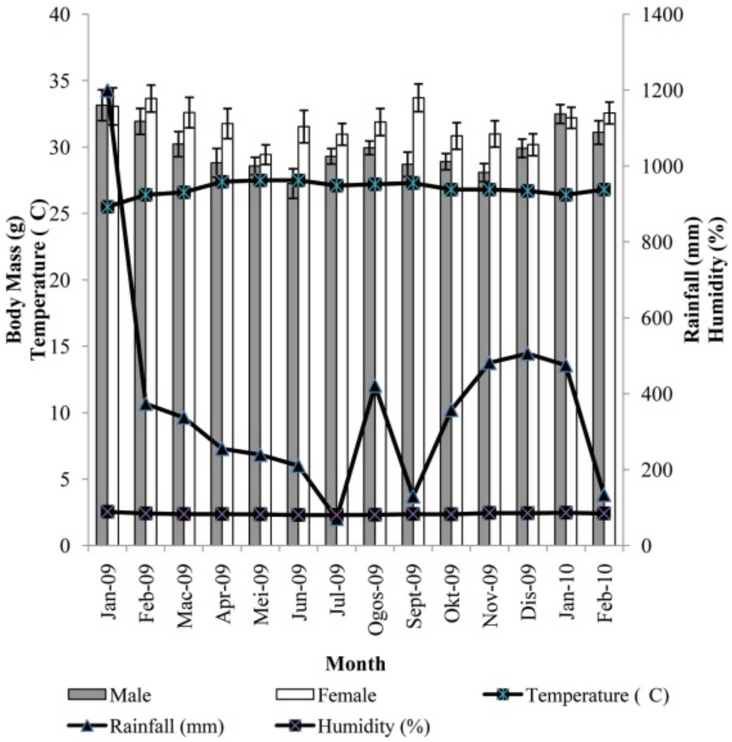

Fig.1: The relationship between the male and female bats' body mass (g) with rainfalls (mm), temperature (° C) and humidity (%) from January 2009 to February 2010 [this study is based on 1328 captures of adult *C. brachyotis* (male: 51 ± 21.09, female 52 ± 19.74 individuals caught each month)].

to feed on various kinds of non-seasonal fruit.

A study in the testes mass of C. brachyotis showed that the peak mass occurred twice in a year (from June to August and December to January) (Marina et al., 2002). Meanwhile, a study by Wong et al. (2002) showed that spermatogenesis occurred throughout the year in the population but peaked in the fruiting seasons.

The highest females body mass was recorded in February 2009 (33.65 ± 5.85 g), which occurred a month after the highest rainfall and the highest male body mass. This could be due to the gestation periods which have caused the increase in body mass. Even though the highest female body mass was recorded in February 2009, the peak of pregnant females (status I) (66.67%) was found to be synchronized with the highest rainfall (see Fig.3). Therefore, rainfall is probably the most important factor in the seasonal reproduction of C. brachyotis. A study by Zortea (2003) indicated that pregnancy peak in Anoura geoffroyi, A. caudifera and Glossophaga soricina occurred in the rainy season.

Food resources are more abundant in the rainy season than in the dry season. Pregnancy, lactation and weaning are the

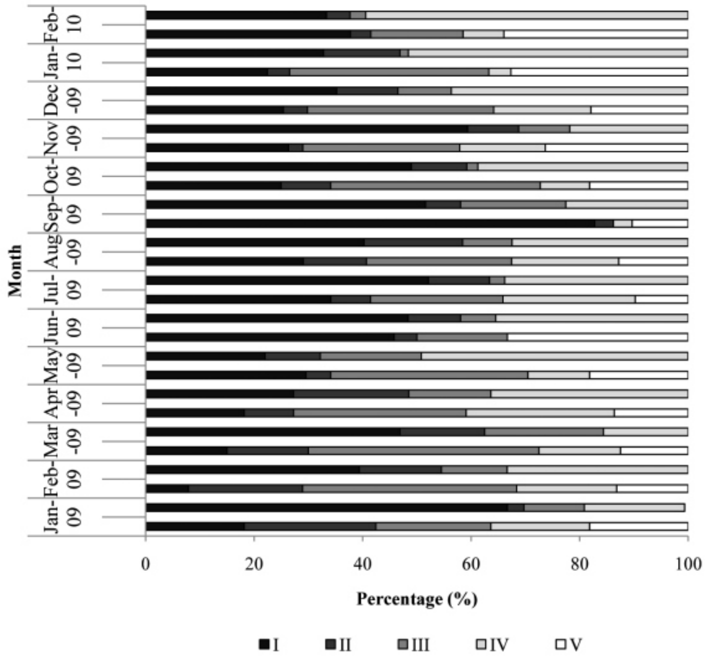

Fig.2: The male (♂) and female (♀) bats' reproductive status (%) for fourteen (14) months period. For male bats: I-Minor testes enlargement, no epididymal distention, II-Testes at or near maximal enlargement, no epididymal distention, III-Testes regressed, cauda epididymal distented, IV-Testes not regressed, cauda epididymal distented and V-No testiscular or epididymal enlargement. For female bats: I-Possibility pregnant, II-Lactating, III-Post-lactating and IV-Not reproductively active.

