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A special issue devoted to the Issues in Forestry

Guest Editor:
Mohamed Zakaria Hussin

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Pertanika is an international peer-reviewed journal devoted to the publication of original papers, and it serves as a forum for practical approaches to improving quality in issues pertaining to tropical agriculture and its related fields. Pertanika Journal of Tropical Agricultural Science which began publication in 1978 is a leading agricultural journal in Malaysia. After 29 years as a multidisciplinary journal, the revamped Pertanika Journal of Tropical Agricultural Science (JTAS) is now focusing on tropical agricultural research. Other Pertanika series include Pertanika Journal of Science and Technology (JST) and Pertanika Journal of Social Sciences and Humanities (JSSH).

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Pertanika is the official journal of Universiti Putra Malaysia. The abbreviation for Pertanika Journal of Tropical Agricultural Science is *Pertanika J. Trop. Agric. Sci.*

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Preface

Forests are essential for human survival and well-being. They harbour two thirds of all terrestrial animal and plant species. They provide us with food, oxygen, shelter, recreation and spiritual sustenance, and they are the source for over 5,000 commercially-traded products, ranging from pharmaceuticals to timber and clothing. The biodiversity of forests—the variety of genes, species and forest ecosystems—underpins these goods and services, and is the basis for long-term forest health and stability. Promoting ways to use forest biodiversity in a sustainable way and with clear social and economic benefits for the poor is the purpose of this special issue of Pertanika Journals.

This Special Issue in Forestry explores the diverse topics from the management to the utilisation of forest resources. This issue also highlights the services provided by the forest especially in ecotourism or park and recreation products and activities development. The papers presented in this issue stress on the advances made through short and long-term research in forest resource management and benefits and consider some of the core challenges to researchers' involvement in various aspects related to the use, sale and management of these resources.

Some of the main findings addressed in this special issue include:

i) How research and development in forestry sectors and forest produce can optimise and vary the use of resources. This can be achieved through sustainable forest management (SFM) in ensuring sufficient timber resources and conservation of environmental stability. Through SFM, the balance between society's increasing demands for forest products and benefits and the preservation of forest health and diversity can be attained. This balance is critical to the survival of forests and to the prosperity of forest-dependent communities.

ii) How ecotourism (i.e. responsible travel) activities in natural areas can conserve the environment and improve the well-being of local people. It is recommended that those who implement and participate in ecotourism activities should follow ecotourism principles such as minimising impact, building environmental and cultural awareness and respect, providing positive experiences for both visitors and hosts and providing financial benefits and empowerment for local people.

This Special Issue in Forestry is intended for academicians, researchers, government officials, NGOs, donors among others as it focuses on the importance of harmonising the conservation of biodiversity and poverty reduction in a variety of forest contexts. It is our belief that the issue will help to communicate the value of Sustainable Forest Management as a reliable framework for safeguarding and delivering a broad range of goods and services in a fair and equitable manner to the widest possible range of stakeholders.

This issue is a concerted effort made possible with the help of many. Specifically, we thank Dr. Nayan Kanwal, the Chief Executive Editor of Pertanika Journals, and his dedicated team for their generous guidance and patience. We also congratulate and thank the authors for their full cooperation and understanding in meeting deadlines despite their tight schedules. Last but not least, we are indebted to the reviewers, whose names are acknowledged at the back of this issue, for providing their critical and timely feedback.

Mohamed Zakaria Hussin

Guest-Editor

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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 ArcMap™ 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

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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 ArcMap™ 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,

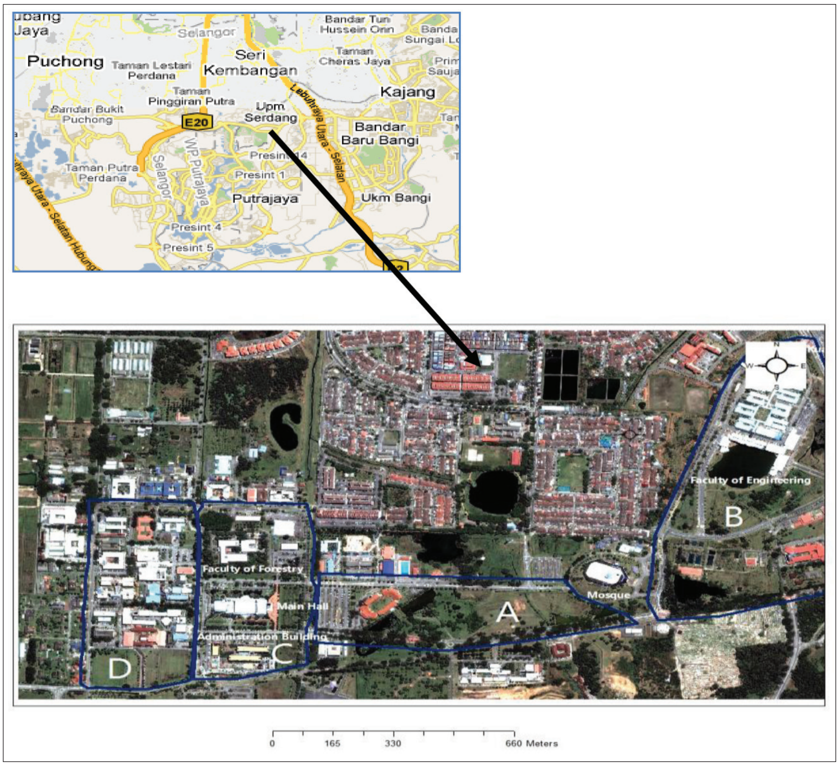

Fig.1: Study area at UPM which was divided into 4 zones A,B,C, and D

etc. Ground data were keyed into MUTIS to calculate hazard rating. The overall activity flowchart is shown in Fig.2.

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, co-dominant 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)

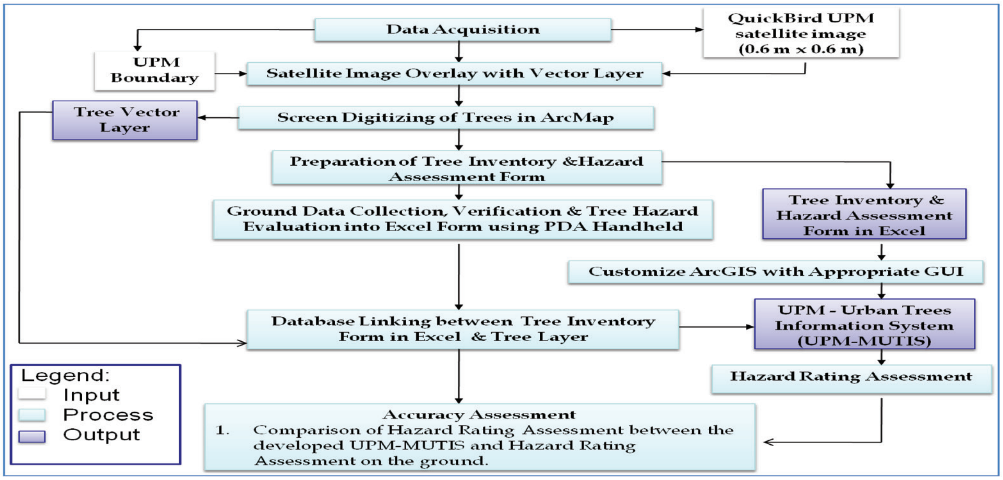

Fig.2: A flowchart showing the overall activities carried out in this study

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:

$$\text{Accuracy percentage (\%)} = \frac{\text{number of correct trees}}{32} \times 100$$

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
1	A0054	medium	medium
2	A0294	medium	medium
3	A0322	medium	medium
4	A0452	medium	medium
5	A0461	medium	medium
6	A0531	medium	medium
7	A0594	medium	high
8	A0610	medium	medium
9	A0615	medium	medium
10	A0672	medium	medium
11	A0696	medium	medium
12	A0734	medium	medium
13	A0760	medium	medium
14	A0816	medium	medium
15	A0875	medium	medium
16	A0880	medium	medium
16	A0897	medium	high

No	Tag_No	MUTIS	Ground Evaluation
17	A0914	medium	medium
18	A0930	medium	medium
19	A0947	medium	medium
20	A0962	medium	medium
21	A0974	medium	medium
22	A0983	medium	medium
23	A0993	medium	medium
24	A1008	medium	medium
25	A1011	medium	medium
26	A1019	medium	medium
27	A1026	medium	medium
28	E0004	medium	medium
29	E0029	medium	medium
30	E0033	medium	medium
31	E0036	medium	medium
32	E0039	medium	medium

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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Licensee Practices on Forest Regeneration in Kuala Balah Permanent Reserve Forest, Kelantan, Peninsular Malaysia

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ABSTRACT

Forest regeneration is important to ensure adequate residual stand for the next cutting cycle in poorly stocked logged-over compartment. A regeneration activity has been implemented at abandoned areas to restructure forest contents for quality and healthy composition of timber species. At the skid trails, logs are drag for preparation, stacking and loading out to the log yard. In such areas, trees could not survive naturally as a result of soil compaction. The areas need to be ploughed prior to planting. Forest licensee is responsible for replanting timber trees at log yards, skid trails and ex-logging camp. This study was carried out to determine forest regeneration activities and to identify issues on sustaining timber yield in Kuala Balah Permanent Reserve Forest, Kelantan. The compartment is managed by Kelantan Integrated Timber Complex (KPK). Primary data were collected from 150 respondents from field staff of KPK, sub-contract field workers and nursery labourers who were engaged in the activities. The respondents were given a questionnaire to survey and identify the problems faced during replanting activities. The study found that forest regeneration activities inevitably allowed proportion of vigorous and quality indigenous timber species and artificially increased the volume of specific regeneration into the logged-over forest for the next cutting cycle.

Keywords: Forest licensee, sustainable forest management, regeneration, sustaining yield

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INTRODUCTION

Sustainable Forest Management (SFM) was developed by the Ministerial Conference on the Protection of Forests in Europe (MCPFE) in 1993, and has been adopted by FAO. It defines SFM as the stewardship and use of forests and forest lands in a way, and rate that maintains their biodiversity, productivity, regeneration capacity, vitality and their potential to fulfil, now and in the future, relevant ecological, economic and social functions, at local, national, and global levels, and that does not cause damage to other ecosystems (MCPFE, 2007). It was recognized by the parties at the Convention on Biological Diversity in 2004 (Decision VII/11 of COP7) to be a concrete means of applying the ecosystem approach to the forest. Both concepts aim at promoting conservation and management practices which are environmentally, socially and economically sustainable, generate and maintain benefits for both present and future generations.

The term "sustainable" was derived from Latin word, "*sus-tenere*" which means uphold. The concept of sustainability comes from the concept of sustained yield forestry (Pearce *et al*., 2003; Ferguson, 1996). It balances between forest products and services, and the preservation of forest health and diversity. SFM maintains or enhances the contribution of forests to human well being, both of the present and future generations without compromising their ecosystem integrity that is their resilience, function and biological diversity (Sayer *et al*., 2005). Obviously, the ecological and economic impacts of SFM depend on a variety of variables - everything from the type of forests involved to the structure of regional economy (Jenkins *et al*., 1999). SFM means not only management of wood and non-wood resources, but also their processing and creation of appropriate economical structure (Strakhov, 2000). This balance is critical to the survival of forests and to the prosperity of forest-dependent communities. However, the level of understanding by loggers is still vague. According to Buang (2001), the progress in establishing SFM was very low and had less impact on the tropical forest.

In Malaysia, the federal government serves as the emblem protector and state serves as the forest managers (Marsh *et al.,* 1992; Mc Morrow *et al.,* 2001). As a member of International Tropical Timber Organization (ITTO), Malaysia has adopted ITTO Guidelines for the Sustainable Forest Management of Natural Tropical Forests and its Criteria for the Measurement of Sustainable Tropical Forest Management (CMSTFM). The silviculture systems applied in tropical forest ecosystems are clear felling or clear cutting, selection felling and shelter wood system (Vandana, 1992). It is a formulated tool, which can be used to conceptualize, evaluate and implement SFM practices. In Malaysia, conventional harvesting of production forests is undertaken on a rotational cycle and a sustained yield management system. Mature trees are tagged for felling at each cycle, thus allowing the logged over area to recover and regenerate before the next harvesting. Under selective logging system, natural forests will return to their former characteristics for better biological functioning. From the point of views of forest licensee, managing a forest in sustainable manner means ensuring for a better benefits for future forest product and services.

Regeneration is a silviculture tool proposed to rehabilitate and to manage harvested forest contents at the maximum level. In particular, it is to enrich the poorly stocked residual stand of logged-over dipterocarp forest by regeneration. Regeneration is when forest licensee selects indigenous commercial species to restore timber trees at post-harvest compartments, i.e. when timber stock and species are inadequate. The activities were devised from the fact that planting was done merely to increase the value per hectare of a forest. Thus, the objectives of this study were to determine forest regeneration practice by licensee and to identify issues on sustaining timber yield in Kuala Balah Permanent Reserve Forest, Peninsular Malaysia.

MATERIALS AND METHODS

Study Area

The study was conducted in Balah Permanent Reserve Forest, in the state of Kelantan, Peninsular Malaysia. The reserve forest is located at 5°16' to 5° 19N and 101° 42' to 101°45'E (see Fig.1). The areas managed under Kelantan Integrated Timber Complex (KPK) are as follows: compartments 42 (70 ha), 43 (258 ha), 46 (215 ha), 114 (198 ha) and 148 (251 ha.) The topography of this area is undulating with slopes ranging from 8 to 55 degrees and elevation above 600 meters. The average rainfall is 2,664 mm per year, while the temperature varies from 27° to 32°C. The driest months are from April to September with an average temperature of 34°C, while the wettest months are from October to February with the average monthly maximum temperature of 30°C. The distribution of rainfall occurs with a major peak in November and a minor peak in March. The area comprised of hill dipterocarp forest. The Dipterocarpaceae family dominates the forest canopy with *Shorea curtisii* as the dominant species. Other economical valuable commercial species are *Shorea parvifolia, Shorea platyclados* and *Sapotaceae*. This ridge forest is characterized by large trees, which are semi-gregarious that forms a dominant stand of large canopy trees along the ridge gigantic soil (FRIM, 2006).

Data Collection

Both primary and secondary data were recorded. Primary data were collected from 150 respondents, namely, the field staff at Kelantan Integrated Timber Complex (KPK) (48), sub-contract field workers (62), and nursery labourers (40), who are engaged in inventory and silviculture activities. The respondents were given a questionnaire each to identify the problems during the replanting activities. In addition, personal interview and site observation were also conducted. Meanwhile, secondary data were compiled from state gazettes, official documents, published report, and other references related to this study. The data were gathered, reviewed and analyzed.

RESULTS AND DISCUSSION

Hill dipterocarp forest of Peninsular Malaysia was characterized by poorly stocked natural regeneration and lack of seedlings in the original residual stand. The

Fig.1: A map of Peninsular Malaysia showing the location of Kuala Balah Permanent Reserve Forest, Kelantan

seedlings are slow in-growth and shade demanding in nature. The objective of Selective Management System (SMS) is to regenerate and to save sufficient number of young potential tree species which vigorously survive from damage during harvesting of the merchantable timber. It is a flexible system which allows determination of the most appropriate cutting regime based on the analysis of pre and post-felling forest inventory data, considering the need of leaving behind sufficient stocking of intermediate sized trees, optimal growth rates and maintaining species composition of the residual forest stand at minimal damage (Hassan-Zaki *et al*., 2004).

The current forest regeneration practice in this area is conducted based on the prescriptions of post-felling inventory imposed in forest compartment. It is an effort to manage the forest resources in a sustainable manner. The regeneration activities focus on various major aspects related to the technical requirement such as selection of species, prime area in logged-over forest, field operation methods, as well as silviculture and map of replanting areas. Activities on regenerating the forest have become more prominent and important in the effort to ensure that relatively poor stocking of logged-over forests is enriched. Several potential commercial indigenous timber tree species that are suitable for regeneration include *S. parvifolia, S. curtisii, S. platyclados, Sapotaceae, K. malaccensis, D. costulata, H. odorata, D. aromatica, Pentaspadon spp., S. wallichi, Heriteria spp.* and *A. borneensis*. In this study, the highest number of trees regenerated was in compartment 46. A total of 2,879 trees were planted in the compartment log yards and 4,097 were regenerated in the skid trails. Only 1,841 trees were planted in the log yards in compartment 42 and 903 trees were planted in the main log yard. At the skid trails, there were about 938 trees planted. The difference in the total trees regenerated was due to the size of both the compartments. The size of compartment 46 is 215 ha, while compartment 42 is 70 ha. Five dominant species planted in this compartment are *S. parvifolia, Anisoptera*, *S. leprosula, S. ovalis* and *S. guiso*.

Among the selected species, *S. parvifolia* is the most desired species planted in the compartments because of the soil and temperature suitability in the areas. In addition, the species has a high growth rate, produce quality wood with high economic values and also market demand. Nonetheless, compartment 148 failed to achieve the target in the main log yard areas, where only 55.14% of the planted trees survived. A total of 72.25% trees in the skid trails survived as a result of the topography characteristics and difficult terrain surrounding the log yard areas. The planted yields could not tolerate desiccation to low moisture contents and remained viable only for a short of period (Chin *et al*., 1988). The highest achievement in the log yard areas is in compartment 42, with 82.5% survival rate, followed by compartments 43 (80.82%), 114 (76.38%), 46 (76.1%) and 148 (55.14%). In the skid trails, the highest achievement was in compartment 46 with 72.66% survival rate, and this was followed by compartments 148 (72.25%), 114 (67.71%), 42 (67.66%) and 43 (63.21%). However, compartments 42, 43 and 114 had failed to achieve the target of 70.0% survival rates.

This study revealed that the problems faced by the forest licensees are as follows:

1. Inadequate support (43.0%): Inadequate support had made some forest staff to become dependent on the goodwill of concession holders. Yield regulation is very important to ensure sustainability under the SMS. Stocking of yields was not sufficient to sustain the continuity of dipterocarp regenerations in the forest. Seeds have to be quickly sowed in the nursery to restore a higher germination percentage. In addition, proper nursery technique and the preparation of planting stock for seeds are highly required to restore higher germination and critical during the regeneration period. Moreover, since different states make different policies, there is no standard procedure used in executing the forest regeneration techniques. Different

treatments will give incomparable results and make it difficult for further study. A comprehensive review of growth and yield (G & Y) data is also essential. The objective of yield regulation is to determine and to ensure that there are sufficient areas for harvesting sustainably during the specific period. The amount is stated as the allowable cut for that period and is usually averaged to a year as the Annual Allowable Cut (AAC). The determination of the AAC is central to SFM as it is to ensure a continuous supply of timber.

2. Climatic or weather conditions (20.0%): The regeneration activities could only be executed during raining seasons and could not to be proceeded when there was no rain for a period of the three consecutive days. The seasons in some areas might be very short. The loggers were much wary of it and thus worked hard to utilize that short period of time to the maximum. For example, the planting months were usually from late August to January in the east-coast states according to the rainy seasons. In particular, the inherent constraints were related to unseasonable climate, which would be overcome to some extent by improving the respective techniques. The areas that were very poor in species composition and wood content are usually in the deeper compartments and remote portions of the forests and need to be enriched.

3. Team work (16.0%): A key factor for SFM is the consideration and involvement of the different stakeholders in various activities. Human factors, such as encouragement of team work, good skill in recognizing appropriate silviculture tools and able to handle work efficiently, can be considered as important elements to ensure the success of regeneration activities.

4. Cost (10.0%): To execute the regenerating activities, the study revealed that the high cost of operation and maintenance was a major problem encountered. Problems related to cost include manpower and labour cost, seedling and yields, fertilizers, silviculture activities, etc.

5. Transportation (7.0%): Transport problem existed when reforestation activities were carried out during bad weather and when logging road is not well maintained by the contractors. Transportation of seedlings to the compartments is one major problem. Distance and shock that had to be endured would render the seedlings as not suitable or ready for planting. Some of the compartments are inaccessible. The only other prerogative to plant in this area is by manual labour to take the seedlings to the planting site which will result in higher seedlings mortality. Healthy seedling is selected through a proper culling process to ensure that those selected can withstand transportation and transplanting shocks.

6. Wildlife disturbances and illegal cultivation (5.0%): Planted seedlings are sometimes mutilated or destroyed completely by wild animals such as wild elephants, wild boars, porcupine etc. Moreover, unscrupulous act of cultivating illegally has been rampant in the states. This is one of the major setbacks faced by the loggers in their effort to execute the regeneration activities. Areas that were once put through regeneration were suddenly cleared and razed to the ground by illegal cultivator. Variable high quality trees were intruded with the planting of fruit trees and other cash crops by the villagers or aborigines, which shifted around searching for fertile areas for upland rice cultivation. Their nomadic culture is an accepted norm. Their next destination of cultivation area could be predictable in some instances, but that this is not necessarily possible in certain cases. Hence, studies that emphasize on effective enforcement of a few simple and basic rules are useful than the proliferation of complex working plans and mathematical yield control methods.

CONCLUSION

Sustainable forest management is a process of managing forest for a continuous flow of desired forest products and services without undue reduction of its inherent values and future productivity, as well as undesirable effects on the physical and social environment. Composition, constitution and structure of logged-over forest do not support polycyclic systems and stocking is not sufficient to sustain continuity of dipterocarp management in future. Since the regeneration dynamics and growth of commercial residual trees is not as high as expected, regeneration activities by forest licensees are essential as a means to improve residual stocking that will definitely be able to overcome some of the forest management issues. From the view of forest licensee, managing a forest in sustainable manner means to ensure better benefits for future forest products and services. Based on our study at compartments 42, 43, 46, 114 and 148 in Kuala Balah Permanent Reserve Forest, it could therefore be concluded that forest regeneration activities inevitably allowed proportion of vigorous and quality indigenous timber species and artificially increased the volume of specific regeneration into the logged-over forest for the next cutting cycle. This balance is critical to the survival of forests and to the prosperity of forest-dependent communities. Good forest governance and policy formulations have to be guided through proper long-term management of the forest resources by maintaining an optimum equilibrium between resource utilization and the need to protect the environment as a pre-requisite for the sustainable production of forest goods and services.

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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 endemic dipterocarps 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.

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INTRODUCTION

Every forest has some biological, environmental and social values, and the values may include rare species, special

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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

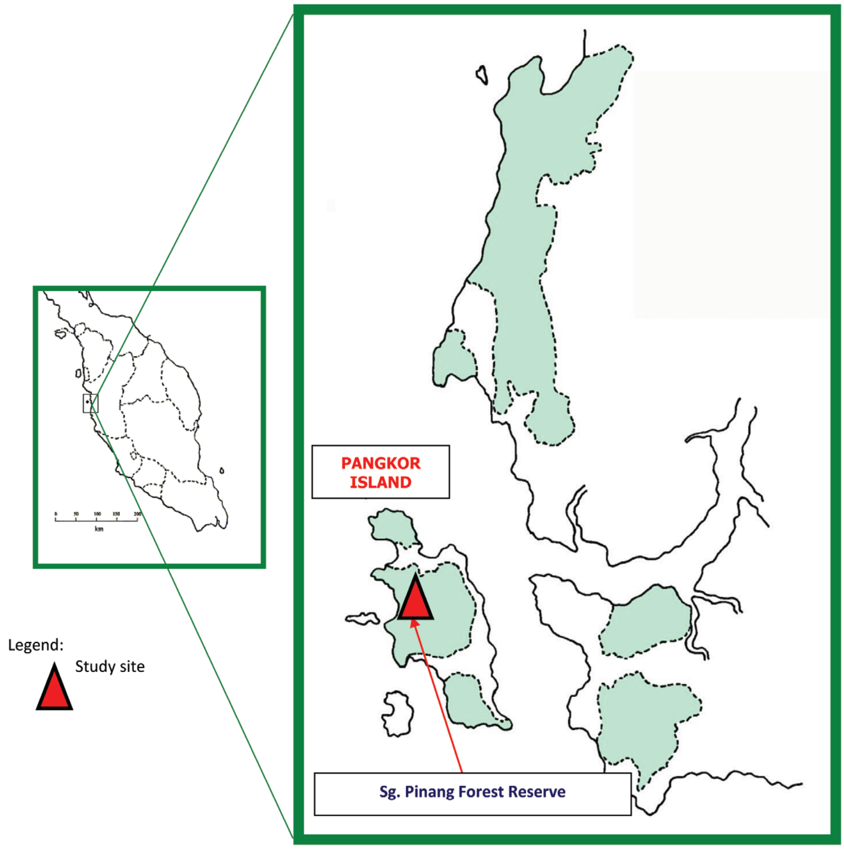

Fig.1: Location of the study site at Sungai Pinang Forest Reserve, Pangkor Island (Adapted from Lee *et al*., 2004)

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 sampling 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 suppressed (T2: 8–15m), shrub (S: 2–8m) and herb (H: lower than 2m) was carried out by using the 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 pauciflora* and *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*

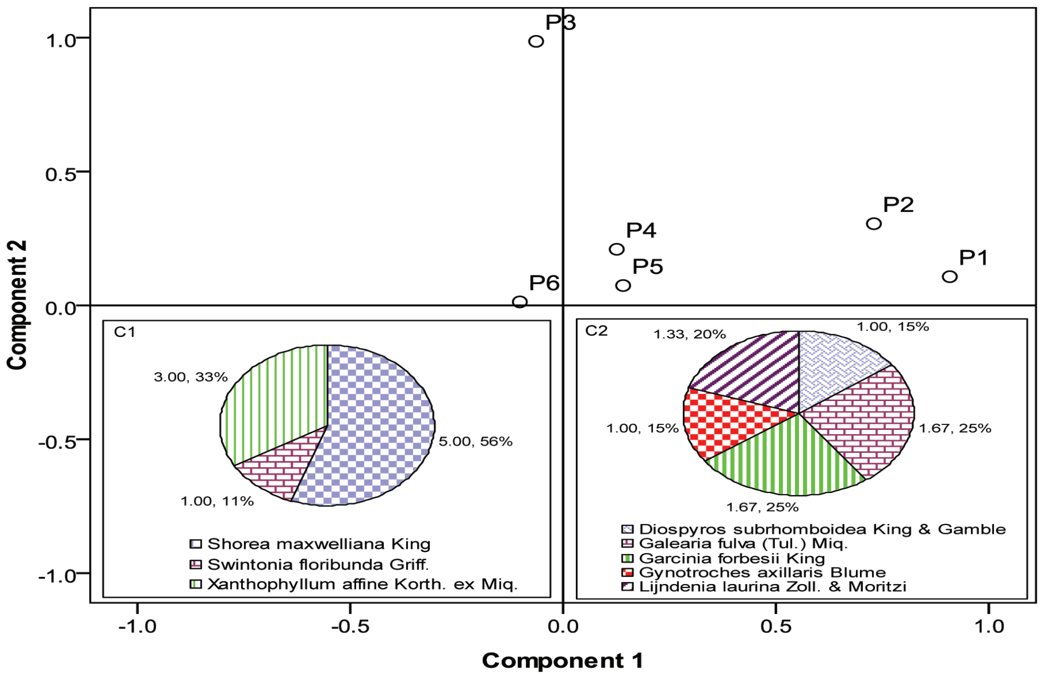

Fig.2. Species domination at the Herb (H)-layer in all plots

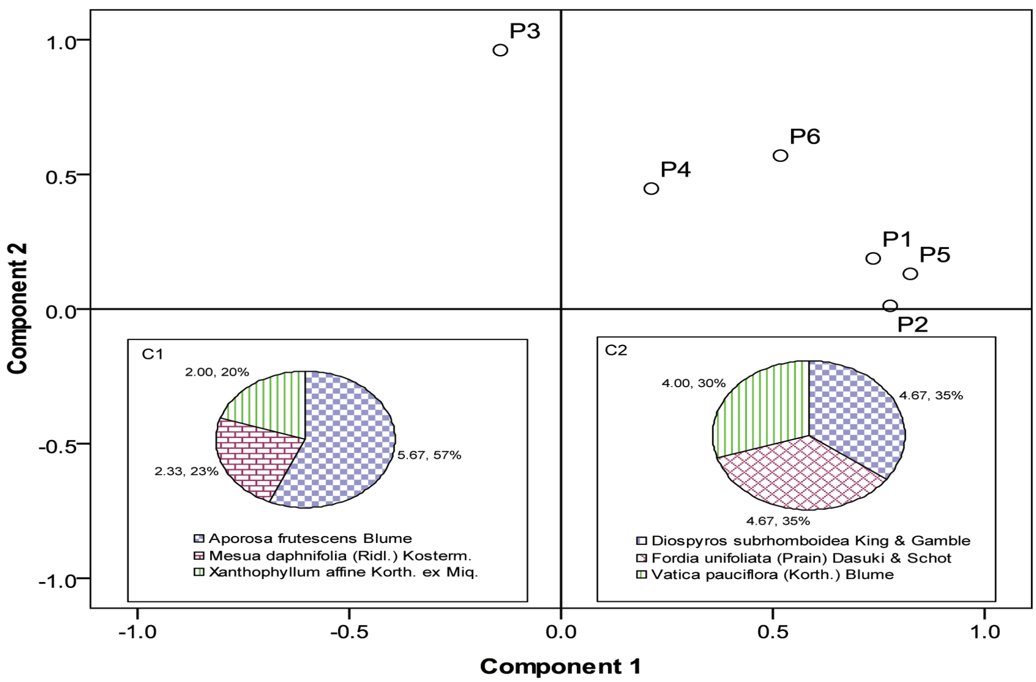

Fig.3: Species domination at the Shrub (S)-layer in all plots

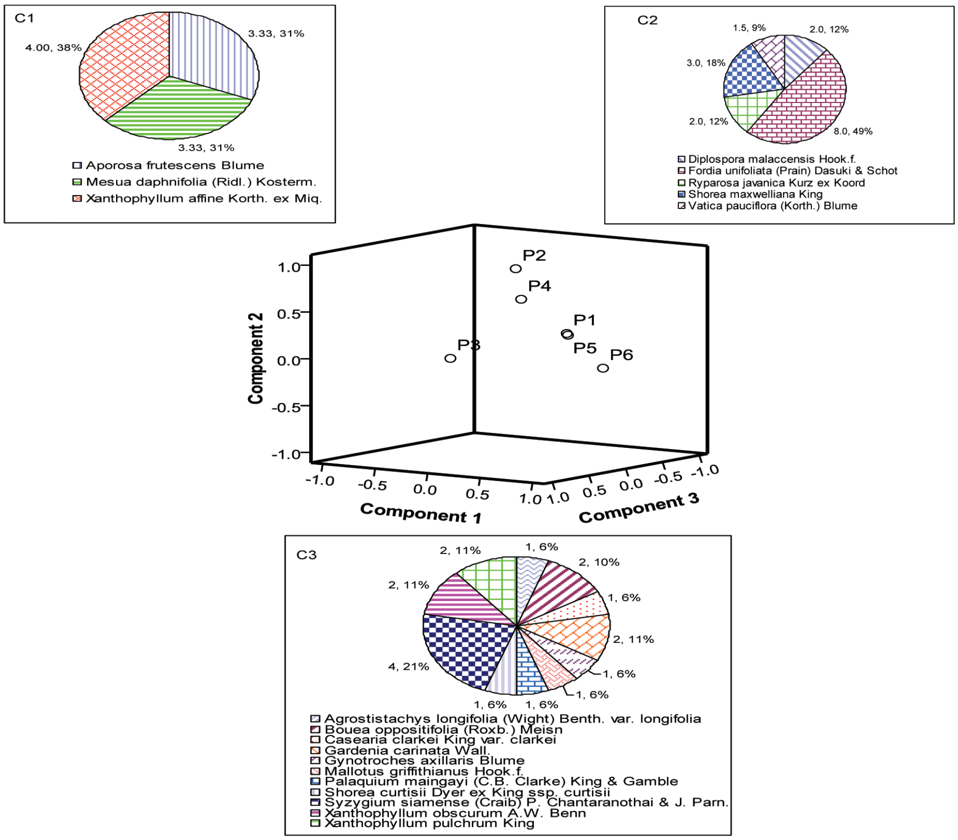

Fig.4: Species domination at the Co-dominant (T2)-layer in all plots

(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 siamense* and *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 (r =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

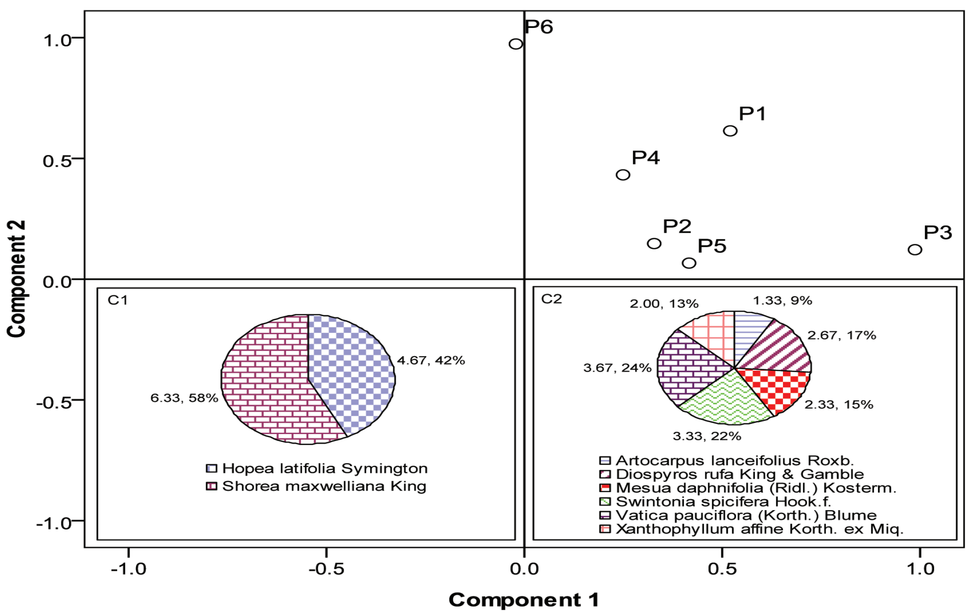

Fig.5: Species domination at the Dominant (T1)-layer in all plots

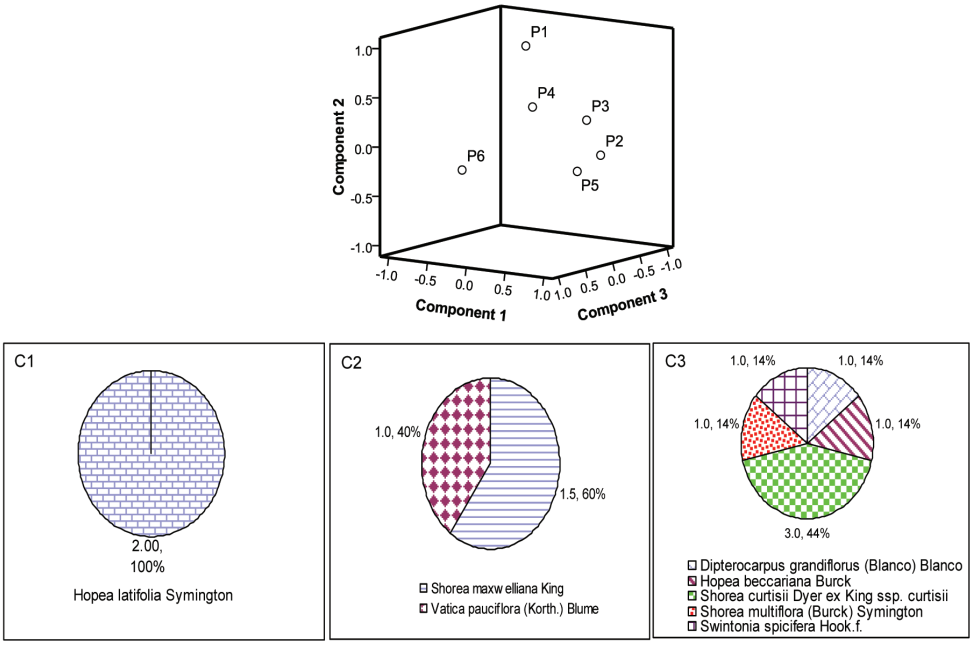

Fig.6: Species domination at the Emergent (ST)-layer in all plots

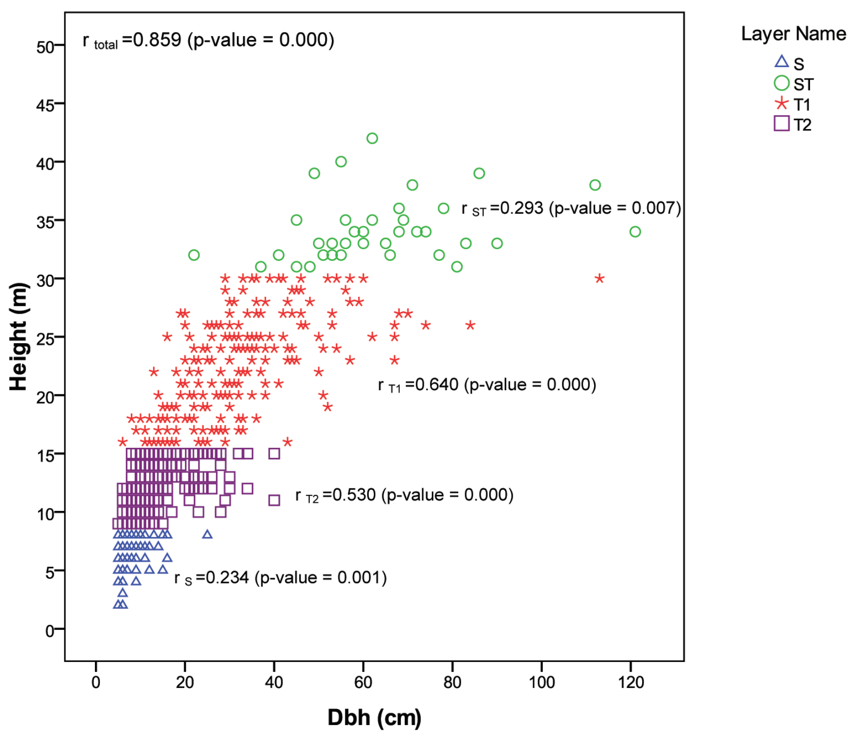

Fig.7: Relation between DBH and height at every layer level in all plots

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 ha[1] (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 replanting 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 $1/D^2H$ showed its superiority over other equations in both species groups. The standard volume equations selected are as follows:

DRM: $V = -0.5994 + 3.1947E\text{-}04D^2 + 0.0370H + 4.2054E\text{-}05D^2H$
(FI = 0.9474)

LRM: $V = 0.2059 + 1.6593E\text{-}04D^2 + 8.3346E\text{-}03H + 4.8974E\text{-}05D^2H$
(FI = 0.9434)

Where,

V is the commercial tree volume (m^3 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

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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 *(Gmelinaarborea*roxb) (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 for *Eucalyptus grandis* (1967b), a general volume table for *Pinuscaribea*mor. (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 1st National 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 *Pinuscaribaea* var. *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 (*Dryobalanopsaromatica*gaertn. 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. Ghani*et 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 $\{(\pi D^2/40,000) \times L \times F\}$, 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 Products, 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 (R^2), and adjusted R^2(R^2_{adj}) 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 often 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 a 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, MHW & HHW)	=	984 trees
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 Non-*Shorea*. 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 (D_{ob}) at dbh (1.3m above the ground or just above the end of taper, if a tree was heavily buttressed);
2. Diameter outside bark (D_{ob}) 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 (D_{ob}) 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 (D_{ob}) at the mid-point of the commercial log length;
5. Commercial log length from points in (2) and (3) above;
6. Diameter outside bark (D_{ob}) at the beginning point of "top" log, if any;
7. Diameter outside bark (D_{ob}) at the mid-point 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 equation[1] 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

[1] The equation derived was classified by diameter at reference point of <76cm and >76cm. For each diameter class, an equation was obtained for each commercial log length class. Equation in each commercial log length class for trees >76cm diameter was in a simple linear form having diameter (D) only as an independent variable.

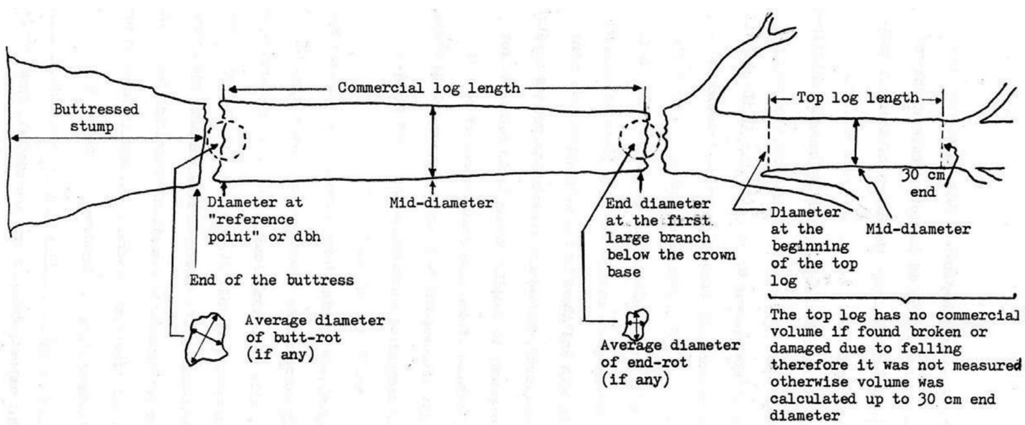

Fig. 1: Illustration of field measurements on a felled sample tree

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:

$$V = \{[A_l + 4A_m + A_s] / 6\} \times L$$

Where

V = Volume overbark (ob), m^3

A_l = cross-sectional area (ob) at the bigger end of the log section (m^2),

A_m= cross-sectional area (ob) at the mid-point of the log section (m^2),

A_s= cross-sectional area (ob) at the smaller end (m^2), 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 R^2 or even adjusted R^2. 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	-	-	-	-

the derivatives of the dependent variable Log_eV, V/D^2, and V/D^2H of the weighted equations are V, D^2 and D^2H, 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. $V = \beta_0 + \beta_1 D^2H + \varepsilon$
2. $V = \beta_0 + \beta_1 D^2 + \beta_2 H + \beta_3 D^2H + \varepsilon$
3. $V = \beta_0 + \beta_1 D^2 + \beta_2 DH + \beta_3 D^2H + \varepsilon$
4. $Log_eV = \beta_0 + \beta_1 Log_eD + \beta_2 Log_eH + \varepsilon$

WEIGHTED EQUATIONS

5. $V/D^2H = \beta_0 + \beta_1(1/D^2H) + \varepsilon$.... Equation [1] weighted by D^2H
6. $V/D^2 = \beta_0 + \beta_1 [1/D^2) + \beta_2 (H/D^2) + \beta_3 H + \varepsilon$ .... Equation [2] weighted by D^2
7. $V/D^2H = \beta_0 + \beta_1 (1/D^2H) + \beta_2 (1/H) + \beta_3 (1/D^2) + \varepsilon$.... Equation [2] weighted by D^2H
8. $V/D^2 = \beta_0 + \beta_1 (1/D^2) + \beta_2 (H/D) + \beta_3 H + \varepsilon$.... Equation [3] weighted by D^2
9. $V/D^2H = \beta_0 + \beta_1(1/D^2H) + \beta_2(1/H) + \beta_3(1/D) + \varepsilon$.... Equation [3] weighted by D^2H

Where
V = dependent variable (commercial tree volume, m^3),
D = dbh or reference diameter (cm),
H = commercial log length (m),
β_i= 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

$V/D^2H = (4.2054E\text{-}05) - (0.5994(1/D^2H)) + (3.1947E\text{-}04(1/H)) + (0.0370(1/D^2))$ .... Equation [7]

Multiplying both sides by D^2H produces the final volume equation:

$V = - (0.5994) + (3.1947E\text{-}04D^2) + (0.0370H) + (4.2054E\text{-}05D^2H)$

Light Red Meranti

$V/D^2H = (4.8974E\text{-}05) + (0.2059(1/D^2H)) + (1.6593E\text{-}04(1/H)) + (8.3346E\text{-}03(1/D^2))$.... 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 byD^2H produces the final volume equation:

$$V = (0.2059) + (1.6593E\text{-}04D^2) + (8.3346E\text{-}03H) + (4.8974E\text{-}05D^2H)$$

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 (m^3) 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 (>1.0m^3) 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 2m^3/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 0.5m^3/tree.

Notes on the Occurrence of Butt- and End-rots 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 butt-rots. No trees, except 1 out of 331 LRM trees measured, showed any sign of end-rot 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. pa*uciflora 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. le*prosula, 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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ABSTRACT

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.

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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) (113° 03.591' E, 03° 12.691' N) and mixed dipterocarp forest (113° 04.105' E, 03° 12.967' 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

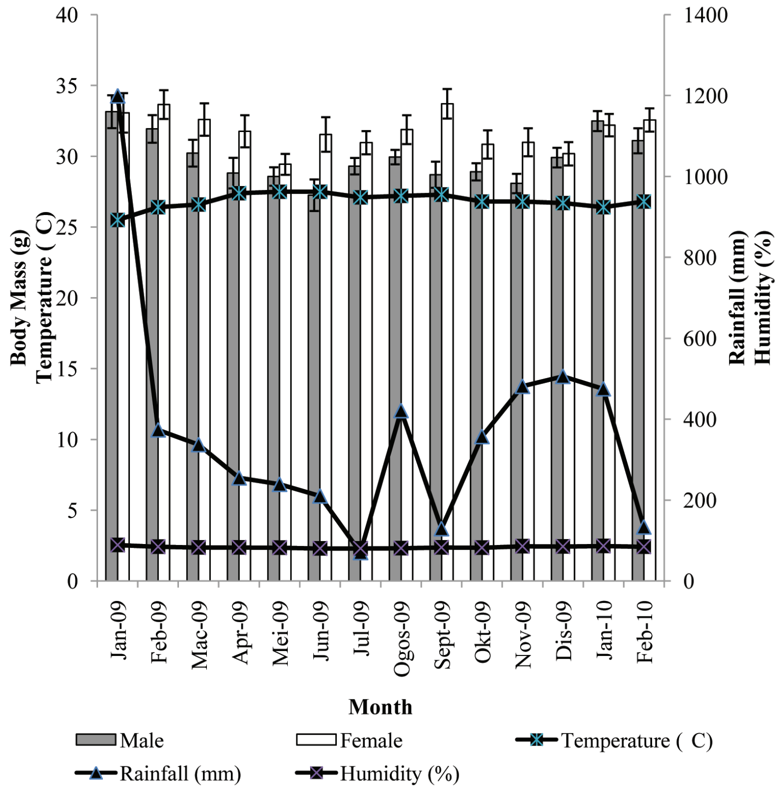

Fig.1: The relationship between the male and female bats' body mass (g) with rainfalls (mm), temperature (^{o} C) and humidity (%) from January 2009 to February 2010 [this study is based on 1328 captures of adult *C. brachyotis* (male: 51 ± 21.09, female 52 ± 19.74 individuals caught each month)].

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 from 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

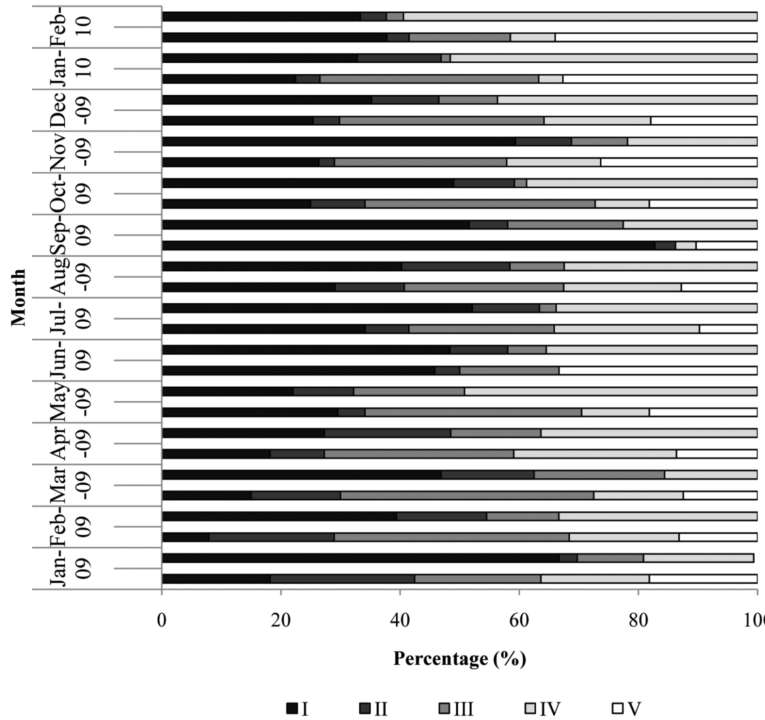

Fig.2: The male (♂) and female (♀) bats' reproductive status (%) for fourteen (14) months period. For male bats: I-Minor testes enlargement, no epididymal distention, II-Testes at or near maximal enlargement, no epididymal distention, III-Testes regressed, cauda epididymal distented, IV-Testes not regressed, 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 month, suggesting that the breeding pattern is non-seasonal. 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 fruit availability throughout the year, as shown by other studies (e.g. Wong *et al*., 2003; Funakoshi *et al*., 1997; Lim (1970). Lim (1970) found peaks in pregnancies to occur

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)

Note: Non-seasonal fruits area available throughout the year

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

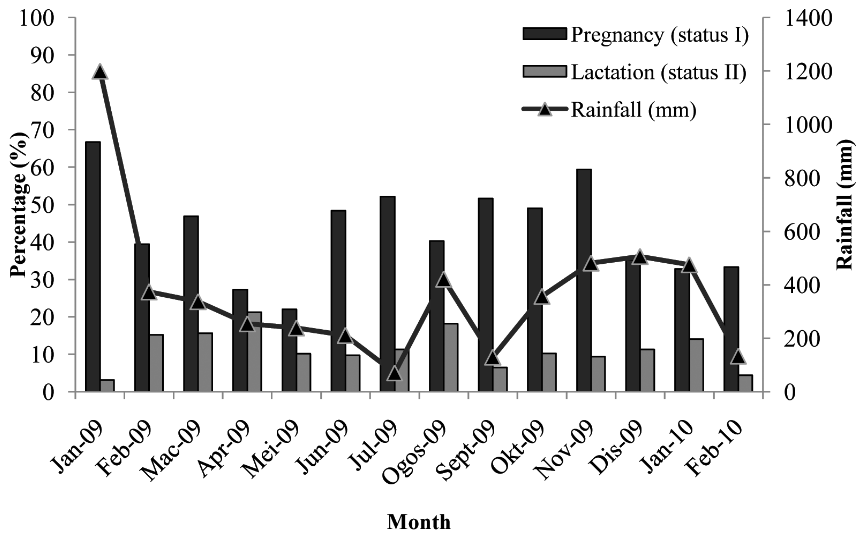

Fig.3: The reproductive status of female *Cynopterus brachyotis* in relation to rainfall pattern from January 2009 to February 2010.

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. brachyotis* is 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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Larval Development of the Bamboo Borer (*Dinoderus minutus* Fabricius) Using Individual Rearing Method

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ABSTRACT

Detailed information on larval development of the powder-post beetle, *Dinoderus minutus,* was investigated using individual rearing method under laboratory conditions at 27±2°C and 75±5% relative humidity. Five classes of head capsules were recorded, indicating five moults from first instar to prepupa. The mean larval duration recorded was 52.8±0.31 days with 8.04±0.12 days for the first instar larva, followed by 9.74±0.20 days, 13.10±0.17 days, 16.20±0.15 days and 5.72±0.13 days, for the second to fifth instar larvae, respectively. The longest instar stage was the fourth instar, with a development time ranging from 14 to 18 days and the shortest was the fifth instar ranging from 4 to 6 days. The highest growth ratio of larva by body weight was 2.70, which was observed between the first and second instars. This indicated that the maximum feeding rate of the larva occurred between these instar stages. The highest growth ratio, with respect to head capsule and larval length, was 1.35 and 1.34 between the fourth and fifth instar.

Keywords: Dinoderus minutus, bamboo borer, powderpost beetle, Bostrychidae, larval development

INTRODUCTION

Bamboo borers of the family Bostrychidae, particularly *Dinoderus minutus,* cause serious damages to felled bamboo culms as well as finished products (Abood, 2008; Garcia & Morrel, 2009; Abood *et al.,* 2010). The beetles bore their way into seasoned bamboo and attack insidiously. If left unchecked, the infested bamboo would be reduced to a relatively intact outer shell with a fully degraded powdery mass within. The adults and larvae cause direct damages by boring and continuously feeding inside the culm. The presence of beetle holes and powdery material coming out from the entrance and exit holes is a manifestation

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of active *D. minutus* infestations (Liese & Kumar, 2003). The presence of entrance and emergent holes and fine powdery frass is typical of powderpost beetle damage characteristics (Abood & Murphy, 2006) and a manifestation of active *D. minutus* infestations (Liese & Kumar, 2003).

Stebbing (1914) describe the larva of *D. minutus* as pale canary-yellow in colour, curved with swollen thoracic segments and prothorax tapering sharply towards the head with body length ranging from 3.00 to 3.75 mm. Ahmed and Zulfiqr (2006) describe mature *D. minutus* larva as grub-like, curved, and range between 2.50±0.21 mm long. Meanwhile, Garcia and Morrel (2009) reported the duration of larval development to range from 40 to 58 days at 25°C on *Bambusa vulgaris.* Plank (1948), however, reported a wider range of larval development times from 21 to 76 days at the same temperature. Ho (1994) reported that *D. minutus* larva takes approximately four weeks to develop into pupa on infested bamboo although the bamboo species used in the observation was not mentioned. Iwata (1984), who investigated on *Lyctusbrunneus,* reported that grouping head capsules or exuvial mandibles of powderpost beetle larvae provide a reliable and useful method for the determination of larval moults for coleoptarous species. This method was also adopted by Kojima *et al.* (1968) and Suzuki (1983) for Japanese Cerambycid and *Lyctusbrunneus*. Nonetheless, there is no available documented information on detailed larval development of *D. minutus*. The studies by Garcia and Morrell (2009) and Ho (1994) provided a brief description on some aspects of the larval development observed in bamboo.

In this study, three different media were tested as rearing material to observe larval development. The media selected were bamboo powder, cassava powder and frass produced from infested bamboo. The latter was selected based on the preliminary observations which indicated that *D. minutus* preferred bamboo frass to freshly ground bamboo powder. Rajor *et al.* (1995), who worked on the chemical characterization of borer dust reported that frass from the bamboo borer on *Dendrocala musstrictus* is a rich source of glucose 1-phosphate.

This particular study was conducted to meet the following objectives: (i) to determine the suitability of individual rearing method for studies on larval development using three different media, and (ii) to obtain detailed information on weight, length, head capsule width and duration of each larval stage using the most suitable medium.

MATERIALS AND METHODS

Insect Supply

Eggs were collected from paired adult beetles for the first instar larvae collection. The collected eggs were placed in Petri dishes lined with black filter paper. Hatchability for the first instar larvae was observed daily. The first instar larvae, weighing less than 0.10 mg, were carefully removed with a fine brush and a single larva was confined into each capsule stuffed with 0.1 g of the medium.

Preparation of the Rearing Medium

Cassava flour, ground bamboo and bamboo frass were used as the rearing media for the study (Fig.1). Freshly dried cassava and bamboo of the species *Gigantochloascortechinii* were ground to powder while bamboo frass was obtained from the infested bamboo culture of *D. minutus*. All the diet used in the study passed through mesh no. 100 (passing particles of less than 150μ diameter). The newly emerged larvae introduced to cassava flour were taken from the eggs produced by the parent beetles cultured in cassava blocks, while the newly emerged larvae introduced to bamboo powder and frass were taken from the eggs produced by the parent beetle cultured on bamboo; 0.10 g of each diet was weighed and placed into gelatine capsules.

Rearing and Inspection of Larva

Each capsule containing rearing medium and a single larva was mounted horizontally on a plastic container (3.5cm in height and 5.0cm in diameter) stuffed with plasticine of 2.0 cm thickness at the bottom. Ten gelatine capsules were placed in each plastic container that was placed in an incubator at 27±2°C and 75±5% relative humidity. 50 larvae were reared for each diet and their development was observed. Larvae were taken out from the capsules on alternate days to inspect for larval exuviae. Each rearing medium was sieved through mesh no. 100 for the third instar onwards. For the early instar larvae, inspection was carefully done under a stereomicroscope. The duration of the larval instars, body lengths, weight and head capsule widths were recorded as soon as exuvia was recorded using a stereomicroscope equipped with NIS-Elements® image analysis software. The growth ratio for *D. minutus* larvae was determined by means of grouping head capsule widths according to Dyar's rule (Dyar, 1890). Different stages of the larvae were also examined under JEOL JSM-6400 scanning electron microscope for further observation.

Statistical Analysis

Larval mortality data were analyzed using a non-linear regression to observe the trend in mortality for different media used in individual rearing. Data obtained from the most successful rearing medium was used

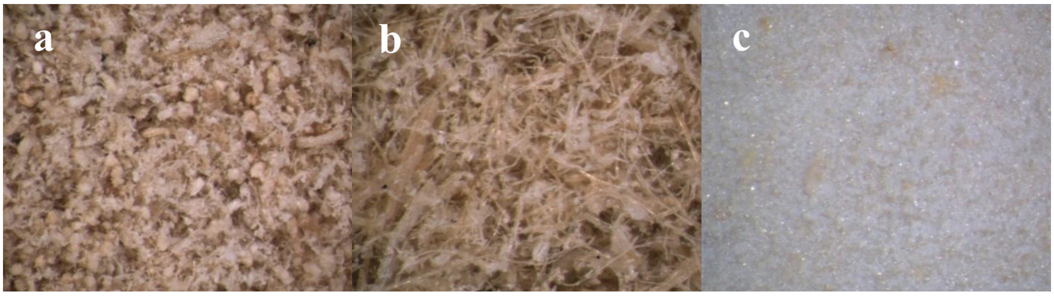


Fig.1: The particles of rearing media (x50); a. Bamboo frass, b. Bamboo powder, and c. Cassava flour

in the analysis on body length and weight, head capsule width and instar duration. One-Way Analysis of Variance (ANOVA) and Duncan Multiple Range Test were used in the analyses.

RESULTS

Mortality of Larva on Rearing Medium

The findings indicated that rearing of larva on bamboo powder resulted with the first mortality on day 2, while complete mortality was observed on day 40. The highest mortality was recorded in the second week of rearing with 30% mortality. Rearing of larva on bamboo frass showed a similar trend in mortality. The highest mortality was also recorded in the second week, with 28% of larva mortality. However, 20% of the larva pupated. Although there was a 10% mortality of larvae on the cassava flour in the first week of rearing, this medium supported the highest survival rate, with 60% successful pupation. Fig.2 shows the trend in the mortality of larva reared on different media.

Table 1 shows the non-linear regression equation of *D. minutus* larval mortality in different rearing media. The results showed curvilinear effect between powder form diet

TABLE 1
The non-linear regression of the larval mortality in different rearing media

Powder state diet	Regression equation	R^2	F value
Bamboo powder	$y=55.53-2.04x+0.01x^2$	0.99	1764.72
Bamboo frass	$y=52.93-1.36x+0.003x^2$	0.98	968.13
Cassava powder	$y=50.91-0.43x-0.002x^2$	0.97	573.98

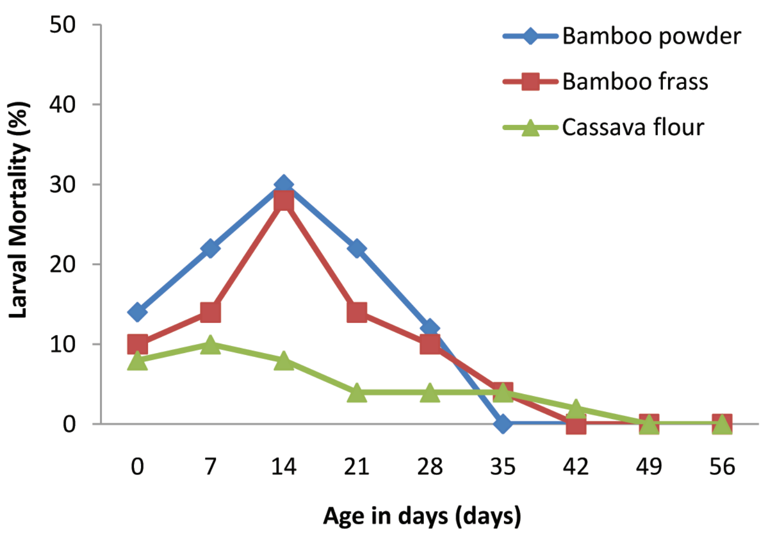


Fig.2: The percentage of larval mortality reared on different media

and the mortality rate of larva throughout the rearing period.

Larval Development

At hatching, young larva inside the chorion bore its way through by a fairly active movement of the terminal abdominal segment. Once the chorion is broken, the larva emerges, posterior end first, and wriggles its way out by contraction of body muscles (Fig.3). The newly hatched larva of *D. minutus* appears creamy white in colour while the head is reddish brown. An observation on the larval development shows morphological changes with succeeding instars (Fig.4 to Fig.6). The maxillary and labial palpi showed prominent changes in length and intensified in colour due to sclerotization. In addition, setae were observed at the posterior abdominal tip and head.

Results from larval development on the most successful rearing medium (cassava flour) showed five classes of head capsule widths representing five moults (Table 2). Table 2 shows the dimension and weight from larval to pupa and the growth ratio obtained using Dyar's Rule. The grouping of the head capsule widths was tested for conformity to Dyar's Rule with the *t*-test method used by Oke and Odebiyi (2008).

The results showed highly significant differences ($p<0.0001$) between succeeding instar stages on larval body length, body weight, head capsule width and duration. The mean head capsule width, body length and body weight for the first instar were 81.45±0.63 µm, 739.26±4.46 µm and 0.06±0.001 mg, respectively (Table 2). The calculated head capsule width for the first instar was 80.74 µm, with 0.87% difference between the observed and the calculated head capsule widths. The ratio increment of the head capsule from the first to the second instar was 1.13. Meanwhile, the duration ranged between 7 to 9 days, with a mean of 8.04 ±0.12 days (Table 3). The ratio of the increment of body weight was the highest from the first to the second instars (2.70).

Fig.3: Eclosion into the first instar larva (X80)

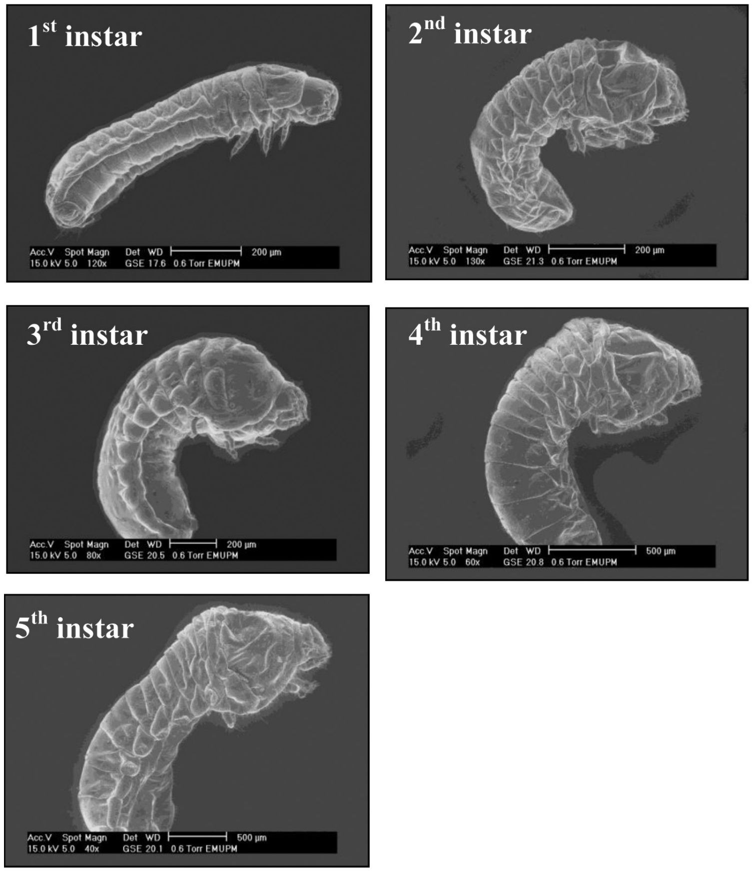
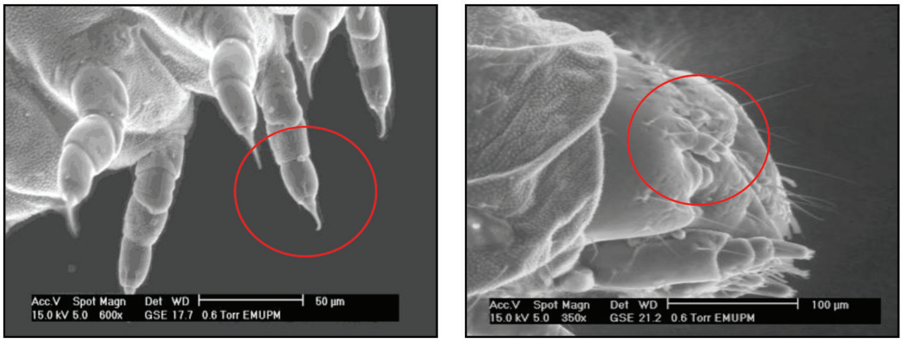


Fig.4: Scanning electron micrograph of the first to fifth instar larva

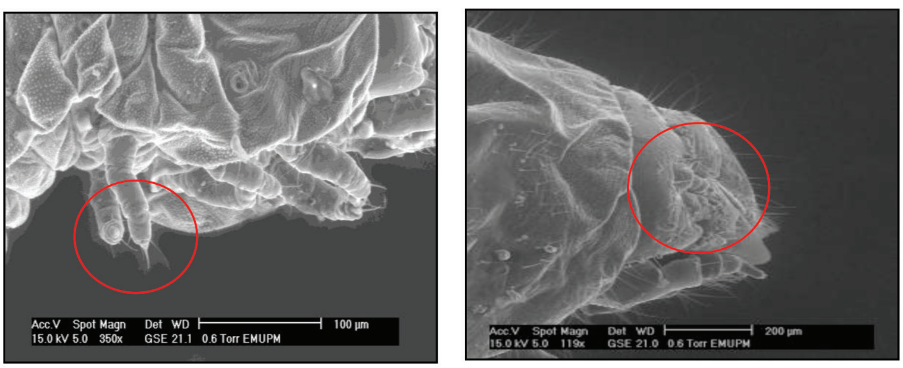
The mean head capsule width, body length and body weight of the second instar were 91.85±0.81, 893.97±5.07 µm and 0.17±0.002 mg, respectively, while the calculated head capsule width was 91.04 µm (Table 2). The difference between the observed and the calculated head capsule widths was 0.88% and the ratio of increment was 1.25. Duration of the second instar ranged between 8 to 12 days, with a mean of 9.74 ± 0.20 days (Table 3). The ratio of the increment of larval body length from the second to third instar was 1.06, which was the lowest ratio compared to the other stages.

The mean head capsule width, body length and body weight of the third instar were 114.74±0.71, 937.50±7.72 µm and 0.27±0.002 mg, respectively, while the calculated head capsule width was 114.14 (Table 2). There was a 0.52% difference between the observed and the calculated head capsule widths. The ratio of increment of the head capsule was 0.77. The duration of the third instar ranged between 12 to 15 days, with a mean of 13.1 ± 0.15 days (Table 3).

The first instar



The third instar



The fifth instar

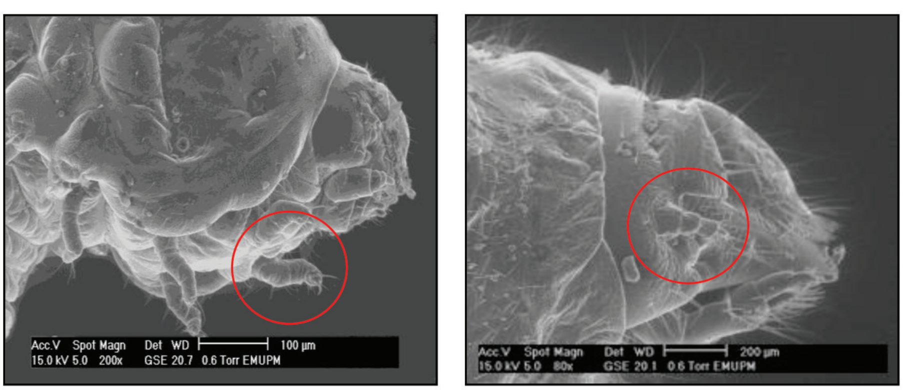


Fig.5: Scanning electron micrograph of changes in leg (left hand side) and antennae (right hand side) in the course of larval development

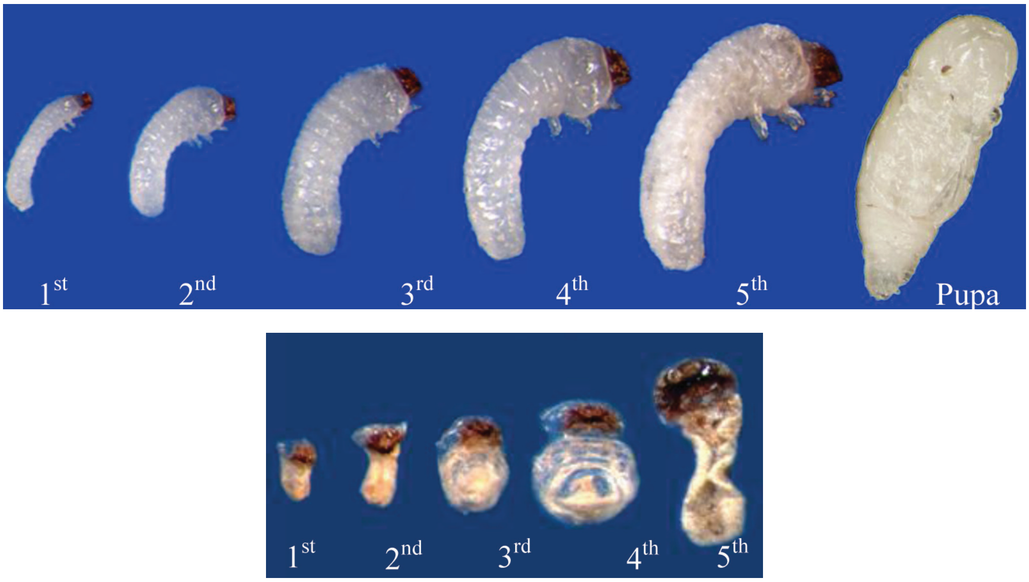


Fig.6: The stereomicrograph of the (a) first instar larva to pupa (X40) and (b) exuviae of larvae (X80)

The mean head capsule width, body length and body weight for the fourth instar were 147.92±1.56, 1224.97±6.96 µm and 0.39±0.002 mg, respectively (Table 2). The difference between the observed and the calculated head capsule widths was 0.3%, and the increment ratio of head capsule was 1.29 (Table 2). The duration of the fourth instar was the longest compared to the other stages, i.e. ranging between 14 to 18 days, with a mean of 16.2 ± 0.15 days (Table 3).

The mean head capsule, body length and body weight of the fifth instar were 199.52±1.45, 1644.53±10.73 µm and 0.61±0.008 mg, respectively, with a head capsule increment ratio of 1.35 (Table 2). There was a 0.08% difference between the observed and calculated head capsule widths. The fifth instar, which was the final instar, took 4 to 7 days with a mean duration of 5.72 days (Table 3) before developing into a pupa. The duration of this instar was the shortest of all the stages.

External Morphology

The head of *D. minutus* larva is the most prominent in the first instar and it gradually recedes beneath the enlarged prothoracic segment. The overall body form was fairly linear in the first instar and attained a more defined curvature in the proceeding instars (Fig.4). The maxillae are located below the mandibles. A distinct claw is present at the terminal leg and is clothed with fine papillae in the later stages. While the antenna in the first instar shows the antacoria and two terminal segments, in the third and fifth instars, four antennal segments are present (Fig.5). The abdomen of *D. minutus* larva consists of ten segments, with spiracles present on the lateral side of urotergites.

TABLE 2
The morphometrics of larva to pupa and growth ratio

Stage		Body length (µm)		Body weight (mg)		Head capsule width (µm)		
		Mean±SE	Ratio	Mean±SE	Ratio	Mean±SE	Ratio	Calculated
Instar	1st	739.26±4.46a (649.32-802.57)	-	0.06±0.001a (0.059-0.071)	-	81.45±0.63a (73.37-89.57)	-	80.74
	2nd	887.55±5.07b (820.78-949.21)	1.20	0.17±0.002b (0.135-0.198)	2.70	91.85±0.81b (80.01-98.77)	1.13	91.04
	3rd	937.49±7.72c (801.74-1067.00)	1.06	0.27±0.002c 0.246-0.305)	1.59	114.74±0.71c (104.55-123.80)	1.25	114.14
	4th	1224.97±6.96d (1104.55-1299.10)	1.31	0.39±0.002d (0.362-0.413)	1.41	147.92±1.56d (130.01-167.59)	1.29	147.48
	5th	1644.53±10.73e (1446.87-1778.46)	1.34	0.61±0.008e (0.504-0.716)	1.58	199.52±1.45e (175.91-221.63)	1.35	199.37

Means followed by the same letter in the same column are not significantly different ($p \geq 0.05$, Duncan Multiple Range Test). N=50

TABLE 3
The developmental periods from the first instar larva to pupa on cassava flour

Stages		Period (days)		
		Mean±SE	Min	Max
Instar	1^{st}	8.04 ± 0.12d	7	9
	2^{nd}	9.74 ± 0.20c	8	12
	3^{rd}	13.10 ±0.15b	12	15
	4^{th}	16.20 ±0.15a	14	18
	5^{th}	5.72 ± 0.13e	4	7
Overall larval duration		52.80±0.31	49	58

Means followed by the same letter in the same column are not significantly different ($p \geq 0.05$, Duncan Multiple Range Test). N=50, ns=non-significant

DISCUSSION

Cassava flour provides a successful medium for individual rearing of *D. minutus* larva and facilitates observations on their development. Higher mortality on bamboo powder and bamboo frass is attributed to significantly lower starch contents compared to cassava flour. Ground bamboo powder has larger more particulate matter (Fig.1) and is believed to adversely affect the delicate larval surface morphology. The results clearly show five classes of head capsules, thus indicating five moults with the total larval development duration of 52.80±0.31 days. There is an accompanying highly significant difference (p<0.001) in the larval body length and weight.

This result differs from the findings by Garcia and Morrel (2009), who reported that *D. minutus* larvae underwent four stadia during its development on the bamboo blocks of *Bambusa vulgaris* at 30°C. It should be noted that in this particular study, all the observations were made using individual rearing method using a nutrient rich medium. Thus, the results are based on the head capsule widths, presence of larval exuviae, larval body increments and growth ratio. These parameters, however, were not reported by Garcia and Morrel (2009). It was observed that the fourth instar larva was capable of developing into prepupa when no food was offered. This resulted in smaller sized adult beetles as compared to those that underwent five instar stages. The development of powderpost larva under individual rearing method has been adopted by Iwata and Nishimoto (1984) on *Lyctusbrunneus*. In the study, *L. brunneus* underwent four to six instars in the course of development. Iwata and Nishimoto (1984) reported that the difference in the instar number is caused by hereditary or endocrinological factors. Esperk *et al.* (2007) reported that food quality and quantity are the most common factors affecting the number of instar in various insects.

The observations on the larval morphology described in this study showed similar characteristics to those reported by Stebbing (1914). In this study, the growth ratio for head capsules increased with succeeding instars. The result shows that the first instar larva exhibited high values in the growth ratio of body length and weight. The growth ratio in body length was significantly (p<0.05) higher between the first and second instar compared to that between the second and third instar. In term of body weight, the highest growth ratio recorded was between the first and second instar.

Dyar (1890) reported that the width of the head capsule increases in a regular geometrical progression in successive instars by a ratio of 1.4. This development has been termed as the Dyar's law, and the recorded ratio of 1.26 for *D. minutus* showed a considerable variation from this value. A study by Oke and Odebiyi (2008) on the flea beetle, *Podagricasjostedti* (Coleoptera) resulted in three instar stages for larva and recorded a ratio of 1.54 for the width of head capsule.

CONCLUSION

The overall larval development period was 52.8±0.75 days, with the longest instar stage ranging from 14 to 18 days for the fourth instar larvae and the shortest instar stage was the fifth instar, ranging from four to six days. Five classes of head capsules were identified, and these indicated five moults from the first instar to the pupa stage. The highest growth ratio (2.70) in terms of body weight, indicating the highest feeding rate, was between the first and second instar. Meanwhile, the highest growth ratio (1.34) in terms of body length and head capsule width (1.35) was found to occur between the fourth and fifth instars.

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Incidence of Fern Contamination in Nodal Segment Cultures of *Shorea parvifolia* Dyer

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ABSTRACT

The greatest drawback in large scale micropropagation of tropical woody forest species is high contamination of cultures. In developing a sterilization protocol for micropropagation of *Shorea parvifolia* Dyer utilizing nodal segments excised from nursery-grown seedlings, it was found that washing 20% (v/v) with Clorox solution for 18 minutes was the best. After six weeks of culture in WPM media supplemented with 10^{-5} M BAP (apart from fungal and bacterial contamination), the nodal segments developed hair-like structures which were amenable to subculture. Upon subculture, green leafy structures developed from the mass of hairy structure after six weeks. These later developed into ferns which are normally found as epiphytes on older forest trees, known as *Asplenium nidus*.

Keywords: Shorea parvifolia, sterilization, contamination, *Asplenium nidus*

INTRODUCTION

Shorea parvifolia Dyer, or commonly known as *Meranti Sarang Punai* in Malaysia is an important timber species under the red Meranti group. It is one of the potential species for plantation purposes due to its multipurpose uses as interior joinery, domestic and light traffic flooring, utility furniture, domestic woodware, manufacture of plywood, railings ceiling framing, and lorry body work. It can grow in different sites and attain high percentage of survival. Propagation of this species is normally

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through seedlings raised from seeds and saplings. However, problems faced in propagating tropical species, including *S. parvifolia*, are related to seed production and seed viability. Its unpredictable flowering and seeding years, including obtaining large quantity of seeds, are becoming an ever increasing problem for large scale plantation programme. Moreover, it produces seeds which are recalcitrant in nature and thus possesses storage problem that will further hinder regular production of sufficient and quality planting materials. Nonetheless, the propagation of this species by stem cuttings is possible to a certain extent from juvenile plants (Aminah, 1991).

Propagation through tissue culture provides an alternative method of fulfilling this requirement. It is envisaged that development of successful micropropagation technique will be a boon to large-scale tropical plantation establishment. Micropropagation of tropical woody species with nodal segments as the initial explants have been reported in *Shorea stenoptera* (Sakai & Yamamoto, 1992), *Dryabalanops lanceolata* (Ishii *et al*., 1992; Sakai & Yamamto, 1992; Yamamoto *et al*., 1993), *S. platyclados*, *S. selanica*, *S. pauciflora*, and *S. laevis* (Yamamoto *et al*., 1993), *Dyera costulata* (Aziah & Darus, 1995) and *Aquilaria malaccensis* (Aziah *et al*., 2000). There are numerous culture methods available for timber tree species and some of the methods are successful in culturing certain species of tree (Pijut *et al*., 2012). Plant tissue culture has been exploited for numerous applications, which include both research and commercial applications. Even though it is possible to mass propagate plants by micropropagation, the greatest problem in this technique is contamination (Altan *et al*., 2010; Cassells, 2012). It is exceptionally very difficult to maintain and grow cultures under *in vitro* conditions that are free from any biological contaminants. The biological contaminants may or may not be pathogens but will influence the growth of the tissue by producing metabolites. This is because the growth of these biological contaminations will compete with the growth of the culture (Cassells, 2012). In most cases, contaminants in plant tissue cultures have been identified to vary in a wide range of microorganisms, including filamentous fungi, yeasts, bacteria, viruses, viroids, mites and even thrips. They may be introduced with the explant, during manipulation in the laboratory, via micro-arthropod vectors (Leifert & Cassells, 2001) or by endophytic bacteria (Pereira *et al*., 2003). On the other hand, fungus contaminants may arrive from the explant or airborne, or enter a culture (Babaoglu *et al*., 2001). Frequent contaminations by bacteria and fungus have lead researchers to incorporate the uses of antibiotics and fungicides to combat the problems (George, 1993; Cassells, 2012). Nevertheless, to date, there has been no report on contamination by epiphytic fern or its allied species on micropropagation work on plants.

Development of suitable sterilisation protocol is needed to eradicate contaminants on the outer surfaces of the explants. However, tissue culturists must address issues that are associated with random endophytic contamination of stock plant tissues by environmental microorganisms (Cassells, 2012). There is a sceptic amongst scientists on the existence of sterile cultures and whether plant cultures can be microorganism free (Leifert, 1990). Thus, this study was undertaken to identify all possible contaminants and to examine the effects of different sterilants and their combinations in the micropropagation of *S. parvifolia*. In addition, this paper records and discusses the incidence of an epiphytic contamination by fern, *Asplenium nidus* in *S. parvifolia*.

MATERIALS AND METHODS

Plant Sources

The explants used for the sterilization protocols were shoot tips and nodal segments. They were obtained from shoots of about 8-9 cm length that were excised from three-year-old *S. parvifolia* seedlings raised in the FRIM's nursery by the Tree Improvement Unit and Seed Technology unit of Forest Research Institute (FRIM) for the purpose of progeny testing. About 100 seedlings were made available for micropropagation studies. They were raised from seeds collected from plus trees of Ulu Tranum Forest Reserve, Pahang. Thus, it was ensured that the fruit/seeds were carefully collected manually by skill climbers and were kept in plastic bags.

These seeds were initially germinated in 2.5cm x 2.5cm polybags containing a mixture of 1:3 (v/v) proportions of sand and soil. They were watered twice daily and maintained in the nursery under 50% shade by covering with a netting for four weeks until the seedlings developed two-leaf stage. They were then transferred into 9cm diameter by 17cm height polybags containing one litre potting medium that was made up of equal volumes of a mixture of forest soil and paddy husk. The seedlings were also watered twice daily and they were fertilised at monthly intervals with commercial fertilizer NPK (12:12:117). Insecticides and fungicides were also applied whenever necessary. The seedlings/saplings were kept initially under 33% light, which was gradually increased to 50% and finally to 70% light.

Development of Sterilization Protocol

The sterilization protocols utilised in this study are as described and summarized in Table 1. In each protocol, the explants were placed in a 500ml Erlenmeyer flask and the volume of each solution was 250ml. Several sterilization methods were adopted and sterilants used include mercuric chloride ($HgCl_2$), benlate (with and without streptomycin), and Clorox (with and without pH) that was adjusted (pH6-pH11). After being subjected to the sterilization procedure, these shoots were further apportioned into 1-1.5 cm stem segments, which included the nodal segments and shoot tips and were utilised as the initial explants. The explants were then cultured in culture tubes (125mm X 25mm) containing 20ml of Woody Plant Medium (WPM) (McCown & Lloyd, 1981) that was supplemented with concentrations of 10^{-4} M to 10^{-7} BAP. A total of 40 explants were used for each treatment.

TABLE 1
The sterilisation protocols developed for nodal segment explants excised from nursery raised seedlings of *S. parvifolia.* Sterilants used include mercuric chloride ($HgCl_2$), benlate, with or without streptomycin, Clorox with pH adjusted (pH6-pH11) and also clorox with pH unadjusted.

Types of Sterilant	Sterilisation Procedure
Mercuric chloride ($HgCl_2$)	Three methods utilised are as follow: i) Method (a): The 8-9 cm shoot-portions were immersed in 70% ethanol for 30 seconds. This was then followed by washing in a mixture of 0.1% $HgCl_2$ mixed with Tween 20 for 10 minutes. The shoot segments were then rinsed in several rinses of sterile distilled water. ii) Method (b) is similar to method (a) except that instead of rinsing in a mixture of 0.1% $HgCl_2$ mixed with Tween 20 for 10 mins, the duration was 15 minutes. iii) Method (c) is similar to Method (b) except that after washing in mixture of 0.1% $HgCl_2$ and Tween 20 for 15 minutes, the shoots were segmented into 1-1.5cm portions and washed in 10% Clorox prior to the last step of rinsing with sterile distilled water.
Benlate	Two methods utilised are as follow: i) Method (d), 8-9 cm shoot segments were immersed in 0.05% Benlate with 200mg/l streptomycin for 2 days. This was then followed by washing in 10% Clorox and subsequently with several rinses of sterile distilled water ii) Method (e) is similar to method (d) but without streptomycin. This was then followed by washing in 10% Clorox and subsequently with several rinses of sterile distilled water.
Clorox with pH adjusted	Method (f), 8-9 cm shoot segments were immersed in 20% Clorox pH adjusted to i) pH 6, ii) pH 7, iii) pH 8, iv) pH 11 for 15 minutes. This was then followed by several rinses of sterile distilled water.
Clorox	Method (g), 8-9 cm shoot segments were immersed in sterile distilled water mixed with Tween 20 for 5 minutes. The Tween 20 solution was then poured off and 20% Clorox was poured into the flask until the solution spills over and was left standing for 18 minutes. Half of the 20% Clorox was poured off and the flask was then hand shaken for 2 minutes. Finally the shoots were rinsed with sterile distilled water 8 to 10 times.

The effects of sterilization protocols on these explants were observed after four weeks in the culture. The contamination percentage for each sterilization method was enumerated by calculating the number of tubes contaminated divided by the total number of tube for the particular sterilization protocol. The data obtained was analyzed using a complete randomised design that was run by the Statistical Analysis System (SAS). Further mean separation tests were evaluated using the Duncan's Multiple Range Test. Means differing at a probability of $\leq$ 0.05% were considered to be significantly different.

Identification of Microbial Contaminants

Prior to identification, the fungi were isolated onto Potato Dextrose Agar (PDA) (DIFCO No. 0013-01-4), which was prepared by suspending 39g in 1 litre distilled or ionised water and boiled to dissolve completely. The

PDA was sterilised by autoclaving at 105 kPa for 15 min. After cooling to approximately 40°C, the molten medium was poured into 9cm Petri dishes in the laminar flow cabinet. The identification of fungi was carried out using the morphological characteristics by the FRIM forest pathologist.

For the identification of the bacteria, samples were first cultured from the explants in Lennox broth (LB) that was prepared by dissolving 20g in 1 litre distilled or de-ionised water and 15 ml volumes dispensed into 25 ml McCartney bottles prior to autoclaving at 105 kPa for 15 min. A loopful of the broth was then streaked onto a 9cm Petri dish containing Nutrient agar (NA) (Merck) and incubated overnight at 30±1°C. The NA media was prepared by dissolving 20g in 1 litre distilled or de-ionised water and sterilised by autoclaving at 105 kPa for 15 min. After cooling to approximately 40°C, the molten medium was poured into 9cm Petri dishes in the laminar flow cabinet at 17 ml per Petri dish.

Single bacterial colonies were isolated and streaked for a second time onto NA to further purify the culture with incubation overnight at 30±1°C. The bacterial cultures were stored at 4°C before despatching to the Malaysian Agriculture Research and Development Institute (MARDI) for identification using the HP5898A Microbial Identification System (MIS). MIS utilises qualitative and quantitative analyses of the fatty acid composition of the organisms (MIS Operating Manual, 1984).

RESULTS AND DISCUSSION

The effects of sterilisation protocols on the nodal segments described above were observed after 4 weeks in culture. The contamination percentage was recorded and tabulated in Table 2. The most effective results were obtained with method (g) using Clorox that recorded only 38.7% contamination. The main contaminants found after four weeks of culture were fungus and bacteria. The fungal contamination observed included feathery white contaminants that were identified as *Collectotrycum* spp. This particular fungus is known to cause damping-off and leaf disease in *S. parvifolia* and infections were observed at the seed, seedling and sapling stages (Elouard & Zakaria, 2000). The bacterial contaminants, which were slimy white or red colonies, were identified using the MIDI Microbial Identification System (MIS). They were identified as *Kleibsella planticola*, *Enterobacter agglomerans*, *Erwin auredora, Erwina herbicola*, *Serratia odorifera*, *Serratia marcesens*, *Serratia proteomaculans*, *Morganella moragnii*, and *Kluyera ascorbata.*

Apart from contamination due to microbial contaminants, the nodal segments derived from the nursery-grown seedlings developed hair-like structures, which were amenable to subculture (Fig.1). After six weeks in the culture, green leafy structures developed from the mass of hairy structure (Fig.2). These later developed into ferns that were normally found as epiphytes on older trees, known as *A. nidus*. The ferns could be multiplied further and spontaneous

TABLE 2
The effects of different sterilization protocols on the nodal and shoot tip explants excised from nursery raised seedlings of *S. parvifolia.* Percentage contamination was observed after 4 weeks in the WPM medium

Types of Sterilent	Code	Sterilisation procedure	Contamination* (%)
$HgCl_2$	a	• 70% ethanol 30 seconds • 0.1% $HgCl_2$+ Tween 20, 10 minutes • several rinses of sterile distilled water	90.7[a]
	b	• 70% ethanol 30 seconds • 0.1% $HgCl_2$+ Tween 20, 15 minutes • several rinses of sterile distilled water	92.0[ab]
	c	• 70% ethanol 30 seconds • 0.1% $HgCl_2$+ Tween 20, 15 minutes • segmented shoots washed in 10% Clorox • several rinses of sterile distilled water	88.0[ab]
Benlate	d	• 0.05% Benlate (Immersed for 2 days) • 10% Clorox • several rinses of sterile distilled water	65.3[c]
	e	• 0.05% Benlate +200mg/l streptomycin (Immersed for 2 days) • 10% Clorox • several rinses of sterile distilled water	70.7[c]
Clorox (pH adjusted)	f i	• 20% Clorox adjusted to pH 6 for 15 minutes • several rinses of sterile distilled water	98.7[ab]
	ii	• 20% Clorox adjusted to pH 7 for 15 minutes • several rinses of sterile distilled water	100 [a]
	iii	• 20% Clorox adjusted to pH 8 for 15 minutes • several rinses of sterile distilled water	98.7[ab]
	iv	• 20% Clorox adjusted to pH 11 for 15 minutes • several rinses of sterile distilled water	100 [a]
Clorox	g	• sterile distilled water with Tween 20 for 5 minutes • 20% Clorox poured into flask until solution spills over and left standing for 18 minutes • pour out half of solution and shake flask for 2 minutes • rinse with sterile distilled water 8 to 10 times	38.7[d]

*Means with the same letters are not significantly different at a= 0.05 according to Duncan's Multiple Range Test

rooting occurred. However, none of these ferns survived upon acclimatization. On the contrary, Mazumder *et al*. (2011) reported that a medicinal fern *Drynaria quercifolia* can be successfully micropropagated only when it was cultured on MS-Z4 medium (Full MS+1mg/L IAA+5mg/L Kinetin+20%CM+300mg/L CH). This indicates the difficulty of constructing a suitable medium for the propagation of fern which is nevertheless a contamination in the present experiment despite the use of the WPM medium.

Fig.1: Development of hairy-like structures (possibly rhizoids) on the nodal segment explants excised from nursery raised seedlings (the diameter of the vial is 25mm)

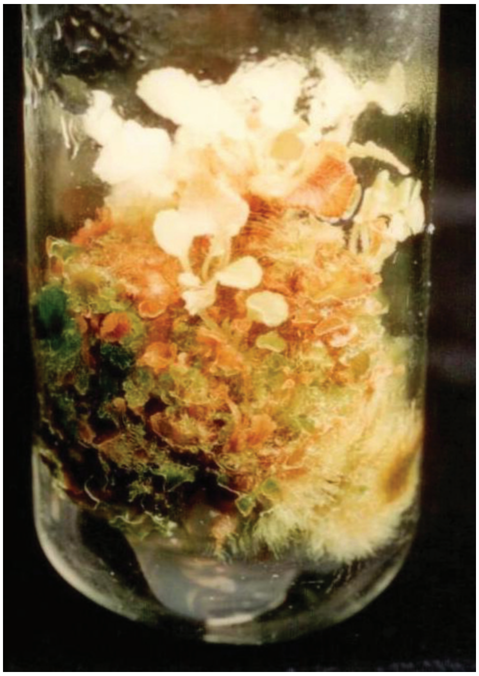

Fig.2: The development of leafy structures, young sporophytes in the mass of hairy-like structures which later developed into ferns (the diameter of the vial is 25mm)

Leifert *et al.* (1991) suggested that plant cultures should not be described as aseptic, sterile or free of contaminants, but instead as “index negative” or “free of detectable contaminants”. The term index negative cultures described the state of cultures that have undergone assessment(s) by one of more microbial indexing method. The term “free of detectable contaminants” should be used for situations where cultures were visibly assessed. In most cases, the microbial contaminants were mycelia fungi, yeasts or bacteria (Leifert, 1990). Contamination may also arise in the cultures that were contaminant-free for several subcultures but became contaminated with bacteria after a long period in the culture due to occurrences of endogenous, endophtytic or internal bacteria that became pathogenic after a prolonged period of latency in the plants (Bastiaen, 1983). Meanwhile, the existence of bacteria in *Pinussyvestris* L. bud was detected by 16S rRNA *in situ* hybridisation and it was found that the bacteria inhabited the buds of every tree examined, primarily colonizing the cells of scale primordium and resin ducts (Pirttila *et al*., 2000). Sudden outbreaks of the bacterial contamination resulting in the loss of whole crops and high contamination rates in commercial concerns make production of some plants uneconomical. Most yeasts, mycelia fungi and bacteria isolated from the plant tissue cultures are not known to be pathogenic to plants in the field (Leifert *et al*., 1994). Laboratory environments, which include the indoor air, have been known to contribute to contamination (Odutayo *et al*., 2007).

However, reports on the bacteria associated with Dipterocarpaceae are not available. In the study conducted by Ramesh *et al*. (2012), no bacterial contamination was observed after sterilization of the explants. However, members of some genus of the bacteria identified have been reported to be associated with some tropical plants. *K. planticola* is a common soil bacteria and its genetically engineered strain has been utilised to assess the potential effects on soil biota and plant growth (Holmes *et al*., 1999). Although *K. planticola* has not been identified as a pathogen of any woody tropical species, its relative *Klebsiella* spp. has been associated with the bark necrosis of *Hevea brasiliensis* (Chee, 1976) and isolated from wilted plant of tomatoes (Williams & Liu, 1976). Similarly, *E. agglomerans* has not been reported to be a pathogen in woody species. However*, E. aerogense* has been associated with bud rot in *Cocos nucifera* (Williams & Liu, 1976), found on the bark of brown bast tree of *H. brasiliensis* (Chee, 1976), and associated with the root rot of *Mangifera indica* (Williams & Liu, 1976). Another member of the genus, *E. cloacae,* has been associated with the trunk canker of *H. brasiliensis* (Anon, 1967) and stem canker in *Lansium domesticum* (Williams & Liu, 1976). *Enterobacter* spp. has also been reported to be associated with stem canker (Williams & Liu, 1976). Khan and Doty (2009) identified the strains belonging to the genus *Enterobacter* as one of the endophtyic bacteria associated with sweet potato plants. Members of the bacteria genera *Erwina* have been known to cause diseases in the *Citrus* genera. *E. citrimaculans* (Doidge) Magrou has been isolated from the branches of *C. mitis* (Blanco)*, E. herbicola* (Lohnis) Dye from leaves of *C. aurantifolia* and *E. lathyri* (Manns and Taubenhaus), Magrau from the scaly bark of *C. grandis* (Williams & Liu, 1976). Meanwhile, *Serrattia marcesens* has been isolated from the brown bast tree of *H. brasiliensis*, (Johnston, 1960), whereas S. *odorifera* has not been reported to be a pathogen of any woody species. *Morganella morganii* and *Kluyvera ascorbata* have not been reported to be isolated from any of the tropical agricultural crop.

One interesting observation in this study is the incidence of fern contamination. The fern *A. nidus,* an epiphyte, was found to have contaminated the nodal segment explants from the nursery-raised seedlings. The ferns only live on the surface of the barks and gather all its water from its roots, which usually form a mat and gradually collect humus. It absorbs the moisture during rain and from dew at nights. The trees with these epiphytes are normally unharmed, except that a large mass of them may have a smouldering effect or breaking a branch due to its excessive weight. Food supply is restricted, except for those that have special humus gathering capabilities. The amount of food needed by ferns is surprisingly small and it can be obtained from the decaying bark, fallen leaves, dust, and debris, which the rain may wash down from higher parts of the tree (Holttum, 1954). *A. nidus* is also known as birds nest fern that is commonly found both in lowlands and the mountains; it is a large epiphyte and found throughout the tropics of the Old World. It is frequently found on roadside trees, as well as in plantations of tree crops and on jungle trees. Long narrow sori are produced along the veins of the upper parts of the fronds and they reach from near the midrib to halfway or more towards the edge. These ferns are found aplenty on trees in the surrounding areas of FRIM's open nursery. The spores could have flown off the fronds of the ferns and landed onto the seedlings of *S. parvifolia* planted in polybags which were left in the open. At the point of explant excision, the spores could have been embedded onto the nodal segments and developed further in the media as conditions are the most suitable for its development.

The hair-like structures formed on the *S. parvifolia* nodal segment, which later developed into leafy structure, is the prothallus of gametophyte stage of the fern. They were amenable to subculture and being confirmed as fern, identified as *A.nidus* by a botanist in FRIM. However, these ferns did not survive upon acclimatization. On the other hand, Khan *et al*. (2008) successfully developed micropropagation techniques for *A. nidus*, whereby an addition of sodium dihydrogen sulphate resulted in differentiation to the sporophytic stage.

CONCLUSION

Loss of cultures caused by a contamination of microbes, which includes fungus, bacteria and yeast, is a major hindrance in the *in vitro* establishment of *S. parvifolia* and other tropical forest species cultures. However, this study has shown that epiphytic ferns such as

A. nidus is a new source of contamination to *in vitro* cultures.

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Effect of Acetylation on the Physical and Static Bending Properties of Cultivated *Rotan Manau* (*Calamus manan*) Grown in Peninsular Malaysia

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ABSTRACT

The physical and static bending properties of cultivated 'rotan manau' (*Calamus manan*) reacted with acetic anhydride at 110 °C for the time intervals of 0.25 to 30 hours were investigated. The study aimed to investigate the effects of various reaction times on the physical and static bending properties. Rattans aged 10 and 13 years were obtained from local rubber tree plantations. This study found that almost all the physical properties of acetylated rattan were not significantly different by age (except specific gravity changes) and reaction periods (except weight gain and OH substitution). The static bending properties varied by rattan age, which the modulus of rupture (MoR), modulus of elasticity (MoE) and maximum load (ML), was not significantly different by reaction period for both ages, except for the MoR of the older acetylated rattan. The acetylation of rattan, performed at 110°C for prolong reaction period, did not impair the static bending properties.

Keywords: Acetylation, cultivated rattan, physical properties, static bending

INTRODUCTION

In addition to natural beauty, rattans are renowned as a material with high flexibility. This property makes rattan easily moulded into a wide range of product applications such as furniture, temporary suspension bridges, crutches, and sport equipment. Recently, rattan has been used as an alternative for timber in new applications such as handles for hammer and hoe, mainly because of the increasing price of timber. These types of product can be classified as semi-structural or structural and require a certain mix of strength properties. Acetylation process

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improves the dimensional stability and decay resistance of wood (Rowell, 2006; Hill, 2006); however, there was concern over the influences of acetylation on the strength properties of wood due to its by-product of acetic acid, which resulted either in the reduction of fibre and lignocellulose contents or a possibility of hydro-thermal effect (Bongers & Beckers, 2003; Jorrison *et al.,* 2005).

The performance of acetylated wood in terms of mechanical properties differs by species, reaction period, and mode of test. The tensile strengths of acetylated Scots pine (*Pinus sylvestris*) and lime (*Tilia vulgaris*) were not significantly different compared to the untreated specimens (Rowell & Banks, 1987). Acetylated beech wood gave a slight increase in modulus of rupture (MoR) and a small decrease in modulus of elasticity (MoE) (Militz, 1991). The MoR and MoE of acetylated pine (*Pinus sylvestris*) reduced by 6% but increased in acetylated spruce (*Picea abies*) by about 7% (Larsson & Simonson, 1994). Acetylated pine (*Pinus sylvestris*) reacted for 1 hour had a higher tensile modulus as compared to the air dried specimens; and even after 4 hours of reaction gave tensile modulus higher than the air dried specimen (Ramsden *et al.,* 1997). The MoE of acetylated radiata pine (*Pinus radiata*) in structural sizes was not significantly different but the MoR was slightly lower than the untreated specimen, although these comparisons were difficult due to high variation (Jorrisen *et al.,* 2005). In term of reaction system, the MoR of acetylated Sitka spruce (*Picea sitchensis*) increased with the increasing WPG, but it was slightly lower in the xylene system compared to the pyridine system and uncatalysed system. The MoE was not significantly different with the reaction systems (Minato *et al.,* 2003). The MoR and MoE in finger jointed acetylated beech (*Fagus sylvatica*) decreased by 141% and 63% as compared to the untreated specimen (Papadopoulos, 2008). It has been hypothesised that the variation of the mechanical properties in acetylated wood is probably caused by either the reduction of moisture content (i.e. lower EMC values), or as a result of the lowering cross sectional area or as a result of cell wall degradation that is caused by prolonged reaction times (Rowell, 1983; Hill, 2006). In contrast to wood, the acetylation of rattan has not been investigated. The acetylation of rubber wood was conducted by Karim *et al.* (2006), but the study was limited to reaction profile and dimensional stability.

This study aimed to investigate the static bending properties of rattan reacting with acetic anhydride and its relation to physical properties.

MATERIALS AND METHODS

Source of Materials

Calamus manan aged 10 and 13 years were studied. The rattans were obtained from small holders of rubber tree plantations at Felda Mempaga in Pahang (about 3^{o} 31' N and 101^{o} 55' E, East Peninsula Malaysia) and Baranang, Selangor (about 2^{0} 56' N 101^{o} 52' E, West Peninsula Malaysia), respectively. The age of the rattan was estimated based on the records of the plantation establishment obtained from the farmers. The two sites share the same climatic conditions such as the characteristic features of the Malaysian climate are uniform temperature, with high humidity and copious rainfall all year round. The type of soil is also similar, as indicated by the establishment of the rubber wood plantations at both locations.

Determination of the Chemical Composition

One whole stem of each rattan age was used for investigating the chemical composition. They were divided into five different portions of the total stem length, namely; basal, upper basal, middle, upper middle and top. Transversely, the middle internode of each portion was divided into three different sections, namely; periphery, intermediate and centre. The rattan particles were oven dried at 60°C for 24 hours and ground with a hammer mill. The rattan flour was equilibrated to 15% moisture content, and passed through sieves to retain the fraction of 0.4 mm to 0.1 mm. The methods used to determine the holocellulose, α-cellulose and lignin contents were in accordance to Wise *et al.* (1946), Cross-Bevan (Tappi T 9m-54; Anon, 1954) and Klason lignin (Tappi T 222 om-83; Anon, 1983), respectively. Six replicates of each chemical element were analysed for each rattan age.

Preparation of the Specimen for Acetylation

Stem from the middle and upper middle portions of both ages, having diameter more than 35 mm and classified as weak rattan (MoR below than 45 MPa), were cut into the size of 5 X 10 X 100 mm^3 (r x t x l). All the specimens were marked, soxhlet extracted with toluene/methanol/acetone mixture (4:1:1) for eight hours and oven dried at 103°C for 24 hours. The specimens were transferred into desiccators and allowed to cool at ambient temperature over silica gel, weighed to 0.1 mg and the volume measured using a digital bed micrometer (Mitotoyo: Kawasaki, Japan).

Acetylation Reaction

Rattan strips were vacuum-impregnated in acetic anhydride at 0.7 kPa for one hour and were kept submerged overnight before they were transferred into acetic anhydride at 110ºC. The reaction was continued for various time intervals (0.25, 0.5, 1, 4, 10, 15, 24 and 30 hours) to give a range of weight percentage gains. The blocks for the longest reaction time were inserted at the start while other specimens were subsequently added to give shorter reaction times. At the end of the reaction period, the reaction was quenched in ice until the liquid temperature reached 20°C. The residue was drained-off and replaced with acetone and cooled in ice for one hour, shaken a few times, discharged, and refilled with fresh acetone. The procedures were repeated twice. The acetylated rattan was finally Soxhlet extracted with toluene/methanol/acetone mixture (4:1:1) for eight hours and oven dried at 103°C for 24 hours. This procedure was sufficient enough to remove all the un-reacted acetic anhydride and by-product of acetic acid (Hill & Jones, 1999). Dry specimens were cooled, weighed and measured as above. Seven replicates for each age and reaction period were used in this study.

Determination the Physical Properties

The specific gravity prior and following modification were measured in according to ASTM D 2395 (Anon 1977). The WPG and bulking coefficient of acetylated rattan were calculated using the following formula:

Weight gain (%) = $[(Wm – Wum)]\times 100$ [1]

Bulking coefficient (%) = $[(Vm – Vum)Vum] \times 100$ [2]

Alternatively, the void volume changes due to acetylation were calculated as adapted from the formula by Bowyer *et al.* (2003).

Void volume (%) = $[(1 – (SGod/SGcw)] \times 100$ [3]

Void volume changes (%) = $[(VMm – VMum)/VMum)] \times 100$ [4]

Where,
Wm = mass of modified rattan.
Wum = mass of unmodified rattan.
Vm = volume of modified rattan.
Vum = volume of unmodified rattan.
SGod = specific gravity of modified or unmodified rattan.
VMm = void volume of modified rattan.
VMum= void volume of unmodified rattan.
SGcw = specific gravity of dry cell wall rattan, 0.655 (Ashaari, 1995).

Determination the Hydroxyl Group

The OH substitution was calculated using the following formula (Hill & Jones, 1999; Hill *et al.,* 2006):

OH groups substitution (mmol g^{-1}) = $[(Wm – Wum)/Wum](MW-1)] \times 100$ [5]

Theoretical molar volumes (cm^3/mole) = $[(Vm – Vu)/M]$ [6]

Where,
MW = molecular weight of acetyl group.
M = number of moles of adduct (=[weight gain in gms] / molecular weight of adduct).

Determination of the Static Bending Test

Acetylated and untreated rattans were conditioned at 20ºC and 65% relative humidity for one week and tested in the same room. The three point bending test in a span of 80 mm and a crosshead speed of 5mmmin^{-1} was set using an Instron machine. The load was positioned onto the tangential surface of the specimens, perpendicular to the grain direction. The moisture content of the specimens was measured after the mechanical testing.

RESULTS AND DISCUSSION

Variation of the Physical Properties

The results for the physical properties obtained from this study are presented in

Table 1. All the physical properties of the acetylated rattan were not significantly different by age, except for specific gravity changes. The older acetylated rattan (7.7 %) had higher specific gravity changes than younger acetylated rattan (6.0 %).