most energetically reproductive stages; therefore, they should coincide with the period of high food availability (Racey, 1982). Although the highest monthly captures of pregnant females occurred in certain months (e.g., January to March 2009 and June to November 2009), pregnant females were captured every suggesting that the breeding pattern is nonseasonal. Compared to pregnant females, the lactating females (status II) showed higher captures in April 2009 (21.21%) and August 2009 (18.18%), suggesting that parturition had occurred. Interestingly in Thailand, the birth periods of C. brachyotis was in March to April and August (Bumrungsri et al.2006), which is similar to the present study.

Based on opportunistic observation (Table 1), the fruiting seasons were recorded in January to February 2009 (Mangifera indica, Fragrea fragrans) and June to October 2009 (Nephelium lappaceum, Durio zibethinus, Mangifera indica, Fragrea fragrans, Artocarpus integer). The non-seasonal fruiting trees, such as Ficus sp., show continuous fruitavailability throughout the year, as by other studies (e.g. Wong et al., 2003;Funakoshi et al., 1997; Lim (1970). Lim (1970) found peaks in pregnancies to occur

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TABLE 1
The fruiting and flowering trees in Bintulu (through opportunistic observations)

Month	Flowering and fruiting trees in Bintulu
January 2009	Dipterocarp trees flowering *Mangifera indica* (mango), *Artocarpus integer* (cempedak), *Fragrea fragrans* (tembusu), *Durio zibetinus* (durian)
February 2009	*Mangifera indica* (mango), *Artocarpus integer* (cempedak), *Fragrea fragrans* (tembusu)
March 2009	*Musa* sp. (pisang), *Piper nigrum* (lada hitam), *Muntingia calabura* (ceri), *Mimusops elengi* (tanjung), *Carica papaya* (betik)
April 2009	*Musa* sp. (pisang), *Piper nigrum* (lada hitam), *Muntingia calabura* (ceri), *Mimusops elengi* (tanjung), *Carica papaya* (betik)
May 2009	*Musa* sp. (pisang), *Piper nigrum* (lada hitam), *Muntingia calabura* (ceri), *Mimusops elengi* (tanjung), *Carica papaya* (betik)
June 2009	*Mangifera indica* (mango) *Durio zibetinus* (durian), *Nephelium lappaceum* (rambutan), Artocarpus integer (cempedak), *Fragrae fragrans* (tembusu)
July 2009	*Mangifera indica* (mango) *Durio zibetinus* (durian), *Nephelium lappaceum* (rambutan), Artocarpus integer (cempedak), *Fragrae fragrans* (tembusu)
August 2009	*Mangifera indica* (mango) *Durio zibetinus* (durian), *Nephelium lappaceum* (rambutan), Artocarpus integer (cempedak), Fragrae fragrans (tembusu)
September 2009	*Durio zibetinus* (durian), *Nephelium maingayi* (rambutan), *Artocarpus integer* (cempedak)
October 2009	*Durio zibetinus* (durian), *Nephelium maingayi* (rambutan), *Artocarpus integer* (cempedak)
November 2009	Dipterocarp trees flowering (*Shorea* sp.) *Musa* sp. (pisang), *Piper nigrum* (lada hitam), *Muntingia calabura* (ceri), *Mimusops elengi* (tanjung), *Carica papaya* (betik)
December 2009	*Musa* sp. (pisang), *Piper nigrum* (lada hitam), *Muntingia calabura* (ceri), *Mimusops elengi* (tanjung), *Carica papaya* (betik)
January 2010	*Musa* sp. (pisang), *Piper nigrum* (lada hitam), *Muntingia calabura* (ceri), *Mimusops elengi* (tanjung), *Carica papaya* (betik)
February 2010	*Musa* sp. (pisang), *Piper nigrum* (lada hitam), *Muntingia calabura* (ceri), *Mimusops elengi* (tanjung), *Carica papaya* (betik)

in January, May, and September and these coincided with the fruit abundance. This finding contradicts the results of Kofron (1997) in Brunei, Borneo and Bumrungsri et al. (2007) in Thailand, who found that the reproductive pattern of C. brachyotis was a continuous bimodal polyoestry with postpartum oestrus. The differences in the C. brachyotis'reproductive pattern are generally associated with different latitudes, which have been found to cause seasonality of rainfall and