In the younger acetylated rattan (Fig.1.1 to Fig.1.10), almost all the physical properties were not significantly different by the reaction periods, i.e. ranging from 6.2 to 9.9% (bulking coefficient), 0.39 to 0.46 (specific gravity following modification), 5.2 to 6.6% (specific gravity changes), 29.5 to 41% (void volume following modification), -8.3 to -17.1% (void volume changes) and 17 to 25 cm^3mol^{-1} (molar volume). In contrast, the reaction period influenced weight gain and OH substitution for both ages. The weight gain was significantly increased from 0.25 hour (12.7%) to 10 hour (16.2%) and levelled-off up to 24 hours (16.1%) before it significantly declined at 30 hours (15.4%) reaction period. Similarly, the OH substitution was significantly increased from 0.25 hour (9$mMolg^{-1}$) to the maximum at 10 hours (12$mMolg^{-1}$) and levelled-off up to 12 hours (12$mMolg^{-1}$) before it significantly declined at 30 hours (11 $mMolg^{-1}$) reaction period.

The same trends were also observed in the older acetylated rattan (Fig.2.1 toFig. 2.10). Almost all the physical properties were also not significantly different by the reaction period ranging from 5.6 to 8.8% (bulking coefficient), 0.34 to 0.43 (specific gravity following modification), 34.1 to 48% (void volume following modification), -7.3 to -16.2% (void volume changes) and 15 to 20 cm^3mol^{-1} (molar volume). The weight gain was significantly higher at 0.25 hour (15.8%) than 0.5 hour (12.1%); the value was then increased at 10 hours (17.2%) and levelled-off up to 24 hours (18%) before it significantly declined to 30 hours (15.9%) reaction period. The OH substitution was significantly higher at 0.25 hour (11 $mMolg^{-1}$) than 0.5 hour (9 $mMolg^{-1}$); the value was then significantly increased at 10 hours (12 $mMolg^{-1}$) and levelled-off up to 24 hours (13 $mMolg^{-1}$) before it significantly declined at 30 hours (21 $mMolg^{-1}$) reaction period. The specific gravity changes were slightly lower at 0.5 hour (5.4%) compared to 0.25 hour (7.5%); the value was then stable from 1 hour to 10 hours (7.1 to 7.7%), followed by increasing to its maximum at 24 hours (9.1%) before slightly declining at 30 hours (7.7%) reaction period. This indicates that the trends of WG and OH substitutions were consistent for both ages, which were levelled-off after 10 hours. The trends of the other physical properties were almost the same for both the ages. Regardless of the reaction periods, acetylation increased the specific gravity and reduced the void volume of rattan of either age.

The maximum WG of the acetylated rattan strip of either age (15.7%) was lower than the acetylated wood (about 25%) as reported by Hill (2006). This was probably caused by the higher cellulose (70.1 to 73.3%) but lower hemicellulose (13.0 to 14.5%) and lignin (17.3 to 19.4%) contents in rattan than those of wood (Tables 2 and 3). In wood, lignin had the fastest

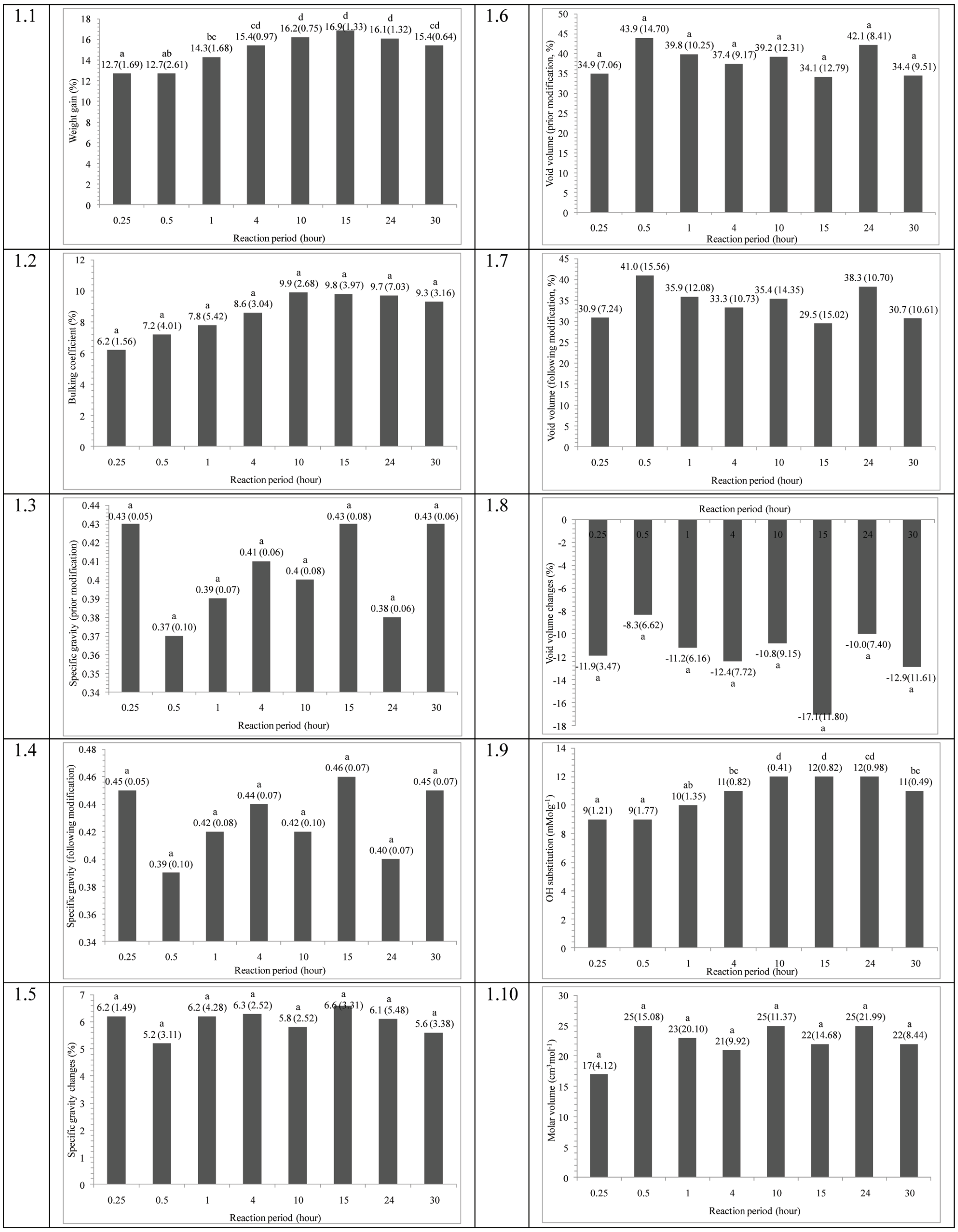

Fig. 1 The physical properties of acetylated rattan aged 10 years used for static bending test.
1.1 Weight gain 1.2 Bulking coefficient 1.3 Specific gravity (prior modification) 1.4 Specific gravity (following modification) 1.5 Specific gravity changes (%) 1.6 Void volume (prior modification) 1.7 Void volume (following modification) 1.8 Void volume changes (%) 1.9 OH substitution (mMolesg^{-1} 1.10 Molar volume (cm^{3}mol^{-1}). The parenthesis is standard deviation. Means followed by the same letter(s) in the same bar are not significantly different at the

TABLE 1
The mean physical properties of the acetylated rattan strip used for static bending test

Properties	Rattan age (years)		DF	F	Significance (Rattan age)
	10	13			
Weight gain (%)	15.0 (2.07)	15.7(2.27)	1	2.94	0.09^{Ns}
Bulking coefficient (%)	8.6(4.15)	7.5(2.95)	1	2.62	0.11^{Ns}
Specific gravity (prior to modification)	0.40(0.07)	0.37(0.06)	1	5.62	0.02*
Specific gravity (following modification)	0.43(0.08)	0.40(0.07)	1	3.35	0.07^{Ns}
Specific gravity changes (%)	6.0(3.27)	7.7(2.78)	1	8.67	0.004**
Void volume (prior to modification, %)	38.4(10.65)	42.9(9.17)	1	5.61	0.02*
Void volume (following modification, %)	34.5(12.10)	38.4(10.27)	1	3.35	0.07^{Ns}
Void volume changes (%)	-11.8(8.20)	-11.3(6.32)	1	0.13	0.72^{Ns}
OH substitution (mMolesg^{-1})	11(1.47)	11(1.61)	1	3.06	0.08^{Ns}
Molar volume (cm^{3}mol^{-1})	23(13.71)	20(8.67)	1	1.60	0.21^{Ns}
Final moisture content (%)	4.4(0.61)	4.1(0.62)	1	9.16	0.003*

*is significant at P<0.05. ** is significant at P<0.01 probability levels. Ns-is not significant. The parenthesis is standard deviation. DF is degree of freedom, F is F distribution.

TABLE 2
The mean values of the chemical composition in rattan

Chemical composition	Rattan age (years)		DF	F	Significance (Rattan age)
	10	13			
Holocellulose (%)	84.0(5.03)	86.3(1.79)	1	5.63	0.02*
α-cellulose (%)	70.1(5.71)	73.3(4.67)	1	5.62	0.02**
Hemicellulose (%)	14.5(6.12)	13.0(4.07)	1	1.33	Ns
Lignin (%)	19.4(5.86)	17.3(5.32)	1	2.18	0.1*

*is significant at P<0.05, ** is significant at P<0.01 probability levels. Ns-is not significant. The parenthesis is standard deviation. DF is degree of freedom, F is F distribution.

TABLE 3
The mean values of the chemical composition in wood

Chemical composition	Types of wood			
	Hardwood$_{1}$	Softwood[1]	European beech[2]	Pine[3]
α-cellulose (%)	42±2	45±2	49.1	52.2
Hemicellulose (%)	27±2	30±5	36.5	22.1
Lignin (%)	20±4	28±3	23.8	26.3

[1]Dinwoodie (2000), [2]Kurschner and Melcerova (1965), [3]Kollmann and Fengel (1965)

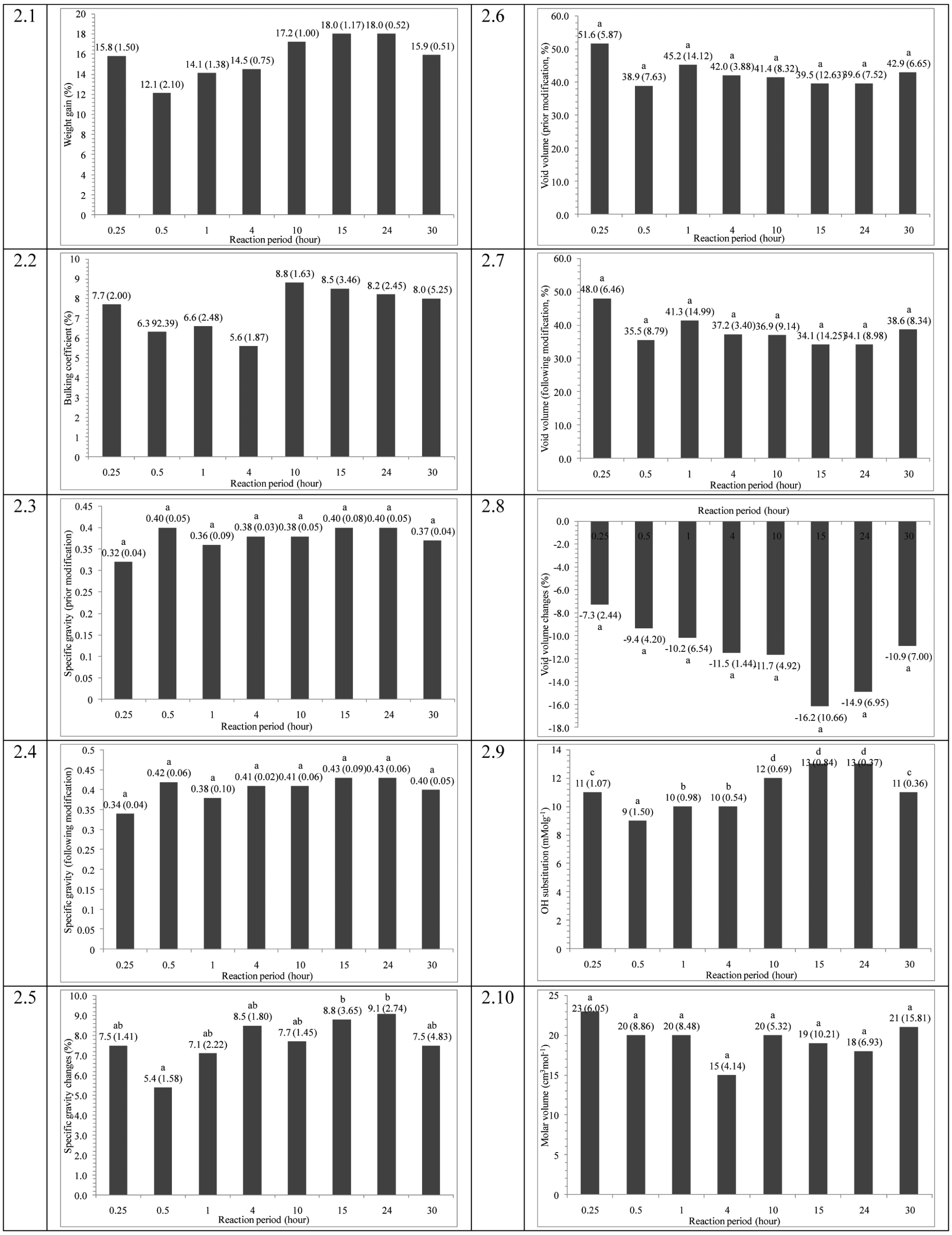

Fig. 2 The physical properties of acetylated rattan aged 13 years used for static bending test.
2.1 Weight gain 2.2 Bulking coefficient 2.3 Specific gravity (prior modification) 2.4 Specific gravity (following modification) 2.5 Specific gravity changes (%) 2.6 Void volume (prior modification) 2.7 Void volume (following modification) 2.8 Void volume changes (%) 2.9 OH substitution (mMolesg^{-1} 2.10 Molar volume (cm^{3}mol^{-1}). The parenthesis is standard deviation. Means followed by the same letter(s) in the same bar are not significantly different at the

reaction with acetic anhydride, followed by hemicellulose and lastly the cellulose (Rowell, 1983). As much of the cellulose is likely to be crystalline, it is inaccessible within the crystalline core for reaction. The time for the levelling-off WG of rattan of either age (10 hours) was faster than in the case of hinoki wood (uncatalysed, about 25 hours) reacted at 125ºC (Li *et al.,* 2000), but not as fast as Sitka spruce (uncatalysed, about 2.5 hours) reacted at 120ºC (Minato & Ogura, 2003). The differences can be explained by the kinetic perspective resulted from different modification procedures. The kinetic of the reaction depends on the access of the reagent to the reaction site and the real chemical reaction (Minato & Ogura, 2003). The difference of the maximum WG between rattan and wood certainly causes the different values of their physical properties.

Variation of the Static Bending Properties

The MoR and MoE varied by age and reaction period (Table 4). In the younger acetylated rattan, the MoR and MoE were not significantly different by reaction period. They ranged from 34.87 MPa to 45.88 MPa and from 1091 MPa to 1452 MPa, respectively.

In the older acetylated rattan, the MoR values (but not for the MoE) were significantly different with reaction period. The MoR was significantly lower after 0.25 hour reaction (20.49 MPa) as compared to the untreated (23.00 MPa) but the value successively increased to the maximum (34.02 MPa) up to four hours of reaction, and then steadily declined with longer reaction times, i.e. 28.35 MPa after 30 hours of reaction. This gave the maximum MoR improvement of 48% (4 hours of reaction) in the older acetylated rattan. In most cases, the MoR and MoE were higher in the younger rattan than the older rattan, regardless of the reaction period. This might be a feature of the higher initial MoR and MoE in the untreated younger rattan. The untreated younger rattan had average MoR and MoE values of 40.94 MPa and 1353.14 MPa, while these were 23.00 MPa and 909.29 MPa in the older untreated rattan, respectively.

The correlation test (Table 5) was performed in order to determine the relationship between the static bending and physical properties of acetylated rattan. The results showed that improvements of MoR and MoE in acetylated rattan were highly correlated with specific gravity of the specimens following modification, as depicted by the highest R^2 values. In contrast, the factor which was the most inversely related to MoR and MoE of the acetylated rattan was percent void volume following modification. However, the final moisture content did not influence the MoR and MoE of the acetylated rattan, despite being significantly higher in the untreated rattan. These trends were consistent for both ages.

The work to the maximum load was not significantly different by reaction period for either rattan age. Generally, younger rattan had a significantly higher work to the maximum load than the older rattan,

TABLE 4
The mean values of the static bending properties

Properties	Reaction (h)	Rattan age (years)		DF	F	Significance (Rattan age)
		10	13			
Static bending (Modulus of rupture, MPa)	0	40.94^{a}	23.00^{ab}			
	0.25	45.88^{a}	20.49^{a}			
	0.5	37.41^{a}	30.07^{bc}			
	1	38.75^{a}	31.01^{bc}			
	4	37.88^{a}	34.02^{c}			
	10	36.40^{a}	31.32^{bc}			
	15	43.51^{a}	28.85$_{abc}$			
	24	34.87^{a}	28.55^{abc}			
	30	40.28^{a}	28.35^{abc}			
	Average	39.27	28.93	1	42.60	0.00*
Static bending (Modulus of elasticity, MPa)	0	1353.14^{a}	909.29^{a}			
	0.25	1452.00^{a}	833.14^{a}			
	0.5	1120.00^{a}	958.00^{a}			
	1	1114.71^{a}	1015.29^{a}			
	4	1168.29^{a}	1043.71^{a}			
	10	1131.00^{a}	973.86^{a}			
	15	1287.86^{a}	928.57^{a}			
	24	1091.00^{a}	870.86^{a}			
	30	1139.57^{a}	897.71^{a}			
	Average	1186.09	938.22	1	37.34	0.00*
Static bending (Maximum load, kN)	0	0.07^{a}	0.05^{a}			
	0.25	0.11^{a}	0.04^{a}			
	0.5	0.09^{a}	0.07^{a}			
	1	0.11^{a}	0.07^{a}			
	4	0.09^{a}	0.08^{a}			
	10	0.09^{a}	0.08^{a}			
	15	0.12^{a}	0.07^{a}			
	24	0.09^{a}	0.08^{a}			
	30	0.01^{a}	0.06^{a}			
	Average	0.10	0.07	1	29.00	0.00*

* is significant at 0.05 probability level. Means followed by the same letter(s) in the same column are not significantly different at the 0.05 probability level. DF is degree of freedom. F is F distribution.

TABLE 5
The correlation tests on the static bending of acetylated rattan

Properties	Modulus of rupture		Modulus of elasticity	
	10 years	13 years	10 years	13 years
Specific gravity (prior to modification)	0.89**	0.82**	0.86**	0.77**
Specific gravity (following modification)	0.90**	0.83**	0.88**	0.77**
Specific gravity changes	0.51**	0.13Ns	0.56**	0.30*
Void volume (prior to modification)	-0.89**	-0.82**	-0.86**	-0.77**
Void volume (following modification)	-0.90**	-0.83**	-0.88**	-0.77**
Void volume changes	-0.80**	-0.61**	-0.77**	-0.65**
Percent weight gain	-0.30*	-0.17Ns	-0.33*	-0.26*
Bulking coefficient	-0.58**	-0.25Ns	-0.64**	-0.50**
OH substitution	-0.29*	-0.17Ns	-0.32*	-0.26*
Molar volume	-0.71**	-0.51**	-0.75**	-0.67**
Final moisture content (following test)	0.17Ns	-0.23Ns	0.32*	-0.01Ns

* correlation is significant at 0.05 probability level, **is significant at 0.01 probability level.

regardless of the reaction period. The averages were 0.10 kN and 0.07 kN in 10 and 13 years old rattan, respectively.

Overall, this indicates that the acetylation of rattan conducted in either short or prolong reaction periods did not significantly degrade the static bending properties, which probably because the reaction was performed at below 120°C. In the acetylation of solid wood, Rowell (1983) mentioned that the upper limit of 120^{o}C was commonly used to minimise wood degradation.

CONCLUSION

Acetylation alters the physical properties of rattan. The trends of the physical properties were found to be almost identical for the acetylated rattan of both ages. Meanwhile, the reaction period only influenced the weight gain and OH substitution of rattan of both ages. The acetylation of rattan at the temperature of 110°C does not significantly impair the static bending properties even though the reaction period is extended up to 30 hours.

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Properties of Resin Impregnated Oil Palm Wood (*Elaeis Guineensis* Jack)

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ABSTRACT

Oil palm wood (OPW) was treated with medium-molecular weight PF resin (mmw-PF) through a modified impregnation-compression method. The method consists of four steps, namely, drying, impregnation, heating, and hot pressing densification. The objective of the study was to optimize the impregnation variables. The overall density of the OPW increased, whereas the density gradient between the two OPW structural elements (namely, parenchyma tissues and vascular bundles) decreased. The weight percent gain (WPG) significantly increased even with a very short impregnation period (i.e. 1 hour). Young's Modulus of the compression parallel to the grain increased by 15 times (from 170 to 2600 MPa) and the shear strength increased by 7 times (from 1.9 to 13 MPa). The strength of the samples was increased exponentially against density increment. The treatment also made the two OPW structural elements to be strongly bonded that helped in enhancing the durability and machining characteristics of the material.

Keywords: Elais guineensis, oil palm wood, wood modification, properties enhancement, impregnation-compression method

INTRODUCTION

As the second largest palm oil producing country, huge amounts of oil palm biomass (fronds, trunks, and empty fruit bunches) are produced in Malaysia annually. More than 26.2 million tons of fronds, 7.0 million tons of trunks and 23% empty fruit bunches per ton of fresh fruit bunches are resulted annually. These huge residues are becoming a major concern because they cause many problems to the planters and are expensive to be disposed off (Bakar *et al.,* 2005, 2007).

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Malaysia and many other countries in the world are now facing problems of wood supply for wood industry. Many efforts have been done to use the oil palm biomass as an alternative material for wood substitution. Oil palm fronds and EFB have successfully been used for fibre-based and particle-based products in Malaysia, and oil palm fibre has been used for paper production in Indonesia. Oil palm stems, however, are still under utilized due to some inherent problems such as instability and density variation of the material (Bakar *et al.,* 2001, 2005).

Oil palm stems are among the three types of oil palm residues that offer the best properties that are comparable to those of wood. The stems can potentially produce oil palm wood (OPW). At the replanting age of 25-30 years, they can reach an average 50 cm in diameter and 10 m in length with 120-130 trees per hectare. This is equivalent to 230-250 m^3 of stems per hectare (Bakar *et al*., 2001). Therefore, huge amounts of OPW can be produced from matured oil palm stems.

As a monocotyledon plant, the best OPW is located at the periphery of the stem, which is in contrast to hardwood logs. Due to this difference, the sawing pattern in producing lumber from oil palm stems needs to be different from that of hardwood logs. The polygon sawing, as shown in Fig.1, is the most suitable sawing pattern. With such sawing pattern, the best tangential outer lumber can be resulted at the highest yield, with a recovery of about 30-35% to the volume of log (Bakar *et al.,* 2006, 2007).

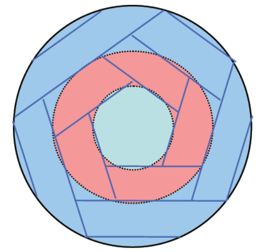

Fig.1: Polygon sawing used to saw the oil palm stem to produce the best tangential outer lumber

It was reported that OPW, even from the best outer lumber, has four main imperfections: very low in strength, very bad in dimensional stability, very low in durability, and very poor in machining characteristic. Hence, finding an effective method to modify the OPW properties has become our main concern (Bakar *et al.,* 2005, 2007).

A number of studies revealed that impregnation treatment and impregnation-and-compression treatment using Phenolic resin can improve the strength, dimensional stability and durability of wood, especially when low-molecular weight PF resins are used (Ibach, 2005; Furuno *et al.,* 2004).

Structurally, OPW consists of two main structures, namely; high-density vascular bundles scattered in thin-walled, low-density parenchyma ground tissues (Bakar *et al.,* 2008; Shirley, 2002) that amount to 70% of the total volume of the OPW (Istie, 2001). Because of that, OPW has a unique characteristic with high density gradient (between the vascular bundles and the parenchyma tissues) and low overall density. This unique characteristic is considered as the main cause to the mentioned material imperfections.

For OPW, we hypothesized that the impregnation-compression treatment is the most suitable treatment method (Bakar *et al.,* 2007). After the impregnation, the resin will penetrate more into the parenchyma tissues than the vascular bundles and reduce the density gradient between the two material structural elements. Furthermore, the compression densification will improve the structural element compactness and increase the overall density of the material. These effects are expected to not only improve the physico-mechanical properties of the material, but also the machining characteristic.

Therefore, the four-step impregnation-compression process was employed in this study (Bakar *et al.,* 2005, 2007). Fig.2 shows the diagram of the process. The objective of the study was to optimize the impregnation variables (i.e. resin concentration and impregnation period) to obtain an effective impregnation-compression treatment method for low-density OPW using mmw-PF.

MATERIALS AND METHODS

OPW outer lumbers of 50-mm thick were extracted from matured, 27-year old oil palm stems collected from University Agriculture Park of Universiti Putra Malaysia. The stems were sawn according to the Polygon sawing pattern as described by Bakar *et al.* (2006). The lumbers were dried to MC of 15 ± 1% and planed on both sides to a predetermined thickness of 40 mm. Only the lumbers with close density range (0.33 to 0.4 g/cm^3) were selected for the process. Immediately after being planed, the lumbers were cut short into samples of 40 mm x 100 mm x 100 mm for radial, tangential and longitudinal directions, respectively. The samples were impregnated under compression (120 psi) with mmw-PF under different solution concentrations and impregnating periods. The molecular weight of the resin was about 1000 (according to the supplier specification).

The density of each individual sample was recorded before the treatment. After being impregnated, the samples were re-dried or heated in an oven set at temperature of 80°C until they reached a target MC of about 50%. This re-drying stage was purposely made to make the resin become partially cured, so that the impregnated samples would not crack during the hot pressing densification, but allow the maximum resin load. Then, the samples were hot pressed at temperature of 150°C for 30 min (until which the resin is assumed

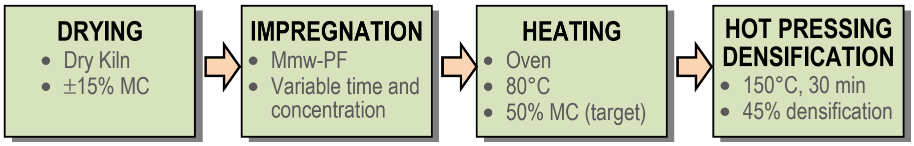

Fig.2: The four-step impregnation-compression treatment process

to be fully cured) until it reached a targeted compression level of 50%. Finally, the samples were conditioned and tested. The compression level was calculated as follows:

$$C = \frac{T_1 - T_2}{T_1} x100\%$$

Where, T_1 is the thickness before the compression and T_2 is the thickness after the compression.

RESULTS AND DISCUSSION

Density

Density is the most important parameter since it affects many other properties of material. The penetration of PF resin into the OPW structure followed by 50% compression increased the overall density of the sample from mean 0.37 g/cm^3 to 0.98-1.15 g/cm^3, which depended on the solution concentration and impregnation period. This was an increase of almost 3 times in density.

The thin-walled parenchyma tissues are more readily to absorb resin (during the impregnation stage) and experience greater level of densification (during hot pressing densification stage) than the vascular bundles. After the treatment, it can be expected that the parenchyma tissues would get greater density gain, and thus, reduce the density gradient between the parenchyma tissues and the vascular bundles. Reduction in this density gradient is expected to affect the other OPW properties to a great extent. Unfortunately, we do not have the apparatus to estimate the density of the two OPW elements for this moment.

PF resin can serve as a bulking and bonding agent in wood (Hill, 2006). These two functions were evident when the mmw-PF resin was impregnated in OPW. The bonding function of PF resin gave better compactness to the parenchyma tissues and the vascular bundles. This was expected as one reason why the treated OPW had much better machining characteristic than that of untreated OPW (Fig.3). The study on OPW planing also supports this result (Chong *et al.,* 2011).

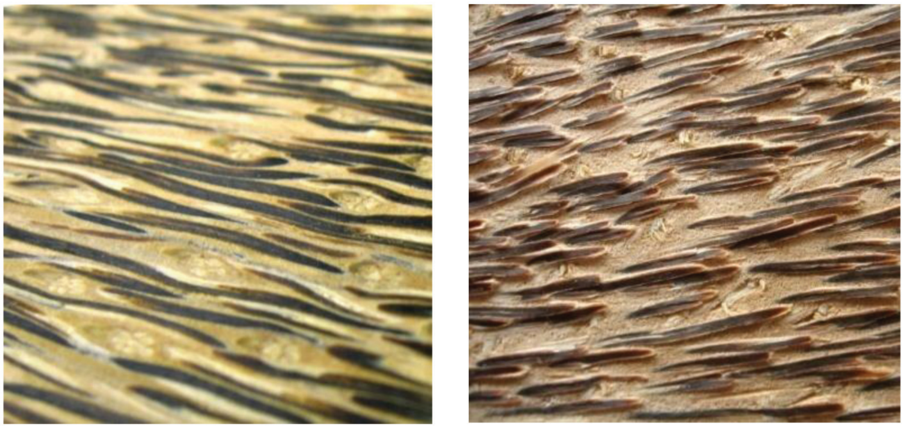

Fig.3: The planing surface of the treated OPW (left) and untreated OPW (right)

Weight Percent Gain (WPG)

The three-fold density increment in the treated OPW mentioned above was caused by two reasons: the 50% densification and the resin uptake. Densification reduced the volume of samples, whereas resin uptake increased the weight of the samples. A high resin uptake, also known as resin load, resin gain, or weight percent gain (WPG), is the main goal in every impregnation treatment of wood (Rowel, 2005). The effect of the treatment condition to WPG is discussed in this section.

The WPGs significantly increased by the increasing of the solution concentration, but they increased less significantly by the increasing of impregnation period (Fig.4). These results suggested that a WPG of 30%, a level which is considered as good enough for better OPW properties, could be obtained with a minimum impregnation period (1 hour) with liquid concentration of 15% to 20%. This is a very short period of impregnation as compared to more than one day needed for the impregnation of softwood with a low-molecular weight PF resin as reported by Furuno *et al.* (2004).

If WPG is the only parameter to consider, then the solution concentration of 20% with 1 hour impregnation period may be chosen. However, other parameters such as dimensional stability, strength and durability should also be taken into consideration. These are discussed in the following sections.

Anti Swelling Efficiency (ASE)

As mentioned earlier, the dimensional stability is one of the OPW weak points, especially when it is used in solid form (Bakar *et al.,* 2005, 2007). The Anti Swelling Efficiency (ASE) was evaluated to know the effective improvement of the treatment on dimensional stability.

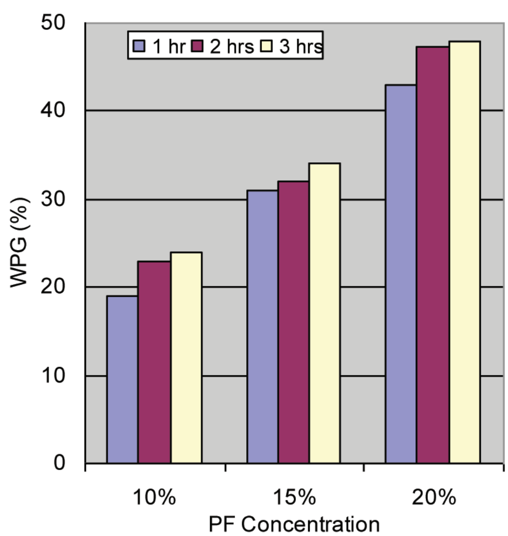

Fig.4: The relationships between PF concentrations and impregnation periods with WPG

An ASE value of 30% was attained by the treated OPW and there was no significant effect of increasing the solution concentration and impregnation period to this parameter (Fig.5). These results suggest that the impregnation with the mmw-PF resin under a concentration of 10 to 15% and an impregnation period of 1 hour were good enough to enhance the dimensional stability of OPW.

It is interesting to note that even though the PF resin used might not penetrate into the cell wall of fibre in the oil palm's vascular bundles (Bakar *et al.,* 2005), it could immediately penetrate into the parenchyma tissues as the bulking agent. This resin penetration helped not only in reducing the density gradient between the parenchyma tissues and vascular bundles, but also blocked the space and access of water that would have been occupied and penetrated by water during the water soaking test. The blocking effect of the resin seemed to be the main cause to this significant swelling reduction to the treated OPW.

The Strength

The strength is another weak point of OPW when it is used in solid form (Bakar *et al.,* 2005, 2007). Young's Modulus at the compression parallel to the grain and the shear strength were evaluated to know the effectiveness of the treatment. Both Young's Modulus and the shear strength were substantially increased. On average, the Young's Modulus increased from 170 to 2600 MPa (an increment of 15 times) and the shear strength increased from 1.9 to 13 MPa (almost 7 times of increment) after the treatment.

It is interesting to note that the Young's Modulus and the shear strength in the treated OPW were increased exponentially over the increment of density. For a better understanding, the specific strength, which is the strength value over the density of

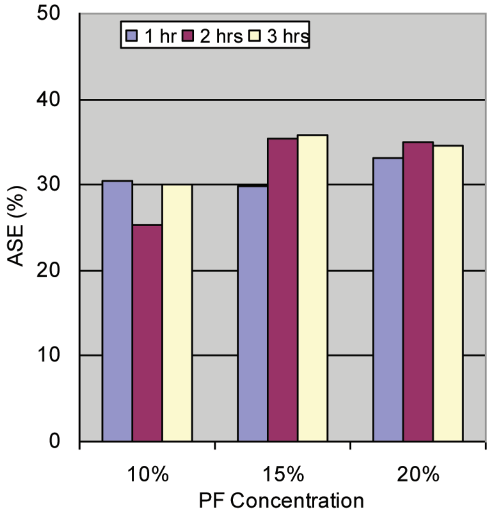

Fig.5: The relationships between PF concentrations and impregnation periods with Anti Swelling Efficiency

material, was evaluated. The specific Young's Modulus was increased by 5 times (from 459 MPa to 2500 MPa), while the specific shear strength was increased by 2.5 times (from 5.1 MPa to 12.5 MPa). Bulking and binding effects of the resin were expected to be the main reason to these exponential strength improvements.

After being impregnated with PF resin and followed by the hot-pressing densification, the whole density of OPW increased and the two material structural elements became strongly bonded. These two effects were expected to cause a significant improvement in the treated OPW strength. Even though only Young's Modulus and shear strength were tested in this study, we expected that other strength parameters were also improved to a large extent.

Durability

Another weak point of OPW is its durability, which belongs to the perishable durability class (Bakar *et al.,* 2005). The durability of the treated OPW was evaluated through a four-week block test method in accordance with the method described in ASTM D3345-93 (ASTM, 2006). The findings revealed that the mean weight loss of the samples due to the termite attack was substantially reduced from 27.9% (untreated) to only 9.6% (treated). A complete (100%) mortality of termite at the end of the test verified the validity of this test.

As mentioned earlier, OPW consists of two main structural elements, namely, vascular bundles and parenchyma tissues. The parenchyma tissues that amount to 70% of the total volume of the wood (Istie, 2001) contain high amount of starch, and thus, are lower in density and very susceptible to termite and fungal attack. However, the presence of PF resin in the treated OPW, which may be toxic to many fungi and insects, improved the durability of the material. This is in line with the finding from previous studies with both high- and low-molecular weight PF resins, that improved the durability class of OPW from perishable to durable (Bakar *et al.*, 2001, 2013).

Machining Characteristics

The other weak point of OPW is its bad machining characteristic (Bakar *et al.,* 2005, 2007). There was no observation made in this study related to this aspect. However, our previous studies revealed that the planing characteristics of OPW were improved from very bad (grade-5) to good (grade-2) (Bakar *et al.,* 2001) or from average (grade-3) to excellent (grade-1) (Chong *et al.,* 2010) after the treatment. Those two studies confirmed that the treatment could significantly improve the machining characteristics of OPW.

Overall, the treatment had substantially improved the properties of OPW, and solved all the four imperfections of the material. In addition, the treatment also gave an attractive red-brownish color to the treated OPW (Fig.3). Hence, with these properties, the material can be used as a high grade alternative material for solid wood.

CONCLUSION

It can be concluded that the four-step impregnation-and-compression process using mmw-PF resin can be used as a practical method to improve the quality of OPW. Based on the properties evaluated, the treated OPW can be proposed as a new high-grade solid wood alternative. On the sectoral aspect, this finding will help reduce the shortage of wood and the dependency of wood supply from forests, as well as solve the problematic oil palm waste disposal in the ground.

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Assessing Timber Extraction by Using the RIMBAKA R2020-A Timber Harvester on a Steep Terrain in Ulu Jelai Forest Reserve, Peninsular Malaysia

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ABSTRACT

In this study, the extraction operation of a RIMBAKA Timber Harvester R2020-A on steep terrain was investigated. A continuous time study was carried out to estimate the operational efficiency of the RIMBAKA timber harvester. Four dependent variables were observed to investigate their impacts on the extraction phases: skidding distance, hauling distance, volume and slope. A total of 48 working cycles were time studied. During the operation, RIMBAKA extracted 3.55 m^3 of logs per cycle and had a machine utilization rate of 78%, with a corresponding productivity of 45.92 m^3/PMH_{15}. The unit cost of RIMBAKA was RM 4.64/m^3. Meanwhile, hauling distance and log volume had a major effect on the productivity of the harvester during the extraction phase. Thus, a better understanding of the integrated effect on the productivity of the RIMBAKA extraction operation, in combination with the rest of machines of the harvesting system, will better help predicting the efficiency and productivity of the whole system.

Keywords: Cost estimation, cycle time, production rate, RIMBAKA, timber extraction

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INTRODUCTION

Decisions regarding the type and configuration of the machines used in timber harvesting operation must be considered during the planning phase to assess their impacts on the economic returns of the harvesting system. An application of reduced impact logging (RIL) machinery in Peninsular Malaysia forest harvesting showed that the overall harvesting cost was increased by 57.4% (Abdul Rahim *et al*., 2009). This high cost precluded the use of RIL equipment and favoured the use of conventional ground base skidder machinery, regardless of the environmental constraints, due to their low investment cost and the larger productivity achieved by the more experienced operator (Pinard *et al*., 2000).

The deforestation rate in Peninsular Malaysia increased by 69% from 19.01 million ha in 1999 to 5.89 million ha in 2010. This situation resulted in timber harvesting operations moving from lowland forests to hilly forests. Due to the impacts of harvesting operations on sensitive sites, a number of efforts have been made by forestry agencies to sustainably harvest forest management units (FMU). Consequently, guidelines have been developed to conduct harvesting operations in the production forest areas (Kamaruzaman & Dahlan, 2008). Since the early 1990s, such efforts have included the introduction of low impact timber harvesting practices particularly for log skidding (Wan Mohd & Mohd Paiz, 2003).

The RIMBAKA Timber Harvester R2020-A (RIMBAKA) was developed and introduced in 2001 to skid logs from rocky and deep narrow corridors, which were difficult and dangerous to operate for conventional ground base skidders. RIMBAKA is a cable skidder machine (Fig.1) operated on steep terrain, and it is

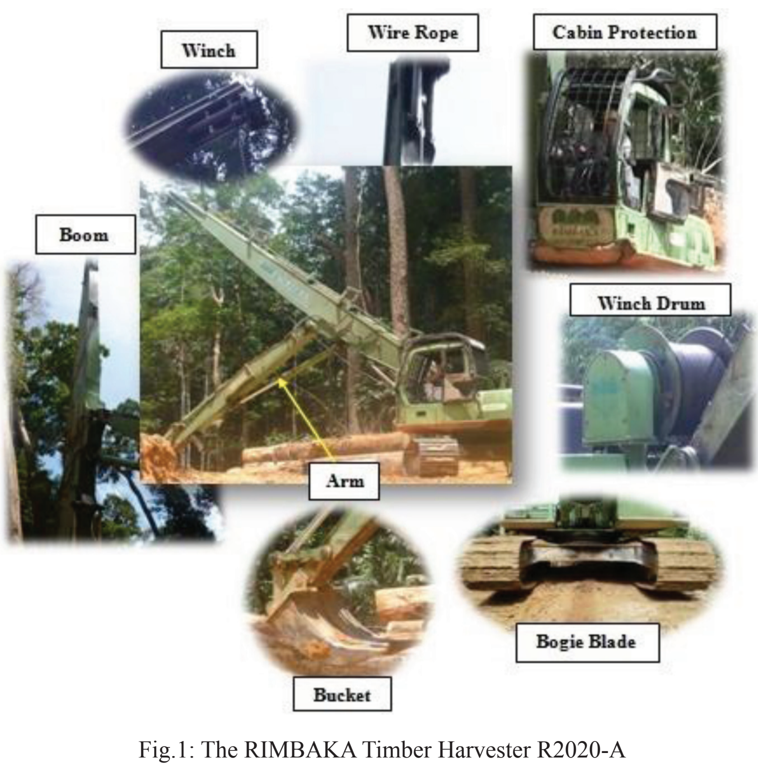

Fig.1: The RIMBAKA Timber Harvester R2020-A

equipped with a winch system and chocker to haul logs from the stump to roadside landings, where conventional ground base skidders cannot operate. The machine is a modified excavator with an added winch set that acts as a cable skidder for log hooking using the ‘fishing’ concept. Thus, it is a ground base machine that uses a cable extraction system that helps diminish the environmental impacts during the timber harvest operation (Baker *et al*., 2007). Yet, RIMBAKA has its own criterion to be chosen as an acceptable skidder machine in timber harvesting operation such as the operational efficiency of its application in terms of economic profits.

The efficiency of machine can be obtained from previous productivity and cost studies (Bavaghar *et al*., 2010). According to Palmroth and Holtta (2004), it is necessary to calculate the efficiency of the machine operating in various topographic and stand conditions. Effectiveness, flexibility and ease of use for operators have been considered in some previous studies for the calculation and analysis of machine costs (Parsakhoo *et al*., 2009). The three factors mentioned above are pivotal when selecting the most suitable machinery in timber harvesting operations (Acar & Yoshimura, 1997). This paper, which is based on time study data collection, was carried out to analyse and examine the production rate and cost of the RIMBAKA operation on a steep terrain timber harvesting operation.

MATERIALS AND METHODS

Study area

The study was carried out at compartment 484 of the Ulu Jelai Forest Reserve (UJFR), located in the Kuala Lipis district of the Pahang state within a 71 ha concession area (see Fig.2). Approximately 4703 m^3 of logs were extracted. This harvesting area was predominantly composed of dipterocarp species such as *Shorea leprosula, Shorea parvifolia* and *Shorea curtisii.* The elevation ranged from 180 m to 680 m, with a maximum slope of 81 degree. The annual precipitation ranged between 150 mm-200 mm, whereas the minimum and maximum temperatures recorded were 15.5^0C and 24.4^0C, respectively. Typically, RIMBAKA and excavator machines used for road work excavation are employed as extraction machines.

Data Collection

A continuous time study for each of the RIMBAKA’s work elements was conducted on 48 extraction cycles. The work elements recorded were travel empty, releasing winch, hooking and unhooking, hauling, travel loaded, sorting and positioning. The times were measured manually using a stop watch and transcribed into hard copy form at the study area. The operation was also filmed using a video camera, and the footage was reviewed in the office in case the manual time records were incomplete (Nakagawa *et al*., 2010). The variables recorded for the extraction operation were hauling distance, skidding distance, log volume and slope.

Estimating Production Rates and Costs

Production rates and costs were estimated by cycle time and variables input recorded in the field. In addition, interviews were conducted with the machine operator and contractor. Productivity was obtained by dividing the volume of log extracted and the time per cycle, and it is expressed in m^3/PMH_{15} (where PMH corresponds to productive machine hour, including delays that do not exceed 15 minutes). Machine rate was calculated from fixed and variable costs (including operator wage) and expressed in Ringgit Malaysia (RM), as shown in Table 1. The RIMBAKA unit cost was calculated following the methodology proposed by FAO (1992).

TABLE 1
Cost calculation for the RIMBAKA operation

Machine Information	Value
Purchase price (RM)	750,000
Salvage value (RM)	150,000
Life in years (yrs)	10
Scheduled hour / yr (SMH)	1,589
Repair & Maintenance (% of Depreciation)	80
Labour fringe benefit factor (% of wage)	30
Expected utilization (%)	70

RESULTS AND DISCUSSION

The production rate of the RIMBAKA ranged from 9.8 to 129.7 m^3/PMH_{15}. From the regression analysis carried out, hauling distance and volume were found to have a significant effect on the Residual Mean Squares (RMS) of the response variable productivity. The following productivity equation was developed from the RIMBAKA's time study data:

Productivity (m^3/PMH_{15}):
$$50.3846 - 1.0186_{hauling\ distance} + 6.2198_{volume}$$

R^2: 0.4203

The correlation coefficient (R^2) of 0.4203 indicates that hauling distance and log volume explain 42% of the variability of productivity. The ANOVA table (Table 2) shows that the estimated productivity equation is significant at $\alpha < 0.05$.

These results indicate that a larger extraction log volume and shorter extraction distance result in an increase of productivity. These results are consistent with those of Wang and Haarlaa (2002) who found that the time variation and productivity varied roughly in a linear fashion with log size. In addition, variation in the slope condition impacts the time required for hauling and subsequently reduces the production rate (Akay *et al.,* 2004). In comparison

TABLE 2
ANOVA table for production rate estimation- Overall goodness of fit

	Sum of Squares	Df	Mean Square	F	Sig.
Regression	18867.841	2	9433.920	18.037	.000(a)
Residual	23536.917	45	523.043		
Total	42404.757	47			

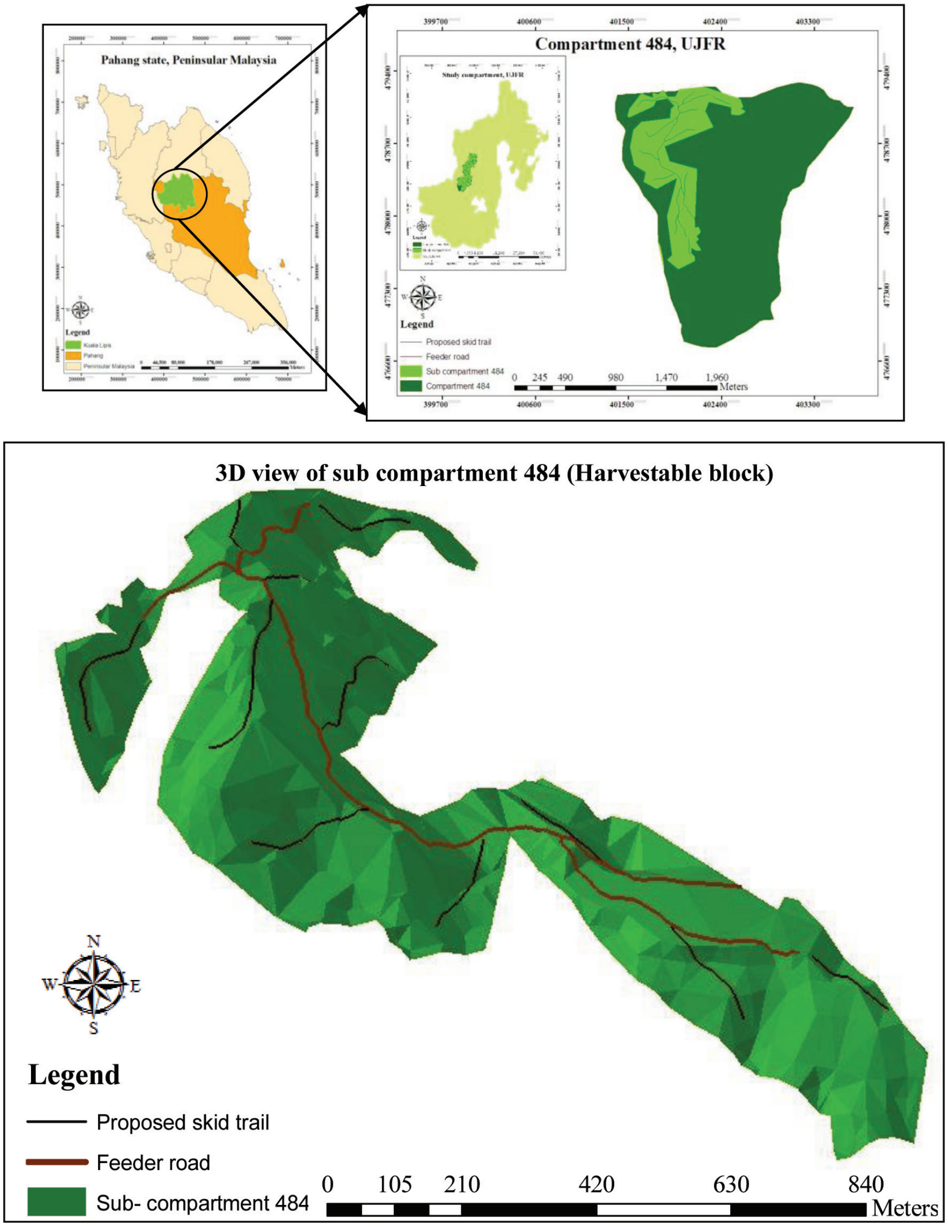

Fig.2: The field study of Compartment 484 located at UJFR, Kuala Lipis, Pahang

to conventional ground based skidding systems working on steep terrain, the productivity of RIMBAKA is averagely bigger than those reported in the previous studies. For example, Saharudin *et al.* (2004) reported a productivity of 45.88 m^3/ PMH_{15} for ground based skidders working in similar conditions. The large production rate and efficient working operation of the RIMBAKA in this study can be explained by the improved technology and machine performance, as well as by the experience (more than 10 years) of the operator (Spinelli & Magagnotti, 2010; Barreto *et al.,* 1998). With a weight of up to 26 tonnes and track width of 3.5 m, RIMBAKA is able to operate efficiently and perform better in log skidding even in undulating slope conditions. This can be explained by the increment of rolling resistance and total load which is evenly distributed to the bogie track over the total contact area, resulting in improved machine traction (Rieppo *et al*., 2002). Eventually, the productivity equation derived from this study may be used to predict the productivity of RIMBAKA and to determine the best practice of machine operation in different harvest areas. However, given that the study results are based on just one trial, the production equation derived may have a limited use when applied to different forest stands with different topographical condition and stand composition. A further investigation should be conducted in different timber harvesting operation areas in order to capture enough variability from the outcomes derived when using different predictive variables (Bavaghar *et al*., 2010).

The operation with RIMBAKA resulted in an hourly and unit cost of RM 213.14/ SMH, and RM 4.64/m^3, respectively. This unit cost value is substantially larger than RM 0.58/m^3 reported by Saharudin *et al*. (2004). This situation is explained by the high initial investment cost, as well as the operational costs associated with higher rate fuel consumption, and more frequent maintenance of bogie tracks, winch drum and winch wire. Akay *et al.* (2004) and Barreto *et al.* (1998) pointed out that harvesting operational and investment costs could be recovered when the equipment operate efficiently. In a study conducted by Holmes *et al*. (2002), it was found that the RIL practice resulted in reduced costs and a 45.7% net profit margin, as compared to only 38.6% net profit margin of a conventional operation. In summary, it is expected that the extended application of advanced RIL technology on steep terrain timber harvesting will result in cost reduction and help protecting other forest values and maintain the forest stand composition.

CONCLUSION

The production rate was found to be primarily affected by hauling distance and log volume. With a rough production rate of 45.92/PMH_{15}, the study conducted on RIMBAKA has shown that the application of improved technology in conjunction with RIL practices can lead to more sustainable forest management during timber harvesting operations. Extraction hourly and unit costs of RIMBAKA were RM213.14/ SMH and RM 4.64/m^3, respectively, and these costs can be reduced with a higher production rate. Among other advantages, the RIMBAKA harvester is more eco-friendly while working on steep terrain and this can help preserve the forest resources for the benefits of future generations. With its capability to haul logs much further from the stump area, a reduced optimum density of forest road and minimum forest canopy opening is anticipated to be attained with RIMBAKA. Consequently, this saving in site preparation planning can contribute towards the overall cost reduction in forest operations. A comprehensive study of all the machines in the whole timber harvesting system may strengthen the predictive equation derived in this study, whilst cost constraints assumption can be verified according to the best management practice applied and may be useful for helping forest manager to make the best decision according to the type of machines and harvesting practices that are chosen.

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Chemical Characterization of *Imperata cylindrica* ('Lalang') and *Pennisetum purpureum* (Napier grass) for Bioethanol Production in Malaysia

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ABSTRACT

Grass is a candidate biomass producer because it is fibrous and it thrives well on poor soils. The chemical properties of two grass species growing naturally and abundantly on idle lands in Malaysia were investigated in this study. The grasses selected were *Imperata cylindrical* ('Lalang') and *Pennisetum purpureum* (Napier grass). For the purpose of analysis, Napier grass was further divided into male and female plants, and stem and leaves. Lignin, hemicellulose and cellulose contents were determined using the TAPPI standard methods. 'Lalang' was found not to be an attractive biomass producer because of its high lignin content (22%) ($P<0.05$). On the contrary, Napier grass, particularly the female stem, had low lignin content (13%) ($P<0.05$) and a favourably high level of cellulose (46%) ($P<0.05$). In the female leaf, lignin content was higher (20.7%), while the cellulose content (30.4%) was lower compared to the stem. Although the cellulose content in the male stem (51%) was slightly higher ($P<0.05$) than the female, its lignin was two-fold above that of the female stem, making it a less desirable biomass producer. Hence, it was concluded that female Napier grass has a good potential of becoming a biomass producer in bioethanol production in Malaysia.

Keywords: Bioethanol, biomass, cellulose, chemical properties, grass, lignin

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INTRODUCTION

Lignocellulose from grasses is one of the major resources for bioethanol as it has short rotation coppices and it is not suitable for human consumption. The characteristics of being high-yield, low nutrient requirement, together with them being easily available throughout the world, have turned grasses into an attractive feedstock for bioethanol production (Hamelinck *et al.,* 2005; Balat *et al.,* 2008). Bioethanol can be produced from several different biomass feedstocks such as sucrose-containing feedstocks (e.g., sugar cane, sweet sorghum), starchy material (e.g., corn, wheat, rice) and lignocellulosic biomass (e.g., wood, rice husk, and oil palm empty fruit bunch) (Balat *et al.,* 2008). However, the production of bioethanol from starch and sugar has been seriously debated over its sustainability as starch and sugar are important food sources for human (Alvira, 2010). Thus, bioethnaol from lignocellulosic material may be a better feedstock as there will be no competition against food crops. This form of energy has been produced and used in many developed and developing countries (Demirbas *et al.,* 2009). For example, bioethanol was introduced into the transportation fuel supply in 1970s by the Brazilian government (Manuel *et al.,* 2007). However, the potential bioconversion in lignocellulosic biomass is often limited by the associated aromatic constituents within the grass fibre, including lignins and phenolic acids, which act as barriers to fibre degradation (Anderson & Akin, 2008). In order to confirm the potential of lignocellulosic biomass of a plant, the chemical composition of the materials must first be determined as it greatly affects on the efficiency of bioconversion (Lee *et al.,* 2007). Lignocellulosic biomass consists of three polymers: lignin, hemicelluloses and cellulose. Lignin is a complex of phenylpropanoid group, which is a common constituent of plant cell walls (Carpita, 1996). Lignins are highly branched, substituted, mononuclear aromatic polymers in the cell walls of certain biomass, especially woody species, and are often bound to adjacent cellulose to form a complex and recalcitrant structure. The lignin contents in both softwood and hardwood (dry basis) ranged from 20% to 40% and from 10% to 40% in various herbaceous species such as bagasse, corncobs, peanut shells, rice hulls and straws (Yaman, 2004). Hemicellulose and cellulose are bonded together by lignin in the microfibril structure. The basic repeating unit of cellulose consists of two glucose anhydride units called a cellobiose unit while hemicellulose is a mixture of various polymerized monosaccharides (Mohan *et al.,* 2006), which also contains some important C_6 sugar (Mohagheghi, 2006). Some of these C_6 sugar can be hydrolyzed into glucose for bioethanol conversion use. Alkaline treatment has been used as a pretreatment method to break down the linkage and release the cellulose. In bioethanol process, cellulose is the most important component as it hydrolyzes into glucose and used in microbial fermentation to produce ethanol.

In this study, the chemical contents of two local grass species available in Malaysia were analyzed. Potential grass candidate can be further explored and used for conversion into bioethanol.

MATERIALS AND METHODS

Plant Materials

Two perennial local grass species, namely, *Imperata cylindrical* (L.) P. Beauv. ('Lalang') and *Pennisetum purpureum* Schumach (Napier grass) were collected from idle lands at Universiti Putra Malaysia, Serdang campus, and from a housing area in Selangor, respectively. The plants selected were in fresh green condition. Napier grasses were collected during their flowering stage at an average height of 2 m. The whole plant was cut using a cutter, about 0.15 m from the base. 'Lalang' was also collected during the flowering stage at an average height of 1 to 2 m. The napier grass was further divided into stems and leaves. The plants were cut into approximately 3 cm and then oven dried at 50˚C until constant weight and later ground into powder form using Wiley's mill. The grass powder was sieved to the size of MESH 40-60 as required by the TAPPI Standard.

Chemical Composition

Plant samples were subjected to different extraction methods according to the TAPPI Standard Method (Anon, 1978), with slight modifications. The adaptation of the TAPPI Standard in this experiment was based on the soft fibre-type of material, which was more similar to the materials found in the pulp and paper industry. Besides, the TAPPI Standard Method is more suitable for the preliminary step to determine the amount of chemical properties in the grass material and it does not require any specific equipment to carry out the experiments, unlike NREL and ASTM. The chemical properties experiment consisted of alcohol-acetone solubility test (TAPPI T6), lignin content test (TAPPI T222), holocellulose content test (Wise *et al.,* 1946) and cellulose content test (TAPPI T203).

Data Analysis

Results were analyzed using SAS program version 9.1.3. (SAS Institute). Procedure Univariate was used in order to determine data normality by conducting Shapiro-Wilk W test and Kolmogorov-Smirnov (K-S) D test. Data were transformed into square root. Procedure General Linear Model (GLM) and Least Square Means (LSM), with probability differences, were used to compare the level of significance between the species, and stems and leaves.

RESULTS AND DISCUSSION

Lignin, holocellulose and cellulose contents of two grass species in Malaysia, 'lalang' and Napier grass were analyzed using the standard methods. Some differences were detected between the species and organ parts. 'Lalang' showed moderate results for the lignin (22.07%), holocellulose (77.69%) and cellulose (51.61%) contents (Figure 1). From the comparison made between 'Lalang' and the male and female Napier grasses, the later had the highest cellulose content ($P<0.05$) (Fig.1). When comparing the stems and leaves of Napier grass, the cellulose content in the male stem was 2.5-folds above that of the leaves (Table 1). Meanwhile, when comparing

TABLE 1
A comparison of the chemical properties between Malaysia local grass species and other crops

Species	Extractives	Lignin	Holocellulose	Cellulose
'Lalang'	18.26	22.07[c]	77.69[a]	51.61[a]
Napier grass - male (Stem)	3.20	29.67[a]	76.73[b]	51.44[a]
Napier grass - male (Leaves)	6.51	28.09[b]	72.62[d]	19.60[d]
Napier grass - female(Stem)	2.68	12.93[e]	77.64[a]	46.01[b]
Napier grass - female (Leaves)	14.89	20.74[d]	75.04[c]	30.39[c]
Wheat straw[1]	n/a	17.00	27.60*	40.70
Corn stalks[2]	3.27	19.00	68.18	42.43
Switch grass[3]	17.54	18.13	25.19*	31.98
Softwood[3]	2.88	27.67	21.90*	44.55

*Hemicellulose; n/a: not available
1: Reference from Tomás-Pejó *et al*. (2009)
2: https://unit.aist.go.jp/btrc/research_result/database/corn-s.htm
3: Reference from Hamelinck *et al*. (2005)
[a] means with the same letters were not significant
The percentages of lignin, holocellulose and cellulose were calculated by taking into account the material's moisture content.

the female leaves and stems, the lignin and cellulose contents were both higher in the stem ($P<0.05$) (Figures 1a & 1b). Between the female and male Napier grass, the male leaves were found to have less than half of the cellulose in the female leaves ($P<0.05$) (Fig.1a), but the female had less than half of the lignin in the male stem ($P<0.05$) (Fig.1b). Male leaves, on the other hand, had approximately 10% more lignin when compared to the female leaves (Figure 1b). There were not many differences in the cellulose and holocellulose contents of the female stem when compared to the male stem (Fig.1a & Fig.1c). These results indicated that the female Napier grass has a good potential of becoming a biomass producer.

Among the four subsets of Napier grass, the female Napier stem was the best for use in bioconversion into bioethanol as it contained the lowest amount of lignin. Lignin is the biggest barrier in the hydrolysis process because it forms a cross-link linkage with hemicelluloses, which prevents the hydrolysis of cellulose into glucose. In general, stems always contain more fire than leaves. In Rye-grass, the stem (39.5%) has more fibre than the leaf (7.9%) (Smole *et al*., 2005). In addition, stem-to-leaf ratio increases and cell walls which undergo secondary thicken and lignification during maturation resulting in increased content of structural polysaccharides (mainly cellulose and hemicellulose) and lignin (Lindgren *et al*., 1980). This explains the higher content of holocellulose and cellulose in the Napier female stem compared to the leaf. In the experiments, 'Lalang' was tested with the whole plant (mixture of stem and leaves); therefore, the Napier grass must be combined to reach a fair comparison.

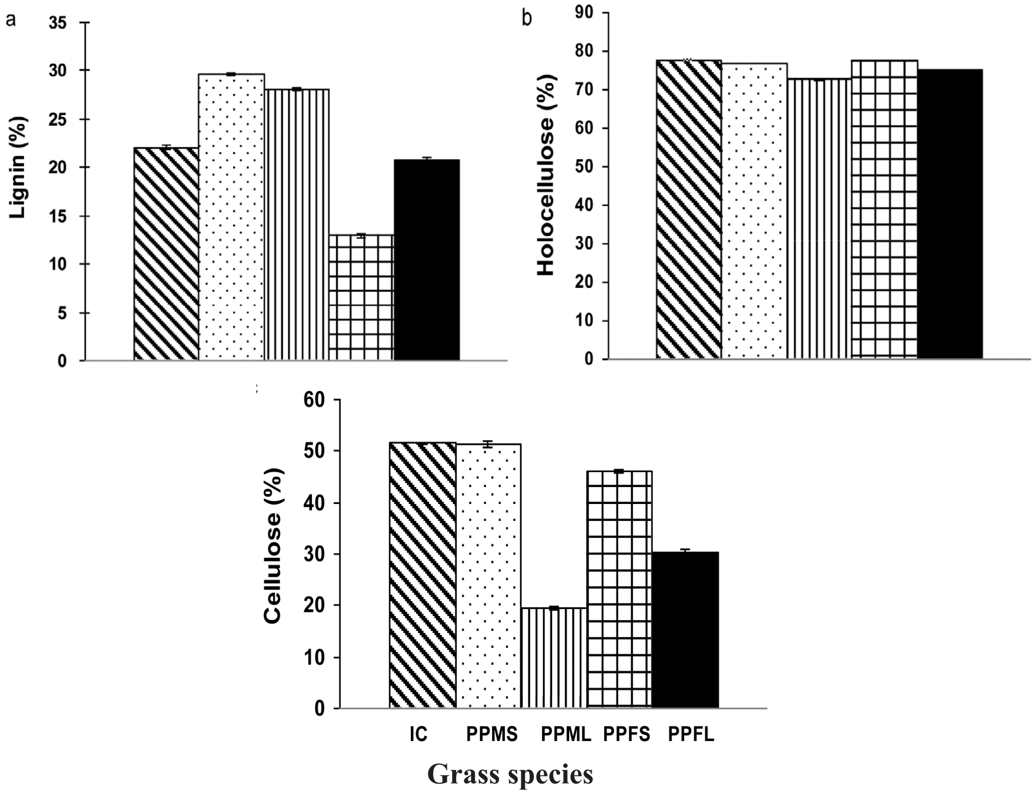

Fig.1: Chemical contents of *Imperata cylindrica* (IC) and *Pennisetum purpureum* (PP) found in Malaysia. Data were the means from six replicates and error bars indicate standard deviations. a) lignin, b) holocellulose, and c) cellulose. MS/ML, male stem or leaves; FS/FL female stem or leaves.

Hence, it was proposed to combine the female Napier stem and leaves together so as to recover more holocellulose and cellulose, which in turn will contribute to higher cellulose content.

Hardwood (24%), softwood (27.67%) and other crops such as wheat straw (17.0%), corn stalks (19.0%) and switchgrass (18.13%) (Table 1) showed similar lignin levels to the Napier grass tested in this study. In addition, Napier grass also had higher cellulose content compared to the other crops (30-42%). One interesting comparison between switchgrass and Malaysian Napier grass was that the latter had a similar or a higher content of lignin and cellulose to switchgrass (18.13% of lignin and 31.98% of cellulose). When we compared the cellulose content found in the Napier grass with that of softwood (44.55%), wheat straw (30%) and others (Table 1), the Napier grass appeared to have a great potential as a biomass producer. Napier grass, especially the female grass, had higher cellulose content compared to other crops, while the lignin content was about the same. In more specific, the local Napier grass had higher or about similar lignin and cellulose contents to switchgrass, but lower lignin content than softwood. Lignin can be a problem when it comes to assessing potential biomass as lignin is a major barrier during hydrolysis due to its recalcitrant structure that protects cellulose from being hydrolyzed into simple sugar. The vessel elements of softwood contained mainly guaiacyl units, which restrict fibre swelling and restrict the disruption of lignin structure (Gibbs, 1958; Ramos *et al*., 1992; Li *et al.,* 2004). Previous research has shown that softwood vessel elements contain a higher ratio of guaiacyl lignins than syringyl lignins (Ramos *et al*., 1992; Gibbs, 1958). The guaiacyl lignin, which consists largely of coniferyl alcohol, will restrict fibre swelling more than syringyl lignin (Ramos *et al*., 1992; Henriksson, 2009). Although the HGS-lignin (Hydroxyl phenol, Guaiacyl, Syringyl) in grass contains all three monolignols (*p*-coumaryl alcohol, conigeryl and sinapyl alcohols), the ratio of *p*-coumaryl alcohol is a lot higher, i.e. approximately 33% (Henriksson, 2009). Therefore, the restriction of fibre swelling is not as high as compared to softwood and hardwood. These altered structures of the material will help in hydrolyzing cellulose into glucose during hydrolysis. This increases the efficiency of ethanol conversion as the 6-ring sugar (C_6) hemicellulose can be easily converted into simple sugar using enzyme hydrolysis or acid hydrolysis method.

The chemical properties determination of lignocellulosic biomass is the first step in bioethanol conversion. The content of chemical properties such as lignin, hemicellulose or holocellulose and cellulose are the main keys to identify the potential of lignocellulosic material in becoming a source of biofuel. Hence, the chemical properties of grasses were determined in this experiment in order to identify the potential of grasses for bioethanol production. We found that the female Napier grass has a potential as a biomass producer.

CONCLUSION

Even though many trees and plants such as *Acacia*, rubber and bamboo produce high cellulose and hemicelluloses contents, they are also rich in lignin. This study has shown that Malaysia's grasses contain less or similar lignin compared to wood and straw. It could be one candidate source of biomass for bioethanol production due to the desirable chemical properties of having less lignin and high or similar content of cellulose compared to woody and herbaceous plants. Among the samples tested, the female stem of Napier grass is the best candidate to serve as a biomass for bioethanol production. Although there are some difficulties in glucose extraction due to the lignin-hemicellulose recalcitrant structures in the fibre, grass material can be pretreated with chemical pretreatment such as diluted alkaline. The significant low content of lignin allows easy extraction of hemicellulose and cellulose after being pretreated. Therefore, in considering the need for lignocellulosic biomass, Malaysia's local grass seems to be a potential candidate due to its abundant availability and its attractive chemical composition.

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The Dynamics of Radial Growth of Three Selected Tropical Tree Species Studied through Knife-cutting Method

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ABSTRACT

Tropical trees which lack distinct growth rings have caused difficulty in estimating the growth rate of those trees. This has resulted in limited knowledge concerning tropical tree growth pattern and rate of increment. This study aimed to assess the radial growth and cell production rate of three selected tropical species, namely, *Macaranga gigantea*, *Endospermum diadenum* and *Dipterocarpus costulatus*, with different diameters at breast height. For this purpose, knife-cutting method was adopted in this study. A knife was inserted through the bark into the outer xylem of a tree to wound the cambium and remove immediately. Wood discs containing wound area were collected from living trees after a period of time. Transverse sections of 20-25 µm in thickness were obtained through sliding microtome and dehydrated in a graded series of ethyl alcohol before staining with safranin and fast green. Dibutyl phthalate xylene (DPX) was used as a mounting medium for preparation of permanent microscope slides. The species-related anatomical response to wounding was identified and used to define the time of marking. Results show that radial growth rate and cell production rate varied across species and tree sizes. *M. gigantea* and *E. diadenum* showed faster growth rates than *D. costulatus*, especially in small diameter classes. Meanwhile, *D. costulatus* had the lowest growth rate and cell production rate. Thus, both the pioneer species are thus considered to grow faster in smaller stem size than larger stem size, while the study succeeding species grow faster in larger stem size than smaller stem size.

Keywords: Anatomical response, growth ring, pinning method, radial growth, tropical trees

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INTRODUCTION

Tree growth consists of axial growth and radial growth (Nobuchi & Sahri, 2008).

It is difficult to estimate the growth rate of tropical tree species as most of these trees lack distinct growth ring (Ohashi *et al.,* 2009). The absence of growth ring in tropical trees is believed as a result of less clear seasonality in the tropical areas (Rozendaal & Zuidema, 2011). The concept of continuous tree growth in the absence of distinct growth ring in tropical trees has been widely assumed (Lang & Knight, 1983; Lieberman *et al.,* 1985, Whitmore, 1990; Worbes, 2002; Nobuchi & Sahri, 2008), and thus, leading to limited knowledge concerning tree growth pattern and rate of increment in tropical trees (Ashton, 1981). Furthermore, studies on the cell production rate in tropical trees are still very much limited. Among other, Nobuchi and Hori (2008) investigated and compared the radial growth and cell production rate between temperate and tropical trees but the tropical species was only represented species i.e., *Eucalyptus camaldulensis.*

Several methods have been used to detect the radial growth rate of tropical trees (Worbes, 1995, 2002). Ohashi *et al.* (2009) stated that the approaches to assess radial growth of tree can be categorized into direct measurement of radial growth increment, such as dendrometer measurement and cambial marking (Ohashi *et al.,* 2001; Baker *et al.,* 2002; da Silva *et al.,* 2002; Mariaux, 1967; Shiokura, 1989; Nobuchi *et al.,* 1995; Sass *et al.,* 1995), and detection of periodicity of wood formation, which includes isotope analyses (Evans & Schrag, 2004; Poussart *et al.,* 2004; Verheyden *et al.,* 2004).

The knife-cutting method (Fujiwara, 1992), which was introduced to improve the pinning method (Wolter, 1968), is an excellent method to study cell production rate. It is a simple and easy method to implement in the field. It enables the timing of marking to be mark accurately and it can be used to study a range of small to large diameter trees (Nobuchi *et al.,* 1993). This method has been applied widely to temperate trees (Shimaji & Nagatsuka, 1971; Kuroda & Shimaji, 1983, 1984); however, it is still rarely applied to tropical trees (Veenin *et al.,* 2006).

The knife-cutting method causes small mechanical wound, which is used to define wood increment from the time of pinning without affecting the physiological process of a tree (Gričar, 2007). Hence, detail understanding of the anatomical response of a species to wounding is essential when implementing this technique (Nobuchi *et al.,* 1995; Kuroda & Kuyono, 1997; Mäkinen *et al.,* 2003; Schmitt *et al*., 2000, 2004).

The objective of the study was to assess the radial growth and cell production rate of *Macaranga gigantea*, *Endospermum diadenum* and *Dipterocarpus costulatus* through knife-cutting method. The species selected consists of tropical pioneer and late-successional species with diameter less than 20 cm and more than 25 cm at breast height (DBH). The comparative approach was used to study the cell production and growth rate of the study species. This is relevant to understand the natural process of forest dynamics, in which the processes are parts of the natural order after disturbance.

MATERIALS AND METHODS

Study Sites and Trees

The experimental site was located at Ayer Hitam Forest Reserve in Selangor, Malaysia. The forest which belongs to tropical rainforest is one of the Dipterocarp inland forests found in the state of Selangor (Faridah-Hanum & Khamis, 1999). The species selected for this study were *M. gigantea*, *E. diadenum* and *D. costulatus*, which were grown in compartment 14. The investigated tree species ranged from very high-light demanding species to shade tolerant species. *M. gigantea* and *E. diadenum* are tropical early successional species, while *D. costulatus* belongs to tropical late successional species (Soerianegara & Lemmens, 1994; Sosef *et al.,* 1998). All the sampled trees are evergreen throughout the year and the exact ages of the trees are unknown. Cambial marking was done to two trees for each species with different diameter ranges. Simple random sampling was adopted for the sampling technique. The descriptions of the sampled trees are shown in Table 1.

Meteorological Data

Throughout the research period, data on the monthly total rainfall and monthly mean temperature of the study site were collected from Pusat Pertanian Serdang Meteorological stations, Meteorological Department of Malaysia. The forest is categorized as rainforest area as it receives monthly rainfall of about 100 mm or more for the major part of a year. The highest rainfall was recorded in September 2010, with the total rainfall of 513.9 mm, whereas the lowest rainfall recorded during the observation period was in May 2011, with the total rainfall of 83.6 mm. The mean temperature ranges from 23.4˚C to 27.7˚C. The highest temperature was observed in May and June, while the lowest temperature was recorded in March. The maximum and minimum relative humidity was 79.1% and 66.9%, respectively.

Knife-cutting Marking

A knife of 0.2 mm in thickness and 10 mm in width was used for marking. Knife was inserted through the bark into the outer xylem of a tree to wound the cambium

TABLE 1
Descriptions of the sampled trees

Species (Family)	Tree Number	Diameter at breast height DBH (cm)
Macaranga gigantea	MGJ 1	13.0
(Euphorbiaceae)	MGM 1	28.6
Endospermum diadenum	EDJ 3	16.7
(Euphorbiaceae)	EDM 3	28.1
Dipterocarpus costulatus	DCJ 2	12.2
(Dipterocarpaceae)	DCM 3	27.2

(Nobuchi & Sahri, 2008). The knife was then removed immediately and the wound site was marked. This method was used on every sample tree on 26 August 2010.

Knife-cutting Sample Collection and Preparation

Wood disc containing wound area was collected from every sampled tree on 18 July 2011. Wood blocks with marked parts were then obtained from wood discs by handsaw. The wood blocks were then incised by handsaw through the centre of long slit-like wound tissue, separating the wood blocks into two parts (Nobuchi & Sahri, 2008; Veenin *et al.,* 2006). One part of the wood blocks was suitably trimmed to smaller size. Transverse sections of 20-25 μm in thickness were prepared using a Leica SM2000 microtome. The thin sections obtained through the sliding microtome were stained for light microscopy observation. A graded series of ethyl alcohol (30%, 50%, and 70%) was used for dehydration (Gričar, 2007). Double staining was adopted, in which sections were stained with Safranin overnight and followed by fast green (Nobuchi *et al.,* 1995). Next, the sections were rinsed off with 95% ethyl alcohol several times to remove excess fast green. Clove oil was then dropped on every section produced. Meanwhile dibutyl phthalate xylene (DPX) was used as a mounting medium for the preparation of permanent microscope slides. A microscopy observation was carried out with Leica Leitz DMRB Microscope.

Softening of Wood Blocks

Since only *D.costulatus* has very hard xylem, the blocks were then softened in Ethylenediamine (Imai *et al.,* 1995; Kukachka, 1978). In this research, wood blocks were treated with 4% Ethylenediamine for about one week before transferring to 50% Ethylalcohol. The wood blocks were then washed with distilled water and ready for sectioning.

Laboratory Analysis

The knife-cutting method was applied to calculate the rate of cell production in the study period (Nobuchi & Sahri, 2008). The total numbers of cells produced in the period between knife insertion and wood block collection were counted to investigate the cell production rate between the sample trees with different species and DBH. The method to calculate the cell production rate of the sample trees was the same as that used in the study by Nobuchi and Hori (2008), in which they compared the cambial activities between tropical and temperate trees. The outermost cell of S1 layer formation cells was used for measurements (Nobuchi & Hori, 2008). S1 formation cell during marking was the cell next to the innermost flattened cells to the pith side in the wound tissue. The initiation of S1 layer formation at the time of wood block collection was identified through polarized light microscope. The total number of cells between S1 layer formation cell line at the time of marking to the S1 layer formation cell line during wood block collected was counted as in Fig.1 (Nobuchi & Hori, 2008).

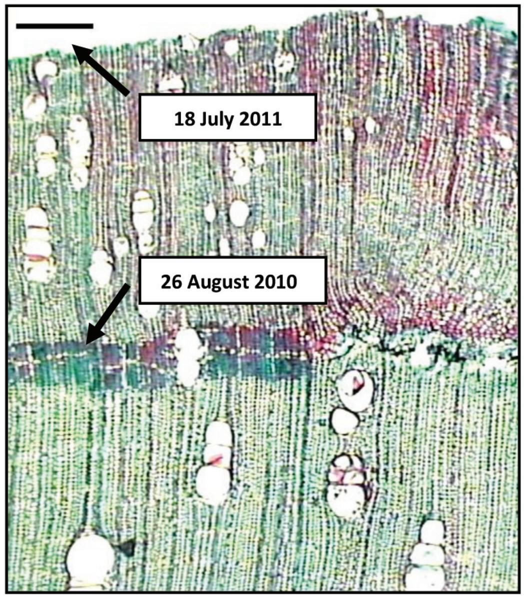

Fig.1: Light micrograph of pinned area showing estimated cambial initials at the time of pinning experiment (26 August 2010) and cambial initials at the time of wood block collection (18 July 2011). Scale bar = 500 µm.

In this study, all the sample trees have the same growing period. The pinning and wood block collection were done on 26 August 2010 and 18 July 2011, respectively, with a total of 326 days.

RESULTS AND DISCUSSION

Anatomical Characteristics of Growth Ring as a Reference Line

The characteristics of growth ring boundary, as a reference line, were investigated in transverse sections. Growth ring is necessary for the measurement of radial growth rate of trees in a given time (Nobuchi & Sahri, 2008).

The transverse sections of *M. gigantea*, *E. diadenum* and *D. costulatus* are shown in Fig.2. *M. gigantea* is diffuse-porous, while *E. diadenum* is semi-ring-porous. A detailed observation revealed that both species had growth rings. These two species showed distinct growth ring boundary in alteration of fibre cell walls thickness, which is useful as reference lines. The cells were radially flattened and had thicker fibre cell walls in the inner side of the boundary than on the outer side. However, *D. costulatus* did not have any distinct growth ring boundary as the cells structure changes were not visible. Sass *et al*. (1995) stated in their study that both *Dryobalanops sumatrensis* and *Shorea leprosula* from the *Dipterocarpaceae* family also do not form annual growth rings, and thus, determination of wood formation was difficult to make. Meanwhile, resin canals are abundant in this species and these are mostly formed in tangential bands, together with parenchyma, giving the impression of

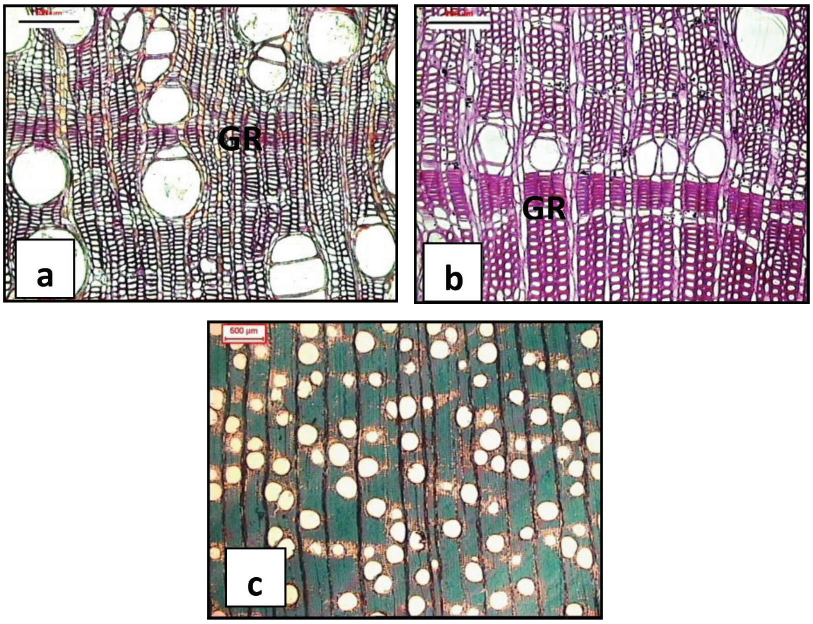

Fig.2: Transverse sections of: (a) *M. gigantean,* (b) *E. diadenum* showing the pattern of a growth-ring boundary with scale bar = 200 µm. GR: growth ring (c) *D.costulata* showing absent of growth ring with scale bar = 500 µm.

growth ring (Gottwald, 1958). Nonetheless, they often fail to run continuously around the stem and often become disappear (Sass *et al.,* 1995).

Anatomical Characteristics of Wound Tissue

The transverse sections of the wound tissues induced by cambial marking in *M. gigantea*, *E. diadenum* and *D. costulatus* are shown in Fig.3. Nobuchi *et al.* (1995) and Ogata *et al.* (1996) stated that wound tissues can be divided into two zones and both these zones were focused in this study. In zone 1, cambial initials and cells in the differentiating zone had been directly affected by the knife-cutting method, as shown in Fig.4. The cambial and enlarging zone cells in this zone were crushed and the cell wall formations were interrupted at the time of marking. They ceased their maturing and retained the cell wall organization at the time of marking, although the cells in this zone were deformed. The cells indicated by the arrowheads are the ones that were initiating S_1 layer formation at the time of pinning (Nobuchi & Sahri, 2008). In zone 2, the cambial and enlarging zone cells were not crushed but indirectly affected by the marking method with plasma membrane intact and showed abnormal differentiation. In this study, zone 1 is termed "directly affected zone" and zone 2 is "indirectly affected zone".

Fig.5 shows the structural characteristics of directly affected zone, which was observed under a polarization microscope and conventional illumination. The crushed

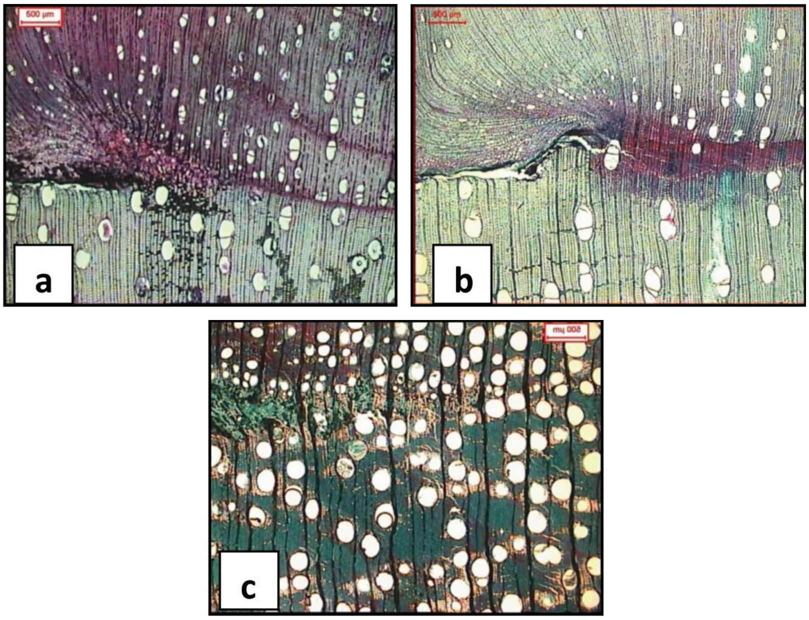

Fig.3:Transverse sections of wound tissue: (a) *M. gigantea,* (b) *E. diadenum,* and (c) *D. costulatus* Scale bar = 500 µm.

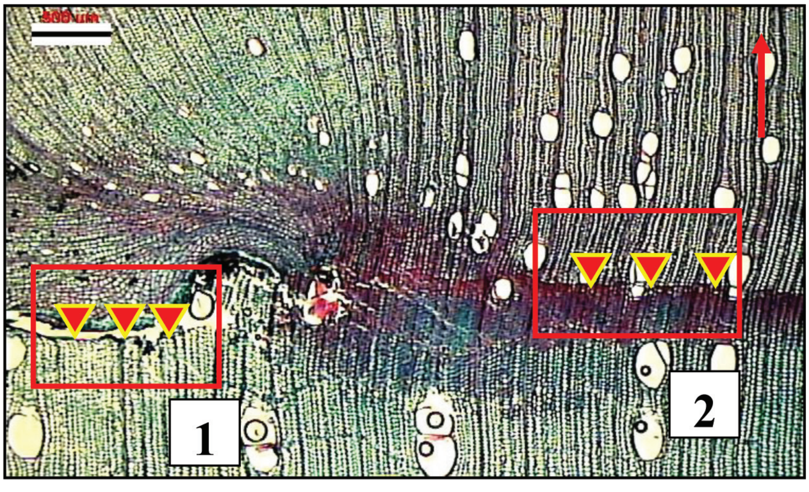

Fig.4: Transverse sections of *E. diadenum* showing wound tissues with two zones marked. Zone 1: tissues directly affected by pinning injury; arrowheads indicate the deduced site of the initiation of S_1 layer formation. Zone 2: tissues indirectly affected by pinning with tissue not crushed but showed abnormal differentiation; arrowheads indicate the deduced site of cambial initials. Arrow indicates the direction of the bark side. Scale bar = 500 µm.

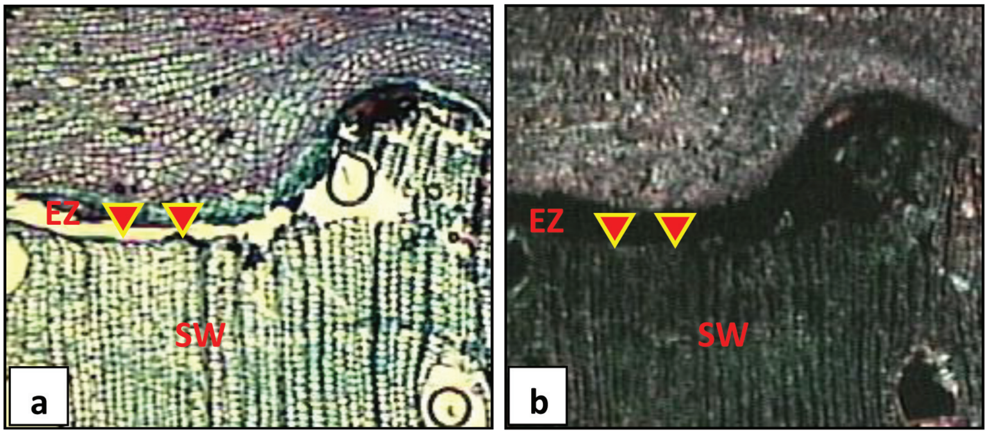

Fig.5: Transverse sections of directly affected zone, corresponding to zone 1 in Fig.3, observed under: (a) a polarization microscope, and (b) a conventional microscope in *E. diadenum*. Arrowheads indicate the deduced site of the initiation of S_1 layer formation. EZ, SW indicates enlarging zone and secondary wall at the time of pinning, respectively.

cells were considered as the cells of cambial while enlarging zone cells as those cells that showed no birefringence (Ogata *et al.,* 1996). The boundary between the crushed and non-crushed cells, as shown by arrowhead in the Fig.5, was therefore judged to be the boundary between the enlarging zone (EZ) and the secondary wall thickening zone (SW) (Ogata *et al.* 1996). The position of S_3 layer formation was not clarified in this experiment.

The anatomical characteristics of indirectly affected zone showed a region of normal wood cells (NW), radially flatten cells (FC), and small diameter vessel elements (SV), from the pith side to the bark side, as shown in Fig.6. Meanwhile, callus-liked cells (c) were formed near the side of marking. The callus-like cells, which corresponded to the enlarging zone cells in the directly affected zone, were believed to have formed by ray parenchyma cells in order to fill the gap formed after knife insertion (Ogata *et al.,* 1996; Nobuchi *et al.,* 1995). The layers of the radially flat cells were considered to be the cambial zone at the time of marking. They remained undifferentiated after marking, and therefore, retained the structural characteristics of cambial zone. However, it is not clear whether the radially flat cells included all the cambial zone cells (Ogata *et al.,* 1996). The cambial initials located above the layers of the radially flat cells were affected by the pinning but plasma membranes remain undestroyed. These cells are considered to have continued their physiological activity and to form wound tissues (Nobuchi *et al.,* 1995). In the region where small diameter vessels were formed, there were points where the number of cell rows increased tangentially, as shown in Fig.6. The small vessels abnormally differentiated from cambial cells were considered to have been affected by cambial

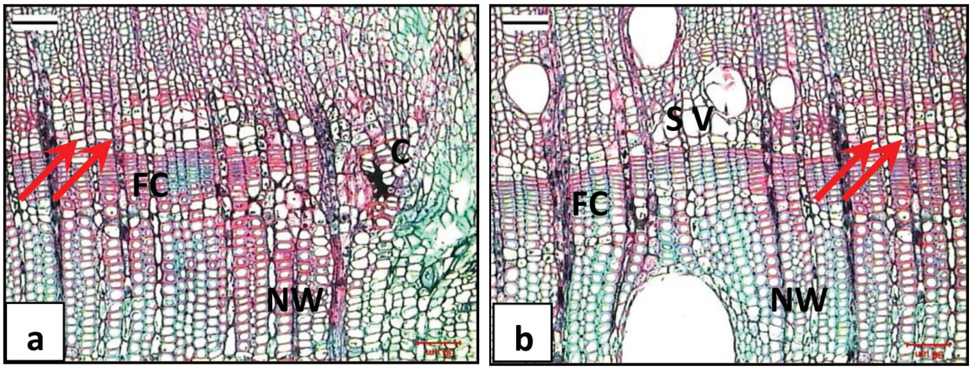

Fig.6: Transverse sections of *E. diadenum*: (a) near direct affected zone with callus tissue; (b) without callus tissues in zone 2 corresponding to indirectly influenced zone. NW: normal wood formed before marking; FC: radially flat cells showing undifferentiated cells affected by marking; C: callus-like cells corresponding to enlarging zone at the time of marking. Arrows show the location of anticlinal division. Scale bar = 30 µm.

marking. Hence, this region is believed to have formed after marking (Ogata *et al.,* 1996). The increases of the cell rows were caused by the anticlinal division of cambial initials. Similarly, Nobuchi *et al.* (1995) stated that the line, which connected to the innermost point of anticlinal division, was theoretically considered as the location of cambial initials at the time of pinning. Thus, it adopted as the marker of the cambial initial at the time of pinning and used for the measurements.

The anatomical characteristics of *M. gigantea* and *D. costulatus,* which include their marking of cambial initials and the cell region having S_1 layer formation, are basically similarly to *E.diadenum*.

Traumatic Resin Canals

In this study, traumatic resin canals were observed in *D. costulatus* but not in *M. gigantea* and *E. diadenum*. Fig.7 shows a sample of the traumatic resin canals in *D. costulatus*. The traumatic resin canals were formed towards the bark side of the line of the estimated cambial initials at the time of marking. Kuroda and Shimaji (1983) and Shiokura (1989) used resin canals to estimate the position of cambial initials at the time of marking. In this study, the formations of traumatic resin canals were not used as the markers of cambial position because they did not reveal the exact position of cambium at the time of pinning.

Cell Production Rate

Table 2 shows the total number of the cells produced in all the sampled trees during the observation period. The results showed that radial growth rate and cell production rate varied with species and tree sizes. Nabeshima *et al.* (2010) stated that the diameter growth of living trees may be different, depending on the tree species, size

TABLE 2
Radial growth and rate of cell production

Species	DBH (cm)	Radial growth (mm)	Rate of radial growth (µm/day)	Number of cells	Rate of cell production (Number/day)
Macaranga gigantea	≤ 20	4987.22	15.30	319	1.0
	> 25	3023.41	9.27	188	0.6
Endospermum diadenum	≤ 20	7643.13	23.45	386	1.2
	> 25	2207.72	6.77	121	0.4
Dipterocarpuscostulatus	≤ 20	1609.52	4.94	68	0.2
	> 25	2164.46	6.64	113	0.3

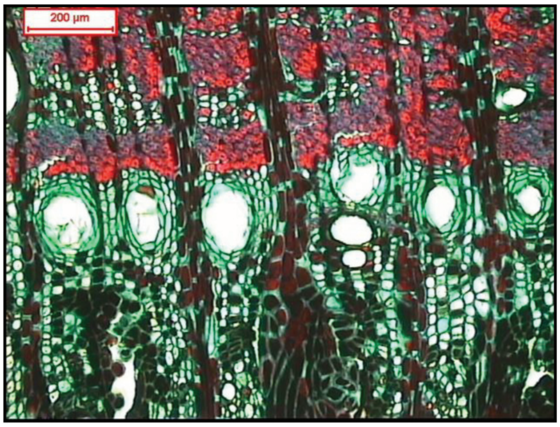

Fig.7: Transverse sections of *D. costulatus* showing traumatic resin canals.
Scale bar = 200 µm

and other tree-relating factors. Theoretical and ecophysiological studies also suggest that tree growth is closely associated with their sizes (Hubbard *et al.,* 1999; Enquist, 2002, Midgley, 2003; McDowell *et al.,* 2005; Nabeshima & Hiura, 2007) rather than with the age of trees (Mencuccini *et al.,* 2005; Matsuzaki *et al.,* 2005; Bond *et al.,* 2007).

During the research period, the two pioneer species, namely, *M. gigantea* and *E. diadenum*, showed higher radial growth rate and cell production rate compared to the non-pioneer *D.costulatus*, especially in small diameter classes. In particular, *E. diadenum* with DBH ≤ 20 cm showed the highest growth rate and cell production rate (number/days) in all the sample trees. On the contrary, *D. costulatus* had the lowest growth rate and cell production rate among all the species investigated. This might be due to the fact that most shade-tolerant species and late succession species have low growth rates (Franklin, 2003). Meanwhile, short-lived pioneers are required to grow faster as they normally cannot withstand and die in shade. Such species normally grow better in areas with the greatest crown exposure (Manokaran & Kochummen, 1992).

According to a research by Kohyama *et al.* (2003) on tree size and growth rate, as a tree diameter increases, the diameter growth rate will decrease. This phenomenon can be seen in *M. gigantea* and *E. diadenum* but not in *D. costulatus*. Both light-demanding pioneer species, with DBH less than 20cm, produced a high growth rate as compared to DBH that is more than 25cm, in which the growth rate drop rapidly. The growth advantage of the pioneers lost with the increasing in the tree size. However, Nabeshima *et al.* (2010) stated that the growth rate of tree would depend on DBH. The research found that the growth of *Acer mono* increased with DBH, while other species (such as *Ostrya japonica*, *Quercus crispula* and *Magnolia obovata*) increased their initial growth that subsequently declined with increasing DBH.

D. costulatus showed much slower growth rates than the other two species. In their study, Manokaran and Kochummen (1992) stated that shade-intolerant understorey species grew much slower than the other tree species. Short-lived shade intolerant species grow at a higher rate than long-lived shade tolerant species and this is believed to be due to their higher intrinsic growth rates at a given irradiance, as well as in high-light site characteristics in canopy gab (Swaine, 1994; Baker *et al.,* 2003). Trees that grow in the understorey of tropical forests usually lack lights, and resulting in very low diameter growth rates (Chazdon & Fetcher, 1984; Clark & Clark, 1999).

D. costulatus with DBH above 25 cm has higher radial growth rate than tree with DBH smaller than 20 cm. This is due to the fact that when trees grow to a certain canopy level, they grow more rapidly to compete for survival. Manokaran and Kochummen (1992) documented that individual canopy species, especially Dipterocarps, are more likely to grow at relatively fast rates so as to reach larger size in a fairly short time.

The results of this study have clearly shown the radial growth characteristics of tropical pioneer and succeeding species. Both the pioneer trees that grow under relatively sunlit conditions throughout their lifecycle have different growth patterns as compared to the tropical succeeding tree species which grow from shaded to sunlight conditions in their lifecycle.

CONCLUSION

The results reveal that species type and size are important elements in describing the radial growth and cell production of a tree. During the research period, radial growth rate and cell production rate varied with species and tree sizes. Generally, *M. gigantea* and *E. diadenum,* which belong to the pioneer species, have higher radial growth and cell production rate than *D. costulatus*, which is a succeeding species in forest succession. *M. gigantea* and *E. diadenum* with DBH less than 20 cm have higher cell productions and radial growth rates than those trees with DBH greater than 25 cm. Both the pioneer species grew faster in smaller stem size than larger stem size. In *D. costulatus*, trees with DBH greater than 25 cm have slightly higher cell production and radial growth rate than tree with DBH less than 20 cm. This means this species grows faster during larger stem size than smaller stem size.

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Effects of Felling Intensities on *Gigantochloa ligulata* Bamboo for Improvement of Shoot Production

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ABSTRACT

Gigantochloa ligulata (buluh tumpat) is considered as one of the commercial bamboo species in Malaysia. Owing to its demand as food, especially in the northern part of the country and since it is relevant to improve production of bamboo shoots, a study on the effects of felling intensity as one of the silvicultural treatments on *G. ligulata* bamboo was conducted at Taman Wetland, in Putrajaya, Malaysia. Three culm felling intensities were applied for four months in 2005. The felling intensities of 0% (control), 30% and 60% were applied twice every two months within the four-month period. There were six replications done and 3kg of organic fertilizer was also applied. The number of shoots sprouted and their weights, including culm number, were monitored. The clump expansion pattern of selected treatment clumps were observed for dead and new shoots sprouted. The shoots were tagged and recorded every week. A shoot, which grew up to 30cm and from the ground, was considered as a shoot. The weights of the shoots with sheath were recorded on a weekly basis. The distribution pattern of the shoot sprouting was also observed. It was found that 30% felling intensity gave extra four shoots, as compared to other intensities, including the control with a value of 0.009 for both the treatments at 0.05 probability level.

Keywords: Gigantochloa ligulata, felling intensities, shoot, weight, culm, clump

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INTRODUCTION

Malaysian bamboos can be found in ex-logging areas and in rural villages

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throughout the country. There are about 70 species of bamboos, out of which 59 are found in Peninsular Malaysia. According to Wong (1995), there are 14 bamboo species (namely, *B. blumeana, B. heterostachya, B. vulgaris, B. vulgaris* var. *striata, D. asper, G. levis, G. ligulata, G. scortechinii, G. wrayi, S. brachycladum, S. grande, S. zollingeri*) that are commonly exploited for commercial purposes. Malaysian bamboos grow profusely in ex-logging areas throughout the country (Azmy 1991), including on hill slopes, riverbanks and flat lands (Ng & Md Noor, 1980).

Bamboo shoots have been relished as food since the early days. Ever since the increase in the consumption of bamboo shoots, the demands for the resources have increased as well (Razak & Jamaludin, 1998). In order to cater for the demands of bamboo shoots, silvicultural treatments such as felling of culms need to be adhered to so as to improve production of shoots, especially in the rural areas. There are two studies on the felling of *Gigantochloa scortechinii* natural stand bamboos in Malaysia. According to Azmy *et al.* (1987), there was a 30% increase in the number of shoots sprouting after 40% felling intensity was applied. Meanwhile, a 60% felling intensity showed an increase in the diameter of *G. scortechinii* (Abd Razak & Azmy, 2009). In 1986, a V-shaped formed of culm distribution pattern within the clump after felling treatments was found to have improved the productivity of *Dendrocalamus strictus* from 6.6 to 8.6 culms per clump. M-shaped thinning was also attempted in 1990 at Joldal area in Bhadravathi Forest Division, in India (Lakshmana 1990). Varmah and Bahadur (1980) stated that felling all culms, except the newly produced culms, would either result in high mortality or a number with poor quality culms.

According to Sharma (1980), bamboo grown areas in the forests of India, Bangladesh, Burma, and Japan bamboo are generally managed according to the “culms selection method”. This method generally removes poor quality culms and retains one or two mature culms which are adjacent to new culms to provide better stability. Ueda (1960) suggested that bamboos of one to three year old must always be left in reserve, cutting culms only over four years old, for the development of new culms. In Indonesia, Yudodibroto (1985) reported that bamboo stands were also harvested selectively.

In order to have a sustainable supply of bamboo shoots in Malaysia and since felling of bamboo culms tends to increase the yield of bamboo shoots, based on studies of other species, it is relevant to conduct a study on the felling of *Gigantochloa ligulata* Gamble (buluh tumpat) to improve shoot production. Thus, a study on the effects of felling intensity on this particular species was carried out at Taman Wetland in Putrajaya to determine the best felling intensity terms of shoot yield. In addition, the distribution pattern of shoots pattern within the clump was also observed.

MATERIALS AND METHODS

The study on the effects of felling intensity on *G. ligulata* bamboo was conducted at Taman Wetland, in Putrajaya, Malaysia. It started from March to June 2005. Meanwhile, the thinning intensities of 0% (control), 30% and 60% were applied twice every two months within the four-month period. The three felling intensities, including the control, were done with six replicates and these altogether comprised of 18 samples clumps. Felling was based on the selection of culms of three year old and above out of the total culms available within the clump. For example, thinning of 30% means three mature culms of three year old and above out of ten culms within the clump were felled. Each clump in all the replicates was applied with 3kg of goat dung of granule form. The organic fertilizer was applied in a circular form around the clump's periphery. The parameters involved were the number of shoots sprouted and the weight of shoots. New shoots were tagged and recorded every week to determine the frequency of the shoots sprouted. A shoot up to 30cm from the ground was considered a shoot. The weights of shoots with sheath were recorded on a weekly basis. In addition, the distribution pattern of the shoots sprouting within the clump area was also observed. The climatic data for the study site from July 2004 to July 2005 and the average soil pH within the experimental area were also taken.

RESULTS AND DISCUSSION

Number of Shoots Sprouted

In Table 1, the F value is 13.13 and the significant level is 0.000. This means there is a significant difference in the number of shoots between the treatments. Only treatment 3 (60%) was found to be not significant.

As shown in Fig.1, Treatment 2 (30% thinning) produced more shoots as compared to Treatment 1 (control) and Treatment 3 (60% thinning) based on the number of shoots sprouted. The maximum number of shoots sprouted is 6, i.e. in week 8 for Treatment 2 (30% thinning). Meanwhile, Treatment 3 (60% thinning) gave the second highest number of shoots sprouted.

TABLE 1
ANOVA of the number of new shoots sprouted

Source of Variation	N	Df	Mean	Mean Square	F value
Treatment		2		62.235	13.13*
Treatment 1 (Control)	6		1.36*		
Treatment 2 (30%)	6		2.68*		
Treatment 3 (60%)	6		1.36ns		
Error		16		4.74	
Total	18	17			

*The mean difference is significant at 0.05 level.
Ns: The mean difference is not significant at 0.05 level.

Weight of Shoots

From Table 2, the F value is 5.826 and the significant level is 0.003. This indicates that there are significant differences between the treatments in terms of their weights of shoots with sheaths.

The total rainfall throughout the study period, i.e. from March to June 2005, was found to have affected the sprouting of the shoots. In March, the rainfall recorded was 200.6 mm and four shoots sprouted, whereas in April, 164 mm rainfall with three shoots sprouted, and in May and June, the rainfall recorded 70 mm and 26.4 mm, respectively, with only one shoot sprouted each. Meanwhile, the average soil pH was 4.87 and the soil temperature was 27.9°C.

Based on the three thinning treatments, Treatment 2 (30% thinning) showed a positive effect on shoot growth over the study period. Nonetheless, Treatment 3 (60% thinning) did not show any improvement over the control. With the increasing number of shoots sprouted, the weight of shoots also increased.

Clump Expansion Pattern

Fig.2 shows the original clumps with the distribution of all the initial available culms before the felling. After the first felling was done according to the assigned felling intensities of 0, 30% and 60% (see Fig.3), the new shoots of *G. ligulata* (buluh tumpat) sprouted not only along the clump peripheries but also within the clumps, especially with 60% thinning intensity (the first month after felling), as illustrated in Fig.4.