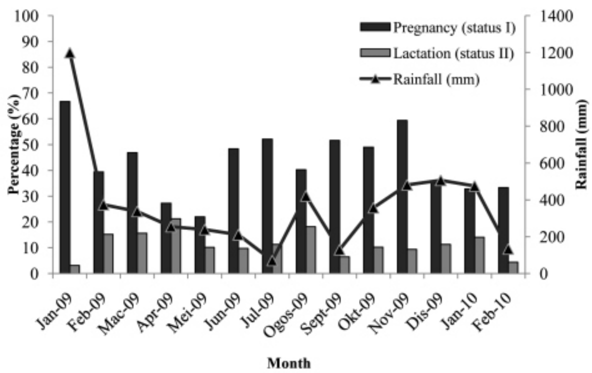

Fig.3: The reproductive status of female *Cynopterus brachyotis* in relation to rainfall pattern from January 2009 to February 2010.

food availability (Racey et al., 2000). Only the male bats' body mass showed significant correlation ($p<0.05$) with the climatic factors (rainfall, temperature and humidity). Kofron (1997) reported that the increase/decrease of adult males' body mass for C. brachyotis corresponded with the bimodal cycle of ripened mangoes in Brunei. However, the increase/decrease adult female C. brachyotis' body mass did not correspond to the bimodal cycle of ripened mangoes. The results suggest that male bats have to gain more energy for the mating repertoire (vocalizations, body movement, special flight patterns, roost defence, urinary tract markings), which is to pursuit the female partners. On the other hand, the body mass of female bats will increase due to pregnancy.

CONCLUSION

In conclusion, the reproductive pattern of the important seed disperser C. brachyotisis non-seasonal and significant correlation only occurs between male bats' body mass and climatic factor. In-depth information of the reproductive pattern of the species will help promote its protection in the forest.

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Rain Forest Recreation Zone Planning Using Geo Spatial Tools

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ABSTRACT

Development and management of forest recreation areas require sound planning. Forest recreation planning is a process of planning recreation areas and their uses in a rational and systematic manner. It is based upon knowledge of the existing state of forest resources, identification of potential recreation sites, identifying pressures from surrounding physical development and the need for proper management of the sites. The advent of Global Positioning System (GPS) and Geographical Information System (GIS) technologies, with their efficient spatial data storage and analysis capabilities, has created a large of opportunities for the development of new approaches to computer processing of or geographically referenced data, hence, adding a new dimension to the management of large volumes of information needed in forest recreation planning. This paper the application of GPS and GIS technologies to map and identify forest recreation zones at Gunung Tebu Forest Reserve (GTFR), in Terengganu, Malaysia. Using GIS spatial modelling techniques, the location and extent of five recreation zones were identified: Campground (7.5 hectares), Hiking (13.7 hectares), Interpretive (4.4 hectares), Picnic (6.7 hectares), and Infrastructure (67.2 hectares). The study showed that GPS and GIS technologies are capable as Decision Support tools in forest recreation planning.

Keywords: Rain Forest, Recreation Planning, Global Positioning System (GPS), Geographical Information System (GIS)

INTRODUCTION

Tropical forests offer a wide variety of attractive landscapes, fauna, flora, rivers and unique geological features that people seek in outdoor recreation (Chee, 1986). Forest recreational activities range from active pursuits like hiking, camping and swimming to the most passive activity such as appreciating the interesting ecological associations, historical and science attractions of the wilderness. The demand for recreational use of the forests in Malaysia increases with population growth, higher educational background, income, mobility and easier access to forest areas. The Forest Department of Malaysia is the main provider of forest recreation resources, managing more than one hundred and fifty forest recreation sites and continuously seeking and setting aside more forests for recreational uses (Anon, 2009).

Forest recreational planning is a complex task. The traditional approach in recreation site planning requires forest managers to identify existing and new recreational resources, followed by identification of zones for specific recreation activity. Thus, an extensive field survey had to be carried out and it resulted in voluminous amount of spatial and non-spatial data both in digital and thematic forms, which in turn had to be stored, displayed and analyzed in the planning tasks.

Information required in forest recreational planning is mostly spatial in nature, and hence, data management and decision making can be improved using geo spatial tools. The advent of GPS and GIS technologies has created an opportunity for computer processing of spatial data, adding

Fig.1: The location of Gunung Tebu Forest Reserve (GTFR) in the State of Terengganu

a new dimension to the management of large volume of information required in decision making process (Healy, 1988). This paper describes the applications of GPS and GIS technologies as Decision Support tools in identifying forest recreation functional zones at Gunung Tebu Forest Reserve (GTFR), in Terengganu, Malaysia.

METHODOLOGY

Study Area

The 25,529 ha Gunung Tebu Forest Reserve (GTFR) is located in Besut District (Fig.1) within the quadrant of latitudes 5° 34' N and 5° 37 N and longitudes of 102° 33' E to 102° 39' E. The topography of GTFR varies from flat to hilly terrains, with the highest point at Gunung Tebu (1037 meters). There are two recreation forests sites at GTFR; the Lata Belatan and Lata Tembakah forests.

METHOD

Outdoor Recreation Resource Survey and Mapping Using GPS

The survey objective was to identify and locate existing and new forest recreation attractions. Existing and new hiking trails were mapped using Garmin GPS. For trails, GPS stations were established at 30 meters interval and their coordinates were recorded. The unique recreation attributes were noted at the stations. Unique fauna along the trails were also recorded. Permanent features such as buildings and campsites were also noted.

Outdoor Recreation Usage and Opinion Survey

A survey on users' opinions towards recreation resource allocation survey was conducted using open-ended questionnaires. The objective was to determine the preferences for the existing facilities and services, as well as future ones. The results were used to establish the criteria identifying forest recreation functional zones in the study site.

GIS Development and Application

The first requirement is GIS database. This involved database design, followed by data automation and database organization to generate the intended information and spatial analysis. The cost effective approach is to have only information required for recreation planning as it is time consuming and costly to collect and store large volumes of data. The second requirement is data automation. This requirement is the ability to and integrate data from various sources in the database. Data sources were existing records, field surveys, remote sensing images and others within the GIS environment. Thirdly, the GIS database must be organized to facilitate easy ad hoc query, generation of new information and spatial analysis. Within the spatial analysis function, the must be able to perform alternative decision scenarios and to display results of advanced spatial modelling technique. The ESRI's ArcGIS Ver. 9.3 software was used in the development of GIS database and spatial modelling application in identifying forest recreation zones.

GIS Database Design

In database design, the basic information is required in the database and both spatial and non-spatial attributes data must be identified. Six main layers were created (see Fig.2): a) Base map, b) topography, c) drainage, d) infrastructure, e) forest and f) other resources.

GIS Database Automation

The GIS database automation processes are:

a. Digitizing existing maps

b. Input of GPS survey coordinates

c. Input of attributes or non-spatial information linked to map features in the GIS layers

d. Data transformation into a common coordinate system

GIS Database Retrieval and Spatial Analysis

The GIS basic operation in the spatial analysis is the ad hoc query and display of spatial features and their attributes. In support of decision-making, "what" and "where" the resources are can be answered quickly. Information on the queried spatial features can be displayed because of the established linkages between the features and their attributes in the database table. Meanwhile, outputs of the query can be viewed in the forms of maps and reports. More importantly, new information and map layers can be generated through various geo-processing capabilities provided by the GIS software.

Various map layers and information were queried from the GTFR's GIS database. The queried locations of the available and

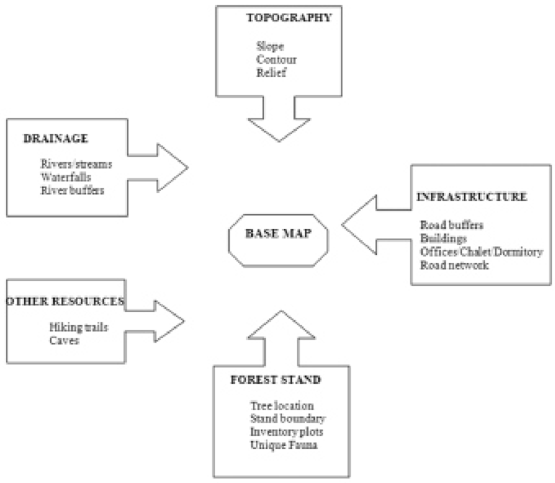

Fig.2: The GIS Database Design for Gunung Tebu Forest Reserve (GTFR)

new recreational resources will be put in the recreation functional zone model in the GIS.

Identification of Forest Recreation

Functional Zones

The advanced operation in GIS, as a decision support tool, is spatial modelling. Here lies the advantage of GIS over cartographic, database and statistical software. The spatial modelling technique allows manipulation of the GIS database to generate new information and visualization of "scenarios" from different decision alternatives. "What if" results enable further analysis refinement before the "best" decision is chosen by the planner? This minimizes risk of poor planning .