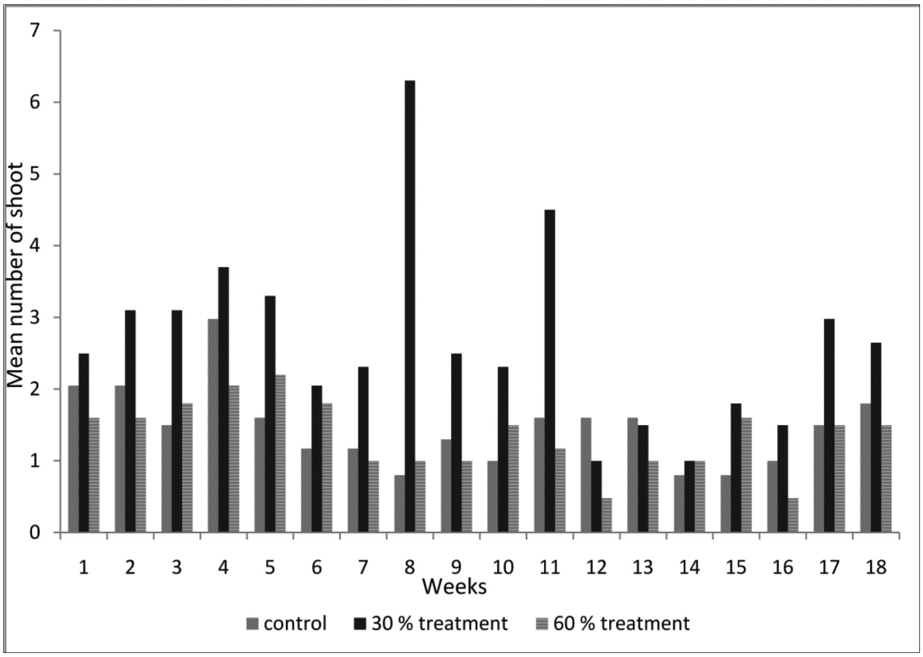

Fig.1: The mean numbers of shoots sprouted over the 18-week period

TABLE 2
ANOVA of the weights of shoots with sheaths

Source of Variation	N	Df	Mean	Mean square	F value
Treatment		2		62316.26	5.826*
Treatment 1 (Control)	6		147.23 *		
Treatment 2 (30%)	6		184.0 *		
Treatment 3 (60%)	6		138.84ns		
Error		16		10695.324	
Total	18	17			

*The mean difference is significant at 0.05 level
Ns: The mean difference is not significant at 0.05 level

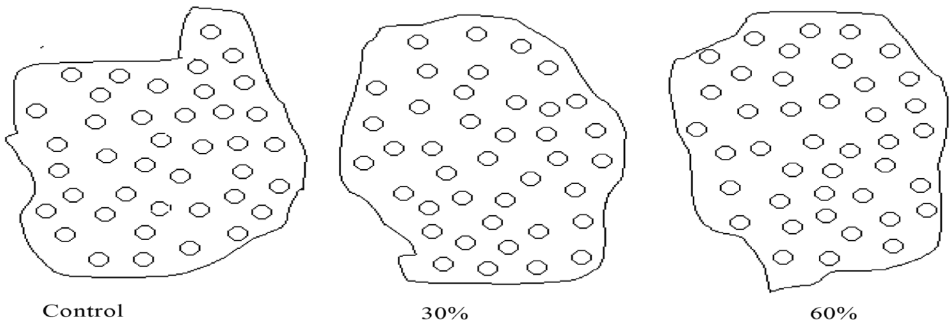

Fig.2: Dispersion map of the standing clump of *G. ligulata* in Putrajaya

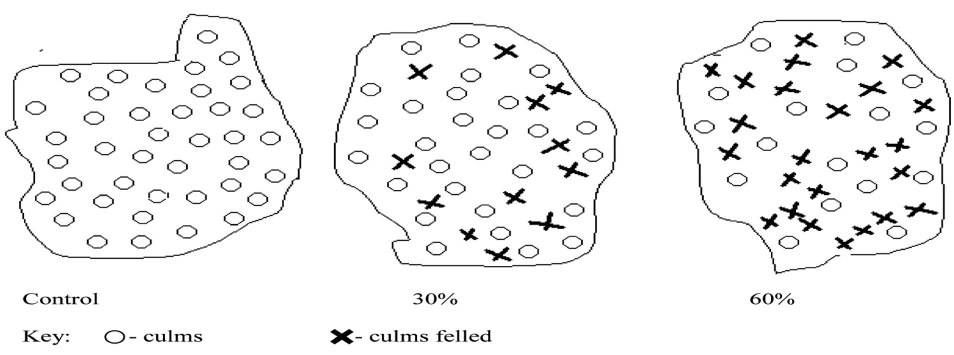

Fig.3: Dispersion map of *G. ligulata* clump in Putrajaya (the first felling)

The sprouting patterns of the shoots in Fig.5 and Fig.6 nearly resembled that in Fig.4, except that in Fig.6, dead shoots appeared within the clumps. Meanwhile, Fig.7 shows that the dead shoots were seen not only along the clump peripheries, especially for the control and the 60% felling intensity, but within all areas of the clumps, specifically for the 60% felling. From the observations, clumps might

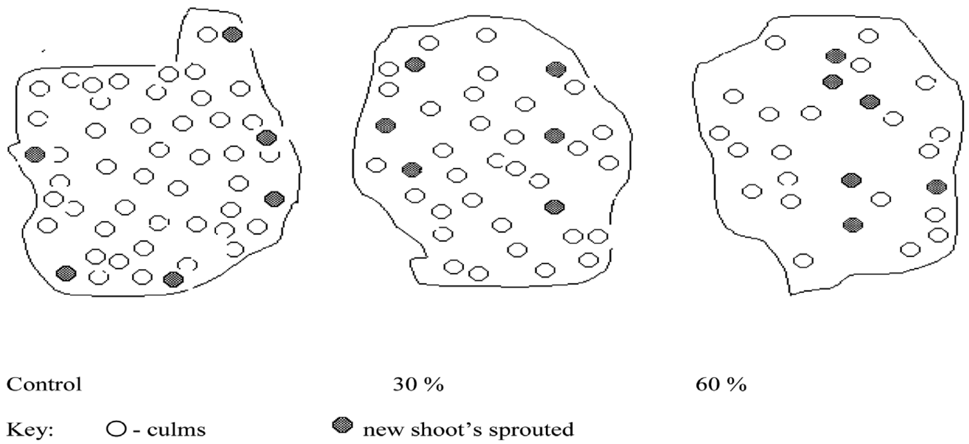

Fig.4: Dispersion map of *G. ligulata* clumps in Putrajaya (the first month after felling)

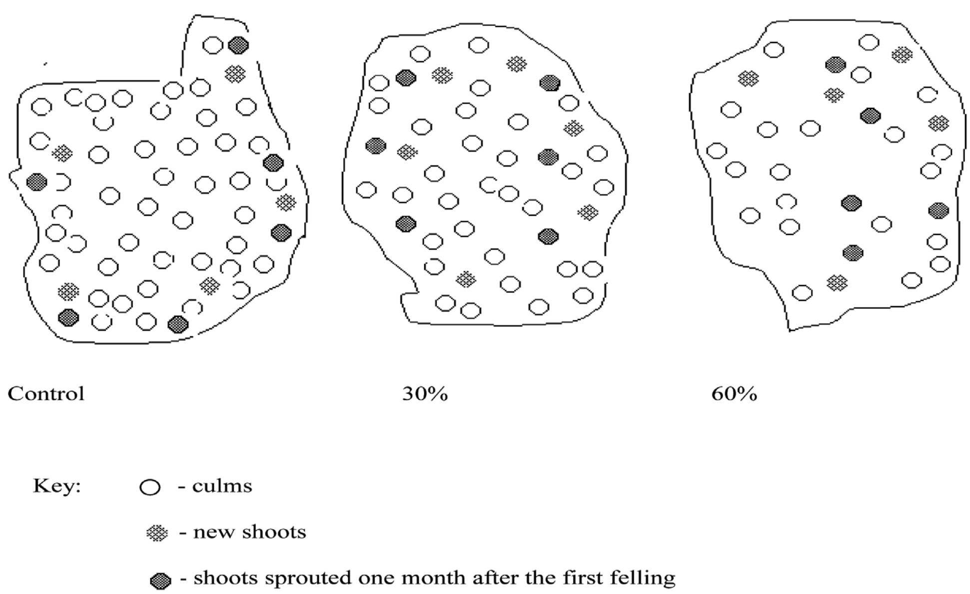

Fig.5: Dispersion map of *Gigantochloa ligulata* clump in Putrajaya (second month after the first felling)

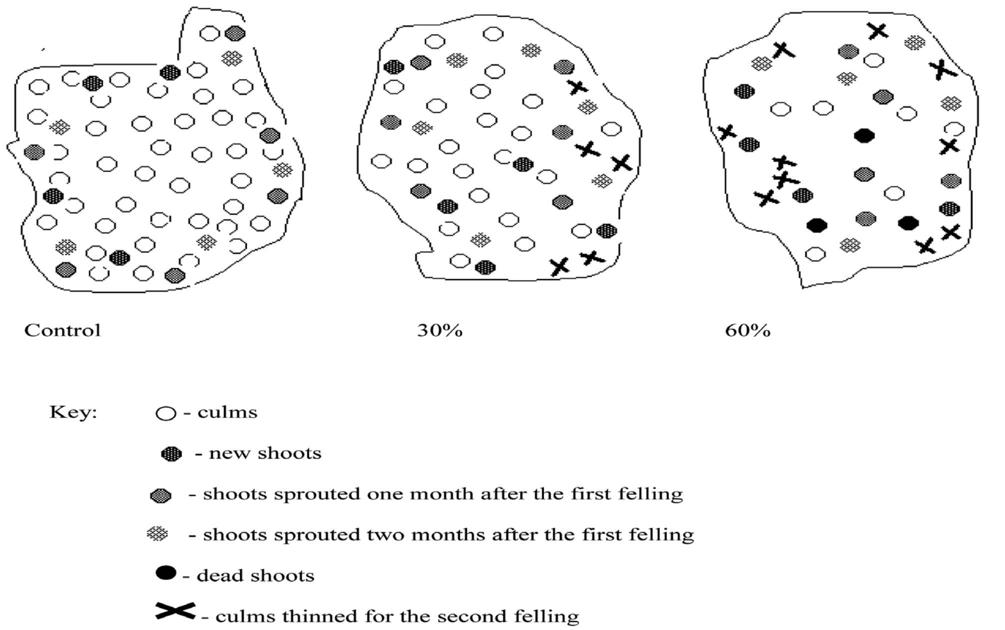

Fig.6: Dispersion map of *G. ligulata* clumps in Putrajaya (third month and after the first and second felling)

expand outwards, i.e. beyond their initial peripheries with the new shoots sprouting within the clumps at available spaces. When the felling was increased from 30% to 60%, it resulted in more dead shoots. According to Azmy (1999), from the regeneration sprouting pattern of shoots without any felling treatments, the clumps with 10 to 30 per clump tended to have the shoots sprouting along the clump's periphery and at the centre of the clumps. This sprouting pattern of shoots was also observed in this study for all the felling treatments. Thus, the shoot sprouting pattern is the same for both the natural stand bamboos of *Gigantochloa scortechinii* and *Gigantochloa ligulata* species in this study. As illustrated in Figure 8, the rainfall from February to April 2005 was between 210 and 180mm and this caused the increase in the number of shoots sprouted between 6 to 4.5 for week 8 and week 11 consecutively. Therefore, rainfall plays an important role in the sprouting of shoots.

CONCLUSION

In this study, 30% felling produced more shoots and higher maximum weights of shoots than 60% felling and the control. This 30% felling was shown to be the best treatment to yield quality and also more shoots of *Gigantochloa ligulata Gamble* (buluh tumpat).

According to Zhou (1981), climate, topography and soil affect the growth and distribution of bamboos. In addition, rain has also been found to help in bamboo shoot production, especially for *Gigantochloa ligulata*.

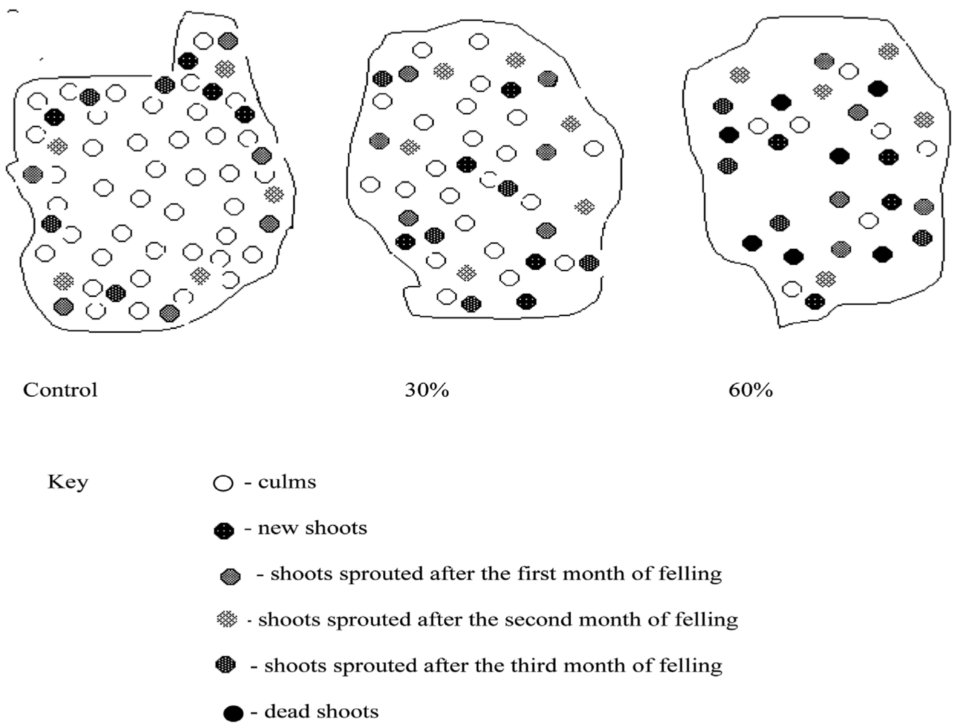

Fig.7: Dispersion map of *Gigantochloa ligulata* clump in Putrajaya (fourth month and after the second felling)

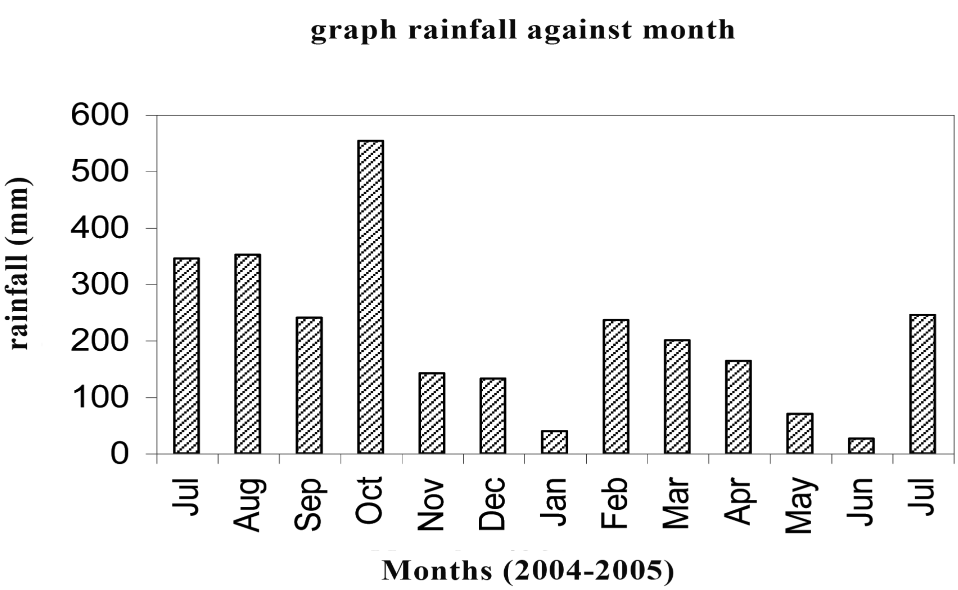

Fig.8: Climatic pattern at the study site (Taman Wetland, Putrajaya) (Source: Perbadanan Putrajaya)

Based on the results of this study, felling bamboo culms helps to increase the number of bamboo shoot sprouts of *G. ligulata*. This will have a bearing on the production of bamboo shoots as food supplement in combating and augmenting future food supply. Thus, the recommended bamboo treatments, especially ones that involve felling process, should be of help to managers and silviculturist involved in planting bamboos for future bamboo shoot productions. In addition, silvicultural can help to increase the income of entrepreneurs, especially for large scale bamboo plantations for shoot production.

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Appraisal of Urban Trees Value Using Thyer Method

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ABSTRACT

Urban tree-planting provides not only environmental benefits, but it also has significant value both socially and economically. Unfortunately, the economic benefits of urban trees are difficult to estimate due to the absence of a well-defined market. A range of methods have been developed to estimate the economic value of urban trees. Hence, this study attempted to appraise the value of urban trees in Kuala Lumpur using the Thyer method. Five hundred and three trees were selected upon consultation with Kuala Lumpur City Hall, and this was followed by field observations, which were carried out with the aim to document tree species, age, circumference, height, crown diameter and tree characteristics. Results indicated that *Pterocarpus indicus* has the highest value, with an estimated mean tree value of RM972,660. Meanwhile, the mean value per tree was estimated at RM435,851. However, the value of urban trees differs with respect to the physical and qualitative characteristics of the tree.

Keywords: Economic benefit, Kuala Lumpur, tree characteristics, tree value.

INTRODUCTION

The rising demand for green space in urban areas such as Kuala Lumpur resonates in most cities throughout the country. Therefore, a developing country like Malaysia should recognise the importance of sustainable management of urban planning in its decision-making process. The principle of sustainable management of urban areas acknowledges this crucial demand and it is reflected in its recommendations.

Up to now, there have been many programmes implemented by the government to increase green spaces such as planting trees along many roads, both in residential areas and urban parks. However, not many appreciate or even understand the

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innumerable benefits that come with urban tree-planting. Not only it benefits the area from an environmental perspective, it also generates economic benefits as well as other intangible benefits (social well-being and aesthetic values) to the urban communities.

Nonetheless, to set a numerical value on these benefits is a challenging task. One of the main reasons is the fact that the market price for these benefits is non-existent. Thus, the absence of such value has led to underestimation of the true values of these benefits and thus has artificially skewed many planning policies and programmes by allocating urban tree-planting the least attention.

Fortunately, there are several methodologies that can be utilised to appraise the value of urban trees in order to provide accurate information for policy-makers to make well-informed decisions.

In the past, researchers used various methodologies to appraise urban tree values. These include the Helliwell (Helliwell, 1967) – Great Britain; Burnley (McGarry & Moore, 1988) – Australia; Standard Tree Evaluation Method (STEM) (Flook, 1996) – New Zealand; Norma Granada (Asociación Española de Parques y Jardines Públicos, 1999) – Spain; Council of Landscape and Tree Appraisers (CTLA) (CTLA, 2000) – United States, Thyer Tree Valuation Method – Australia (Thyer, 2002); and VAT03 Model – Denmark (Randrup, 2005).

Watson (2002) evaluated a range of methodologies for tree appraisals. These include Helliwell, Burnley, Standard Tree Evaluation Method (STEM), Norma Granada and Council of Landscape and Tree Appraisers (CTLA). Nine appraisers have evaluated six different species using these methodologies. During the calculations, the disparities between the findings by the appraisers have a strong positive relationship between the coefficient of variation (CoV) and the mathematical operations.

Therefore, the reliability of the appraised methodologies may weaken if the results from the appraisers vary too greatly. In addition, the value of the appraisals may vary due to several factors such as tree size, species, location, condition and special factor. Moreover, these methodologies may provide an understanding of the values of public trees in the designated green areas through the provision of some good indicators.

In general, urban trees are considered as public goods and the maintenance cost is borne entirely using public funds. Often, these urban tree-planting programmes require significant amounts of financial investment. Therefore, an estimated true value of tree-planting may justify public funding of such programme. In Malaysia, research in this area is still very limited and currently, there is generally no well-accepted methodology available to appraise the value of urban trees.

Based on the realisation of the potential greater value of such programme, for the first time, this study attempted to appraise the value of urban trees in Malaysia. In specific, this study aimed to estimate the true value of urban trees in Kuala Lumpur, Malaysia, using the Thyer method.

MATERIAL AND METHODS

Study Site

The study was conducted in the capital city of Kuala Lumpur, Malaysia. The city is located between 03° 10’ 00’’ N latitude and 101° 42’ 00’’ E longitude. Kuala Lumpur has been ear-marked as a major development area to be awarded a modern city status by 2020 (KLCH, 2003 & 2007).

Tree Selection

The selection of urban trees to be appraised was based on consultations with the Department of Landscape and Recreation of Kuala Lumpur City Hall. The urban trees under the scope of study are located along five major roads, namely; *Jalan* Ampang, *Jalan* Cheras, *Jalan* Kuching, *Jalan* Raja Laut and *Jalan* Sultan Ismail. These roads were chosen based on their status as “protocol roads” or main roads that lead to administrative buildings such as the Kuala Lumpur City Hall, Bank Negara, and other significant areas in Kuala Lumpur (Sharifah Dora, personal communication, 2009).

There are ten popular species of urban trees planted along these roads. The trees are *Acacia holosericea* (Akasia perak), *Bauhinia* spp. (Tapak kuda), *Calophyllum inophyllum* (Bintangor laut), *Ficus benjamina* (Ara), *Hopea odorata* (Merawan siput jantan), *Mimusops elengi* (Bunga tanjung), *Pelthophorum pterocarpum* (Jemerlang), *Pterocarpus indicus* (Angsana), *Samanea saman* (Rain tree) and *Tabebuia pallida* (Pink tecoma). All these trees were tagged and meticulously recorded by the Kuala Lumpur City Hall.

As stated earlier, this study attempted to apply the Thyer method as a means to appraise the value of urban trees. This method was chosen as it is a widely used methodology given the availability of data. The Thyer method requires data to be collected and collated using field data sheets. These data sheets contain information of measurements and observations in relation to the physical characteristics and qualitative features of the trees. Other information required includes tree inventory reports and planting costs, which were made available by Kuala Lumpur City Hall.

Data and information from 503 trees were measured and recorded (namely, the physical and qualitative characteristics). The measurements include the diameter at breast height (dbh), tree height, circumferences and crown diameter. The qualitative characteristics of each tree included vigour, condition, structure, health condition, quality, special situation, and quality characteristics. These qualitative characteristics were measured based on the qualitative score in accordance to the Thyer method.

Appraisal Method

Thyer Method

The Thyer method was developed in Sydney, Australia in 1984 (Thyer, 2002). The valuation reflects the contribution that trees render to the landscape, an expression of the positive qualities of the tree, and the extent to which these are appreciated. According to Thyer, the valuation for this method include measurements of several factors such as the size factor (S), age factor (A), physical and social qualities factor (Q), significant index (SI) and the planting cost (P) of trees in order to obtain the value of urban trees (V).

All measurements for the attributes of size factors (S) were calculated in meters, including tree height, area of canopy from side view, average diameter to dripline and tree circumference. A Haga altimeter was used to measure and to record tree height. The recordings were taken at a distance of 15 meters from any standing tree. The reason for this distance was to avoid trees fronting the measured trees, which tended to block the reading of tree height. If the measurements were taken at a further distance (> 15 meters), the view of crown height would overlap with the front trees. Additionally, diameter and tree circumference readings were recorded at 1.3 meters above the ground at breast height (dbh). This is a standard measurement for tree diameter in forestry study.

The Thyer method applies a standard parameter in the calculation of the age factor (A) through the assessment of tree age, multiply by 0.02 and adding 0.5. The physical and social qualities factors (Q) were calculated based on qualitative score. The indicators for the physical qualities factors (Qi) are the health of the trees, environmental benefits, life expectancy beyond the present time, re-establishment potential of the same species on site, and the rate of growth over the first 10 years. Meanwhile, the scales for the physical quality factors (Qi) range from the scores of 0, 1, 2, 4 and 8. In addition, the indicators for the social quality factors (Qii) are social benefits, form and features, as well as social significance. The scales for social quality factors (Qii) scores are 0, 2, 4, 8 and 16. The scores for the total Qi scores were then added with the total scores of Qii to obtain the physical and social qualities factors (Q). The significant index (SI) was calculated through the multiplication of the size factor (S), age factor (A), and physical and social factors (Q).

Data on planting cost (P) was obtained based on the average landscape industry rate report provided by the Kuala Lumpur City Hall for various species and tree sizes. The formula to calculate the value of a tree is as follows:

Tree value (V)
= significance index (SI) [size factor (S) × age factor (A) × physical and social qualities factors (Q)] × planting cost (P)

[1]

Statistical Analysis

Statistical analysis and description of the data for the urban trees include the mean, minimum, maximum and standard deviation. In this study, the mean value of urban trees was calculated based on the species, diameter class and height class. In addition, the relationship between height and diameter at breast height (dbh), as well as between crown diameter and diameter at breast height, (dbh) was also examined.

RESULTS AND DISCUSSION

The characteristics of the urban trees measured, based on the selected urban tree species, are presented in Table 1. The results of this study indicated that *P. indicus* has the highest mean height of 22.52m, mean diameter at breast height (dbh) of 66.64cm, mean crown diameter of 14.51m, mean circumference of 2.09m, mean age of 74 years, mean tree volume of 2.85m^3 and mean significant index (SI) of 1095.34. A possible explanation for this is that *Pterocarpus indicus* is a fast growing tree and it provides much needed shades within the shortest growth time (Wee & Corlett, 1986).

Fig.1 presents the relationship between tree height and *dbh*, while Figure 2 shows the relationship between tree crown diameter and *dbh*. Both the figures demonstrate that there is a positive relationship between tree parameters, height and *dbh*, r = 0.442, and crown diameter and *dbh*, r= 0.524. The positive correlation signifies that as tree height and crown diameter increase, there are corresponding increases in the *dbh* of urban tree species as well. As the r value gets nearer to 1, the relationship between tree height and *dbh* becomes stronger.

Table 2 presents the overall estimated tree values. The average tree value ranges from RM82,953 to RM972,660. The estimated total value of 503 observed urban trees is RM4,358,510 and the mean value per tree is RM435,851. The highest tree value is indicated for *P. indicus*, with the estimated mean value of RM972,660 per tree. The tree attributes that affect the value of trees include tree height, *dbh*, crown diameter, planting cost and the significance index.

The estimated mean values for each species, based on the tree height class, are presented in Table 3. Five species, namely, *A. holosericea*, *Bauhinia* spp., *H. odorata*, *P. pterocarpum* and *S. saman,* show a positive relationship between mean tree values and tree height class. Among the selected species, *C. inophyllum* shows that the mean tree value is negatively correlated with tree height class. Most of the urban trees in the study area are planted within good planting distance; therefore, the crown diameter of the trees is able to grow unobstructed by adjacent trees.

The results reveal that *S. saman* species has the highest mean tree value with respect to tree height class, which is amounted to RM5,637,578. The estimated mean tree values ranged from RM144,870 to RM1,395,182.

Table 4 depicts the estimated tree values for each species based on tree *dbh* class. The five species, namely *Bauhinia* spp., *C. inophyllum*, *H. odorata*, *P. indicus* and *T. pallida,* reveal that the mean tree value is positively related with tree *dbh*. Meanwhile, *T. pallida* provides the highest mean tree value with respect to tree *dbh* class, which is, RM4,934,034 per tree. The estimated mean tree value ranged from RM231,298 to RM1,647,600. The urban trees that are in good condition possess higher potential to expand its *dbh* over time. Most urban trees within the study scope are in dire state. In more specific, there are insufficient room for the roots to grow and thus the growth

TABLE 1
Descriptive statistics of tree characteristics by species

Tree Species	N		Tree Height (m)	Crown Diameter (m)	Circumference (m)	Dbh (cm)	Tree Age (years)	Significance Index (SI)
Acacia holosericea	11	Mean	16.41	12.10	1.30	41.37	46	510.47
		Std. Deviation	3.47	1.47	0.70	22.20	25	164.16
		Variance	12.07	2.15	0.49	492.81	607	26,949.10
Bauhinia spp.	7	Mean	8.66	7.09	0.79	25.17	28	93.41
		Std. Deviation	2.87	2.86	0.11	3.62	4	46.61
		Variance	8.23	8.17	0.01	13.13	15	2,172.67
Calophyllum inophyllum	15	Mean	10.90	8.32	1.21	38.60	43	187.00
		Std. Deviation	1.11	0.40	0.25	7.88	9	77.06
		Variance	1.22	0.16	0.06	62.17	75	5,938.07
Ficus benjamina	9	Mean	14.49	11.87	1.88	59.93	67	597.93
		Std. Deviation	8.30	8.28	1.56	49.53	55	591.42
		Variance	68.93	68.58	2.42	2,453.03	3033	349,780.97
Hopea odorata	22	Mean	14.77	7.59	0.60	19.16	21	264.88
		Std. Deviation	1.84	1.37	0.21	6.77	7	116.38
		Variance	3.40	1.89	0.04	45.82	56	13,544.11
Mimusops elengi	6	Mean	8.27	6.88	0.75	23.93	27	215.00
		Std. Deviation	0.33	0.73	0.36	11.47	13	27.77
		Variance	0.11	0.54	0.13	131.54	166	771.29
Pelthophorum pterocarpum	110	Mean	14.81	11.51	1.35	43.03	48	441.85
		Std. Deviation	3.73	3.83	0.55	17.54	19	275.22
		Variance	13.90	14.67	0.30	307.56	380	75,747.93

cont'd Table 1

Pterocarpus indicus	185	Mean	22.52	14.51	2.09	66.64	74	1,095.34
		Std. Deviation	5.71	3.89	0.59	18.71	21	976.91
		Variance	32.64	15.12	0.35	350.16	432	954,349.11
Samanea saman	100	Mean	16.18	13.59	1.85	58.81	65	918.66
		Std. Deviation	4.76	4.96	1.04	33.20	37	1,453.68
		Variance	22.66	24.60	1.09	1,101.93	1362	2,113,172.47
Tabebuia pallida	38	Mean	15.79	9.85	1.38	44.02	49	583.70
		Std. Deviation	5.87	4.55	0.62	19.86	22	910.31
		Variance	34.48	20.74	0.39	394.27	487	828,660.80
Total	503	Mean	17.74	12.54	1.68	53.54	59	769.11
		Std. Deviation	6.24	4.61	0.82	26.07	29	976.72
		Variance	38.92	21.28	0.67	679.48	838	953,983.24

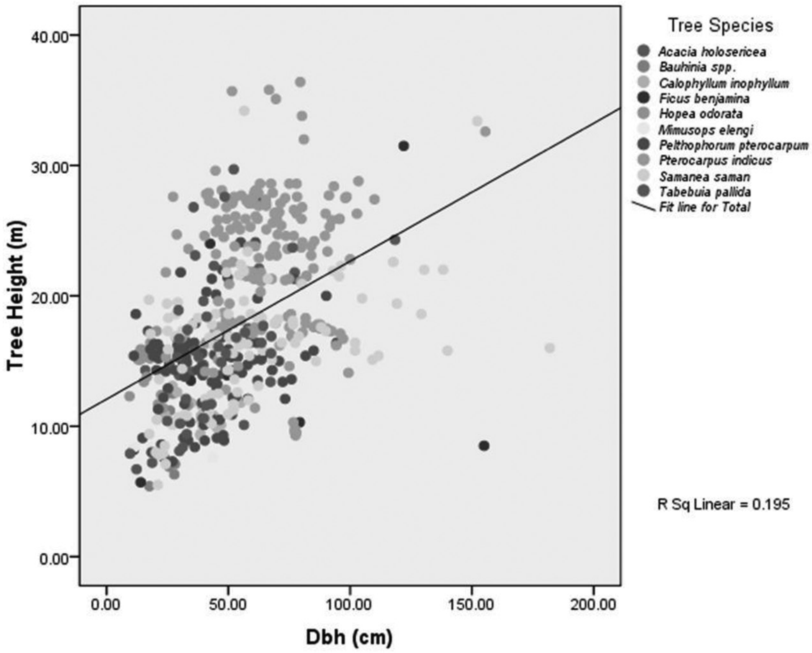

Fig.1: The relationship between tree height and dbh

TABLE 2
Descriptive statistics of tree values

Tree Species	N	Mean (RM)	Std. Deviation
Acacia holosericea	11	453,293	145,775
Bauhinia spp.	7	82,953	41,392
Calophyllum inophyllum	15	166,058	68,428
Ficus benjamina	9	530,963	525,184
Hopea odorata	22	235,214	103,345
Mimusops elengi	6	190,914	24,663
Pelthophorum pterocarpum	110	392,364	244,398
Pterocarpus indicus	185	972,660	867,494
Samanea saman	100	815,766	1,290,864
Tabebuia pallida	38	518,324	808,354
Average all trees		435,851	411,990
Total Value	503	4,358,510	4,119,898

TABLE 3
Average tree value by tree height class

Tree Species	N	Height Class (m)	Mean (RM)	Std. Deviation
Acacia holosericea	8	10 - 14.99	394,442	91,523
	3	20 - 24.99	610,230	161,669
Bauhinia spp.	4	< 9.99	59,353	12,536
	3	10 - 14.99	114,419	48,010
Calophyllum inophyllum	3	< 9.99	175,269	55,016
	12	10 - 14.99	163,755	73,350
Ficus benjamina	3	< 9.99	247,912	243,240
	4	10 - 14.99	357,023	286,950
	1	20 - 24.99	1,681,864	-
	1	> 25	924,979	-
Hopea odorata	7	10 - 14.99	135,692	46,410
	15	15 - 19.99	281,658	88,508
Mimusops elengi	6	< 9.99	190,914	24,663
Pelthophorum pterocarpum	12	< 9.99	170,209	90,064
	39	10 - 14.99	336,997	189,259
	47	15 - 19.99	424,220	214,905
	11	20 - 24.99	664,056	353,446
	1	> 25	731,653	-
Pterocarpus indicus	8	< 9.99	200,956	15,447
	10	10 - 14.99	370,690	238,237
	42	15 - 19.99	877,175	494,874
	47	20 - 24.99	747,621	420,600
	78	> 25	1,316,001	1,136,362
Samanea saman	7	< 9.99	49,270	19,692
	25	10 - 14.99	228,711	120,830
	53	15 - 19.99	734,666	473,556
	13	20 - 24.99	1,946,269	1,851,692
	2	> 25	5,637,578	5,967,934
Tabebuia pallida	6	< 9.99	75,190	42,811
	9	10 - 14.99	310,114	324,066
	16	15 - 19.99	401,226	257,630
	4	20 - 24.99	1,755,998	2,137,679
	3	> 25	1,003,517	30,763

cont'd Table 3

Total	49	< 9.99	144,870	94,963
	117	10 - 14.99	283,764	191,292
	173	15 - 19.99	614,806	435,932
	79	20 - 24.99	990,897	1,033,845
	85	> 25	1,395,182	1,433,677

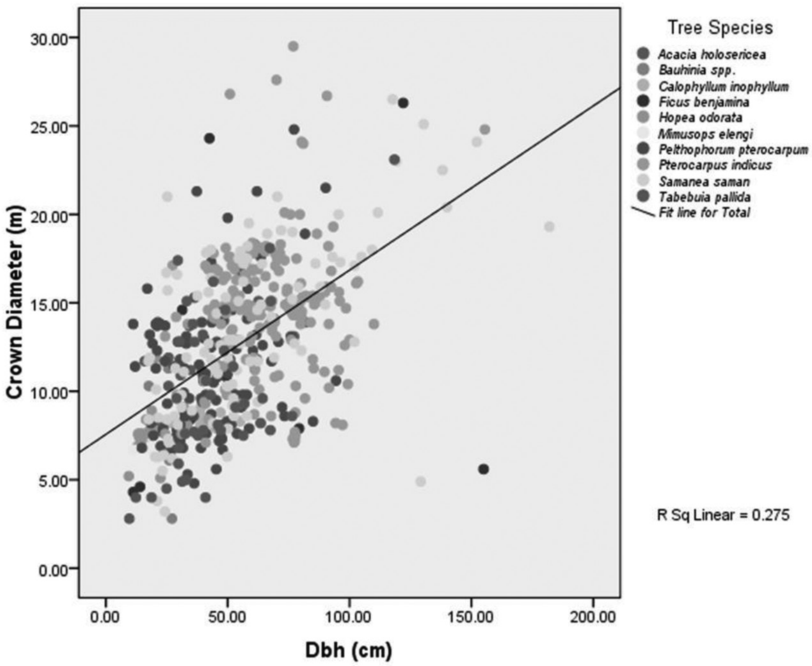

Fig.2: The relationship between tree crown diameter and dbh

TABLE 4
Average tree value by tree dbh class

Tree Species	N	Dbh Class (cm)	Mean (RM)	Std. Deviation
Acacia holosericea	1	< 19.99	347,960	-
	7	20 - 39.99	401,082	96,752
	2	60 - 79.99	516,943	7,700
	1	> 80	796,803	-
Bauhinia spp.	1	< 19.99	56,193	-
	6	20 - 39.99	87,413	43,461
Calophyllum inophyllum	10	20 - 39.99	162,133	69,262
	5	40 - 59.99	173,908	74,020

cont'd Table 4

Ficus benjamina	2	< 19.99	107,802	23,397
	2	20 - 39.99	458,728	450,345
	2	40 - 59.99	949,768	1,035,339
	1	60 - 79.99	292,962	-
	2	> 80	726,555	280,615
Hopea odorata	14	< 19.99	231,029	53,731
	8	20 - 39.99	242,537	163,042
Mimusops elengi	3	< 19.99	181,481	23,424
	2	20 - 39.99	206,322	34,581
	1	40 - 59.99	188,397	-
Pelthophorum pterocarpum	8	< 19.99	332,765	164,328
	42	20 - 39.99	363,783	181,015
	41	40 - 59.99	327,743	177,991
	15	60 - 79.99	643,305	328,948
	4	> 80	533,000	559,292
Pterocarpus indicus	7	20 - 39.99	468,904	313,793
	59	40 - 59.99	764,166	376,180
	78	60 - 79.99	869,004	553,905
	41	> 80	1,555,897	1,474,106
Samanea saman	3	< 19.99	302,356	212,514
	25	20 - 39.99	257,001	214,616
	38	40 - 59.99	526,299	364,951
	14	60 - 79.99	976,495	457,134
	20	> 80	2,028,712	2,455,494
Tabebuia pallida	3	< 19.99	42,546	8,657
	15	20 - 39.99	353,467	336,029
	13	40 - 59.99	462,758	330,856
	6	60 - 79.99	552,799	360,579
	1	> 80	4,934,034	-
Total	35	< 19.99	231,298	133,426
	124	20 - 39.99	310,581	224,374
	159	40 - 59.99	550,289	380,038
	116	60 - 79.99	825,400	514,072
	69	> 80	1,647,600	1,814,710

of the tree dbh is disturbed. A research by Ning *et al.* (2008) found that factors such as unhealthy soil, construction-related stresses, environmental pollution and heavy traffic are the main causes for low survival rate and unhealthy growth of the urban trees along many main roads.

CONCLUSION

In summary, due recognition should be accorded to urban trees as a provider of many benefits to communities. This value can now be described and represented in monetary terms. However, the study has demonstrated that the values of urban trees may differ based on their size, age, quality characteristics and planting cost.

Thus, a proper management of urban trees is crucial to ensure improved health of the surrounding urban communities, as well as to enhance functional values and at the same time, maintain the quality of the environment. It is hoped that the outcome of this study will assist decision-makers to justify the prioritisation of tree management programmes in urban areas.

Any urban tree-planting programme should invite community participations, whose collective decisions have cumulative impacts on the survival of the urban trees. In addition, environmental education and awareness programmes are equally crucial in the efforts to ensure the well-being of the trees. The monetary values attached to the trees within the study area justify the investment and expenses required for sustainable urban tree management programmes. These programmes should also include ones that involve removal of hazardous (including dead and declining) trees. This is critical to ensure public safety and to minimise damages and liabilities arising from improper disposal or lack of efforts in the removal of hazardous trees. The removal of dead and declining trees will provide more spaces for responsible tree replanting exercises. More importantly, the maintenance costs for healthy trees are much lesser than that of the cost incurred to maintain hazardous, especially dead and declining trees.

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Scoping the Potentials and Pitfalls of Rural Tourism Policies: Constructivism as a Theoretical Lens

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ABSTRACT

The effectiveness of policies has always been debated worldwide. In a broad perspective, there are two main types of policies; the preventive and the punitive. While some policies take a certain type, there is no conclusive evidence to support their effectiveness. The potentials and pitfalls of policies largely lie in the level of policy-making, where the analysis studied in how policy makers define problems and embed them in public policies. These include the gap in the knowledge of the nature and the extent of the problem between what is assumed to be correct by policy makers and the real nature of the situation, the level of awareness of the policies between its stakeholders, the level of acceptance and belongingness towards these policies and the level of implementation and execution of the policies. All these aspects can be summarised by the lack of interaction between policy makers and the stakeholders, which happen in most cases due to the top-down adoption in policy-making strategies. In Malaysia, the policies to retain the original setting of its rural tourist destinations are widely available. The state and federal lawmakers have enacted a range of laws and policies intended to mitigate the societal and environmental risks presented by tourists. However, a similar observation of the problems in public policy is seen in the Malaysian rural tourism context, where the lack of interaction between policy makers and its stakeholders, and the flaw in the system have led to the lack of these policies being intertwined with each other. Therefore, a multi-layered adoption should be used to encourage actors' participation and interaction. The purpose of this paper is to scope the potentials and pitfalls of rural tourism policies from a constructivist perspective. The model employed to assist

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this study is the actor-network theory approach, where the problem is addressed using constructivism as a theoretical lens. This approach uses a qualitative design to enable the exploration of the current policy structure and the perception of the stakeholders.

Keywords: Policies, punitive, preventive, actor-network theory, rural tourism, constructivist

INTRODUCTION

In the past half century, the tourism industry has emerged as one of the world's most powerful, yet controversial, socio-economic forces (Telfer & Sharpley, 2008). Tourism is a fast growing industry, and more importantly, it is a valuable sector that contributes significantly to the nation's overall economy. The International Tourism Organization states that international tourist receipts are estimated to have reached USD919 billion worldwide as compared to USD851 billion in 2009. Moreover, tourism generates a significant amount of foreign exchange earnings that contribute to the economic growth of countries (Tadasse & Nsiah, 2008). This industry (worldwide) is known to effect the economies and lives of communities and has been deemed to improve the lives in many different destinations, apart from being proven to be a beneficial for many destinations. In the recent years, there is emphasis on the understanding of tourism and places with relations to nature and the role of tourists' performance. This has led to the areas of policy and practice developments in the tourism industry to grow in prominence (Jóhannesson, 2005).

When a policy is introduced, no one will know who gets "What, When and How" or what line of action will eventually take. During the course of creating and implementing policies in a multi-actor situation, various stakeholders often view problems and solutions differently, resulting in various stakeholders trying to aim the direction of the policy to suite their needs (Hanberger, 2001).

The effectiveness of policies is often debated worldwide; there are generally two types of policies. These include policies that are preventive (rewarding) and those that are punitive (punishing). These two types of policies are widely used in many areas of interest, and they act as the basis for policies to achieve their intended objectives. While some policies take a certain nature, there is no conclusive evidence to support their effectiveness. The potentials and pitfalls of policies largely lie in the interaction gap between policy makers and other stakeholders.

The state and federal lawmakers have enacted a set of laws and policies intended to mitigate the societal and environmental risks presented by tourists. Malaysia is considered a rural tourism paradise as it has at least 19 national parks, jungle, hill resorts, and Southeast Asia's highest mountain, Mount Kinabalu. In addition, its culture, arts and traditions of multi-racial-multi-ethnic communities are a tourist attraction and an economic gold mine. This industry is deemed very important and serious attention is needed to sustain tourism in Malaysia (Siow, Abidin, Nair, & Ramachandran, 2011).

Rural Tourism Policy Issues

Rural tourism is seen as a form of sustainable development that promotes productivity in areas of the rural zones. The objectives of this form of tourism are to bring out employment, create better income distribution, preservation of village environment and local culture and at the same time raising host community's participation and presenting methods to confirm beliefs and traditional values within new circumstances (Mahmoudi *et al.,* 2011).

Tourism in Malaysia has been part of the political plan since 1987. This is especially seen when the Federal Government took the agenda of developing tourism as a part of the major economic sectors. The main objective of the agenda was to gain economic growth and employment in the rural areas through this industry (Hjulmand *et al.,* 2003). The Malaysian economy was traditionally dominated by the primary commodities but it soon evolved into the manufacturing sector in the 1970's (Hanim, Salleh, Othman, & Ramachandran, 2007). Rural tourism, however, was first introduced to Malaysia through the New Development Policy (NEP) between 1971 till 1990. Its main concern was to address the regional economic inequalities and poverty faced by the Malays in Peninsular Malaysia. Like other sectors, this policy intensified the rural tourism sector through intense development of the rural areas in Malaysia (Awang & Aziz, 2011).

Today, the policies in Malaysia to retain its original setting in the context of rural tourism are widely available. The state and federal lawmakers have enacted a set of laws and policies intended to mitigate the societal and environmental risks presented by tourists. Under the federal governance, several bodies oversee the welfare of rural tourism through its policies. These include the Ministry of Tourism, Ministry of Natural Resources and Environment and Ministry of Rural and Regional Development. Other agencies/departments falling under these ministries that also have some levels of policies governing rural tourism include Department of Environment, Department of Marine Park Malaysia, Department of Wildlife and National Parks, Forest Research Institute Malaysia, Forestry Department Peninsular Malaysia, Community Development Department, Department of Orang Asli Affairs and Institute for Rural Advancement ("The Malaysia Government's Official Portal," 2011). However, other governmental agencies could also be indirectly involved in public administration.

Malaysia's government practices a decentralised political system, where it is often difficult to reconcile the interests of federal, state and local governments. For example, Malaysia's island marine parks are under the control of the federal government in terms of its administration and management. However, these islands come under the jurisdiction of their respective state governments (Jordan *et al.*, 2002). This can further be a challenge as 4 out of the 13 states in Malaysia are run by the opposition ("Malaysia's Penang state Getting back its mojo," 2011). Other complications include certain states not being in favour of some tourism promotion acts sanctioned by the federal government as the promotions were against the local norms (Awang & Aziz, 2011).

Amongst all the available policies, the National Ecotourism Plan that was drafted by the Ministry of Culture, Arts and Tourism and World Wide Fun for Nature (WWF) in 1996 acts as a backbone for the rural tourism policies in Malaysia. The aim of this plan is to assist the Government, both at the Federal and State levels in the development of Malaysia's ecotourism potentials, with the effective tools for conserving of the natural and cultural heritage of the country, while providing socio-economic benefits to the local communities (Chin, 2010).

Synthesizing the policies across the federal and state levels shows that there is evidence indicating two distinct approaches with the rural tourism. These include the movement towards ecotourism and 'home stay program'. The general context for the rural tourism policies in Malaysia is largely preventive in nature. This is seen through its objectives of non-coercive methods, which are mostly to encourage and educate the importance of compliance of these policies. Observations of these policies also suggest that there is a lack of interactions between policy makers and its actors, and the lack of these policies being intertwined with each other. According to Awang and Aziz (2011), the potentials of tourism policies in Malaysia have not reached its optimum because of poor policy implementation and the lack of alignment between the federal and state governments.

The objective of this paper was to study the actor-network theory approach (ANT) through the constructivist's theoretical lens. This is a conceptual paper, from a qualitative approach where the researchers are able to explore the current policy structure along with the stakeholder perception towards these policies.

MATERIALS AND METHODS

The design of the study used was purely qualitative, whereby secondary findings using literature reviews were utilized as a method to coin the emerging themes stipulated below.

Preventive Policies

Policies that are preventive, rewarding, or having pull measure perceived to be non-coercive in nature and are more attractive (Steg, 2006). Over the past 20 years, professionals, consultants and academics alike have placed emphasis on the importance of a reward system in policies. This form of reward system has been gaining popularity because it increases the competitive strategy of organisations. However, it is imperative to understand that the design of the reward policy structure (Bodenstein & Furness, 2009) and its communication to actors will make a difference in the success and failure of it (Shields *et al.,* 2009). An interesting finding has mentioned that the reward systems help improve policy systems and that the honesty of the actors cannot be taken for granted (Falkinger & Walther, 1991).

Punitive Policies

Policies that are punitive, punishing or having the push factor is perceived as coercive, have the tendency of making environmentally unsound behaviour more expensive and less attractive (Steg, 2006). Studies have shown that old policies can be irrelevant to the current day and age. This means that the "get tough" philosophy that was adopted by previous policymakers should be replaced by a lenient approach (Benekos & Merlo, 2008; Merlo & Benekos, 2010). They added that if one were to look at the perspective of policymakers, going soft on policies would be synonym to the 'kiss of death of their political careers' as they would appear to be soft on crime. However, others suggest that the support for punitive policies is significantly related to perceiving knowledge of a certain ideology, where in the research (Surette, Chadee, Heath, & Young, 2011) is seen as a set of realistic and accurate form of reactions.

Situational Analysis - Attributes to the Potentials and Pitfalls of Policies

Scholars have suggested that there are 4 main factors influencing the effectiveness of policies. These include public acceptability of policy measures, individual factors such as awareness (Prior, 2009; Shields *et al.*, 2009; Steg, 2006), the gap in the knowledge of the nature and the extent of the problem between what is assumed suited by policy makers and the real nature of the situation (Dwyer, 2011; Prior, 2009), and proper execution of policies (Filtenborg *et al.,* 2002).

One of the most important obstacles of a policy and policy development is public opinion. In every kind of policy, public acceptability (which includes effectiveness and fairness) is seen as the key-dynamics in policy development (Allen, 2002). The appropriateness of public policies is often driven by the perception of individuals and society. These beliefs and perceptions are influenced by judgments, prior experience, knowledge and the education and information efforts by policy makers (Kneeshaw *et al.,* 2004). Policy makers must take into consideration that certain policies may work in some communities within a geographic context, but not all (Cowart, Sutherland, & Harris, 1995; Kneeshaw *et al.*, 2004). Therefore, it is important that policy must follow the development of local programme leadership and control, where top-down policies can set standards and provide training, while serving as a catalyst for bottom-up implementation. Such efforts can bring high levels of local acceptability and support towards the policies (Cowart *et al.*, 1995).

Policy awareness is essential for stakeholders' benefits (Narayana, 2006). In particular, the political awareness, knowledge and engagement in policies to its agents remain one of the key issues associated with policy effectiveness. Policy studies have shown that most individuals in the masses are not very knowledgeable in policies. While some of them are well informed, it is easy to generalize that the typical citizen appears to be poorly informed (Claassen & Highton, 2008). Studies have also shown that awareness of the policy does not deter offenders from offending these policies. However, it does impact the community by enhancing consciousness and heightening awareness of offenses among lay people (Shin & Lee, 2005). On the other hand, Duncan (2007) postulates in his findings that actors are aware and understand the available policies, but have little effect on social outcomes. This largely rests on the policy maker's assumption of rational choice, and in turn, creating a 'rationality' mistake.

In most areas of social policy, government programmes are often implemented with little regard to evidence, which has caused billions of dollars and it still needs to address the critical needs of a society (Heinrich, 2007). The need to understand the scale and nature of the problem addressed provides a necessary underpinning for policies. The challenge comes when policy makers make meaning of certain keywords that represent a different meaning to other agents. These problems arise when policymakers make assumptions of keywords, where the words and descriptions have an ontological reality, and therefore, can be measured in order to get the 'true picture of these words in one aspect of the social world, namely, the world of stakeholders. This picture will provide a basis for interventions by policymakers who wish to alter or create policies. There is also evidence that policymakers are unwilling to explore beyond the empirical level of what they observe, and hence, fail to investigate what really happens within the stakeholders in order to seek out explanations on why certain phenomena happen (Prior, 2009). On the other hand, scholars have suggested that policymakers would sometimes have to listen to their 'political master' in placating this pressure and would rather develop policies rationally, weighing up the evidence of their findings appropriately (Duncan, 2007).

Thus, policy makers must find ways to ensure successful implementation of the policies, as this will involve a large influx of federal money. The importance of identifying the actual working of the proposed policies produces information regarding the challenges to policy reform and to correctly interpret evaluation results is highly recognized as a challenge (Cooley, 2010). Studies have shown that there are several major attributes that contribute towards the implementation levels of policies. Firstly, the support of the organized interest and civic capacity, where stakeholders play a crucial role in showing interest in the policy objectives. Secondly, the influence of oppositional interest, where non-governmental organisations or opposition parties play a pivotal role in pressuring policy makers towards implementing the policies, and thirdly, the fiscal capacity or stress that can be supported throughout the policy implementation (Sharp, Daley, & Lynch, 2010). Some studies have shown that it is based on principal-agent breakdown, whereby principals have the inability to formulate clear policy outcomes or to adequately supervise the implementation of their goals (Spillane, Reiser, & Reimer, 2002).

INSTRUMENT

Understanding Different Agencies through Actor-Network Theory

Actor-network Theory or ANT is a patterned network of heterogeneous relations, or an effect produced by such a network. This relational and process-oriented sociology assumes agents, organizations and devices as 'interactive effects'. Therefore, ANT is an effect of the interaction between materials and strategies of organization (Law, 1992). The fundamental importance of ANT is that it is not materialist oriented. Therefore, it does not intent to divide humans and non-humans but with the intension to understand that there is a simultaneous presence of different 'agencies'. These agencies can be humans, machines or even symbols that are treated in heterogeneous actor-network (Plesner, 2009).

Actor-Network Theory in Tourism through the Constructivist Lens

The Actor-Network Theory (ANT) is worth considering as a framework for the study of tourism. This theory will guide scholars in tourism on how and what to study in tourism (Vanderduim, 2007). This is because ANT establishes important insights for tourism research (in this case, research in rural tourism policies) as it provides a possibility to bypass dualism and also to take into consideration the significance of materials in the concepts and practices of tourism. ANT, therefore, provides the ability to deal with relational materiality of the social world, where it provides an avenue for research to identify how tourism happens through hybrid network practices of different actors while providing the opportunity to grasp multiple relational orderings (Jóhannesson, 2005). In short, tourism is held together by active sets of relations in which the human and the non-human continuously exchange properties, bringing some form of structural order to the whole picture at large (Vanderduim, 2007).

What actor-network theorists now seek to investigate are the means by which associations come into existence and how the roles and functions of subjects and objects, actors and intermediaries, humans and non-humans are attributed and stabilized (Murdoch, 1997).

In the context of rural tourism in Malaysia, the characteristics of its actors can be conglomerated to tourist operators, local officials, federal and state officials, tourist and civil society. Therefore, rural tourism is a complex system of actions with specific operating logics, composed of a multitude of actors. In involves multiple objects and non-human elements into the composition, alongside with actors (Murdoch, 1997). In order for policies to work, the relationship between these elements must be bridged, creating a heterogeneous environment crucial for the effectiveness of policies.

In order to achieve this, the researcher will need to adopt an inductive, comprehensive approach, which accumulates the experiences of actors and the sense that they give to their actions and how they view the reality of the system they operate (Jolivet & Heiskanen, 2010). This procedure will be guided through the constructivists' worldview.

Constructivism has increasingly been of more importance in the social science perspective and has even become more predominant in other areas. The constructivist sees that reality is a social construct (Alvesson & Sköldberg, 2009; Chua *et al.,* 2010). Those on this spectrum base their viewpoint on "relativism", where realities are capable to be in the state of it being from multiple, intangible mental constructions, socially and experiential constructions. The constructivist is guided by the fact that the belief system relies on the basis relativism and not so much on realism (Perera & Sutrisna, 2010).

The constructivist's epistemological approach looks as the transactional and subjectivist viewpoint, whereby the assumption of the investigator and the investigated object are interactively inclined (Guba & Lincoln, 1994; Perera & Sutrisna, 2010). In other words, the values of the investigator are inevitably influencing the inquiry, and that the findings are literally created by the investigation proceeds (Guba & Lincoln, 1994). However, Perera and Sutrisna (2010) mentioned that with such standpoint, the conservatism will be challenged for having such distinction as compared to the more traditional ontological and epistemological of the other paradigms. Accordingly, the constructivist, unlike other paradigms, sees the object and the subject as a single entity and not as a dichotomy. Hence, ANT creates a suitable incubator by bridging the gap between policy makers, stakeholders, and the environment.

The methodology that surrounds a constructivist would be the nature of the social construction that the individual can be elicited and refined through interaction between investigator and respondent. Using the hermeneutical techniques, the final aim is to distil a consensus construction that is more in-depth and sophisticated than any techniques of contractions (Guba & Lincoln, 1994).