Prior to modelling and identification of forest recreation functional zones at GTFR, the recreation zones must first be determined. The five recreation functional zones were:

- Campground
- Hiking
- Interpretive

• Picnic
• Infrastructure

As the names suggest, these zones reflect the primary recreation activities to be in these locations. Users' preferences obtained from the Outdoor Recreation Usage and Opinion Survey were analyzed and considered in determining the criteria for respective activity zones.

Using the GIS software for spatial modelling, the vector based binary model approach was used. A similar approach was chosen in some previous studies, specifically

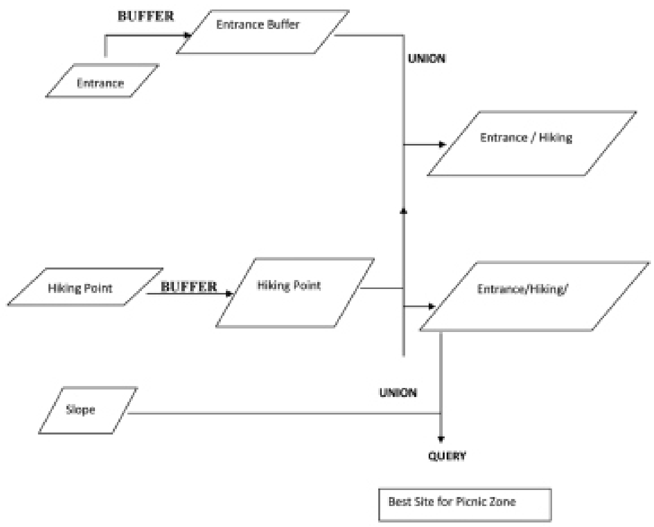

Fig.3: The flowchart of GIS Spatial Modelling Process for Picnic Zone

for site and habitat suitability analysis (Isaac et al., 2008; Silberman & Rees, 2010) was used and several phases were involved. These included the generation of new map layers and database queries. Geo processing capabilities, such as "surface generation (slope), "buffering" and "union" tools, were also applied. The "query" function was the final application used to identify the forest recreation zones based on the predetermined user preference criteria. The output created visualization of the respective zone locations, together with spatial statistics. The Picnic Zone identification is used to illustrate the GIS spatial modelling process.

The logical expression for "Query" (using the predetermined criteria for "Picnic zone") is as follows:

IF land is within 200 meter buffer of the main entrance
AND land is within 250 meter buffer of first hiking trail
AND land has slope less than 15 degrees
THEN the land is selected as Picnic Zone

The above expressions are translated
into the ArcGIS software modelling
commands, as follows:

INSIDE .LE. 1 AND WITHIN .LE. 1 AND SLOPE-CODE = 73

Where,

INSIDE Areas within 200 meters buffer from main entrance

WITHIN Areas within 250 meter buffer from first hiking trail

SLOPECODE Slope code

The attribute code values in the database are:

INSIDE 1 (in 200 meters buffer from the main entrance)2 (outside 200 meters buffer from the main entrance)

WITHIN 1 (in 250 meters buffer from the first hiking trail)2 (outside of 250 meters buffer from the first hiking trail)

SLOPE –CODE73 (0 – 15 degrees)83 (16 – 25 degrees)84 (greater than 25 degrees)

RESULTS AND DISCUSSION

Recreational Resources

With GIS, retrieval and display of natural features and recreational resources of the study site can be carried out. Fig.4 shows the general topography of the study area. LANDSAT TM satellite image of GTFR draped over drainage features is also shown (Fig.5). The "Query" function also enables the visualization of the existing and new recreational resources, specifically the location of the present recreational forests, maps of hiking trails measured in the field using GPS, and the elevation ranges in the study site (Fig.6). This information is necessary as an input into the recreation planning process, where planners are provided with a useful perspective of the study site. The GIS stored information on the

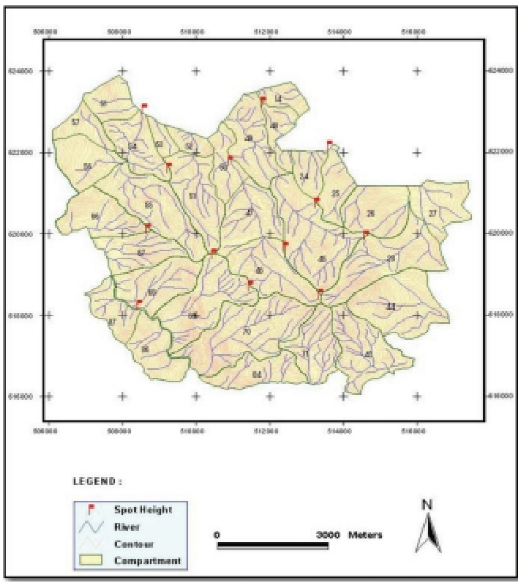

Fig.4: The Topographic Features of Gunung Tebu Forest Reserve, Malaysia

recreation resources can be displayed easily upon request. The spatial analysis capability of the GIS software can also generate new information useful for decision support and modelling such as slope classes (Fig.7).