In the study of the quality of tourist experience, Jennings *et al*. (2009) redefined that the levels of interpretation of quality (for example) would be seen differently from one individual to another. Hence, Jennings *et al*. (2009) stated that a constructivist's adoption would be able to identify the quality of the tourist's experience in more detail and in-depth. Therefore, finding out the underlying meanings of quality, tourism and experiences from the different angles of stakeholders can only be experienced through the lens of a constructivist.

RESULTS AND DISCUSSION

Table 1 below postulates the four elements of policy effectiveness, showing the plausible reasons that can contribute to the potentials and pitfalls of tourism policies. The effectiveness of policies is seen from the perspective of general tourism in Malaysia and also rural tourism in Malaysia.

Public acceptability of policy measures

Policies for the general tourism in Malaysia involve its local residents to participate in the entrepreneurship of its local products. It is possible to correlate that once these local residents engage in these entrepreneurial activities, they will have some level of acceptance towards the policies. From the rural tourism context, the involvement of the private sector is still limited. This can well be a sign that the private sector sees the policies as unfair or ineffective. Moreover, visitors see locals as 'objects' and 'products' of rural tourism and they hardly participate in businesses related to tourists. Situations as such can cause the locals to perceive that the policy is unfair, contributing to the ineffectiveness of the policy.

Individual factors such as awareness

Policies from the general tourism aspect can be seen as effective. This is a good attempt as it creates awareness amongst the public. Nonetheless, in order to understand the full extent of its effectiveness, there is still a need to measure the success levels of these campaigns. From a rural tourism sense, there is a discrepancy in awareness in both the individual level and the agency level. This could mean that policies from the rural tourism sense are still lacking to create awareness in its stakeholders.

Gap between assumed and actual knowledge

While examining Fig.1 and Fig.2, it is apparent that the creation of policies used a top-down approach. This is because all the agencies involved are made up of governmental and non-governmental organizations, where the stakeholders such as the local and corporate communities are largely excluded. This phenomenon can create gaps of knowledge between what is assumed to be correct by the policy makers and what the actual situation at hand is.

Proper execution of policies

On the general tourism aspect, Awang and Aziz (2011) postulate that execution of policies is unequally distributed throughout the country. This is seen through the discrepancies in its promotional activities that are more rampant in certain states. This sort of policy execution can dampen its full capabilities of it being fully effective.

It is evident that the general tourism context has certain flaws in its policies. Hence, it is not surprising that the rural tourism context will have similar findings. These preliminary findings prove that the policies governing both tourism and rural tourism in Malaysia have some strength and weaknesses. With this basis, it is imperative to acknowledge these strengths and weaknesses in order to build policies that will serve to the full potential.

At this juncture, it is possible to connote that a multi-layered approach be adopted in order to encourage actors' participation and interaction. This step will ensure that the policies available are there to protect and conserve and at the same time bring economic value to the industry. The purpose of this paper is to further scope the potentials and pitfalls of the rural tourism policies

TABLE 1
The Effectiveness of Tourism Policy

No.	Factors of Effective Policies	Tourism in Malaysia	Rural Tourism in Malaysia
	Public acceptability of policy measures	• Policies focus more on domestic tourism through local residents involvement in entrepreneurship in product development and services (Mohamed, 2002)	• The involvement of the private sector is still limited (Mohamed, 2002). • Locals continue to be mere ‘objects’ or ‘products’ to be gazed by the visitors and natives never run businesses related to tourists (Mohamed, 2002)
	Individual factors such as awareness	• Malaysian Government and other NGO’s conduct campaigns to raise the level of awareness on conservation. This is done through campaigns to raise the level of awareness on conservation issues throughout the country (Daud, 1999)	• The initiative to introduce tourism as a core subject in local universities, as well as schools (Mohamed, 2002) • Lack of environmental consciousness is evident in the rural tourism setting as some Malaysians are seen washing their vehicles in the river (Mohamed, 2002).
		• Government departments, private businesses and the public at large are made aware of the deteriorating world environment and the need to conserve and preserve nature through sustainable development (Daud, 1999)	• 10 out of 15 agencies do not really understand the principles and concepts of ecotourism and 30% have little relation with the government; another 30.8% admitted have no relation with the government (Mohamed, 2002)
	Gap of knowledge of the nature and extent of the problem between what is assumed suited by policy makers and the real nature of the situation	• Figure 1.0 shows the chart on how Tourism Malaysia engages with ministries and departments in the planning, maintaining and controlling of tourism activities. However, no local representatives were present in the making.	• Figure 1.1 shows the chart on how the Malaysian Ecotourism Plan was formulated. Stakeholders were made up of different governmental bodies. However, no local representatives were present in the making.
	Proper execution of policies	• Unequally distributed amongst the region as suggested by the plan. This was caused by lack of promotion through poor policy execution (Awang & Aziz, 2011).	• Despite availability of policies, international tourist have voiced out their concerns with regards to the ambivalent policies implementation in Taman Negara National Park (Ramachandran, 2009)

from a constructivist's perspective. The model that is aimed to assist this study is the actor-network theory approach, where the problem will be addressed using constructivism as a theoretical lens. This approach will use a qualitative design as it enables the exploration of the four elements so as to identify the effectiveness of the current policy structure, and also the exploration of stakeholders' perception.

CONCLUSION

In order to learn more about the effectiveness of a policy, scholars would need to investigate the potentials and pitfalls of rural tourism policies. The four elements of policy effectiveness, whether preventive or punitive, have been identified in this study, namely: (1) public acceptability of policy measures; (2) individual factors such as awareness; (3) the gap of knowledge of the nature, and (4) the extent of the problem between what is assumed suited by policy makers and the real nature of the situation and proper execution of policies. Rural tourism is seen as a form of sustainable development that promotes productivity in area of the rural zones. In Malaysia, it is seen as one of the economic engines of tourism. Policies pertaining to the protection of rural tourism are available in Malaysia. The preliminary findings have shown the strengths and weaknesses that are evident in the policies of rural tourism. However, due to the lack of interaction between policy makers and its actors, and the lack of these policies being intertwined with each other has caused these policies to be less effective as they should be. The Actor-Network Theory (ANT) will assist

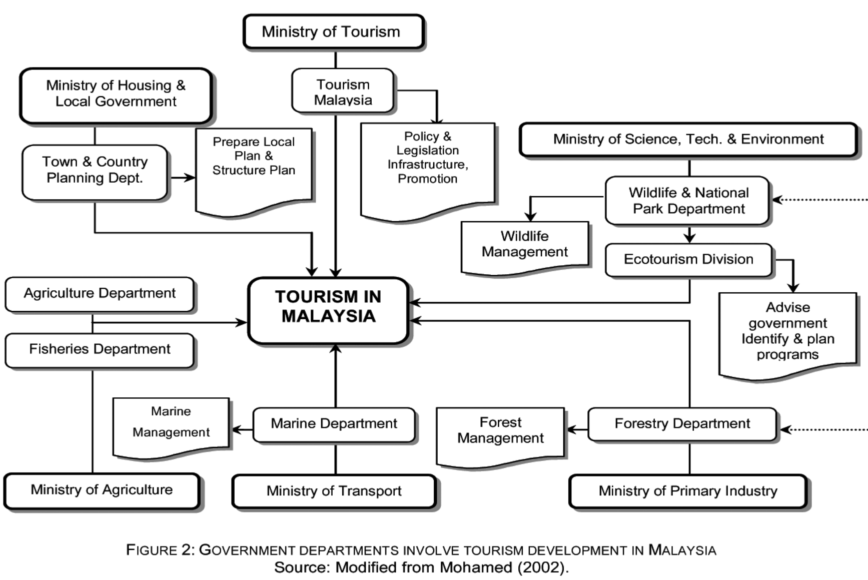

Fig.1: The engagement of the ministries and departments in the planning, maintaining and controlling of tourism activities (Marzuki, 2005)

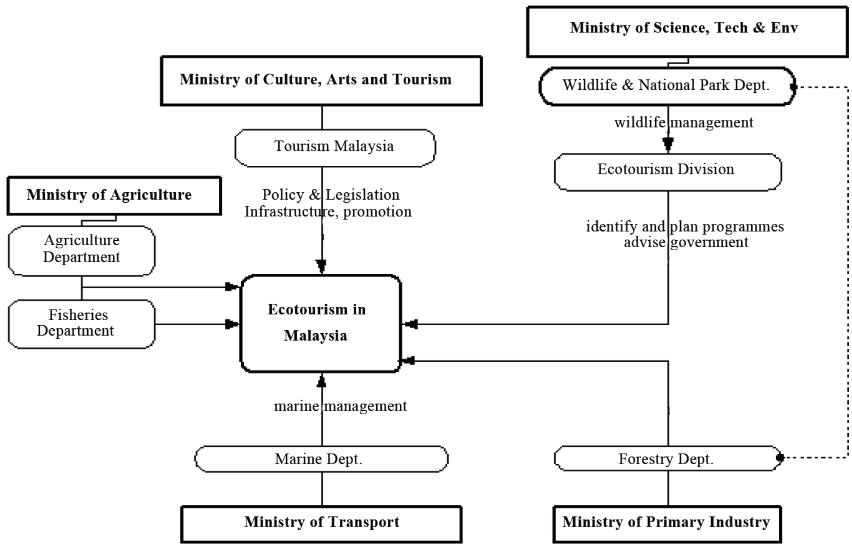

Fig.2: The engagement of the ministries and departments in the formulation of the Malaysian Ecotourism Plan (Mohamed, 2002)

in this investigation using constructivism as a theoretical lens. This bridges the gap between policy makers, stakeholders, and the environment, making it heterogeneous, and hence serving as a tool in identifying the four elements of effective policy creations.

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Local Community Participatory Process and Intervention Procedure in Mangroves Ecotourism of Marudu Bay, Sabah

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ABSTRACT

Mangrove forest extensively colonizes the coastal front of Malaysia, including Sabah state of Northern Borneo. In Marudu Bay in Sabah, it was not harnessed by local communities for ecotourism purposes to complement their incomes mainly from fishing activities. The objective of study was to assess local community's participation in mangrove ecotourism and the intervention procedure needed for success of such a project. The method involved stakeholder analysis using three consultation workshops comprising of key informants and selected villagers as primary stakeholders. Focus Group Discussion (FGD) was followed to elicit responses on ecotourism development within the locals' surroundings and impacts in their daily lives and future undertakings. Results from stakeholder analysis showed that the local communities have the urgency to participate in ecotourism as a new opportunity while supporting mangroves protection. In fact, most of them were found to be willing to provide the services needed to protect the mangrove ecosystem. The intervention needed included support for business activity including ecotourism products and activities development, identification of local leadership/players to spearhead the activities, technology transfer such as technical and facilities assistance, and human capacity building. As for sustainable endeavour, collaborations with big and successful tourism players are crucial to bring their clients to the site as extended visit.

Keywords: Stakeholder, community participation, focus group discussion, intervention procedure, sustainable venture.

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INTRODUCTION

Mangrove vegetation is thought to be originated in the Indo-Malayan region. Mangrove forest presents a unique landscape with taxonomically diverse species that serves as a source of lifeline for mangrove communities. The vegetations have subjected to inundation of intertidal waves from high tide to low tide along coastal areas. It plays a crucial role as a habitat for many life forms and ecological processes. The mangroves serve as a giant filtering system of effluents and beaches stabilization and are important for fish breeding and marine life. Mangrove forest comprises of a habitat that is dominated by stands of mangrove trees (*Rhizophora* spp., *Brugueira* spp. and *Lumnitzera* spp.) and other species that adapted well to the local weather and conditions. The wildlife population found in this habitat includes primates mainly the macaque and birds species which comprise of resident and migratory species.

In Malaysia, mangrove forests are widely distributed in several parts along the coastal areas. Mangrove forests provide sources of wood and marine resources besides the amenities for the local communities. Most village communities are made up of the people who live in the vicinity since ancient times where they traditionally exploited mangroves for commercial products such as timber for construction materials and wood for charcoal production.

In many regions of Asia, local people exploited mangrove forests to sustain their daily lives. The locals encroach into the forests, cut trees, and collect minor forest produce to be sold for economics gains. The mangroves are cleared for aquaculture or physical development. Conservation is neglected, and this leads to further degradation and destruction of those resources. Engagement and participation by the local community in the management of mangrove forests will be able to mitigate the problems. This can be done through ecotourism, which involves low impact activities to the forests. Eco-tourism is defined as ‘environmentally responsible travel and visitation to relatively undisturbed natural areas, in order to enjoy and appreciate nature (and any accompanying cultural features – both past and present) that promotes conservation, has low visitor impact, and provides for beneficially active socio-economic involvement of local populations’ (Ceballos-Lascurain, 1996). Llewellyn (2000) claims that ecotourism also aims to contribute to conservation, sustainable development and poverty alleviation by bringing sustainable benefits to national and local economies.

Many people travel to remote places to experience the environment and natural beings found in it. People are brought closer to the environment and with nature-based attractions (Wearing & Niel, 1999; Dowling, 2001). Meanwhile, Dowling (2001) identified five important keys that are fundamental to ecotourism. These are nature-based activity, ecologically sustainable, environmentally educative, locally beneficial and able to generate satisfaction among tourists. Hence, ecotourism entails the three core criteria, namely, emphasizing on nature-based attractions, learning opportunities and management practices that adhere to the principles of ecological, socio-cultural and economics sustainability (Blamey, 2001; Fennell, 1999; Weaver, 2001a, b). In related situation, Cato (2009) and Adams (2006) viewed sustainability as a concept that encompasses three main dimensions, namely, social, environmental and economics.

Ecotourism development in many locations connotes economic opportunities, multi-faceted development activities, creative and inter-disciplinary collaboration, interactive engagement with local communities (Abdullah *et al.*, 2000). Among other, it has become an attractive proposition to many protected areas and resource managers. Therefore, the most appropriate ecotourism should be used as a comprehensive and effective management strategy to safeguard the natural environment by means of engaging the local community as a responsible group.

Branton (1999) claimed that setting up ecotourism development in local areas requires careful planning and management through a closed collaboration with the local communities. If it is to contribute to sustainable development, the host community should be given appropriate education in ecology, cultural and its economical importance (Abdullah *et al.*, 2006). The locals have to actively participate and involve in related ecotourism activities when introduced (Wall, 1997; Knowles-Lankford & Lankford, 2000). As ecotourism becomes clear and beneficial to the community development, the locals will realise that they will gain much in increasing their incomes compared to their traditional work. Simultaneously, the locals are able to conserve the natural resources which can be depleting.

Sabah mangrove forests represent a rich biodiversity that can serve as an ecotourism attraction. It has its own uniqueness with its local cultural characteristics for ecotourism development. In Marudu Bay, however, mangroves are still not fully utilized for tourism industry (Ministry of Tourism, Culture & Environment Sabah, 2005). The main problem is that the local community still lack the knowledge and skills required for the ecotourism industry although they realise the benefits that come along with it. The objective of this study was to assess the local community participatory process and the intervention procedure needed in ensuring its success.

MATERIALS AND METHODS

The mangroves in Marudu Bay in Sabah, located in the northern part of Borneo, could be found in dominance covering most of the coastal front (Fig.1). The town of Kota Marudu is located about 130km from Kota Kinabalu (the capital city of Sabah), which is about 2 hours' drive from the city.

Consultation workshops involving three Focus Group Discussions (FGDs) were conducted in the District Office of Kota Marudu made up of the key informants and one in its community hall. The techniques used in this study included identifying issues and main problems identification by the participants. The main focus was to determine the potential for ecotourism based on the mangrove resources in the coastal area of Kota Marudu so as to improve

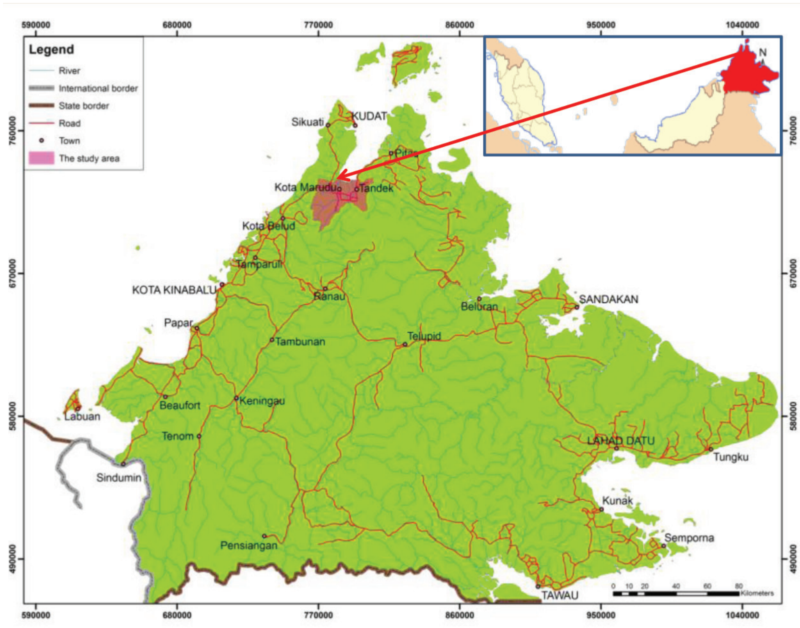

Fig.1: The map of Sabah in Malaysia (inset) and the location of Marudu Bay in Sabah

the local livelihood, to increase income and the overall community development. Then, an intervention procedure would be suggested for application to enable the local participations in the ecotourism businesses.

Key informants from 10 villages located in Marudu Bay were chosen for the exercise began from 2009 ended in 2010. One FGD was participated by key informants made up of 22 heads of villages (*Ketua Kampung*) and one FGD with 40 villagers from the 10 coastal villages, i.e., fishermen, farmers, businessmen, boat operators, etc. The other workshop included the 24 officers, government agencies such as district offices, forest departments, fishery departments, state tourism, NGO representatives and related institutions.

The workshop was administered through brainstorming procedure using facilitation technique by the researchers. Notes were taken and information gathered was analysed so as to design the participatory and intervention procedure for stakeholders (Abdullah & Yip, 2008).

RESULTS AND DISCUSSION

The outcomes from the stakeholder consultation workshop showed that the participants recognised mangrove forest and its surroundings which have rich biodiversities that make up the core components of ecotourism. It possesses the aesthetic, education, and scientific values and a multifaceted socio-cultural ecosystem. The responses also reflected that ecotourism is perceived by the locals as a new opportunity to be developed for everybody's benefits, besides protecting the coastal areas from waves, erosion or pollutions, illegal logging and needs for future generation.

Another crucial issue identified was the locals with low income have the desire for alternative employment. The main problem however is that they have inadequate knowledge and also lack the skills to participate actively in the ecotourism industry. They highly opined that ecotourism development would be able to support their livelihood as they were not satisfied with their present employment. In particular, the locals wanted to be involved as ecotourism operators, meet visitors and work as tourist guides, operate trips to mangroves, islands, wildlife and bird watching, homestay, resort or restaurant operations, or as general workers and boat operators. So far, none of them has been in any form of business ownership or possesses any licence to conduct tourism activities.

The local people felt that there were no reasons for them not to participate in the ecotourism industry. In fact, they have the interest or motivation, time, and confidence, with family blessing though most of them have no capital, skills or opportunities to start the ecotourism business. Hence, if given the opportunities, capital and entrepreneurship training such hosting or services related businesses, most of the respondents would like start own businesses in the near future. Significantly, the participation from the local community and the benefits generated from ecotourism development would determine the success of the initiatives (Moscardo, 2011). From FGD, the key informants from the government institutions and NGOs provided the information and ideas related to the local ecotourism problems. Marudu is not included in the Sabah Tourism Plan, and therefore, it is not promoted as a tourism destination and being by-passed from the main tourism road, i.e. the Kudat District (e.g. the tip of Borneo as a main attraction).

From the stakeholder analysis, it was found that an intervention procedure is needed. Local leadership or actors have to take up the leading role. During the implementation process, initial support such as field technical assistance is needed to make the activity run uninterrupted and directed as planned (Currie *et al*., 2009). Activity design, provision of services and supplies, general operation and maintenance of facilities can be developed by appropriate agencies or universities. The locals are very much willing to participate in the ecotourism as individual operators through co-operation or associations.

A summary of the overall participatory process of the local communities in the mangrove ecotourism and intervention procedure when required is shown in a model illustrated in Fig.2.

CONCLUSION

The engagement of the local people through participatory process and intervention procedure will ensure the success of community ecotourism development programme. Identification and prioritisation

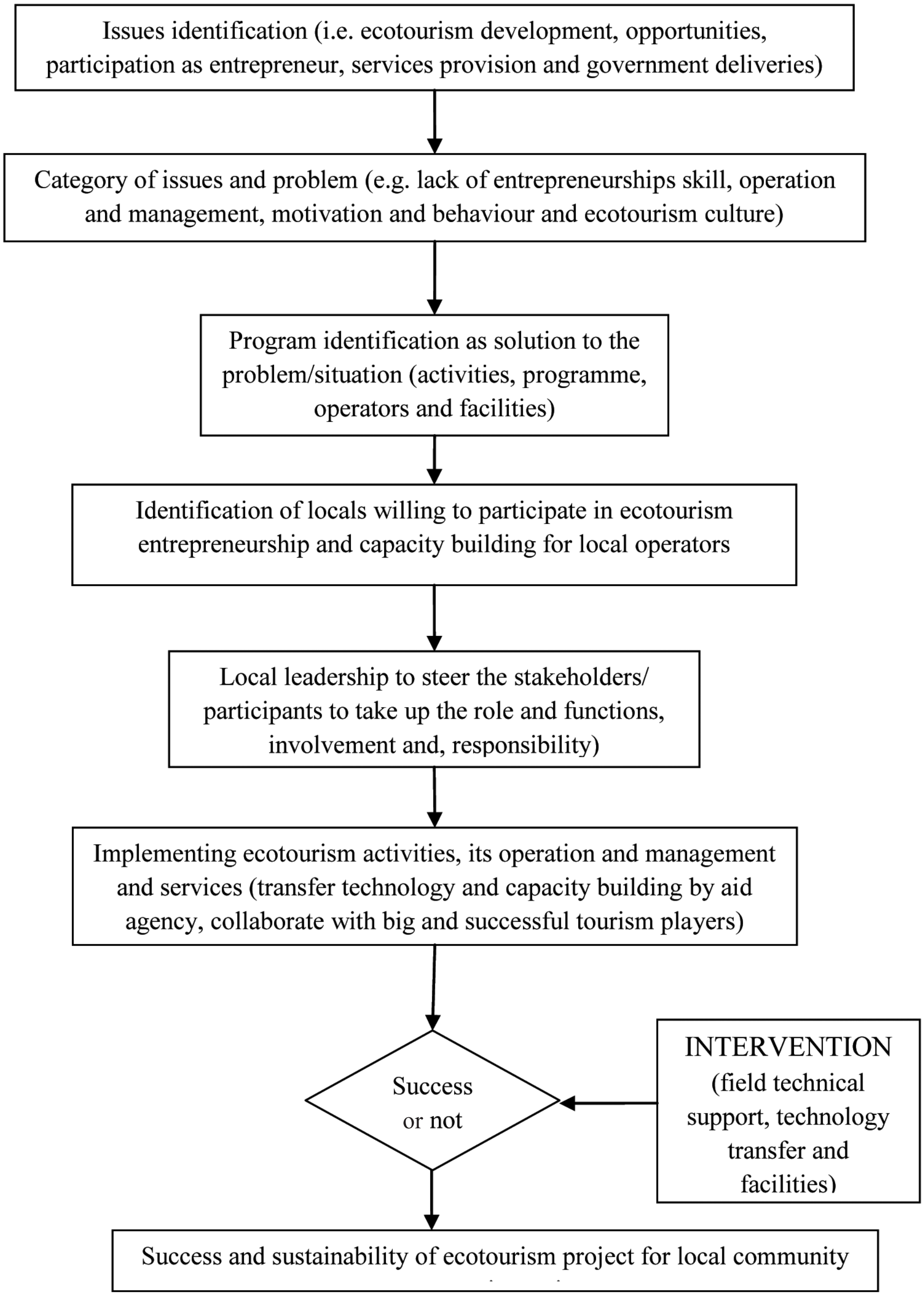

Fig.2: Local community participatory process and intervention procedure in the mangrove ecotourism in Marudu Bay

of the local issues and problems, local community interests are crucial for future development. The local support and willingness to participate in the ecotourism development will help to protect the mangrove ecosystem for sustainable use. These include activities and programme identification and its implementation, determination of local leaderships to spearhead the activities, technical support and facilities required, technology transfer and human capacity building.

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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 field of opportunities for the development of new approaches to computer processing of spatial or geographically referenced data, hence, adding a new dimension to the management of large volumes of information needed in forest recreation planning. This paper describes 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

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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 for 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 collect 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 GIS 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 stand, 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

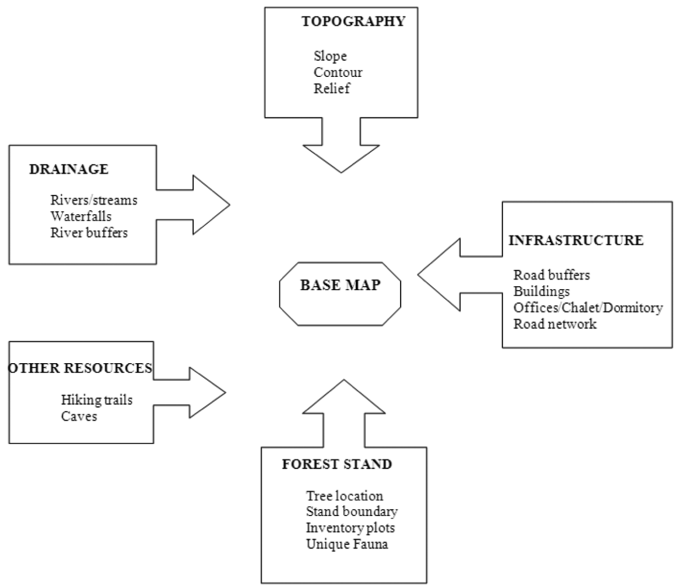

Fig.2: The GIS Database Design for Gunung Tebu Forest Reserve (GTFR)

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 and refinement before the "best" decision is chosen by the planner? This minimizes the 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

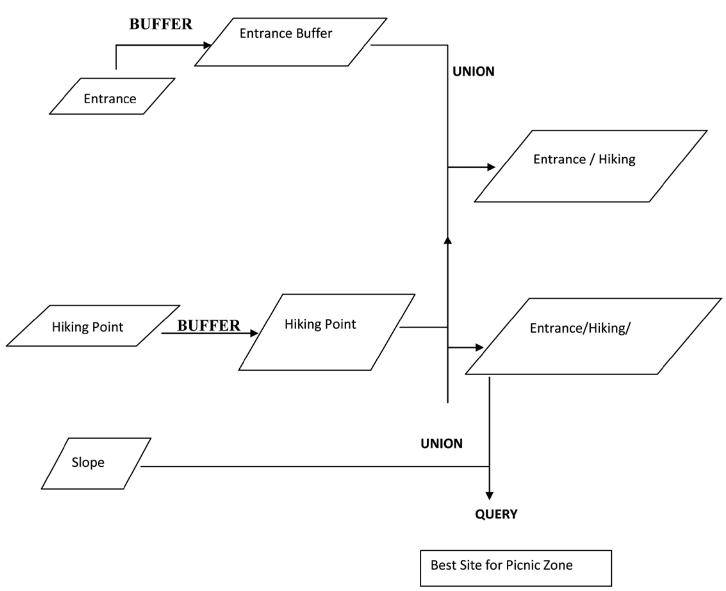

Fig.3: The flowchart of GIS Spatial Modelling Process for Picnic Zone

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
SLOPE-CODE	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 – CODE	73 (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

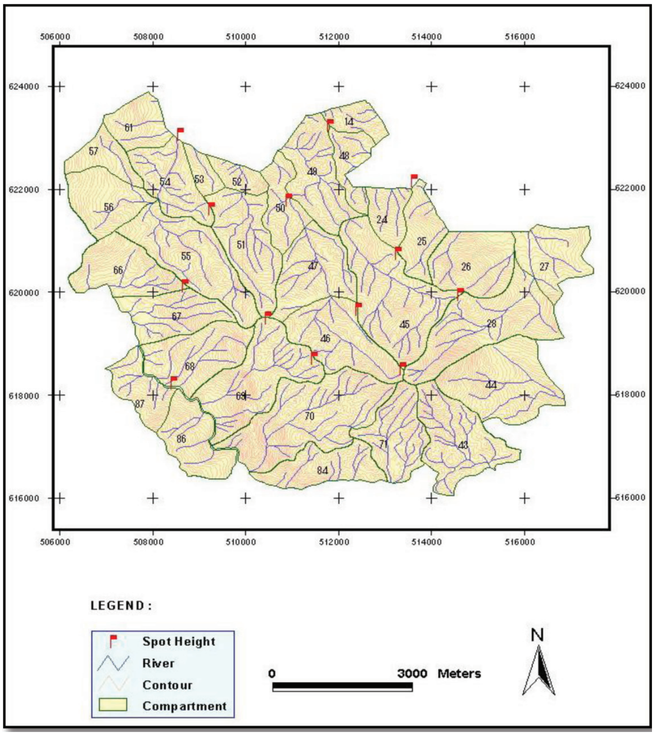

Fig.4: The Topographic Features of Gunung Tebu Forest Reserve, Malaysia

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

cont'd Table 1

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

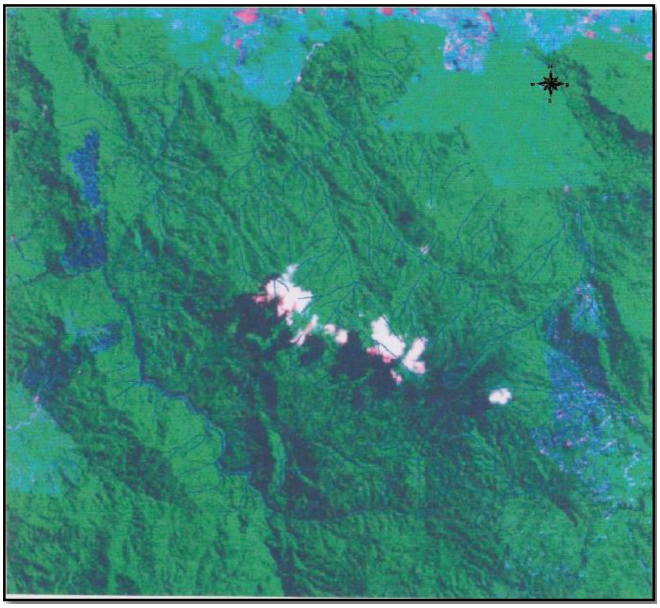

Fig.5: The Landsat TM Satellite Image of Gunung Tebu Forest Reserve, Malaysia Draped over Drainage Features

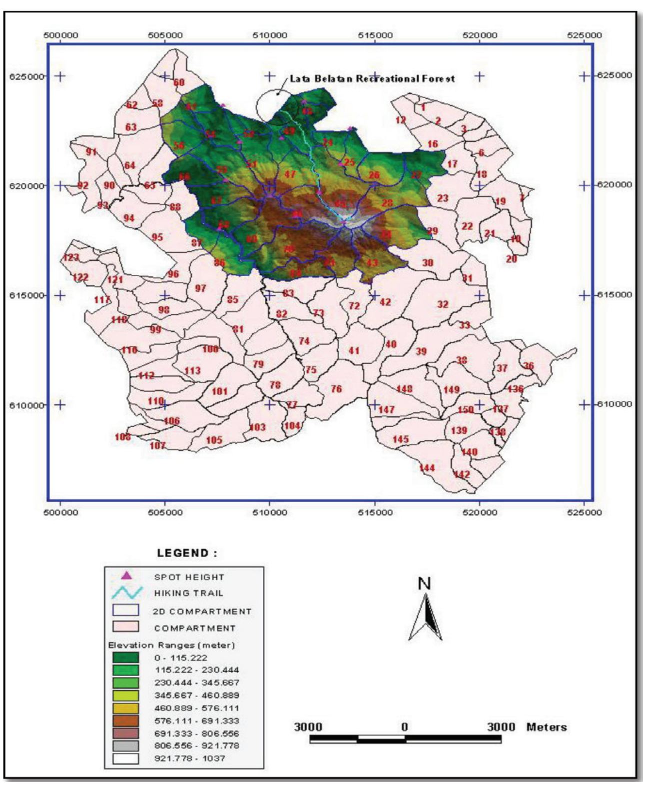

Fig.6: Gunung Tebu Forest Reserve, Malaysia, Elevation with Hiking Trails

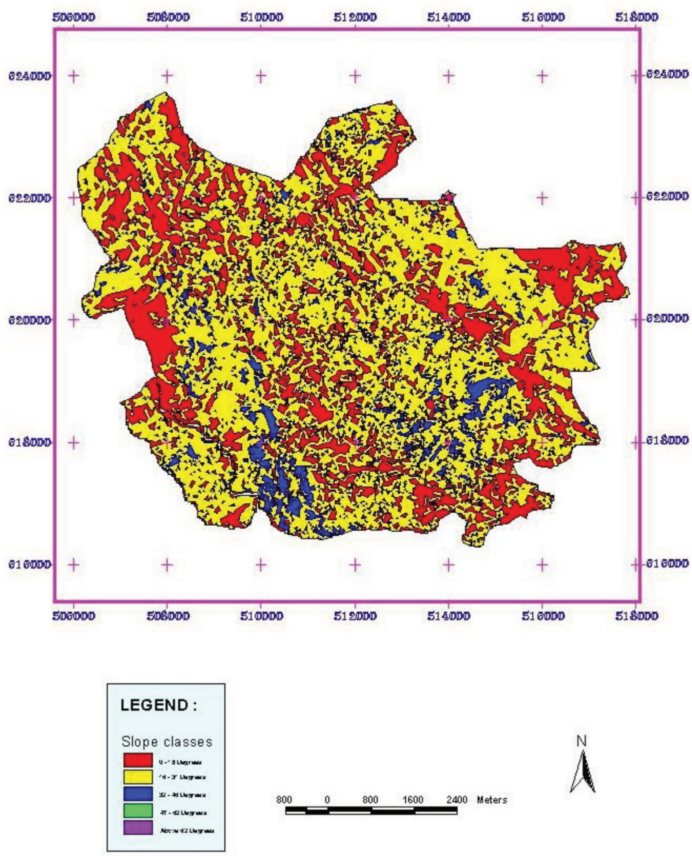

Fig.7: The Slope Classification of Gunung Tebu Forest Reserve, Malaysia

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

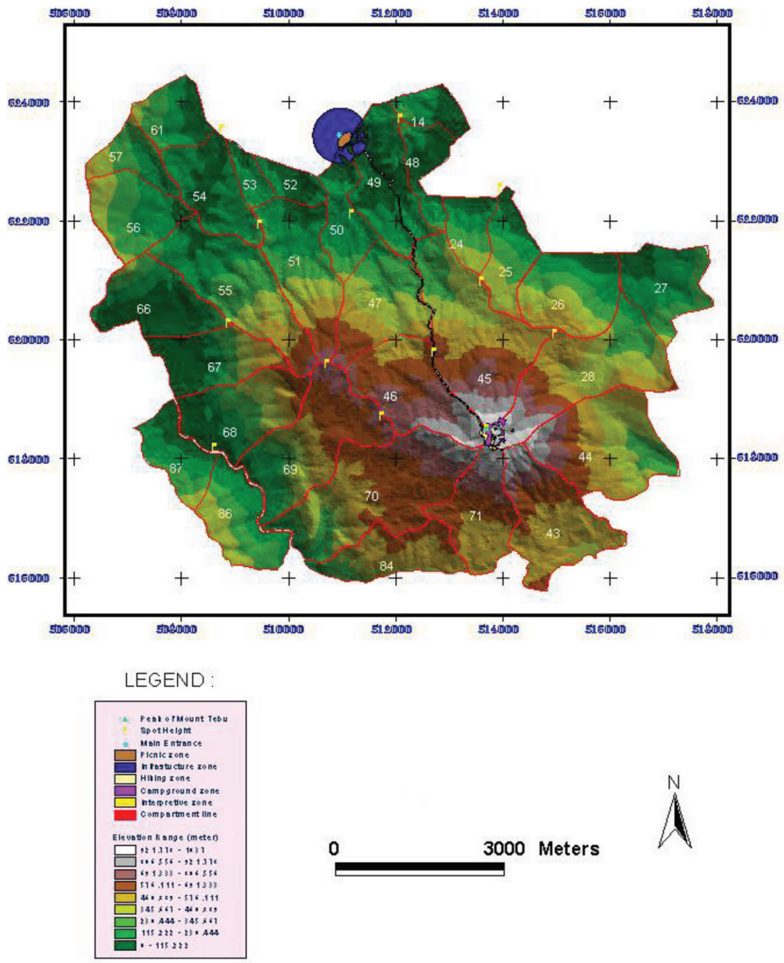

Fig.8: The Slope Classification of Gunung Tebu Forest Reserve, Malaysia

that 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

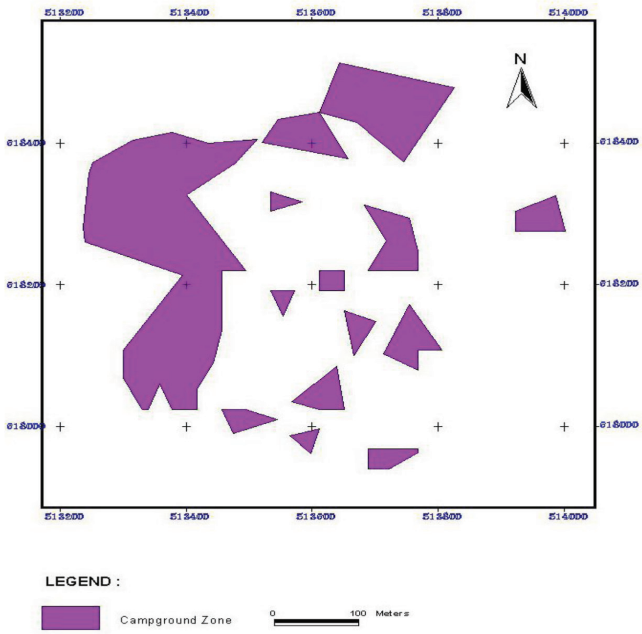

Fig.9: The Campground Zone of Gunung Tebu Forest Reserve, Malaysia

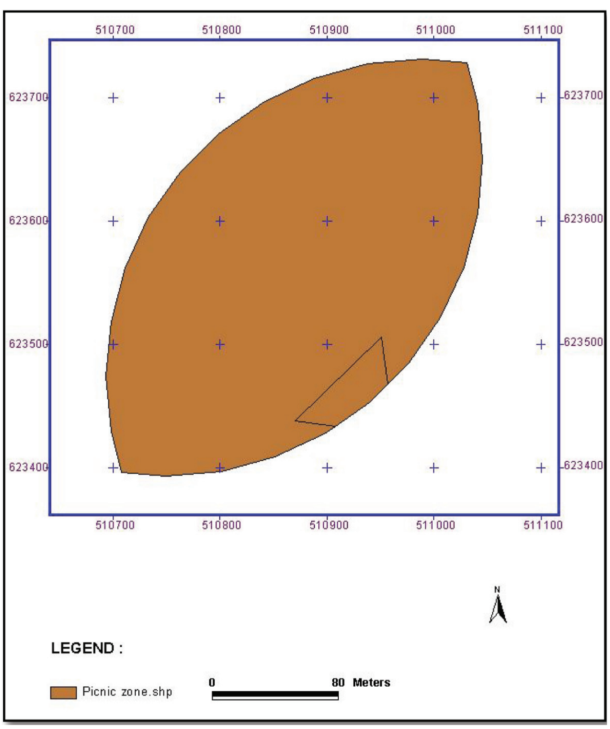

Fig.10: The Picnic Zone of Gunung Tebu Forest Reserve, Malaysia

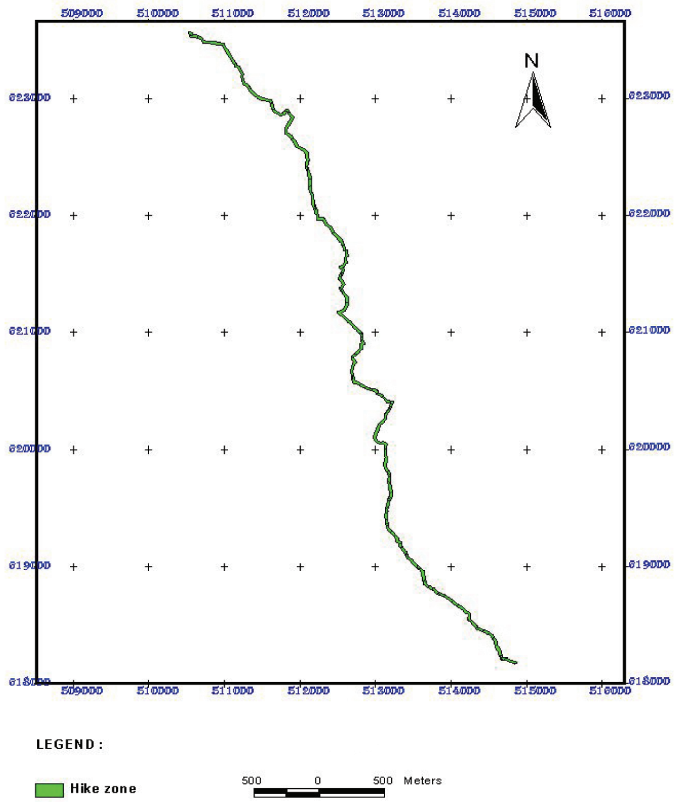

Fig.11: The Hiking Zone of Gunung Tebu Forest Reserve, Malaysia

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.

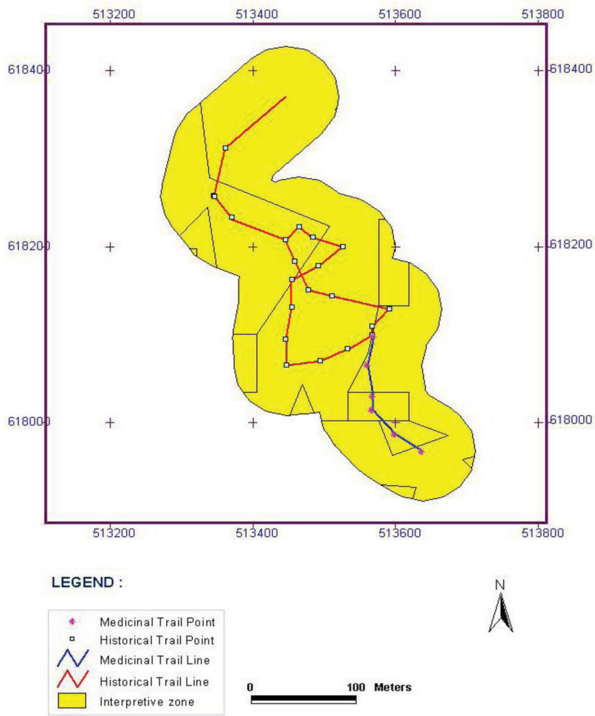

Fig.12: The Interpretive Zone of Gunung Tebu Forest Reserve, Malaysia

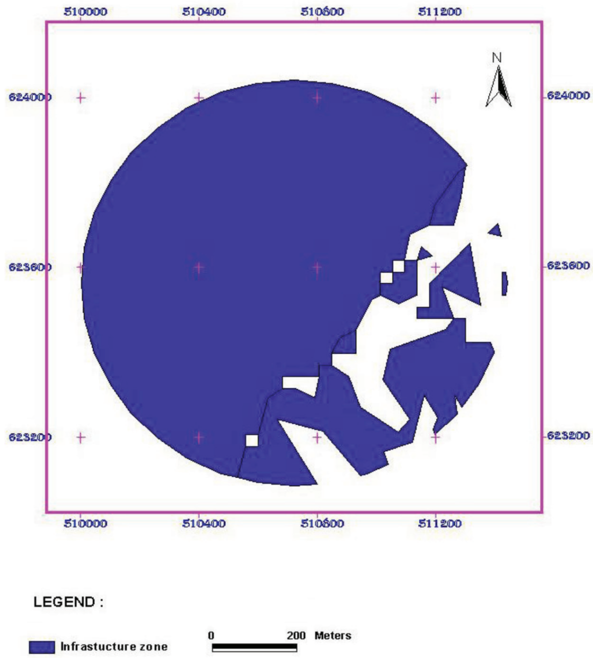

Fig.13: The Infrastructure Zone of Gunung Tebu Forest Reserve, Malaysia.

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Effectiveness of Wetland Interpretation in Affecting School Children's Attitude Towards Scratching of Trees

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ABSTRACT

Scratching or carving on trees by visitors is a common depreciative behaviour in most recreational forest. Besides spoiling the tree's beauty, damaging its wood, causing infection, thwarting tree's growth or even causing its death, scratch marks on trees will potentially make visitors feel angry and uneasy. Wetlands Environmental Interpretation Program (WEIP) was designed by the Forest Research Institute of Malaysia (FRIM) to tackle this problem. About 72 fifth graders of two approximately similar classes from a National Primary School in FRIM were participants of an experiment. The effects of WEIP on the children's attitude towards depreciative behaviour were investigated. A self-administered questionnaire was given *in situ* to both the intervention and control groups. The respondents' behaviours were monitored for depreciative behaviours. The results revealed that interpretive learning experiences positively affected the school children's attitude towards scratching on trees. The message conveyed through environmental interpretative learning experiences could help resource managers in curtailing depreciative behaviours by influencing human attitude on the negative acts on flora, fauna, human and the environment.

Keywords: Wetland, environmental interpretation, attitude, depreciative behaviours, conservation

INTRODUCTION

The Wetland Environmental Interpretation Program (WEIP) was a systematically designed environmental learning experience. It was developed and evaluated based on two fundamental grounded theories, namely, the Theory of Reasoned Action (Ajzen & Fishbien, 1992) and Bennett's Hierarchy of Program Effectiveness (Bennett, 1976). A thematic interpretive trail, known as the Sebasah Trail, was developed with 10 interpretive stations. The stations are used to reveal the main interpretive theme in a

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storyline. The theme was “Appreciating wetlands ecosystems that keep on serving humans”.

The storyline was designed to help visitors gain positive perceptions towards the complexities of being in co-existence within a wetland environment. Interpretive messages also provoke people to appreciate preservation of unique ecosystems by not engaging in depreciative behaviours. This study produces evidence on how interpretive learning experiences like WEIP can positively affect human attitude on depreciative behaviour.

DEPRECIATIVE BEHAVIOURS AND THEIR NEGATIVE IMPACTS

Depreciative behaviours seem to be noticed and taken into account in conservation efforts as more of Malaysia’s natural treasures and landscape disappear. Today, due to the increase in the population, the demands for recreation areas have increased, thus, depreciative activities such as scratching on trees may have serious impacts on our natural resources in the long run. Tree scarification is also experienced by the recreational areas in the Forest Research Institute Malaysia (FRIM), in Kepong, Malaysia. This is due to the demands for public recreation areas by people from the ever expanding residential areas adjacent to FRIM.

Increasing affluence and leisure time, stimulated by the change in values and life styles, depreciative behaviour could further escalade as more areas became accessible to people. With increasing participation in outdoor recreation by local people, this problem is likely to intensify (Wirshing *et al*., 2003). In most forested-natural, recreation areas, the effects of depreciative behaviour may be significant and show both physical and psychological impacts. The observable findings can be seen in physical destruction. Many facilities such as signboards, exhibits, labels, signs and buildings suffer serious damages and can be very costly to repair. This form of devastation or defacement causes some natural features to get damaged beyond restoration (Sharpe, 1976).

The low level of responsiveness and the lack of feeling of ownership among users, one can see the scars of depreciative behaviours in FRIM today. Noor Azlin and Syamsul (2001) reported that depreciative behaviours in FRIM’s recreational areas included littering, damage to facilities, graffiti and improper use of signs.

In investigating depreciative behaviour, it is apparent that there are two aspects contributing to the problem. Sharpe (1976) claims that the first aspect is behavioural, i.e. the complex inner elements, and the second that is the physical aspect, i.e. the external environmental factors. It is believed that the behavioural aspect of depreciative behaviour is determined by controls from within an individual. Through an understanding of human nature and behavioural psychology, the interpreter can have an effect on these controls.

MANAGING VISITORS' DEPRECIATIVE BEHAVIOURS

Humans are capable of modifying biophysical systems from local to global scales. The mediator of these modifications is human behaviour which interfaces between human cognition (social and psychological) and human actions (social and biophysical). Aleesa *et al*. (2003) examined the effects of knowledge, personal attribution and perception of ecosystem health on depreciative behaviours in the intertidal zone of Pacific Rim National Park and Reserve. The study revealed that most resource damaging acts perpetrated by tourists were intentional but not intended to be vandalism or done for the purpose of damaging something and are more correctly termed 'depreciative behaviours'.

According to Roggenbuck (1992), researchers and managers have implemented a host of direct and indirect management actions to tackle the impacts caused by depreciative behaviours by visitors. Persuasive communication, education and related indirect management techniques have often been preferred because they do not contravene visitors' freedom and are often considered as more cost-effective than direct actions such as regulations and law enforcement (Hendee & Dawson, 2002). Written appeals posted on signs are the persuasive communication technique commonly used by park and recreation management agencies, even though other types of media such as computers, the internet and television are also increasingly used (Doucette & Cole, 1993; Manning, 2003). While many studies have evaluated the effectiveness of written appeals, only a small number are directly linked to visitor-impact management issues. Collectively, these studies have investigated the attractiveness and the ability to capture attention from written appeals, visitors' preferences of appeals, knowledge gained, as well as attitude and behaviour change. Namba and Dustin (1992) suggested that depreciative behaviour mitigation would be most effectively addressed by providing information about the behaviour and its consequences. Roggenbuck (1992) concluded that persuasion or interpretation was an effective means of doing this, particularly in the situations where the behaviours were uninformed, unintentional or careless. According to persuasive communication and interpretive research, four factors (namely, sources, message, channel and receiver) influence the effectiveness of the communication process.

One important purpose of nature interpretation, such as signs and written appeals, is to transfer knowledge to receivers so as to influence their attitudes and behaviour. Dowell and McCool (1986), who evaluated low-impact education messages, revealed that boy scouts had increased knowledge on a post-test after they had been shown a booklet and slide shows on leave no trace (LNT) practices. Knowledge levels were tested again; a month following completion of the programme revealed that the scores had significantly decreased, although they were still above pre-test scores. This finding suggests that there is a need to reinforce newly acquired information.

On the other hand, Leung and Attarian (2002) reported that there was only a slight increase in visitor's knowledge when surveyed four to six weeks after they had been exposed to trailside LNT signs on resource impact topics. A small increase in the visitor's knowledge was also found with the trailside interpretive signs in an Australia ecotourism setting (Hughes & Morrison, 2002).

BEYOND THE DEFINITION OF ENVIRONMENTAL INTERPRETATION

Freemen Tilden (1957) defines interpretation as "an educational activity which aims to reveal meanings and relationships through the use of original objects by first-hand experience, and by illustrative media, rather than simply to communicate factual information." Sharpe (1976) added that interpretation is a service for visitors to parks, refuges and similar recreation areas. Although visitors to these areas come for leisure, many also wish to learn about the area's natural and cultural resources. Ham (1992) remarked that environmental interpretation involves translating the technical language of a natural science or related field into terms and ideas that people who are not scientists can enthusiastically understand.

Environmental interpretation programme benefits visitors, managers or service providers as well as natural resources in park and recreation areas. In fact, it enriches a visitor's experience and gives a clearer picture of natural processes. It can also be used to affect the visitors' attitude on the importance of preserving it. Hence, it is an effective tool that can be used by recreation managers and service providers to reach out to the public. A knowledgeable, caring and sensitive individual, with a positive attitude towards the environment, will make wiser decisions on matters related to environmental management. This positive attitude will also reduce unnecessary destructions of park properties by the visitors, resulting in lower maintenance and replacement costs.

This research was conducted with the objective to examine the effects of interpretive learning experiences like WEIP on the school children's attitude towards scratching on trees.

MATERIALS AND METHODS

Design of the Study

The Wetland Environmental Interpretation Program (WEIP) was developed to affect the school children's knowledge, emotion and behavioural intentions towards the negative impacts of depreciative behaviours, particularly scratching on trees on flora, fauna, human and environment. This study provided the first step in creating reliable and valid data on the impacts of this type of programme.

This study was conducted using a quasi-experimental approach as the only deviation from true experimental design was that the subjects were not selected randomly. This deviation was necessary as all the subjects in a class were used in the study and therefore randomness was a non issue. Furthermore, the purpose of the study was to examine the effectiveness of WEIP after controlling for extraneous parameters and not generalizing the findings to school children's attitudinal changes. Three major components of this research were control, manipulation and observation. In this study, relevant independent variables were manipulated, while any other extraneous variables[1] were prepared as a control.

Control plays a vital role in this study to unambiguously evaluate the effects of WEIP on the children's attitude. Meanwhile, manipulation of independent variables involved the setting up of different treatment (intervention) groups. WEIP was used as an intervention for the group of students taking part in the WEIP programme. Three primary independent variables or attitudinal structures that were evaluated were changes in the cognitive, affective and behavioural processes, both before and after the intervention on the negative impacts of scratching on trees (Fig.1).

Study Site

This study was carried out along the Sebasah Trail in Forest Research Institute of Malaysia (FRIM), in Kepong, Kuala Lumpur, Malaysia. The Sebasah Trail, coupled with the 10 interpretive stations, served as the parameters for the experimental intervention.