Forest Recreation Functional Zones

The five recreational functional zones and their aerial extent are shown in Fig.8 and summarized in Table 1, respectively

TABLE 1
Area Distribution of Forest Recreation Functional Zones

Zone Classification	Area (ha)
Campground	8
Hiking	14
Picnic	4
Interpretive	7
Infrastructure	67

Campground Zone

A campground zone for 7.5 hectares was identified near the peak of Gunong Tebu. The rationale was to provide campers with seclusion for an “optimum” outdoor enjoyment. The backcountry campground type was the most preferred (see Fig.9).

Picnicking is the most popular activity in GTFR. The Lata Belatan Recreational forest is maintained as the Picnic Zone at the study site. The river corridor is popular for bathing as it provides picnickers

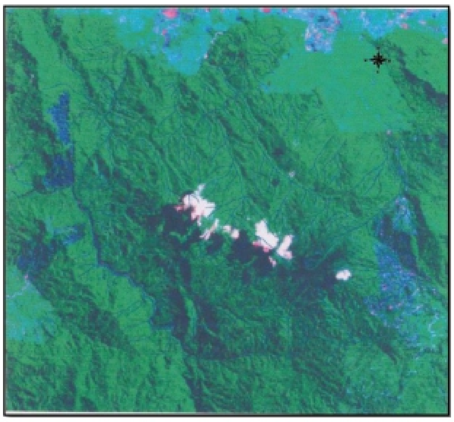

Fig.5: The Landsat TM Satellite Image of Gunung Tebu Forest Reserve, Malaysia Draped over Drainage Features

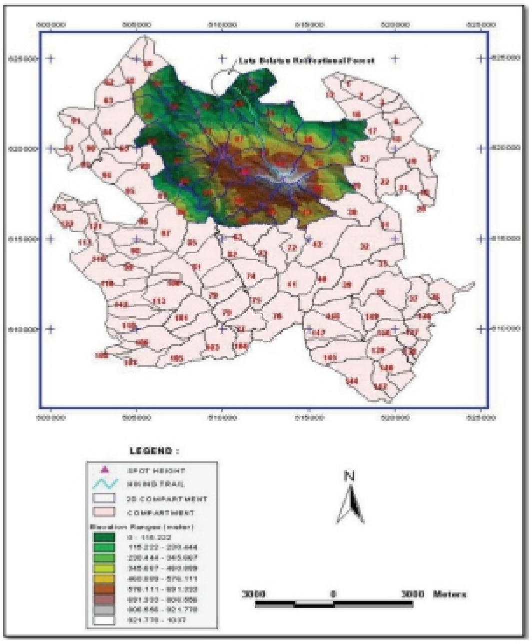

Fig.6: Gunung Tebu Forest Reserve, Malaysia, Elevation with Hiking Trails

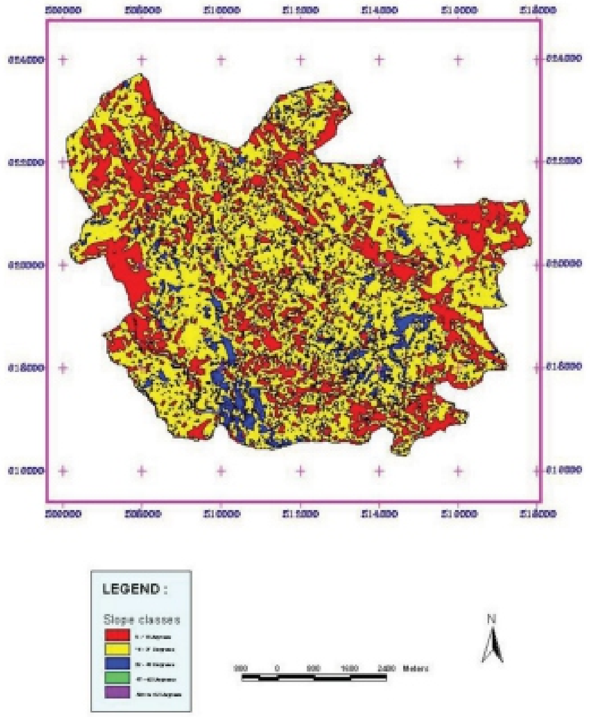

Fig.7: The Slope Classification of Gunung Tebu Forest Reserve, Malaysia

with a nice forest setting for family or group oriented activities. Included in the Picnic zone is a general–use picnic area covering 4.4 hectares (Fig.10). This zone requires establishment of developed activity infrastructure. Developed activities not only add to the convenience, safety and enjoyment of the users, they also serve to keep the people grouped together in places designed to accommodate them, and hence, centralizing wear which reduces soil and water pollution, facilitates rubbish clean-up and infrastructure maintenance.