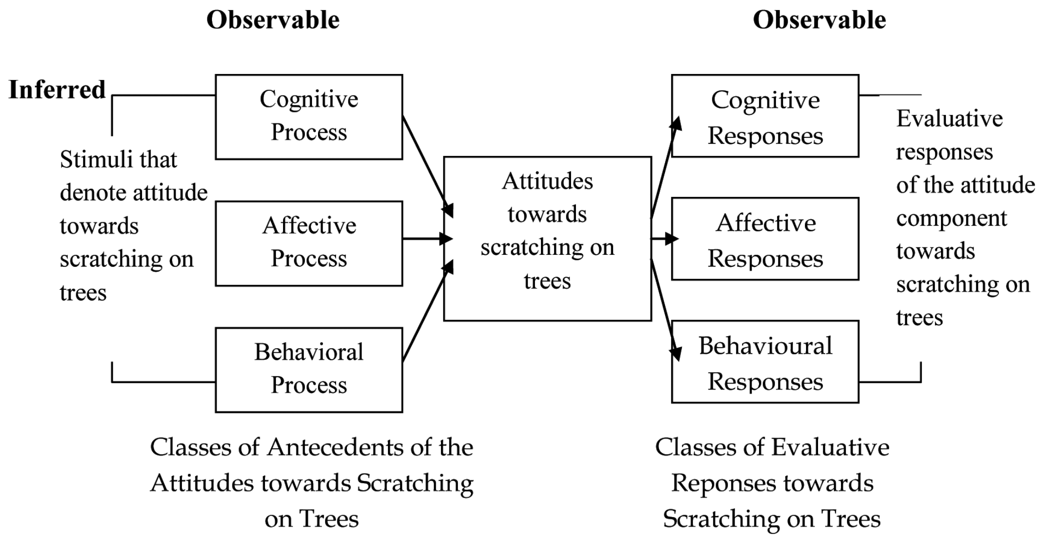
Measurement and Instrument

The changes in the children's attitudinal structures were measured using a self-administered questionnaire before and after the programme. A questionnaire with bipolar five-point Likert scaled attributes was used to measure the changes in the respondent's knowledge, emotional and behavioural intentions. Each construct comprised of at least 10 items requiring a response on a bipolar five-point score gradient from low to high.

Subjects and Sampling

Seventy two (72) standard five pupils (11 year olds) from two approximately similar classes were selected from a National Primary School in FRIM. One class served as the programme (intervention) group and the other served as the control group. Both the programme and control groups were then divided into five smaller groups, respectively. Each of the ten groups was supervised by a facilitator and an observer. The pupils were selected because of their school's proximity to FRIM and they were not involved in UPSR (the major examination for Malaysian Primary School Children). Eleven year old pupils are regarded as being old enough to participate in WEIP, which involved trekking exploration along the Sebasah Trail. In addition, the school was also selected because it is abutting the FRIM compound.

[1] Extraneous variable: Refer to a variable that is not related to the purpose of the study but may have an effect on the dependent variable (Ary *et al*., 1996). The extraneous variables for this study include the students' intelligence and their socio-demographic background.



(*Source*: Adapted and Modified from Fishben & Ajzen, 1992; Eagly, 1993)

Fig.1: The Physiological Construct of the Attitudes and the Application of the Theory of Reasoned Action

Observation on the Nature of the Depreciative Behaviour in FRIM

The research activities started with an early observation on the nature of the depreciative behaviour among the visitors to FRIM using an observation sheet. The observation was conducted in order to answer the first research question addressed in this research, that is, "what kind of depreciative behaviour that was occurring in FRIM, where and when the behaviours occurred and who are the people involved in it". Some evidence was collected during the observation including some photographs and where the behaviours were recorded.

Data Collection and Analysis

WEIP was carried out by three (3) research officers, one (1) assistant research officer, two (2) research assistants, two (2) general supporting staff and four (4) intern students from the Forest Recreation and Nature Education Section of FRIM. Meanwhile, twelve (12) undergraduate students from Universiti Putra Malaysia (UPM) were also trained as observers for this study. Before the programme was started, a set of pre-test questionnaire was given to each of the respondents in both the programme and control groups.

Firstly, the intervention group attended a presentation by the researcher. Then, both the groups went for an exploration hike along the Sebasah Trail. In order to maintain the internal validity of the research designs, no verbal or non-verbal instructions and interpretation on the negative impacts of scratching on trees was given to either group during the hike. Then, the students' behaviours, particularly of the depreciative kind, were recorded by a group of trained observers along the trail. Finally, both the groups answered the post-test questionnaire after their hike to compare their responses from before and after the intervention.

Test for internal consistency of the items within the constructs (Cronbach's Alpha coefficient) was done the proportion of variance that was consistent in a set of scores. The data were analyzed using the paired sample T-test at 95 percent level of confidence.

RESULTS

Respondents' Profiles

All the 72 respondents chosen for this experimental research were from two standard five classes (11 year olds) from a National Primary School in FRIM. They were from two approximately similar standard five classes of the school. A quasi-experimental design (all the students were picked without random selection) was used for this study under the existing situation of classroom setting. A total of 38 students from one class served as the programme (treatment) group and 34 other students from the other class formed the control group. Most the students are males (52.8%) and the rest are females (47.2%). Majority of the students (56.9 %) chose cartoon as their favourite television programme. Some of their favourite cartoon programmes are 'SpongeBob Squarepants', 'Transformers', 'Naruto', 'Doraemon', 'Spies Girl', and 'Kampung Boy.' During their leisure time, most of the students spent their time playing football (18.1%), cycling (16.7%), reading (13.9%) and playing badminton (12.5%).

The Nature of the Depreciative Behaviours and the Visitors' Negative Behaviour in FRIM

Observations carried out from November 2004 to Mac 2005 revealed that littering was an endless problem in FRIM. It occurred most seriously at the wetland and waterfall areas. Meanwhile, improper uses of facility signs were also common, where vandalism of the signage was observed and improper use of station markers as exercise stations or places to perch on, were also rampant.

The visitors had also purposely scratching or carving trees as obvious scratch marks could visibly be seen along FRIM's nature trails. Another serious problem discovered in FRIM was illegal collection of flora and fauna. This was found to be mostly done by joggers who entered FRIM. Among the common collections include mushrooms, durians and other fruits, as well as plants with medicinal properties. On the other hand, observation results also indicated that children, teenagers, and adults collected tortoises, prawns and fish.

Reliability Analyses of the Cognitive, Affective and Behavioural Intention Constructs towards Scratching on Trees among the Respondents

The scale for cognitive process resulted in a low Alpha Coefficient value of 0.419. The inter item correlations for the items in the scale ranged between 0.136 and 0.328. Meanwhile, the scale for the affective process had an Alpha Coefficient value of 0.556. The inter item correlations for the items in the scale ranged between 0.231 and 0.437. The scale for the behavioural

TABLE 1
A Comparison of the Effectiveness of Wetlands Environmental Interpretation Programme in Affecting Attitudinal Structures towards Scratching on Trees between Programme and Control Groups

Depreciative Behaviours	Groups	df	Attitudinal Structures					
			Cognitive		Affective		Behavioural Intention	
			t-value	p-value	t-value	p-value	t-value	p-value
Scratching on Plants	Programme	37	-3.024	0.005	-2.175	0.036	-0.578	0.567
	Control	33	-1.308	0.200	-3.057	0.004	-0.812	0.422

intention process resulted in a high Alpha Coefficient value of 0.715. The inter item correlations for the items in the scale ranged between 0.180 and 0.615. All the items in the three scales were kept for the new subscale construction since these are the best measures available and the multiple items indicators are by far more reliable than the single ones. The errors in these subscales were reduced and the 5 point Likert scale was also improved considerably.

A Comparison of the Changes on the Attitudinal Constructs towards Scratching of Trees between the Programme and Control Groups

As shown in Table 1, the use of WEIP as an intervention was found to be effective in increasing the children's knowledge towards scratching on trees. Compared to the control group (t=-1.308, p=0.200), children in the programme group (t=-3.024, p=0.005) were more likely to develop a basic belief that scratching of a tree would bring negative impacts to the tree. They were more likely to believe that scratching on trees would damage its wood, harmful to the tree, thwart its growth and might also lead to its fatality.

However, children from both the programme (t=-2.175, p=0.036) and the control groups (t=-3.057, p=0.004) were more likely to become emotionally affected after the programme. In more specific, the WEIP intervention was found to be not effective in affecting their emotion towards the depreciative behaviour. Most children from both of the groups were more likely to feel uncomfortable and disturbed to see scratch marks on a tree. For them, scratch marks on the trees spoil its beauty and also ruin the overall scenic of a natural area. The exploration hike along the Sebasah Trail was found to be sufficient enough to affect the children's emotion towards the negative impacts of scratching on trees.

As for behavioural intention, there was no significant difference found within the control group (t=-0.812, p=0.422) and the programme group (t=-0.578, p=0.567). In other words, WEIP was not effective in affecting these children's behavioural intention towards scratching on trees. This means they were more likely to not taking any action when seeing other people scratching on a tree. They most probably would be silent and just let the perpetrators with the behaviour or walk away from the site.

CONCLUSION

As asserted by Eagly (1993), attitudes are manifested in the cognitive, affective and behavioural responses based on cognitive, affective and behavioural processes. According to Eagly (1993), attitudes can be formed mostly or exclusively based on any one of the three types of processes. It may be formed primarily by affective or behavioural processes or by a mix of processes. Moreover, Eagly (1993) further asserted that when human directly encounter attitude objects, attitude formation will probably occur by a variety of processes. Thus, it is concluded that WEIP is effective in affecting the attitude of selected school children towards scratching on trees. Through interpretive learning experience at the site, the programme has positively strengthened the children's beliefs that scratching of trees will bring negative impacts to the tree. They were more likely to believe that scratching of trees would damage its wood, harmful to the tree, thwart its growth and might also lead to its fatality after the intervention.

Wetland interpretation setting can be a difficult yet rewarding venue for presenting an environmental interpretation programme. Even though short interpretive programme such as WEIP may bring short-term impacts, repetitive and continuous efforts in providing effective yet enjoyable learning experiences to our children may bring long-term effects. Through this type of programme, there is a possibility of creating young stewards of the environment who will continue to make environmentally sound decisions throughout their lives. If taught early, it is anticipated that these children would grow into adults who valued the environment and helped to protect it. Hence, this study has confirmed that Wetland Environmental Interpretation Program (WEIP) is effective in affecting the attitude of selected school children towards scratching on trees at FRIM's wetland area.

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Ecotourism in Taman Negara National Park: Issues and Challenges

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ABSTRACT

Ecotourism is one type of tourism that promotes conservation and minimises visitor impacts. This exploratory study employed a semi-structured face-to-face in-depth interview. This study involved 9 visitors in Taman Negara National Park (TNNP). It was designed to identify recent issues and problems faced by the management of TNNP. Current issues and problems faced at the park, including pricing policy dilemmas and the current funding situation, were identified and also discussed. It was found that the main problem at TNNP rooted from inefficiency in pricing policy. Other problems included natural resource conflicts, visitor management and environmental degradation. It is therefore debatable that the main ingredient for the survival of TNNP is the commitment and participation of the stakeholders involved, which comprised of the government, the park authority, private sector, local community, etc.

Keywords: Taman Negara National Park, ecotourism, pricing policy, in-depth interview, qualitative research.

INTRODUCTION

Ecotourism involves visiting untouched natural areas. It promotes conservation, encourages low visitor impact and creates socio-economic involvement of the local population. Eagles (1992) asserted that ecotourism is one of the fastest growing sectors (estimated as growing at 10-15% annually) compared to other types of tourism. Chong (2002) added that ecotourism is the fastest growing form of tourism in Malaysia. This is due to the growth rate, which is an average of 35% a year and accounts for 10% of the total tourism receipts. A total

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of 918,523 visitors were recorded to visit Sabah in 2001. From this number, 406,009 were international visitors, and most of them had visited ecotourism places in Sabah such as the Kinabalu National Park, Danum Valley, etc. Malaysia has adopted the International Union for the Conservation of Nature (IUCN) definition of ecotourism. It stipulates that:

> *…environmentally responsible travel and visitation to relatively undisturbed natural areas, in order to enjoy and appreciate nature (and any accompanying features - both past and present), that promotes conservation, has low visitor impact and provides the beneficially active socio-economic involvement of local populations* (Ceballos-Lascurain, 1996).

This definition emphasises five main aspects, namely: (1) low impact on the environment and on the local culture; (2) covering nature as well as culture; (3) preventing damage as far as possible; (4) repairing whatever damage is unavoidable; and (5) benefits for the people of the area. The Department of Wildlife and National Parks (DWNP) is responsible for the management of ecotourism in Malaysia. The functions of DWNP in ecotourism include: (1) identifying and planning ecotourism programmes; (2) planning and preparing interpretive programmes and materials; (3) advising and providing input regarding ecotourism activities to various government and non-governmental organizations, inside and outside the country; (4) assisting the Ministry of Tourism Malaysia with the planning and implementation of the National Ecotourism Plan; and (5) coordinating zoological gardens programmes and activities.

The most popular destination for ecotourism is the national park. Ecotourism is a new approach to the preservation of wild areas which are fragile and threatened. Poor management of the national park, due to an inefficient pricing policy, can lead to several other problems such as destructions of natural resources. Therefore, this study attempted to identify issues and challenges that would make the ecotourism industry more uncontrolled and vulnerable, as these might cause more harm than good to the environment. This paper consists of 6 sections. It starts with a general orientation of the study. Section 2 discusses study area, i.e., Taman Negara National Park (TNNP), and Section 3 focuses on the research methodology. Meanwhile, Section 4 presents results of the study, and Section 5 provides discussions and recommendations. Finally, section 6 presents a conclusion to the study.

TAMAN NEGARA NATIONAL PARK (TNNP)

Malaysia comprises Peninsular Malaysia, Sabah and Sarawak. In total, there are 24 national parks in Malaysia (Tourism Malaysia, 2009) and three of them are Peninsular Malaysia (Pahang National Park, Endau Rompin National Park and

Penang National Park), and six in Sabah (Kinabalu Park, Tunku Abdul Rahman Park, Bukit Tawau Park, Crocker Range National Park, Pulau Tiga Park and Turtle Islands Park). Meanwhile, fifteen others are in Sarawak (Bako National Park, Mulu National Park, Niah National Park, Lambir National Park, Similajau National Park, Kubah National Park, Gading National Park, Batang Ai National Park, Matang National Park, Semenggoh National Park, Sama Jaya National Park, Loagan Bunut National Park, Wind Cave National Park, Tanjung Batu National Park, and Talang Satang National Park).

TNNP covers the largest vicinity and it is located in three states, namely, Pahang, Kelantan and Terengganu. TNNP is claimed to be home to one of the oldest tropical rain forests in the world. It is Peninsular Malaysia's greatest national park and it covers an area of 4,343 sq. km (DWNP, 1989). It first received protection in 1925, when the state of Pahang established legislation for 130,000 ha of it as Gunung Tahan Game Reserve (DWNP, 1986; 1987). It was declared a national park through enactments by the states of Pahang, Kelantan and Terengganu in 1938/39 and given the name King George V National Park (Rubeli, 1976). Following independence in 1957, the name was changed to Taman Negara, which means 'national park' (DWNP, 1986; 1987). The Taman Negara Enactments of 1938 and 1939 encompass three legislations. As noted before, TNNP straddles three states, Pahang, Kelantan and Terengganu, with each state having its own legislation. The largest is Taman Negara Pahang (2,477 sq. km), followed by Taman Negara Kelantan (1,043 sq. km) and Taman Negara Terengganu (853 sq. km).

Visitors' Profile

It has been found that the trend and visiting pattern are changing. It appears that international visitors are the dominant groups that have visited TNNP. This is in

TABLE 1
Malaysian and International Visitors to TNNP, 2001 - 2009

Year	Malaysian visitors	International visitors	Total
2001	26149	32383	58532
2002	30108	30048	60156
2003	33326	20904	54230
2004	31233	28793	60026
2005	37819	33812	71631
2006	40877	38881	79758
2007	40358	41616	81974
2008	39579	44563	84142
2009	40617	46057	86674

Source: DWNP, 2010.

contrast with the previous times, where more Malaysian visitors visited the park. Table 1 shows a total of 46057 international visitors (53.1%) visited TNNP as compared to 40617 Malaysian visitors (46.9%) in 2009. It also shows that the total number of visitors keeps increasing year by year.

Charges for Permits and Licences at TNNP

Recently, TNNP has implemented several charges for permits and licences issued to their visitors. These cover entrance permits, fishing licences, camera licences, camping fees, the canopy walkway and the hide. Visitors are entitled to enter the park for a month on a payment of RM1 as an entrance permit. Other charges are shown in Table 2.

TABLE 2
Charges of Permits and Licences at TNNP

Permit and licences	Charges (RM)
1. Entrance permit	RM1/entry
2. Fishing licence	RM10/person
3. Camera licence	RM5/camera
4. Camping fee	RM1/day/person
5. Canopy walkway	RM5/person
6. Hide	RM5/person/night

Source: DWNP, 2005.

METHODOLOGY

The current study is an exploratory qualitative research which applied in-depth interview as its main method. The qualitative method involves a process where the researcher describes some characteristics of people or events without any elements of measurement. In other words, it is a method that has been designed to capture the social life experienced by participants. It differs from the quantitative method, where all these experiences are categorised and determined by the researcher. Three important characteristics of the qualitative method are: (1) Most of the data are in the forms of written and spoken words, and observation; (2) There is no direct numerical interpretation in qualitative data; and (3) The motive in the qualitative method is often exploration.

Jennings (2001) found that the qualitative approach is grounded in the positivist social science paradigm, which primarily reflects the scientific method of the natural sciences. It is often designated as an 'art' when compared to quantitative research, which is rigorous and scientific (Decrop, 1999). According to Gilbert (1993), qualitative methodologies allow researchers to discover levels of deeper meaning. As a result of the process of gathering in-depth information, qualitative research is subjective and it involves a small number of participants in the research process (Gunn, 1994). Finn *et al.* (2000) noted that qualitative research has the opportunity to present detailed snapshots of the participants under study. One of the limitations of qualitative research, however, is the total time involved in data collection, analysis and interpretation. Babbie (1998) explains that qualitative research involves more time in order to examine holistically and aggregately subjects' interactions, reactions and activities.

There are many types of qualitative method; these include in-depth interviews, participant observation and ethnography. The most popular of these is the in-depth interview; so it was applied in this study. Maykut and Morehouse (1994, p. 46) stated that:

> *The data of qualitative inquiry is most often people's words and actions, and thus requires methods that allow the researcher to capture language and behaviour. The most useful ways of gathering these forms of data are participant observation, in-depth interviews, group interviews, and the collection of relevant documents. Observation and interview data is collected by the researcher in the form of field notes and audio-taped interviews, which are later transcribed for use in data analysis.*

In-depth interview is commonly used to determine individuals' perceptions and opinions. The method is described as a 'conversation with a purpose'. Similarly, Kvale (1996) also states that interviews are conversations, and defines qualitative interviews as 'attempts to understand the world from the subjects' points of view to unfold the meaning of peoples' experiences, and uncover their lived world prior to scientific explanations' (Kvale, 1996, p. 1). Babbie (1998, p. 282) sees an in-depth interview as 'a mainstay of participant observation, used both by participant observers and by researchers who make no pretence of being a part of what is being studied'. Several advantages of in-depth interviews have been identified. These include exploring the boundaries of a problem, obtaining evidence for a particular problem or issue, evaluating potential solutions and managing the research process. In-depth interviews were chosen for the current research work because more and wider information could be elicited. Furthermore, skilled interviewers can gather information that may be left out through a survey or other techniques. Thus, the main role of the in-depth interviewer is to explore the respondents' points of view, feelings and perspectives. Such interviews have also been used to obtain systematic descriptions of interviewees' experiences. On the other hand, a disadvantage of this technique is that it involves personal interaction; sometimes we are not free to share our feelings with a person whom we do not know.

TNNP was used as a setting because it is one of the places for ecotourism in Malaysia. The respondents participated in the study were visitors who have had some experiences at TNNP. This research applied semi structured face-to-face interviews with 9 visitors from various backgrounds. The shortest interview was approximately 40 minutes, while the longest was around 1 hour 30 minutes; allowing the interviewees to identify and talk more on issues in TNNP. A standard interview guide was developed and used for all the interviews. All the interviews were recorded. Data analysis in the qualitative research starts with collecting the required information from the field and sorting it into categories. The information received is formatted into a story, and finally written into a report (Denzin & Lincoln, 1994). According to Creswell (1994), qualitative research is a process of sorting information from interview transcripts, observational notes, documents and visual material. This study applied the technique of finding similar phrases and themes in in-depth interview analyses. In other words, this particular technique emphasises two items or characteristics, namely; word repetition and key words in context. D' Andrade (1991, p. 294) observes word repetitions as 'the most direct indication of schematic organisation in naturalistic discourse is found in repeated associative linkages'. In this study, word repetitions were analysed informally. This was done by noting the words that are synonyms and used by respondents frequently. Word repetitions can also be analysed formally by using a computer. Nonetheless, this study did not utilize any computer analysis because of the nature of the data gathered. It is easy to find word repetitions manually, as the data or information is precise and short. Meanwhile, key words were identified through the key words used in the interviews.

RESULTS AND FINDINGS

This section discusses issues and problems that have been identified from the in-depth interviews. It focuses on five issues, namely; pricing dilemmas and funding, resource conflicts, visitor management, and environmental degradation.

Pricing Dilemmas and Funding

Nowadays, the crisis in funding and problems of insufficient funds are the main items on the agenda at most park management meetings and conferences. Insufficient funding is highly related to the pricing system on permits and licences at the park, especially the entrance fee. An inappropriate or a low entrance fee will result in insufficient revenue, thus creating other problems at the park such as overcrowding, environmental deterioration and poor park facilities, as mentioned in the following:

> *Undercharging for parks increases the cost to the national treasury of maintaining the parks estate and fails to maximize revenue, much of it in the form of badly needed foreign exchange* (Goodwin, 2000, p. 247).

An efficient pricing system is a tool for achieving sustainable management of park resources. Font *et al.* (2004) listed six main methods for raising funds to protect areas, and these included entrance fees, user fees, concessions and leases, direct operations of commercial activities, taxes, as well as volunteers and donations. However, according to Sherman and Dixon (1991), there are five main methods for revenue generation in protected areas: user fees, concession fees, royalties, taxation and donations. In some cases, income from entrance permits and user fees is sufficient enough for the maintenance and operations of national parks and protected areas. However, some parks are in critical situation, as they face insufficient funds for park maintenance and operation.

Most of the respondents agreed that the current entrance permit of RM1 is too low. This is clearly evident in the following statement:

> *Entrance permit is only one ringgit. Too low. We got everything is this park. Beautiful rain forests, wildlife but we just pay only one ringgit. I went to other national park in Sarawak. We have to pay more. People now can afford to pay more because they got higher income and I can see they appreciate nature nowadays* [Respondent 3].

> *I was surprised for the entrance fee. When you want to enter this park you have to pay one ringgit only. In this time, what can you do with one ringgit?* [Respondent 9].

In the case of TNNP, the price of permits and licences is set by the Treasury. It is based on an Enactment of 1938/39. The price is proposed by the DWNP and must be supported by the Ministry of Tourism and the Cabinet before it goes to the Treasury (DWNP, 1987). Respondent 2 and respondent 8 have their own opinion about the setting price of TNNP:

> *Somebody told me that the entrance permit has been there for ages. This park should properly set the price, since Taman Negara is a unique product. As our heritage, it is invaluable. Moreover, Taman Negara should also look at the current price of other national parks* [Respondent 2].

> *I'm not very sure who put the price of the entrance fee. Responsible group should check the price. It is very cheap price* [Respondent 8].

One of the issues faced by the parks and protected areas today is the issue of obtaining funds for their operations or their survival (Fennell, 1999). As solutions to this problem, there are suggestions that parks should be operated as business entities or that they should be privatized. TNNP is not free from the problems of insufficient funding. It has traditionally relied on the support from the government of Malaysia. To run the park, TNNP is highly dependent on allocations from government and other sources such as private companies and donations. In terms of the financial situation at TNNP, most of them knew that TNNP has recently received some funding from the government and the private sector. Respondent 4, respondent 7 and respondent 9 stated that:

> *I was told that this park gets some funding from the government and private company. Park should get more sponsors from private companies. In order to cut costs,*

they can optimise their current staff by asking them to carry out maintenance or operating tasks such as cleaning the trails. They should not hire part-timers for those tasks [Respondent 4].

Giant company such as Petronas, Shell and Sime Darby should donate some of their money. Example, Honda had contributed some of their sales for the conservation of rhinoceros [Respondent 7].

Some private companies have done their job. Maybe they think it is their responsibility. I heard that some companies gave this money to this park for helping this park for the operation and maintenance [Respondent 9].

Meanwhile, one of the most effective and successful methods for revenue generation appears to be the entrance fee. Some parks employ a fee system whereby all income received goes back into the park's individual account. Studies have shown that visitors are more willing to pay higher entrance fees if the revenue is used for conservation and improving the quality of services (Font *et al.*, 2004). In 1989, Botswana raised the entrance fee for foreigners to their protected areas by 900%. Surprisingly, two years later, the number of tourists visiting their places increased by 49%, and this resulted in an increase in the parks' revenues. Dharmaratne *et al.* (2000) believe that because these resources are unique, management authorities feel that they can charge higher prices. Walpole *et al.* (2001) and Zaiton (2008) found that international visitors were willing to pay more for fees at national parks.

Most of the respondents suggested that TNNP increased their permit and licence fees, especially the entrance permits to generate extra revenue. Some of them, including respondent 3 and respondent 2, said that the best option was through entrance permits. Respondent 3 and respondent 2 asserted that:

…… There are several actions that can be taken to increase their income. Firstly, increase the price of the current permit, especially the entrance permit. The charge has been there for a long time [Respondent 3].

The funding depends on the visitors' arrival time. When the number of visitors increases, TNNP's income will eventually go up. Along the same line, TNNP should increase the entrance fee and boost sponsors or donations from public and private sectors [Respondent 2].

Resource Conflicts

Dearden (2000) identified three reasons for resource conflicts in national parks. The first conflict is over legitimate resources within the national parks. This conflict arises between recreation/tourism areas and the requirement to protect these resources for current and future generations. This means the park authorities are confused whether to fully exploit them or to preserve them for later. Consequently, conflicts arise between tourism and conservation. The second conflict is closely related to activities within the park. When a place becomes a national park, all the activities such as collecting wood and hunting animals will become illegal. Therefore, conflict occurs, especially over developing the country; these resources are often sources of income. This statement is supported by respondent 1 and respondent 9:

> *This Taman Negara is a source of income for aboriginal people. Before this, they collect honey, wood and plant from this forest, suddenly, government take this forest. What happen to them? Where would theyfind food and how would they survive?* [Respondent 1].

> *This forest is a place for Orang Asli. They were born here; they built their house here. This is where their life is. Forest is where they can find food such as small animal, medicine, fruits, for them and sometime they sell them* [Respondent 9].

The last conflict is over 'external threats'. In other words, land uses outside the national park sometimes have detrimental impacts on the protected national park. National parks today also face issues on managing the tourists and alleviating tourism's impact.

As noted, national parks are the main sources of income for aboriginals and local people. However, when a national park is opened to the public, all the activities including collecting forest products are illegal. This often encourages poaching by aboriginals and local people. Respondent 8 gave the opinion that poaching is one of the most critical recent problems in TNNP. This can be seen in the following statement:

> *I think poaching is one of the problems at this park. I've seen in the newspaper before that it involved activities such as collecting forest product and c animals and then sell them at the higher price. There is a demand out there. I think this problem exists because the jungle used to be their place before. This forest is their life. It is not easy to change their mind because they believed they can take whatever they want from this forest* [Respondent 8].

Poaching of forest products is a current problem at TNNP. According to DWNP (2005), there were 2,581 cases in contravention of the Protection of Wildlife Act 76/1972 in 2003. One of DWNP's major recent activities is the enforcement of the Protection of Wildlife Act 76/1972.

Activities under this Act include the protection and patrolling of the wildlife reserve, forest reserve and important wildlife habitats where endangered wildlife species still exist (DWNP, 2005). The duties of DWNP are to inspect licensed dealers and private premises and control other forms of wildlife exploitations.

Respondent 5 proposed that TNNP hire more staff in order to combat this problem. In addition, she also said that Taman Negara should have better cooperation with the army in the attempt to minimize the poaching problem. This will perhaps help reduce poaching, and at the same time, reduce the operational costs of the park. Respondent 7 believes that the poaching problem could be solved through the involvement of the local people and aboriginals in park decisions.

Visitor Management

Visitor management in national park is particularly important for the sustainability of ecotourism resources. The problem of overcrowding and an excess of visitors is closely related to visitor management. One of the important issues related to national park is overcrowding. In the case of TNNP, this park is open throughout the year and there is no restriction on the number of visitors coming to the park. Respondent 1 and respondent 8 gave their opinions:

> *I can say there is a lack of visitor management at this park. People can enter this park without limit. You can see from the walking trails. The walking trail condition is so bad* [Respondent 1].

> *I can see there's too many people allowed to enter this park. When too many people are allowed to enter, many problems will arise, especially overcrowding* [Respondent 8].

The problem of overcrowding can be minimized by taking preventive action, such as limiting the number of visitors. Most of the respondents felt that limiting the number of visitors could overcome several problems at the park including erosion problem. Other possibilities forwarded were organizing special events out of the peak season (as suggested by respondent 7) and creating more attractive places at the park, which would avoid difficulties such as overcrowding in certain parts of TNNP (respondent 5). The two respondents gave their opinions as follows:

> *Another option to explore is new accesses to Taman Negara, which would be introduced by organizing special events out of peak season. This, in turn, will ease the congestion problem during those busy times* [Respondent 7].

> *....This park should explore more places or create new tourism products. This will help to reduce congestion problems and avoid tourists from crowding just certain places* [Respondent 5].

Environmental Degradation

Studies by Chin *et al.* (2000) at Bako National Park found that 69% of the visitors littering around the park as either a 'slight problem' or a 'serious problem'. This was followed by erosion along walk-trails (62%) and damages to natural vegetation (57%). Meanwhile, Yong (1990) identified several environmental problems at TNNP. These included: (1) littering problems by visitors, especially on walking trails, river banks and camp sites; (2) waste water disposal into the Sungai Tembeling; (3) sandy soil along the trails and camp sites; and (4) erosion along river banks. Erosion along Sungei Tembeling is caused by the waves created by boats passing along the river and by illegal logging activities in some parts of the park.

Respondent 3 found that erosion was a problem which occurred recently at the park. Several parts of the park, such as the trails and camp sites, are heavily used. The problem becomes worst after heavy rain as this makes the trails muddy. In order avoid mud, some visitors create new trails and this causes soil erosion and destruction of vegetation. Respondent 3 also made a suggestion that TNNP be closed for a certain period. He stated that:

> *... Some of the trails are overused and the soil is seriously eroded. Taman Negara should close this park for a certain period; let's say 3 months in order for the trails to be repaired and the soil to be recovered. Last but not least, it should also limit the number of visitors* [Respondent 3].

Respondent 6 agreed with respondent 3, saying that:

> *Walking trail is so muddy and erosion is bad. When the rain is heavy, you can see a lot of water on the trail. Also, some part you can see problem of land slide* [Respondent 6].

Littering also occurred in popular places such as the walking trails, river banks, camp sites, and canopy walkways. This led to environmental problems in these areas. Waste such as plastic bags and plastic bottles will result in air pollution if they are burnt, and contamination if buried. These are explained by respondent 1 and respondent 5 in the following statements:

> *I can see two problems, which are littering and insufficient number of staff to pick up the rubbish. ... TNNP should regularly carry out inspections or rounds and strictly enforce the rules* [Respondent 1].

> *I don't understand with the attitude of some people. They throw rubbish where ever they want. I can see a lot of bins in the park but still they don't want to use the bin* [Respondent 5].

Respondent 6 believes that environmental problems could be minimised through a mixture of the following measures: conservation education, information, law enforcement and participation. Perhaps this combination can ensure that the park be successful for the present and future generations. Respondent 6 is firm in his belief that the park should:

> *Also, try to get local communities' involvement in planning and decision-making processes and spend on education and conservation programmes for both visitors and the local community.*

DISCUSSION AND RECOMMENDATIONS

The main problem at TNNP is rooted in an inefficient pricing policy. The finding reported that entrance permit is very low. For this the respondents suggested a revised in the pricing policy could be a tool for generating extra income and smoothing the flow of finance at TNNP. So far, the government has been a major source of funding for certain national parks, especially those in developing countries. This has been the case for TNNP, but the park authority has to find other ways of raising funds for the survival of the park as well. Besides funding from the government, several mechanisms have been identified to raise park revenue including increasing income from private funding as discussed by some of the respondents.

The findings also revealed that resource conflicts also occurred in TNNP. Poaching can be minimized by creating a close relationship between park authority and the local communities, including aboriginal people. Meanwhile, the involvement of the local community in policy-making and decision processes is important in ensuring that their opinions and ideas are heard by the park's authority. At the same time, such processes will enable TNNP to obtain better cooperation from the local community. Other actions include increases in law enforcement and fines for people who contravene the protection of Wildlife Act 76/1972. In 2003, the total revenue collected from enforcement activities was RM1,677,826.00 (DWNP, 2005). Of this figure, compound cases recorded RM76,508.00 and fines were around RM48,000.00 (DWNP, 2005).

As reported in the study, the best option to reduce congestion at TNNP is an attempt to channel the visitors into less crowded areas. This can be done by exploring and providing new places to attract them. Meanwhile, the trends in visitor arrivals in the peak season can be used by the park authority as guidelines in designing an efficient pricing system. As discussed earlier, pricing can be used as a tool to solve several problems such as overcrowding in TNNP. For example, the park authority can set a higher price during peak season or different prices for weekdays and weekends to assist in alleviating congestion problems. Finally, TNNP can design several programmes outside peak season as a strategy for attracting visitors.

As evident from the interview, environmental degradation is also one of the important issues at the park. There are various options for TNNP to reduce environmental problems in the park. The most vital is to educate visitors and the local community about the importance of the rain forest and why it should be conserved. By increasing the level of awareness, especially among visitors and in the local community, people may be made to feel that they should take the responsibility and to cooperate with TNNP to ensure the park's survival for future generations. Hence, educating the visitors as well as the local community on the importance of sustaining the environment is critical so that they will understand and support the management's strategies in TNNP. In addition, it is clear that there is an apparent need to increase the promotion in term of tourism sustainability. Also reported is the fact that TNNP could limit the number of visitors, especially during the peak season to minimize the problems of overcrowding and erosion.

CONCLUSION

Ecotourism management will increasingly become a subject of interest as ecotourism activities are gaining popularity around the world. This paper has identified issues and challenges faced by TNNP. The findings showed that inefficient pricing policy, resource conflict, visitor management and environmental degradation occurred in TNNP. A national park is an untouched area of natural environment, which requires the maximum level of protection and was created to safeguard certain areas of the earth, land and water surfaces from market and other forces. National parks are also areas that contain natural resources of ecological importance or unique beauty, or flora and fauna of special importance.

Based on the preceding discussion, it is important to note that one of the major challenges in the management of ecotourism is to comprehensively develop a structured and integrated plan for environment management, particularly at TNNP. Accordingly, this requires a strong collaboration from respective stakeholders, which include Department of Wildlife and National Parks (DWNP), Department of Environment (DOE), and Ministry of Tourism Malaysia. More importantly, it is vital to involve the local community in the ecotourism sustainability planning so that they can suggest relevant ideas and consequently, value their endangered resources more highly.

Ecotourism in national parks brings benefits to the local communities through employment opportunities, and this increases the levels of income. However, proper planning is needed, because without it, such developments will bring negative effects to the economy, society and the environment. Similarly, a careful planning of visitor carrying capacity is also required to avoid congestion problem that impairs the environment in national parks. An overwhelming number of visitors will create a burden on the environment, and thus affect the habitat of flora and fauna. Thus, it is possible to suggest that the government, the private sector, local community and other stakeholders are the ones that safeguard the sustainability of ecotourism resources in TNNP.

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Sub-Pixel Technique of Remotely Sensed Data for Extracting Bamboo Areas in Temengor Forest Reserve, Perak, Malaysia

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ABSTRACT

Various approaches can be used to map bamboo in forested areas, including the use of airborne and space-borne remote sensing data. In remote sensing, thematic maps are created from numerical data collected by sensors that measure the amount of reflected energy from different land cover types. These data are then translated into an image by assigning visible colours to the numerical value. Remote sensing technique has been proven to be effective for mapping timber resource but the use of this technology in the mapping of bamboo resources in Malaysia is still new and yet to be explored. The traditional method of classification in remote sensing is by using supervised classification of mixed pixel; however, the use of sub-pixel classifier is recently gaining momentum. This study applies the sub-pixel classification technique in processing SPOT 5 (path/row: 268/339) satellite data to identify and map bamboo areas in Compartment 26 of Temengor Forest Reserve in Perak. Ground verification was done to check the accuracy of classification from the sub-pixel technique. This study identified about 4.61 ha (15.4%) bamboo areas from the 60 ha of the total area in compartment 26 of Temengor Forest Reserve. The estimated bamboo culms were 4,062 and the accuracy of mapping was 86.6%. This paper demonstrates that remote sensing is capable of identifying bamboo areas through sub-pixel-based technique with acceptable results. In future studies, high resolution satellite remote sensing should be considered for better results.

Keywords: SPOT 5 data, sub-pixel classification, bamboo mapping

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INTRODUCTION

Natural stand bamboo grows profusely in forest throughout the whole of Malaysia. Wild bamboo populations are found in forest gaps, especially in post-logging areas, river banks, hill side and ridge tops and sometimes in patches on flat lands and hill slopes (Ng & Noor, 1980). Most of the bamboos found wild in forests are *Gigantochloa scortechinii*, *Schizotachyum grande*, *Schizotachyum zollingerii*, *Dendrocalamus pendulus*, and *Gigantochloa ligulata* (Azmy, 1991). Bamboo sometimes occurs as a secondary growth on abandoned clearing where shifting agriculture is being practiced. The areas where bamboos grow have an annual rainfall of 1200 to 1400mm and a mean annual temperature of around 32°C or less. The plants can be found up to 1,530 meters on the hills. Once established, bamboo thickets are difficult to eradicate (Ng & Noor, 1980).

One of the most important aspects in managing bamboo resource is acquiring reliable information on the status of the resource availability in forest. This includes knowing the spatial distribution of the bamboo areas and ability in pinpointing the areas on the map. Information on bamboo distribution in natural forests is essential for bamboo management and productivity. Classification of the bamboo and their quantification in the past were done through manual surveys and these traditional methods are rather expensive and time consuming. Voluminous amount of the data collected cannot be updated quickly when involving large areas, while the cost of manual update can be very high. In the case of mapping bamboo areas, appropriate digital analysis can be done to differentiate between bamboo and other bushes or secondary vegetation areas. Various approaches can be used to map the resources, including remote sensing technique. In space-borne remote sensing, maps are created from numerical data collected by sensor on the satellites that measure the amount of reflected energy from different land-cover types. These data are then translated into an image by assigning visible colours to the numerical values. Image generated from this procedure reveals distinction in habitat such as forest types, bamboo areas, logging track, and rivers (Khali, 1995).

However, the usefulness of the remote sensing data in bamboo inventory has not been fully explored. Uncertainty arises when the behaviour or ecology of bamboo is not well examined. Attempt was made to use data obtained from space-borne satellite to map bamboo areas in the forest (Kamaruzaman, 2007; Wan Zuraidi & Kamaruzaman, 2000). Optical remote sensing images contain a mix of pure and mixed pictures element (pixels). Meanwhile, digital image classification techniques consider a pixel as a unit belonging to a single land cover class. However, due to limited image resolution in some remote sensing data, pixels often represent ground areas, which comprise two or more discrete land cover classes (Foody & Boyd, 1996). Thus, in order to measure the strength of membership in a pixel, the sub-pixel technique can be used as fuzzy logic (Foody *et al*., 1997; Anastasios *et al*., 1999). A sub-pixel classification assigns a pixel to different classes according to the areas and yield a number of fraction spectral members equal to the of land cover classes.

Classification of mixed pixels leads to errors that make the subsequent area estimation inaccurate. These errors are caused by the premise of classification that all pixels are pure, i.e., consisting of a single ground cover type, while in fact they are not. The spectral confusion caused by mixing of ground cover types is outlined in Fig.1. It has been proven that the remote sensing technology is extremely useful and has been widely used in the extraction of forest information and monitoring of forest changes (Mohd Hasmadi *et al*., 2006). However, the conventional technique of pixel-based classification of remotely sensed data can not accurately identify the bamboo resources due to complexity of bamboo spectral signature in forested areas.

The approach in remote sensing image classification using the sub-pixel classification method has the potential to identify and distinguish features more efficiently and accurately as compared to the classical parametric method approach. Thus, identification and classification of bamboo using sub-pixel classification method was applied in this study. The approach was implemented using Erdas Imagine software and SPOT-5 image that covers the Compartment 26, Temengor Forest Reserve, Gerik, Perak.

METHODOLOGY

Description of the Study Area

The study area is located in Compartment 26, Temengor Forest Reserve, Gerik Perak (Fig.2). Temengor Forest Reserve in northern Perak is a 130 million year old forest, designated as an Environmentally Sensitive Area (ESA) Rank 1 under the National Physical Plan. It is situated nearest to Royal Belum Forest Reserve and lies between the latitudes 5˚53.704'N to 5˚53.371'N and the longitudes 101˚61.679'E to 101˚61.763'E. Temengor Forest Reserve covers an area of about 300,000 hectares in the Belum Valley. Meanwhile, Royal Belum that is bordered by Royal Gerik, Perak, is located about

Source :Hasan and Mohammad Reza, 2007

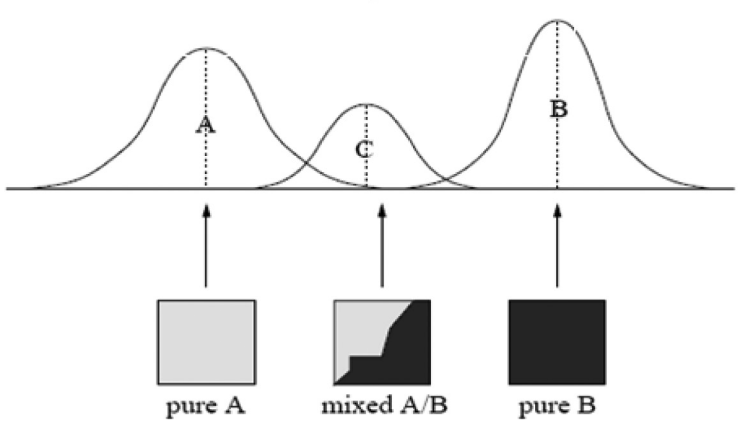

Fig.1: The confusing ground cover types by mixed spectral/pixel.

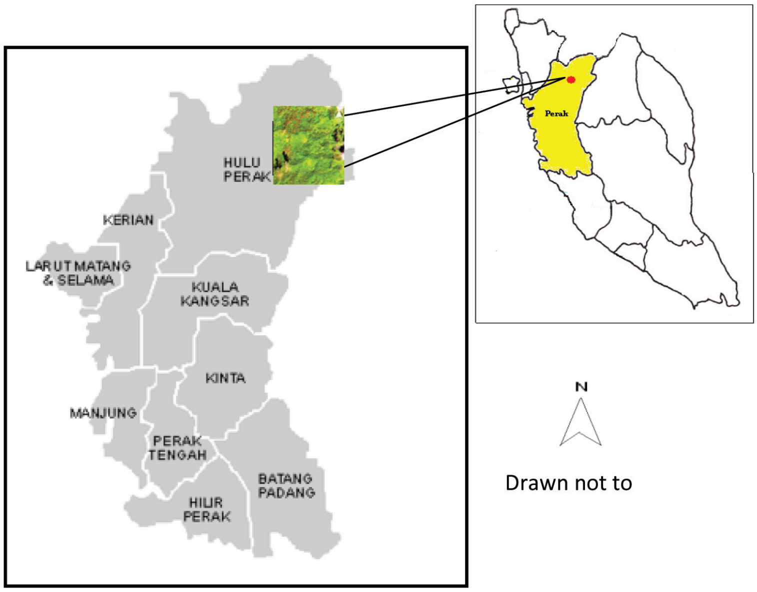

Fig.2: A map of Peninsular Malaysia showing the study area

30 km from Jeli, Kelantan. The average rainfall is about 2,700mm per year with a minimum of 2,665 mm and maximum 2,890 mm per year, respectively. The mean daily temperature is 24.3˚C with the minimum at 20.8 and the maximum at 33.5˚C. The topography of the area is undulating plain with alternating hilly terrain.

Materials and Methods

SPOTt-5 digital satellite image of the study area (path/row 268/339), with a spatial resolution of 20 m taken on 4 November 2009, was acquired for the study (Fig.2). The image was provided by the Malaysian Agency of Remote Sensing (MARS). Garmin Global Positioning System (GPS) was used to determine the position of the bamboo in Temenggor F.R. It was used during the ground verification to verify the location of bamboo on the ground. GPS receiver is accurate to within ± 10 m radius. The software used in this study was Erdas Imagine version 9.1, with a sub-pixel classifier extension module. ArcView Version 3.2 was used to produce the bamboo map.

Methodology

The composition of bamboo in the forest is basically trees, grass, soil and shrubs. Each bamboo class is a combination of these basic materials in different proportions. Thus, the sub-pixel analysis is useful for decomposing pure bamboo materials and the abundance of each material can be extracted from the image. The steps involved in the approach are illustrated in Fig.3. To extract bamboo material, automatic endmember method was used. Considering the nature of forest endmember mixture, a linear sub-pixel analysis model was applied to remotely-

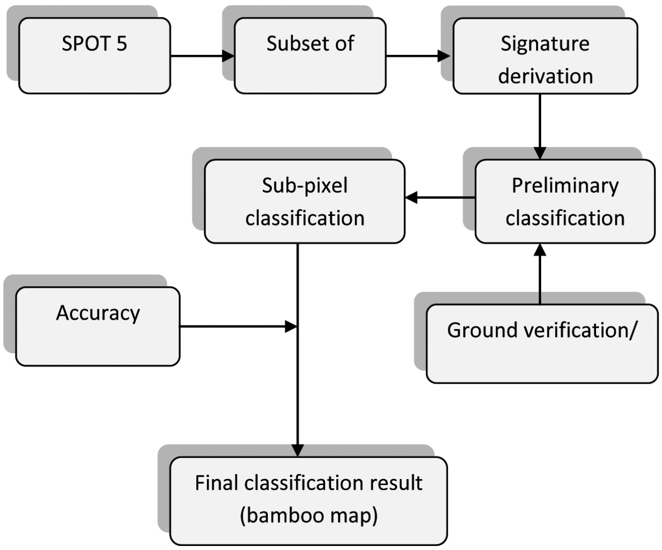

Fig.3: A flowchart of the bamboo mapping in the study

derived surface reflectance data using endmember to extract abundance images of bamboo materials. The supervised sub-pixel techniques based fuzzy and statistical approaches used is Maximum Likelihood Classifier (MLC). Meanwhile, the statistical methods are based on the assumption that the frequency distribution for each class is multivariate normal. Once this assumption is met, sets of parameters (such as mean, standard deviation, variance, covariance, etc.) were calculated from the data.

The procedure to estimate the accuracy of these parameters is called the parametric method. The decision rule assigns each pixel having pattern measurements or features X to the class c, whose units are most probable or likely to have given rise to feature vector X. It assumes that training data statistics for each class in each band are normally distributed as Gaussian in nature. In other words, the training data with bi- or tri-modal histograms in a single band are not ideal. In such cases, the individual modes probably represent individual classes that should be trained upon individually and labeled as separate classes. This would then produce uni-modal, Gaussian training class statistics that would fulfil the normal distribution requirement. MLC makes use of the statistic including the mean measurement vector $\bar{x}_j$, for each class and the variance covariance matrix $\sum_j$. It allocates the pixel to a class having the highest probability density. The probability function can be written as follows (Polubinskas *et al.*, 1995):

$$p(x/j) = \frac{1}{(2\pi)^{n/2}\left|\Sigma_j\right|^{1/2}} e^{(-1/2[(X-\bar{x}_j)^T \Sigma_j^{-1} (X-\bar{x}_j)]}$$

where $p(x/j)$ is the probability density function of a pixel X as a member of class j, n is the number of bands, X is the vector denoting spectral response of pixels $\bar{x}_j$ the mean vector and $\sum_j$ variance covariance of a class are given by the following equations, respectively;

$$\bar{x}_j = \frac{\sum_{i=0}^{N_t} X_i}{N_t}$$

$$\sum_j = \frac{\sum_{i=0}^{N_t} (X_i - \bar{x}_j)(X_i - \bar{x}_j)}{N_t(N_t - 1)}$$

where N_t is the total number of the training pixels for class j. The soft classification output was derived from MLC using a posteriori probability, which was computed from:

$$p(x/j) = \frac{p(j)p(x/j)}{\sum_{j=1}^{c} p(j)p(x/j)}$$

where, p(x / j) is the a posteriori probability of a pixel belonging to class j, p(j) is the a priori probability of the class j and c is the number of classes. The posteriori probabilities were used for class proportion in a pixel and thus, reflected soft classified outputs.

Digital Image Classification Using Sub-Pixel Classifier

Environmental correction was performed to compensate the variation in the atmosphere and environmental conditions during image acquisition. This corrected image was applied for signature derivation and classification. In order to derive a sub-pixel signature other background was removed leaving a candidate of material of interest (MOI). The output signature file was created using the training set, along with the source image, the environmental correction file, and the material pixel fraction in the training set. The mean material pixel fraction was specified by MOI and the fraction of the pixels was estimated. A sub-pixel of the training set considers the material signature as common to all pixels resulting in an equivalent whole pixel signature. The whole-pixel signatures of MOI used in this study are more than 80%.

Ground Verification

The reference points for the ground verification of the classified bamboo areas were selected from the preliminary classified image of SPOT 5. Field work was carried out in a period of four days in Mac 2011. On the ground points that were selected for bamboo areas that appeared in the preliminary classification were identified and recorded. It is important to note that some bamboos classified in the image were different on the ground. This is due to the fact that the ground cover has confused spectral by mixed pixel. A total of 35 sample points were recorded using the GPS receiver for verification data through line transect survey. The survey teams collected field data following transects across the study area. Fig.4 depicts a sampling technique conducted during field work. The bamboo stand characteristics such as culm and clump were measured and recorded. In forest,

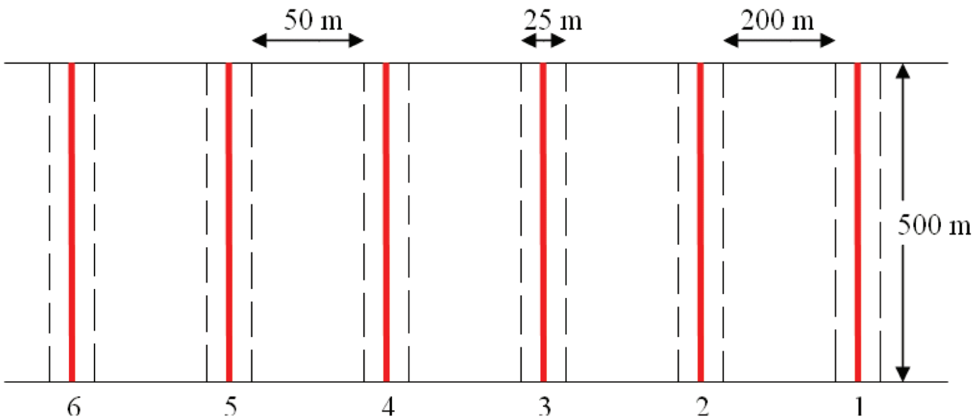

Fig.4: The sampling technique of line transect survey

bamboo has low coverage unless occurs in open, shrub land, logged over forest and forest roads. The coverage of 25% or higher of bamboo areas were used for this study.

Accuracy Assessment

The classification result was assessed using field verification based on the final classified image. The data were organized in confusion or error matrix, from which both the overall classification accuracies on the individual classes could be calculated. The overall accuracy of the classification is 86.6% and the kappa coefficient is 0.84. The assessment indicated that the sub-pixel classification for bamboo mapping could achieve good result in the study area.

RESULTS AND DISCUSSION

Output Overall Bamboo Distribution

The classification algorithms mentioned in this study were used as the supervised sub-pixel classification technique. Results of the bamboo classification approach in compartment 26 of Temengor Forest Reserve, Perak are presented in Fig.5. Light green indicates the location of bamboos while dark green represents non-bamboo. In general, each clump of bamboo consults of different numbers of culms. The quantification of bamboos in the study area was made based on the image's pixel in the image (Kamaruzaman, 2007). From the field survey, the number of pixel/culm was counted as 2470 pixels/ 869 culms = 2.84 pixel/culm. The total pixels of bamboos within the study area of 30 ha are 11,536 pixels and the spatial resolution of imagery is 20 m, so the estimated quantify of bamboos is 4062 culms and the estimated area of bamboo is 4.61 ha or 15.4%. The calculation is shown below:

11,536 / 2.82 pixel/culm	= 4062 culms of bamboo
11,536*400 m²	= 4,614400 m²
	= 4.61 ha

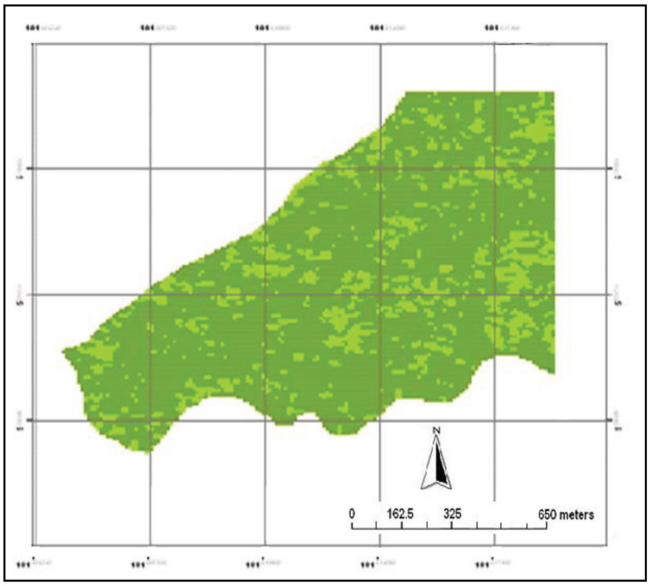

Fig.5: Bamboo distribution (light green) in compartment 26, Temengor Forest Reserve, Perak

Ground Verification

Bamboo photographs were captured during ground verification as evidences to show that it matched with the actual position and bamboo features in the classified image. Fig.6 shows ten of the sample bamboo photographs on the ground during field work and their locations. On the ground, the most common bamboo species found was *Schizostachyum grande* (Buluh Semeliang), but other species found were *Gigantochloa Scortechnii* (Buluh Semantan) *and Bambusa vulgaris (*Buluh minyak). This particular species can be easily found dispersed along the secondary forest road, in ex-log yards and forest camps. The overall accuracy of the classification is 86.6% and the kappa coefficient is 0.84.