Hiking, one of the most popular activities among users in GTFR, gives enjoyment at the vistas, unique spots and diverse environments along the trails established at Gunung Tebu (Fig.11). In managing hikers, strict zoning and separation of competing user groups are necessary. The identified hiking zone covers an area of 13.7 ha.

Interpretive Zone

The 6.8 ha interpretive zone is recommended at Gunong Tebu peak (see Fig.12). This was based on the existing and new nature trails

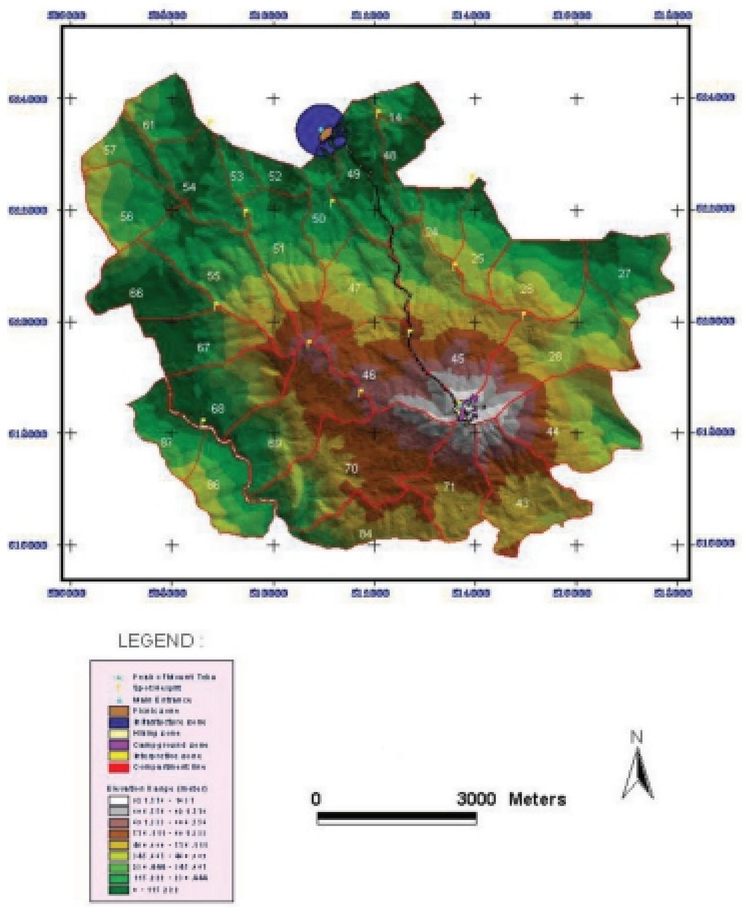

Fig.8: The Slope Classification of Gunung Tebu Forest Reserve, Malaysia

hat were identified and mapped using GPS and GIS. Two new trail lines, with trail points characterized by "Medicinal" and "Historical" themes, will be established. This zone is intended to connect users to the legacy, cultural and natural heritage of Gunong Tebu from their first-hand experience. Planners can increase users' recreation enjoyment and experiences by using interpretive techniques such as signage and brochures.

Infrastructure Zone

The infrastructure zone is located at the main entrance of Lata Belatan Recreational Forest (Fig.13). This 67.2 ha zone contains facilities needed to administer and manage GTFR. The administrative offices, infirmary, equipment storage sheds, service personnel living accommodations, store and a central washhouse are sited in this area.

The best location for the administration area is at the end of the existing public access

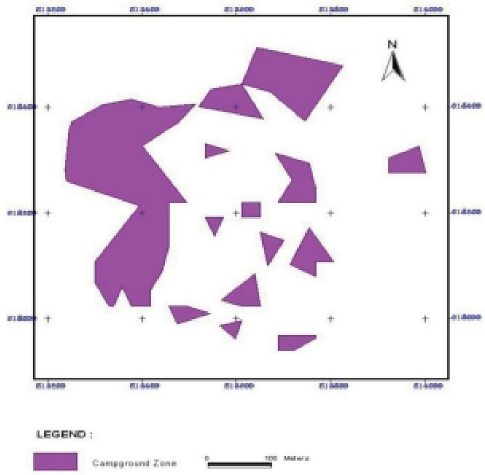

Fig.9: The Campground Zone of Gunung Tebu Forest Reserve, Malaysia

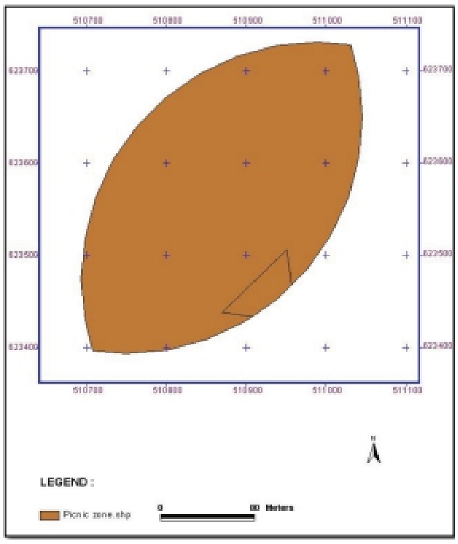

Fig.10: The Picnic Zone of Gunung Tebu Forest Reserve, Malaysia

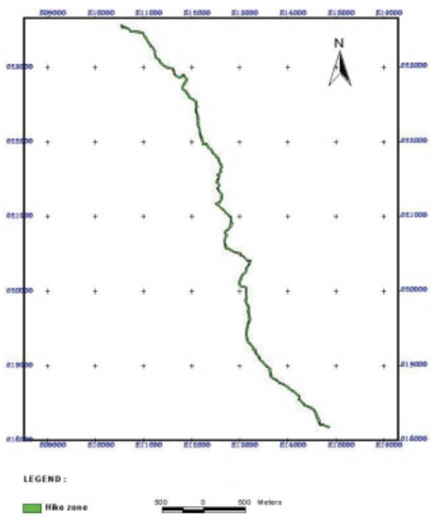

Fig.11: The Hiking Zone of Gunung Tebu Forest Reserve, Malaysia

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road. This is more suitable for supplying information and greeting incoming visitors. Being in the vicinity of the main entrance, it is first seen by visitors upon their arrival and last seen before departing. Information on the proper use of the GTFR facilities and public safety can be disseminated in this zone. The road should pass in front of the administrative buildings with adequate parking facilities for staff and the public.

CONCLUSION

The GPS application and GIS spatial modelling techniques have provided some useful information for Forest Recreation Functional Zone Planning at Gunung Tebu Forest Reserve (GTFR). These tools can be used for decision support as alternatives to the traditional manual planning approach. However, it is crucial to note that an effective GIS implementation is possible only when a comprehensive and accurate database is available.

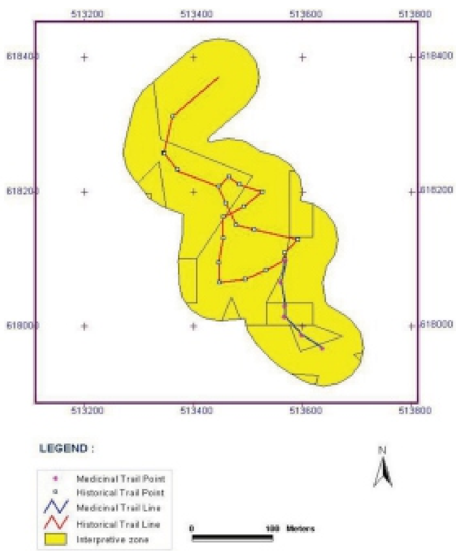

Fig.12: The Interpretive Zone of Gunung Tebu Forest Reserve, Malaysia

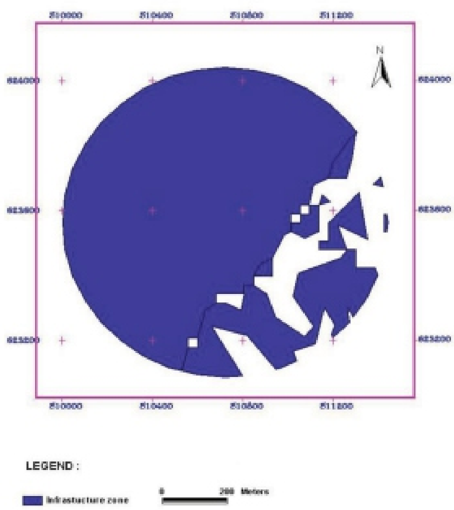

Fig.13: The Infrastructure Zone of Gunung Tebu Forest Reserve, Malaysia.

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