CONCLUSION

Bamboo resources are significant for non-wood forest products especially for furniture industry, and as sources of income. They also provide significant effects on the biodiversity on the forest ecosystem. Therefore, understanding the spatial patterns and temporal dynamics of bamboo stock is important for biodiversity conservation resource management. In natural forest, bamboo "pure" compositional materials are basically trees, shrubs and soil/bare soil, and a bamboo class is somewhat a linear mixture of these materials. This study proposed an approach that uses a sub-pixel analysis to map bamboo areas. The study in compartment 26 of Temengor Forest Reserve, Perak showed that the proposed technique could classify bamboo pixels and reduce difficulty, and consequently improve

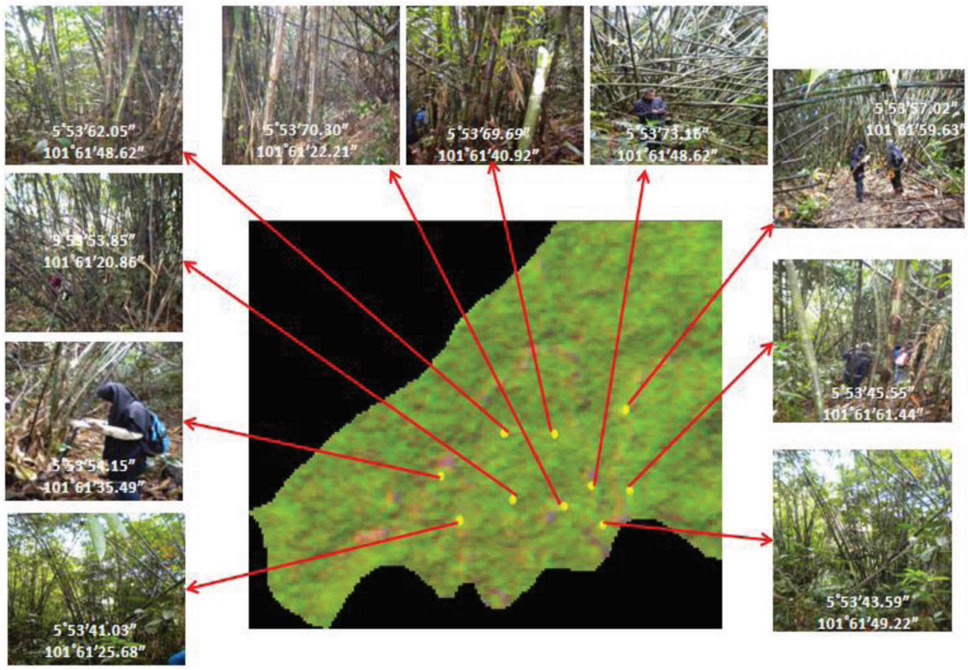

Fig.6: Some ground photographs of bamboo areas during field work.

the classification accuracy. Apart from using the sub-pixel classifier on SPOT 5 data, it is recommended that the use of higher resolution image (such as Quickbird, Ikonos and Hyperspectral) be attempted to examine the possibility of getting better results. Further study may focus on the extraction of more spectrally pure bamboo by integrating human knowledge and ecological factors.

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Protecting Biodiversity outside Natural Forests: Environmental-friendly Oil Palm Plantations as an Off-reserve Strategy in Peninsular Malaysia

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ABSTRACT

Malaysian palm oil industry has been associated with tropical deforestation and faunal biodiversity loss. Despite the numerous forest reserves and protected areas, biodiversity conservation should be extended into agricultural areas including commercial oil palm. Scientific studies have clearly demonstrated that oil palm monocultures are poor substitute to natural forests. However, those studies have also indicated that oil palm-dominated landscapes support substantial biodiversity including forest species. With respect to ecological services, some species are known to be important in controlling pest outbreaks in oil palm plantations. Previous studies have shown that oil palm cultivations are effective carbon sinks. The central remaining knowledge gap of how palm oil-producing countries should conserve biodiversity within the existing oil palm plantations and smallholdings is addressed in this study. Thus, thematic review process that was organized around a topic of interest was used. In more specific, 53 journal articles investigating or highlighting the impacts of commodity crops cultivation on biodiversity were reviewed. It was proposed that oil palm-dominated landscapes be managed for conservation outcomes similar to that have been implemented in forest reserves and protected areas.

Keywords: Biodiversity, oil palm, conservation, plantations, smallholdings, ecological services, carbon sinks, off-reserve strategy

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INTRODUCTION

In some developing countries, commercial agricultural areas, including those in exotic oil palm (*Elaies guineensis*) plantations, are established at the expense of natural forests (Donald, 2004; Koh & Wilcove, 2008; Koh *et al*., 2011). In return, massive forest conversion and fragmentation through clear-cutting has caused unprecedented biodiversity loss (Fitzherbert *et al*., 2008; Wilcove & Koh, 2010). Most of the affected natural forests include those areas that are already designated as forest reserves or protected areas. However, in some producer countries such as Malaysia, oil palm plantations were converted from other commodity crop plantations (e.g. coconut and rubber) (Basiron, 2007; Koh & Wilcove, 2008).

Oil palm crop has contributed significantly to the economic revenues of Malaysia (Basiron, 2007; Hardter *et al*., 1997). Similarly, Malaysian palm oil industry has also created job opportunities for poor people in the rural areas and improved their standard of living (Basiron, 2007). Their substantial contributions in the socio-economic development may prolong upstream plantation business in this country. Unfortunately, this may create conflict between palm oil-producing countries and environmental activists in developed countries. Due to some controversial issues, palm oil-based products are currently boycotted by environmental NGOs in those countries (Nantha & Tisdell, 2009; Tan *et al*., 2009). Some issues of concern with oil palm plantations are deforestation, species extinction, and environmental pollutions.

As consumer countries (e.g. the United States and European Union countries) are becoming increasingly concerned with environmental issues, palm oil stakeholders (e.g. government agencies, smallholders, and plantation companies) should implement conservation measures within oil palm-dominated landscapes. Environmental-friendly crops have become a trend and are currently in great demand. For example, some coffee and cacao plantations in developing countries are currently being certified as bird-friendly. This has opened a new and greater market for such coffee and cacao products in developed countries with environmental concerns. Furthermore, there have been many ecological studies to support conservation schemes or practices on fauna implemented in those commodity crop plantations (Clough *et al*., 2009; Greenberg *et al*., 1997a, 1997b; Philpott *et al*., 2008).

JUSTIFICATIONS FOR ENVIRONMENTAL-FRIENDLY OIL PALM AGRICULTURE

To date, environmental management practices have been implemented to transform agricultural areas into environmental-friendly plantations (e.g. zero burning technique prior to replanting and bio-control programs to suppress pest organisms). However, those practices may be insufficient to protect biodiversity effectively. Palm oil stakeholders should be praised to carry out such conservation measures but they also need to be motivated to do more to conserve farmland biodiversity.

Neglecting biodiversity conservation within oil palm plantations is a counterproductive because of several reasons: (1) biodiversity resources can be found in oil palm-dominated landscapes. Planted oil palm areas cover more than 4,000,000 ha of oil palm plantation estates and more than 700,000 ha of semi-traditional smallholdings in Malaysia (MPOB, 2011), (2) most protected areas and forest reserves are surrounded by oil palm plantations and smallholdings (e.g. Taman Negara, Krau Wildlife Reserve, and Endau Rompin National Park), (3) the application of agrochemicals such as pesticides and herbicides in oil palm-dominated landscapes, if uncontrolled, may harm wildlife or kill non-target fauna, (4) high conservation value species (e.g. elephants, tigers, and pangolins) may be persecuted or illegally hunted within oil palm-dominated landscapes, (5) the palm oil industry, through its downstream operations (processing factories), has caused environmental pollution (e.g. water quality) which may further degrade wildlife habitat, and (6) limited data on the number of ecological studies conducted in oil palm-dominated landscapes worldwide for supporting biodiversity conservation in industrial plantations.

This review paper discusses the possibility of transforming conventional oil palm agriculture into environmental-friendly cultivation areas. We reviewed 53 relevant research papers written in the past three decades that thematically investigated the ecological impacts of various commodity crops (e.g. oil palm, rubber, and coffee) on biodiversity. Those papers provide evidence to justify the move to incorporate agricultural areas such as oil palm into an off-reserve protection strategy. We argue that the existing oil palm-dominated landscapes can be equally important as protected areas in terms of biodiversity conservation. This can be justified by the amount of biodiversity that the oil palm-dominated landscapes can sustain.

INDUSTRIAL OIL PALM EXPANSION

Introduced from tropical Africa, oil palm (*E. guineensis*) has been successfully established in industrial plantation estates and semi-traditional smallholdings in many Southeast Asia countries (Williams & Hsu, 1970; Turner & Gillbanks, 1974; Hardter *et al*., 1997; Basiron, 2007; Tan *et al*., 2009). The growing demand from the domestic and international market has turned oil palm cultivation into a profitable business for palm oil-producing countries. Palm oil has become one of the major exports in Malaysia, Indonesia, Papua New Guinea, and Thailand, surpassing other commodity crops.

Thus, the palm oil industry is an important economic tool for developing countries to combat hardcore poverty, as demonstrated by successful palm oil producers like Malaysia and Indonesia (Koh & Wilcove, 2007; Lam *et al*., 2009; Tan *et al*., 2009). These countries, however, also support a high concentration of tropical biodiversity in the region. Industrial oil palm expansion has been associated with the decline of charismatic fauna such as the Orang utans (*Pongo spp.*) and their habitat in Borneo and Sumatra (Gaveau *et al*., 2009; Nantha & Tisdell, 2009). To date, scientific evidence has indicated that oil palm plantations support lower biodiversity than natural forests (Koh, 2007; Fitzherbert *et al*., 2008; Danielsen *et al*., 2009; Wilcove & Koh, 2010).

Oil palm monocultures have replaced lowland tropical rainforest directly and indirectly (Lambert & Collar, 2002; Danielsen *et al*., 2009; Yule, 2010). Direct conversion of lowland tropical rainforest to oil palm cultivation areas occurred when forested lands were clear felled primarily for the purpose of oil palm planting. Indirect conversion occurred when forested lands were clear felled for the planting of other commodity crops but later converted into oil palm cultivation areas. However, by either direct or indirect conversion, commercial logging usually precedes agricultural expansion in many cases. This particular scenario is very common in the present-day Malaysia, and has been the case since the British-colonial days (Kumar, 1986; Berger, 1990). A high profile Malaysian government sponsored, large-scale oil palm cultivation scheme, the Federal Land Development Authority (FELDA) has received financial support from the World Bank to open up vast tracts of primary rainforest in the interior of Peninsular Malaysia since the 1950s (Berger, 1990; Basiron, 2007). As a consequence, much of the remaining pristine or undisturbed tropical rainforest of the peninsula is located in the highlands, far from the coastal areas, where oil palm plantations have been established.

CURRENT OIL PALM MANAGEMENT

Commercial oil palm monocultures are established in industrial plantations, but some are planted in smallholdings. These plantations cover more than 50 ha of planted oil palm areas. Workers, mostly foreign labourers, are employed to harvest oil palm fruit bunches manually. In order to ensure maximum harvest, the application of agrochemicals such as fertilizers and pesticides is common in oil palm plantations. To date, their effects on human, ecosystem, or wildlife are almost unknown. However, Integrated Pest Management (IPM) has been implemented to reduce the dependency on pesticides in oil palm plantations. For example, barn owls (*Tyto alba*) have been used to control rat populations (Wood & Chung, 2003). In addition, tree planting has been used as a tool for reforestation and wildlife corridor within oil palm plantations. Plantations are protected from harvest theft and wildlife poachers by security guards, trenches, and boundary fences.

Environmental-friendly plantations are defined as those managed by companies which have been recognized by the Roundtable on Sustainable Palm Oil Organization (www.rspo.org) as being sustainable palm oil producers. This is in contrast to conventional plantations that were not operated according to biodiversity-friendly guidelines and did not necessarily comply with the minimum environmental standards (e.g. zero burning of oil palm biomass). Semi-traditional smallholdings can be defined as oil palm cultivation areas that were less than four ha and owned by independent farmers or government-funded land-scheme settlers (e.g. FELDA settlements). These smallholdings usually comprised more than one age class of oil palms intercropped with commercial crops (e.g. bananas, coconuts, cassavas, coffee, pineapples) or indigenous fruit trees (e.g. durians and rambutans).

PALM OIL CERTIFICATIONS AND BIODIVERSITY STUDIES

Palm oil certification standards, such the Roundtable on Sustainable Palm Oil (RSPO) aimed for sustainability indicators for palm oil production, have been judged to be inadequate by environmental NGOs and conservation scientists (Bhagwat & Willis, 2008; Fitzherbert *et al*., 2008; Groom *et al*., 2008; Laurance *et al*., 2010). The Principles and Criteria of RSPO have been promoted by palm oil industry stakeholders and the World Wildlife Fund for Nature (WWF). Unfortunately, the standards were not supported by any scientific evidence.

Under Criterion 5.2 of the Principles and Criteria of RSPO; "the status of rare, threatened or endangered species and high conservation value habitats, if any, that exist in the plantation or that could be affected by plantation or mill management, shall be identified and their conservation taken into account in management plans and operation". We argue that this criterion gives greater priority to protected species but it does not seriously consider the conservation of the majority of non-protected species. In addition, there are very few protected species that can be found in oil palm plantations (Donald, 2004; Koh, 2008; Azhar *et al*., 2011). Large-sized mammals rarely inhabit oil palm plantations. However, these wild animals may pass through plantations to move between protected areas (Ickes, 2001; Kawanishi & Sunquist, 2004; Linkie *et al*., 2007).

Hence, participation by palm oil stakeholders is needed in order to increase more scientific work that can enhance biodiversity conservation. Their involvement is critical, and very costly to ignore, because without ecological considerations in their management policies, more species (especially endemic ones) and their natural habitats are likely to be lost. Therefore, oil palm dominated landscapes should be managed not only for profits but also to conserve farmland biodiversity. This suggestion needs to be supported by scientific work, which will provide detailed information across management regimes (Donald, 2004; Groom *et al*., 2008). We believe that previous studies are inadequate because most researchers have surveyed only plantations but not smallholdings (Aratrakorn *et al*., 2006; Peh *et al*., 2006; Koh, 2008; Edwards *et al*., 2010; Sheldon *et al*., 2010). In addition, those studies, particularly on birds, also did not take into account of wetlands or migratory species in the assessment of the biota in oil palm plantations.

To the best of our collective knowledge, only a handful of studies have been undertaken to investigate faunal diversity in oil palm-dominated landscapes, particularly in vertebrate animals. The ecological impacts of the palm oil industry on biodiversity are perceived as being highly predictable, causing ecologists to lack the motivation to research on this issue (Danielsen *et al*., 2009). Meanwhile, negative campaigns by environmental NGOs portray oil palm-dominated landscapes as 'green dessert' devoid of wild flora and fauna. This perception is as bad as the one espoused by some stakeholders of the palm oil industry that oil palm-dominated landscapes are solely established for crop production, and not for conservation.

BIODIVERSITY LOSS IN ESTABLISHED PLANTATIONS AND SMALLHOLDINGS

Conservation scientists have used forest birds in their snap-shot survey in oil palm-dominated landscapes. They have analyzed species occurrence and/or population abundance. Their findings suggested that the values for bird species richness was lower in oil palm plantations than in natural forests (Aratrakorn *et al.,* 2006; Peh *et al.,* 2006; Koh *et al.,* 2008; Edwards *et al.,* 2010; Azhar *et al.,* 2011). In particular, Azhar *et al.* (2011) reported that oil palm-dominated landscapes supported 42% of total bird species found in logged peat swamp forest (Table 1). In contrast, some studies have suggested certain individual species, for example, Red Junglefowl (*Gallus gallus*) was abundant in oil palm plantations than in natural forests (Azhar *et al*., 2008). With respect to oil palm management regimes, smallholdings supported higher bird species richness than plantations (Azhar *et al.,* 2011).

A few studies have investigated forest mammals in oil palm-dominated landscapes. These studies showed similar poorer values for mammal species diversity in commercial plantations than in natural forests (Bernard *et al*., 2009; Maddox *et al.,* 2007; Normua *et al*., 2004). Likewise, studies on forest arthropods in oil palm plantations have indicated similar results (Turner *et al*., 2009; Fayle *et al*., 2010). Overall, those published research papers have shown that oil palm-dominated landscapes, irrespective of the management regimes, are not totally inhospitable to some faunal groups. This finding supports the implementation of conservation measures within oil palm-dominated landscapes.

Biodiversity resources found in commercial plantations may not be similar to natural forests with respect to species richness and composition. Rare species may be completely absent in agricultural areas, but these areas may support hundreds of common species including forest fauna. Some forest species may come to commercial plantations from time to time. These may include migratory and wetland species (Azhar *et al*., 2011). Moreover, some species may even inhabit plantations for good. Oil palm-dominated landscapes may offer habitat heterogeneity to wildlife. Eco-tones (i.e. two or more intersectional

TABLE 1
Birds (82 species) recorded in oil palm-dominated landscapes (plantations and/or smallholdings) as well as in logged peat swamp forest in Peninsular Malaysia

Species	Detection site
Oriental Pied Hornbill, *Anthracoceros albirostris*	Plantations and smallholdings
Rhinoceros Hornbill, *Buceros rhinoceros*	Plantations and smallholdings
Blue-crowned Hanging Parrot, *Loriculus galgulus*	Plantations and smallholdings
Long-tailed Parakeet, *Psittacula longicauda*	Plantations and smallholdings
Blue-eared Barbet, *Megalaima australis*	Plantations and smallholdings
Coppersmith Barbet, *Megalaima haemacephala*	Plantations and smallholdings
Lineated Barbet, *Megalaima lineata*	Plantations
Scarlet-backed Flowerpecker,*Dicaeum cruentatum*	Plantations
Common Iora, *Aegithina tiphia*	Plantations and smallholdings
Green Imperial Pigeon, *Ducula aenea*	Plantations
Peaceful Dove, *Geopelia striata*	Plantations and smallholdings
Spotted Dove, *Streptopelia chinensis*	Plantations and smallholdings
Thick-billed Pigeon, *Treron curvirostra*	Plantations
Pink-necked Pigeon, *Treron vernans*	Plantations and smallholdings
Striped Tit-babbler, *Macronous gularis*	Plantations
Dark-necked Tailorbird, *Orthotomus atrogularis*	Plantations and smallholdings
Ashy Tailorbird, *Orthotomus sepium*	Plantations and smallholdings
Rufous-tailed Tailorbird, *Orthotomus sericeus*	Plantations and smallholdings
Common Tailorbird, *Orthotomus sutorius*	Plantations and smallholdings
Yellow-bellied Prinia, *Prinia flaviventris*	Plantations and smallholdings
Rufescent Prinia, *Prinia rufescens*	Plantations
Rufous Woodpecker, *Celeus brachyurus*	Plantations
Common Flameback, *Dinopium javanense*	Plantations and smallholdings
Red-eyed Bulbul, *Pycnonotus brunneus*	Plantations
Yellow-vented Bulbul, *Pycnonotus goaivier*	Plantations and smallholdings
Olive-winged Bulbul, *Pycnonotus plumosus*	Plantations and smallholdings
Cream-vented Bulbul, *Pycnonotus simplex*	Plantations
Little Spiderhunter, *Arachnothera longirostra*	Plantations and smallholdings
Crested Goshwak, *Accipiter trivirgatus*	Plantations
Black Baza, *Aviceda leuphotes*	Plantations
Black-shouldered Kite, *Elanus caeruleus*	Plantations and smallholdings
White-bellied Sea-Eagle, *Haliaeetus leucogaster*	Plantations
Brahminy Kite, *Haliastur indus*	Plantations
Black-thighed Falconet, *Microhierax fringillarius*	Plantations
Crested Serpent Eagle, *Spilornis cheela*	Plantations and smallholdings
Changeable Hawk Eagle, *Spizaetus cirrhatus*	Plantations and smallholdings

cont'd Table 1

Species	Detection site
Dusky Eagle Owl, *Bubo coromandus*	Smallholdings
Buffy Fish-owl, *Ketupa ketupu*	Plantations
Spotted Wood-owl, *Strix seloputo*	Plantations
Large-tailed Nightjar, *Caprimulgus macrurus*	Plantations and smallholdings
Red Junglefowl, *Gallus gallus*	Plantations and smallholdings
Barred Buttonquail, *Turnix suscitator*	Plantations
Plaintive Cuckoo, *Cacomantis merulinus*	Plantations
Lesser Coucal, *Centropus bengalensis*	Plantations and smallholdings
Greater Coucal, *Centropus sinensis*	Plantations and smallholdings
Common Koel, *Eudynamys scolopacea*	Plantations and smallholdings
Stork-billed Kingfisher, *Halcyon capensis*	Plantations
White-throated Kingfisher, *Halcyon smyrnensis*	Plantations and smallholdings
Red-throated Flycatcher, *Ficedula parva*	Plantations
Asian Brown Flycatcher, *Muscicapa dauurica*	Plantations
Asian Paradise Flycatcher, *Terpsiphone paradisi*	Smallholdings
Pied Faintail, *Rhipidura javanica*	Plantations and smallholdings
Forest Wagtail, *Dendronanthus indicus*	Plantations
Richard's Pipit, *Anthus novaeseelandiae*	Plantations and smallholdings
Blue-tailed Bee-eater, *Merops philippinus*	Plantations and smallholdings
Blue-throated Bee-eater, *Merops viridis*	Plantations
Dollarbird, *Eurystomus orientalis*	Plantations and smallholdings
Ashy Drongo, *Dicrurus leucophaeus*	Plantations
Slender-billed Crow, *Corvus enca*	Plantations and smallholdings
Large-billed Crow, *Corvus macrorhynchos*	Plantations
Black-naped Oriole, *Oriolus chinensis*	Plantations and smallholdings
Oriental Magpie Robin, *Copsychus saularis*	Plantations and smallholdings
Flyeater, *Gerygone sulphurea*	Plantations
Brown Shrike, *Lanius cristatus*	Plantations and smallholdings
Tiger Shrike, *Lanius tigrinus*	Plantations
Baya Weaver, *Ploceus philippinus*	Plantations and smallholdings
White-headed Munia, *Lonchura maja*	Plantations and smallholdings
Black-headed Munia, *Lonchura malacca*	Plantations
Scaly-breasted Munia, *Lonchura punctulata*	Plantations and smallholdings
Asian Glossy Starling, *Aplonis panayensis*	Plantations and smallholdings
Jungle Myna, *Acridotheres fuscus*	Plantations and smallholdings
White-vented Myna, *Acridotheres javanicus*	Plantations and smallholdings
Hill Myna, *Gracula religiosa*	Plantations and smallholdings
Edible-nest Swiftlet, *Aerodramus fuciphaga*	Plantations and smallholdings

cont'd Table 1

Species	Detection site
Pacific Swallow, *Hirundo tahitica*	Plantations and smallholdings
Purple Heron, *Ardea purpurea*	Plantations and smallholdings
Chinese Pond Heron, *Ardeola bacchus*	Plantations
Little Egret, *Egretta garzetta*	Plantations
Cinnamon Bittern, *Dupetor flavicollis*	Plantations
Yellow-bittern, *Ixobrychus sinensis*	Plantations
White-breasted Waterhen, *Amaurornis phoenicurus*	Plantations and smallholdings
Red Wattled-lapwing, *Vanellus indicus*	Plantations and smallholdings

Source: Azhar *et al.* (2011)

habitat edges) may provide different micro-habitats to various species. Hence, we propose oil palm plantations, together with smallholdings, be considered as an off-reserve strategy that can complement forest reserves and protected areas.

ECOLOGICAL SERVICES IN OIL PALM AGRICULTURE

Studies have also shown insect defoliators of oil palm such as bagworms and nettle caterpillars, beetles are being regulated by natural enemies that include pathogens, parasitoids and predators (Sankaran & Syed, 1972; Cheong *et al*., 2010). These natural enemies collectively maintain the pest population in a relatively stable equilibrium below the economic threshold. However, anything destabilizing the regulatory mechanisms provided by those natural enemies would likely to cause serious pest outbreaks (Dutcher, 2007). The effectiveness of natural enemies in maintaining the pest population can be enhanced through conservation and habitat manipulation.

Natural enemies can be conserved through reducing the effects of pesticides on them. Their numbers and activity can be improved through the provision of food, often nectar and pollen sources, permanent habitats or refuges, and alternate prey or hosts. One of the practices in providing these resources is through manipulating vegetation diversity of the ecosystem. This practice has been adopted in oil palm plantations where nectariferous plants, like *Euphorbia heterophylla*, *Cassia cobanensis*, *Antigonon leptopus* and *Turnera subulata*, are planted to attract beneficial insects, particularly parasitoids (Basri *et al*., 1995). These parasitoids feed on nectar and extra-floral secretions and parasitize phytophagous insect pests. Thus, a conservation effort towards maintaining these natural enemies should be part of the management practices for all oil palm plantations and smallholdings.

MITIGATING CLIMATE CHANGE

Commodity crop plantations such as oil palm are the most effective carbon sink for absorbing atmospheric CO_2 in terrestrial ecosystems. Hence, such plantations can mitigate man-made global warming (Anderson, 2008). Surprisingly, oil palm, *E. guineensis,* has proven to be effective in reducing CO_2 concentration due to its photosynthetic efficiency compared to other tropical vascular plant species. Durrene and Saugier (1993) noted that light saturated rate of net CO_2 assimilation in oil palm was 20 µmol CO_2 m^{-2} s^{-1} at PAR (Photosynthetic Active Radiation) compared to some other fast growing plant species such as *Acacia mangium* (10-14 µmol CO_2 m^{-2} s^{-1}), *Acacia aulacocarpa* (7-8 µmol CO_2 m^{-2} s^{-1}), *Tectona grandis* (14.5 µmol CO_2 m^{-2} s^{-1}), and *Macaranga gigantea* (8-11 µmol CO_2 m^{-2} s^{-1}), *Dyera costulata* (10-12 µmol CO_2 m^{-2} s^{-1}) and *Shorea leprosula* (6 µmol CO_2 m^{-2} s^{-1}) (Sapari, 2008; Shida *et al*., 1999; Rajendrudu & Naidu, 1997; Ishida *et al*., 1996; Zipperlen & Press, 1996). As a C3 type plant, *E. guineensis* is able to tolerate high levels of CO_2. In a nutshell, the species is able to tolerate twice the amount CO_2 in comparison to other plant species (Ibrahim *et al*., 2010). Even though oil palm-dominated landscapes may promise a high carbon sink value, this does not warrant future oil palm expansion into natural forests, for the amount of biodiversity loss may be greater.

FUTURE DIRECTIONS

Tropical deforestation should never be allowed to make way for new commercial plantations in the future because of dramatic biodiversity loss. For example, 48 – 60% of bird species will be lost due to forest conversion to oil palm cultivation (Azhar *et al.,* 2011). The expansion of oil palm monocultures should only be implemented in replace of other croplands. Biodiversity found within oil palm plantations outside natural forests should also be protected.

We suggest that the palm oil industry in Malaysia embrace the transformation of the conventional plantations into environmental-friendly ones. Then, these environmental-friendly plantations could be implemented as an off-reserve protection strategy in addition to crop production. Another proximate solution would be palm oil stakeholders maximize harvest yield per ha from the established plantations. This solution will remove the pressure to open new sites for plantations from the remaining primary and secondary forests.

In addition, palm oil companies should be encouraged to maintain forest patches within their oil palm plantations. Wildlife in those forest patches will not be susceptible to poaching if hunters are not allowed to access those oil palm plantations. Meanwhile, the surrounding forest reserves or protected areas may as well be better protected from hunters if these areas are buffered by such plantations. In contrast, Edwards *et al*. (2010) suggested that conservation investment be diverted from the retention of forests patches within oil palm-dominated landscapes to the protection of contiguous forests.

RECOMMENDATIONS AND CONCLUSION

The existing oil palm plantations and smallholdings should be managed for conservation outcomes as well as for economic purpose. Scientifically, oil palm plantations are poorer in terms of biodiversity than natural forests (Donald, 2004). For example, bird diversity in established plantations is only a fraction of the ones that were found in natural forests. However, this should not discourage palm oil stakeholders from implementing conservation measures in oil palm-dominated landscapes. Some conservation scientists have supported the implementation of conservation measures in the existing plantations and smallholdings (Koh, 2008; Najera & Simonetti, 2010; Azhar *et al*., 2011; Foster *et al*., 2011; Jambari *et al*., 2012).

Farmland biodiversity, including forest species, may stand better chances if stakeholders can transform conventional oil palm agriculture into environmental-friendly plantations. Palm oil stakeholders may have to be open to implementing new conservation practices that have been successfully applied elsewhere or in other commodity production areas. These practices may need to be supported by scientific evidence-based studies (Foster *et al*., 2011). Hence, long-term studies will be important to assess some of the recommended practices. We recommend that palm oil stakeholders implement the following practices in environmental-friendly plantations:

1. Set-a-side areas or patches of native vegetation for biodiversity conservation (Fischer *et al*., 2006; Wilson *et al*., 2009). These areas may include fragmented forests and/or rehabilitated forest corridors (achieved by tree planting) within oil palm plantations. This measure may increase landscape connectivity between sub-populations. Additional tree planting will enhance the capability of commercial plantations to absorb atmospheric CO_2.
2. Unpolluted aquatic habitats may include man-made ponds, irrigation canals, and flood-control drains (Czech & Parsons, 2002). Water-birds would benefit greatly from the creation of such aquatic habitats.
3. Bio-control applications including barn owl and predatory insects (Wood & Chung, 2003). This measure may reduce the use of hazardous pesticides and adverse effects of agro-chemicals on non-target fauna.
4. Prescriptive grazing to control unwanted vegetations (Dennis *et al*., 2001). This measure may reduce the use of hazardous herbicides and provide organic fertilizers into soils.
5. Prevent illegal hunting by providing security guards (e.g. auxiliary police force and CCTVs) and physical barriers (e.g. perimeter fencing and trenches) (Hayward & Kerley, 2009).
6. Removal of introduced predators (e.g. feral dogs and cats) from plantations

and smallholdings (Nogales *et al*., 2004). These predators may gradually exterminate local birds and small mammals.

Commercial oil palm agriculture in Peninsular Malaysia should not increase at the expense of natural forests, but conversion from other agricultural land uses should continue. In the existing oil palm plantations and smallholdings, biodiversity loss should be mitigated through the implementation of conservation measures. In order to conserve biodiversity, stakeholders in the palm oil industry should work together with conservation scientists to manage commercial plantations. Natural forests will be better protected from poaching and illegal logging if they are surrounded by neighbouring environmental-friendly oil palm plantations.

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Exploring Hard and Soft Domestic Ecotourists Preferences towards Selected Eco-friendly Attributes of Ecolodges in Kinabalu Park, Sabah

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ABSTRACT

The emergence of the term ecotourism in the 1980's has brought forward numerous developments in ecotourism industry including the discovery of special niche segments, specifically the 'ecotourists', as well as specialist accommodation type, specifically the 'ecolodges'. Although a number of studies have been published with regards to ecotourists' traits and ecolodges guideline, limited information is available on the domestic ecotourists' preferences towards the characteristics that ecolodges embody. Hence, this study is an attempt to address this deficiency by looking at the preferences of two contrasting ecotourist segments, namely, hard and soft domestic ecotourists in Kinabalu Park, a World Heritage Area in Sabah, Malaysia. A discriminant analysis was performed using 403 samples in Kinabalu Park, and it revealed two ecotourist segments with significant differences of preferences towards six constructs of ecolodges. It was also found that hard domestic ecotourists displayed significant differences in preferring eco-friendly attributes as compared to the soft domestic ecotourists on the variables measuring nature based attractions, services and comfort, location and type of accommodation. Soft domestic ecotourists tend to resemble the mass tourists as they placed importance towards services and comfort but disliked being in remote locations. The results of this study demonstrate that ecotourist segments deserve specific considerations by ecotourism managers to cater accommodation packages based on their specific preferences in order to ensure a quality ecotourism ex*perience.*

Keywords: Ecotourists, ecolodges, accommodation preferences, Eco-friendly accommodations, Hard-soft ecotourists, ecotourism spectrum, domestic ecotourists

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INTRODUCTION

Since their emergence in 1990's, ecolodges have brought success to a few noted ecotourism areas in the world that portray a model of successful ecolodge management, as observed in cases in South Africa, Australia, New Zealand and the Asia-Pacific regions (Buckley, 2003). The users of ecolodges are usually ecotourists, who are usually more apt to purchase eco-friendly products while travelling. This suggests the realization of why it is crucial to uncover information in regard with the ecotourists' needs and preferences on ecolodges. The fact that a few studies have profiled the distinctiveness of ecolodge patrons (Kwan *et al*., 2008) makes it more crucial to identify what these special market segments really represent, especially in developing countries such as Malaysia that rely heavily on promoting nature based tourism.

The ecolodge, which surfaced around the 1990's, is perhaps the most distinctive component of the specialized ecotourism industry (Weaver, 2001). An ecolodge can be said to be the product of ecotourism, which is grounded by the principles of ecotourism in terms of its compliance to the three integral components of ecotourism: nature based, learning and interpretation, and socio-economic sustainability. What makes an ecolodge important is its ability to provide a way for ecotourism to fully implement the criteria and principles of ecotourism, as accommodation is a crucial necessity in every ecotourism site. Like ecotourism, ecolodges have developed over the years in response partly to the destructions made by mass conventional hotels that exist primarily all over the world (Timothy & Teye, 2009).

Russell *et al*. (1995) describe the ecolodge as a nature dependent lodge that meets the principles of ecotourism. Similarly, this definition is strongly attributed by Mehta *et al*. (2002), who state that an ecolodge must exemplify the three principles of ecotourism, which are nature conservation, local people's benefits and interpretive components. Furthermore, Gardner (2001) generally presumes the ecolodge as a small lodge designed to blend with the cultural and natural environments and is located within or adjacent to a highly protected area. Additionally, an ecolodge also utilizes the green technology in its management and operations. Eco-travel is usually related to ecolodges as they are presumably one of the ways for tourists to enhance the "green tourist" within them.

ECOTOURISTS AND ECOLODGES

Ecotourists usually possess distinctive traits or positive behaviours such as their involvement in nature based areas, their tendency to learn more about nature and their usual willingness to be more sustainable in socially and environmentally manners (Weaver & Lawton, 2002). These traits are associated with the three main components of ecotourism, which are nature based, learning and educational, and the sustainability component (Blamey, 1997; Eagles *et al*., 2002). Hence, an environmentally conscious attitude towards the environment or any object will usually produce a positive evaluation such as agreement towards a statement.

Environmentally conscious tourists are usually associated as ecotourist in the ecotourism world. The terminology of hard-soft ecotourists is contributed theoretically by the works of Laarman and Durst (1987) and proven empirically by the work of Weaver and Lawton (2002) who manifested the three segments of hard, structured and soft ecotourists. Similar studies which look into ecotourist characteristics empirically have also been done by, among other, Beh and Bruyere (2007), Hvenegaard (2002) and Palacio and McCool (1997). There seemS to be certain pattern of traits deriving from the hard end of the ecotourism spectrum to the soft end of the ecotourism spectrum.

However, unlike ecotourists, ecolodges seem to be a highly manifested subject in ecotourism. Nonetheless, the amount of research on ecolodges is still lacking as compared to other conventional accommodations such as hotels and motels. This is because, although accommodations, such as eco-resorts are considered important, it is not substantial enough to override the motivation for visit (Fennel, 2008). This notion is supported by Wight (1997), who states that accommodation is merely an enabler to overall accommodation experience, suggesting that the tourists select the experience first, and then only select the accommodation.

Furthermore, the academic literature on ecolodges mentions that the references on this subject matter are still limited (Kwan *et al*., 2008). Even though previous research mentions specialist accommodations and owner operators of these types of accommodation, related resources on ecolodges are still scarce (Wight, 1997). Hence, studies on ecolodges at present are important because there is a need for the tourism industry and all personnel involved to realize that ecolodges are able to foster long-term beneficial impacts on the ecotourism industry.

Most studies on ecolodges focus on assessing various attributes of the accommodation. However, studies concerning the ecolodges and owner-operators are still limited (Wight, 1997). In a primary study, which used both hotel and ecolodge attributes, Kwan *et al*. (2008) used 41 attributes to measure the Importance-Performance assessment, and found that the five highest attributes were associated with three service features, which were staff's friendliness, value for money and facility sanitation, and two environmental features that were rated highly, namely, scenery and the quality of the environment. It was reported that one of the lowest ranked attributes was the availability of onsite entertainment, which indicated that the ecolodge patrons did not expect entertainment, a characteristic which is to be expected in ecotourism.

In addition, Osland and Mackoy (2004) used open-ended questions to determine which lodging attributes were the most important in choosing lodging. The researchers found that there were two most frequently mentioned attributes: proximity to birds and cost. Similar studies also reported on the importance of location (Haig & McIntyre, 2002) and price (Pearce & Wilson, 1995). Moreover, the study conducted by Osland and Mackoy (2004) was notably an interesting one, as it used two methods; the first method involved members from the American Birding Association (ABA) which was employed to list factors pertaining to the attributes of lodging selection, while the second method involved an observation on the ecotourists in the ecolodges of Mexico, Costa Rica and Ecuador. The methods provided responses from various ecotourists' backgrounds (i.e. birders to common ecotourists in the ecolodges) that subsequently revealed the top two attributes between both groups of participants, which were the location of natural area and the price.

Chan and Baum (2008) conducted in-depth interviews with 29 European ecotourists in Sukau Rainforest Lodge, focusing on questions with regards to negative and positive experiences of ecotourism. The study discovered that there were three major themes for the responses towards the ecotourism experiences, which were seeing wildlife in their natural habitats, basic accommodation, and learning and acquiring knowledge. This study used the expressions of experience and found six expressive dimensions: hedonism, interaction, novelty, comfort, stimulation and personal safety. These dimensions were regarded as positive experiences. The conclusion for this study suggests that ecotourism experience can be expressed in expressive dimensions as reported, which are associated with affection and functionality in experience.

Generally, the findings from the ecolodge studies are related to the core ecotourism principles, and the mentioned studies largely contribute to the service and facility components. Notably, because the nature of an ecolodge as an accommodation is to provide service and hospitality, it is therefore understandable that a huge part of it concentrates on the service features rather than the ecotourism core principles. It is perhaps the most understudied area on ecolodges, i.e. the ecolodge principles. However, it is also understood that getting the responses on ecolodge principles poses limitations in terms of the respondents' knowledge. Firstly, it has been reported that even ecotourists and other types of tourists have limited knowledge of ecotourism (Wurzinger & Johansson, 2006). Secondly, even ecolodge patrons have narrow knowledge on the functions of ecolodges (Kwan *et al*., 2008). Hence, to find facts on contributing crucial information in improving the ecolodge industry in ecotourism, the participants involved may need to have sound knowledge in ecotourism and ecolodges.

Indeed, the identification of the participants is important before obtaining useful information on the subject of ecolodge. Although there may be no harm in obtaining direct information on a group of visitors on the subject of ecolodges, there are certain limitations on the information obtained, which may not be reliable. Firstly, visitors as tourists, may be subjected to the concept of a "dualistic nature" (Weaver, 2001); for example in which they may change from being ecotourists to a mass tourists, or vice versa. Hence, the information given by them may be influenced by their present nature at that point of time. Secondly, we have no indication at all on their knowledge on what ecolodges are and their basic principles. Hence, they may subconsciously answer question based on what they feel is appropriate to be answered, not based on what they know. Furthermore, they may also be inclined to subconsciously answer questions which do not reflect them entirely as they are obliged to meet certain perceived social responsibilities.

Having this in mind, the current study was designed in such way that the participants were segmented into two contrasting ecotourist groups; the hard domestics and soft domestics. The hard domestics refer to the hard ecotourists inclined to the hard end of the ecotourism spectrum (Weaver & Lawton, 2002) while the soft domestics refer to the ecotourists who are inclined towards the soft end or mass ecotourism (Weaver & Lawton, 2002). This priory identification allows for countering the limitations of having a "dualistic nature" within the participants themselves, which further explores whether each contrasting groups display preferences that are supposedly demonstrated.

STUDY OBJECTIVE

The purpose of this paper is to identify whether different ecotourist segments differ in their preferences on the characteristics of ecolodge. This is an important piece of information to show that ecotourists should not be assumed to be homogenous not only in their travel characteristics, but in their selection towards ecotourism products as well, notably the ecolodges. It further substantiates that the hard-soft ecotourism continuum can be incorporated into the selection of ecotourism accommodation attributes, which in turn, allows for packaging of different products based on different ecotourist segments.

METHODOLOGY

Study Site and Respondents

A self administered questionnaire was given to 403 participants visiting Kinabalu National Park in Sabah, Malaysia. Kinabalu National Park is a World Heritage Area in Sabah, Borneo, famously known for Mount Kinabalu, which has a vast and endemic species of flora and fauna. It is located in Sundaland, which comprises one of the biodiversity hotspots in the world (Myers *et al*., 2000). The respondents comprised of two identified domestic ecotourist segments which were classified as hard and soft domestics. Initially, the segments were derived using a Discriminant Analysis that had successfully classified 158 hard domestics (39.2%) and 134 soft ecotourists (33.3%) as well as 111 participants who were classified as 'other segments' (27.5%). For the purpose of this paper, the focus lies on only the hard and soft domestic segments.

Measures

The instrument used for this study has three sections (A, B and C) which measured different constructs. The first section is used to determine the three segments of hard domestics, other ecotourists and soft domestic ecotourists. The first section consisted of 33 items which segment the ecotourists as seen from their psychological characteristics towards ecotourism principles. The characteristics of the ecotourists can be associated with their associations towards ecotourism experiences, which include their general behaviour towards ecotourism principles, anthropocentrism, travel arrangements, trip preferences, services priorities, and activities. The concept of segmentation in this study is applied according to the psychographic segmentation concept, which includes a person's lifestyle, attitudes, opinions and personalities (Horner & Swarbrooke, 2007). Subsequently, the two most contrasting segments of hard domestic ecotourists and soft domestic ecotourists were then isolated and explored individually.

Section B of the instrument measures the attributes of the ecolodges. The questionnaire was constructed based on the ecotourism principles, which comprised of nature based attractions, local community sustainability and attributes pertaining to surrounding setting and landscape, structure and material, as well as the locality of the accommodation. The two other attributes include the type of accommodation preferred, as well as the services and comfort of the accommodation. A total of 15 items were used to explore the ecotourists' preferences, which include nature based attractions ($\alpha = 0.74$, 3 items), services and comfort ($\alpha = 0.75$, 2 items), location ($\alpha = 0.67$, 2 items), surrounding and landscaping ($\alpha = 0.77$, 3 items), structure and material ($\alpha = 0.81$, 3 items) and the preferred types of accommodation ($\alpha = 0.48$, 2 items). Section C of the questionnaire measures the general demographic characteristics of the respondents.

RESULTS

Hard and Soft Domestic Ecotourist Segments

The ecotourist groups in this study were identified by their responses towards three different statements that were initially asked in the Section A of the questionnaire. Each statement reflected different traits which characterized three different ecotourist types. Their original responses were thch statements reflects different traits which characterized three different ecotourists types. Then used to cross validate with their responses towards several constructs involving their ecotourism experiences. Although initially the discriminant analysis derived three groups, the hard and soft ecotourist groups were isolated in this study based on cross validations of the discriminant analysis (Table 1). The cross validation was done to validate the predicted groups by splitting the sample randomly into two sub-samples. The sub-samples were then used for deriving the functions and classification trial (Klecka, 1980). From the results of the cross validations,

TABLE 1
Cross validations of the ecotourist groups

		Ecotourist type	Predicted Group Membership			Total
			Hard	Other	Soft	
Original	Count	Hard	88	31	36	155
		Other	53	65	55	173
		Soft	17	15	43	75
	%	Hard	56.8	20.0	23.2	100.0
		Other	30.6	37.6	31.8	100.0
		Soft	22.7	20.0	57.3	100.0
Cross-validated	Count	Hard	78	39	38	155
		Other	65	49	59	173
		Soft	19	22	34	75
	%	Hard	50.3	25.2	24.5	100.0
		Other	37.6	28.3	34.1	100.0
		Soft	25.3	29.3	45.3	100.0

Table 2 shows the final number of the cross validated ecotourist groups obtained from the Discriminant Analysis.

TABLE 2
Ecotourist segments obtained from the discriminant analysis

Ecotourist type	Frequency	Percentage (%)
Hard	158	39.2
Other	111	27.5
Soft	134	33.3
Total	403	100

Ecotourists Preferences towards Ecolodge Attributes

The results for the analysis of variance with Tukey post-hoc are shown in Table 3. The attributes for nature based attractions were measured using three items which reflected the closeness with nature. There were significant differences of the means found between the hard domestic ecotourists and the soft domestic ecotourists (F = 7.24, p = .001). It was observed that the hard domestic ecotourists (M = 4.17) displayed a higher tendency to prefer nature-based attributes during their stay in an accommodation as compared to the soft domestic ecotourists (M = 4.05).

Services and comfort were measured by the importance of services and comfort the tourists would like to have during their stay. Hard domestic ecotourists (M = 2.90) rated services and comfort significantly lower than soft domestic ecotourists (F = 10.127, p = .001). The soft domestic ecotourists placed the importance of having air-conditioned rooms higher than the hard domestic ecotourists. They also had higher ratings on the attributes measuring luxurious items in the accommodation, whereas the hard domestic ecotourists (M = 2.82) rated them lower than the former segment.

TABLE 3
A comparison of the ecotourists' preferences on the ecolodge attributes

Ecolodges' attribute construct	Items	Ecotourist type[1]				
		Hard	Other group	Soft	F	p-value
Nature-based attractions	I enjoy activities in the natural setting of the rainforest.	4.17[a]	3.88[b]	4.05[b]	7.24	.001*
	I feel pleasant if I peek outside my room window to see that I am surrounded with lush green trees.	4.06[a]	3.76[bc]	3.73[bc]	9.15	.001*
	It is important that the hotel I choose makes me feel close to nature.	4.23[b]	4.04[a]	4.29[b]	3.78	.024*
		4.20[ac]	3.84[b]	4.14[ac]	8.14	.001*
Services and comfort		2.90[a]	3.32[b]	3.29[b]	10.127	.001*
	It is important for me that the place I am staying provides air conditioning rather than ceiling fan.	2.97[a]	3.45[bc]	3.43[bc]	11.746	.001*
	My ideal hotel would have luxurious king size bed with bathtubs, satellite TV and internet access.	2.82[a]	3.19[bc]	3.16[bc]	5.341	.005*
Location		3.87[a]	3.54[bc]	3.45[bc]	12.010	.001*
	I do not mind if the hotel I choose is located far from the city.	3.93[a]	3.59[bc]	3.60[bc]	6.97	.001*
	I would not mind staying in accommodation located deep inside the rainforest.	3.82[a]	3.48[bc]	3.30[bc]	11.544	.001*
Surrounding and Landscaping		4.12[bc]	3.83[a]	4.06[bc]	7.95	.001*
	I like if the hotel I am staying at harmonizes with the natural setting of the place.	4.13[ab]	3.84[c]	4.07[ab]	5.716	.004*
	I would choose a hotel that makes me feel at peace with nature.	4.19[ab]	3.87[c]	4.17[ab]	7.307	.001*
	Being able to connect with nature spiritually is a valuable experience for me during travel.	4.03[a]	3.77[b]	3.96	3.671	.026*

cont'd Table 3

Structure and Material		4.06^{a}	3.78^{b}	3.98^{a}	7.40	.001*
	I like staying in hotels that uses natural colours to blend with the natural environment.	4.00^{ab}	3.73^{c}	4.00^{ab}	4.93	.008*
	I like staying in hotels that was designed with cultural elements.	3.94^{ab}	3.68^{c}	3.94^{ab}	4.57	.011*
	Building accommodation should use environment-friendly materials.	4.11^{a}	3.79^{b}	3.92^{b}	6.443	.002*
	Preserving the environment should be considered in initial planning of hotels.	4.18^{a}	3.90^{b}	4.08	4.537	.011*
Type 2		3.79^{a}	3.50^{bc}	3.58^{bc}	6.24	.002*
	I prefer camping as I want to experience nature at its best.	3.68^{a}	3.48^{b}	3.41^{b}	3.82	.023*
	I prefer staying in wooden lodge that has natural elements.	3.89^{a}	3.51^{b}	3.75^{b}	6.435	.002*

Note:
[1]Cell entries are means based on a five-point Likert scale; 1 = Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree. Means with different superscripts indicate *significant differences at $p < .05$.
[2] Interpreting the superscripts example: There is a significant difference in the means for the "type" of accommodation between the hard and soft ecotourists.

The attribute measuring the location of accommodation was created to find out the preferences of the ecotourists towards the position of the accommodation from the intended ecotourism place. It was found that the hard domestic ecotourists (M = 3.87) scored significantly higher than the soft domestic counterparts. The hard domestic ecotourists do not mind whether the accommodation is located deep in the forest or far away from the city. This result was supported as the hard domestics tended to choose the 'hard type of accommodation spectrum' due to their desire to be absorbed in the tranquillity of the forest. Furthermore, they would not mind travelling on rough terrains to reach secluded areas as they normally preferred this 'hard' type of experience in ecotourism.

No further differences were reported between the hard and soft domestic ecotourists towards the attributes measuring surrounding and landscaping; however, the hard domestics had a higher rating towards "being able to connect with nature spiritually". Structure and material attributes were measured using four items, which included the usage of natural colours, incorporation of cultural elements in design, usage of environmental-friendly material, and preservation of environment in initial planning of accommodation. As expected, the hard domestic ecotourists displayed a higher tendency to agree in the usage of natural colours and the usage of environmental-friendly materials to build the accommodation, as compared to the soft ecotourists.

The attribute for the types of accommodation was measured by using two items, which captured the types of accommodation preferred by the ecotourists. The items measured their preferences for the hard type of accommodation (i.e. camping) and their preference to stay in an accommodation that reflects natural elements. The hard domestic ecotourists were highly agreeable on the types of accommodation that reflected rustic or primitive elements. In particular, they preferred camping as they wanted to experience nature at its best compared to the soft domestics ($F = 3.82$, $p = .023$) who preferred a more comfortable type of accommodation.

Respondent's General Characteristics

The highest percentage of the domestic ecotourists age was between 21-30 years old, which accounted for almost half of the percentages (see Table 4). The figure seems to drop lower consecutively through the age group with respondents aged over 50 year old ranking in the least percentages, with 3.7%. In terms of gender, there seemed to be an equal proportion of the male and female respondents in this study. The equal proportions of gender in nature based visitors are considered as expected in this present time, as females tend to play a more active part in engaging in nature based tourism. Single respondents made up 58.6% of the study, which is a little over half of the figure, compared to the married respondents which accounted for 39.7%. This could be no surprise as this type of group presumably faced less constraints in term of the availability of time and money to visiting national parks. Most individuals in this study (34 percent) earned an average income of RM1001-RM3000 per month. It is reported that income affects the spending of visitors, as reported by Thrane (2002) and Lee (2001). The preconceived notion in the nature based tourist is that the tourists are highly educated, and hence they are associated with high income. Compared to South Carolina tourists, the number of Malaysian visitors holding a graduate level degree in this study is lower than the 31.4 percent found by Weaver (2011).

DISCUSSION AND CONCLUSION

The hard domestic ecotourists seemed to display a higher tendency in preferring eco-friendly accommodations, which was displayed in their higher ratings on the attributes reflecting the ecolodges, as compared to the soft domestic ecotourists. The individuals who fell under the 'hard domestic ecotourists' category displayed keenness towards eco-friendly attributes, which somehow revealed their true nature as hard ecotourists. On the other hand, soft domestic ecotourists were portrayed to display keenness in wanting for more comfortable accommodations, as evident in their desires for comfort and services.

TABLE 4
Respondents' general characteristics

	Demographic profile	Frequencies	Percentages (%)
Age	Below 20	48	11.9
	21-30	218	54.1
	31-40	81	20.1
	41-50	35	8.7
	Over 50	15	3.7
	Undisclosed	6	1.5
Gender	Male	208	51.6
	Female	195	48.4
Marital Status	Married	160	39.7
	Single	236	58.6
	Single Parent/Divorced	2	0.5
	Undisclosed	5	1.2
Income	Below 1000	85	21.1
	1001-3000	137	34.0
	3001-5000	50	12.4
	5001-7000	5	1.2
	7001-9000	4	1.0
	9001-10000	6	1.5
	Over 10001	1	0.2
	No Income (Student/Retiree/Housewife)	78	19.4
	Undisclosed	37	9.2
Educational level	Primary school	2	0.5
	Secondary school	101	25.1
	Diploma	119	29.5
	Bachelor degree	144	35.7
	Graduate degree	28	6.9
	Vocational school	2	0.5
	No formal education	1	0.2
	Undisclosed	6	1.5
Occupation	Professional and managerial	145	36.0
	Academician and researcher	15	3.7
	Skills and technical workers	32	7.9
	Business and services	74	18.4
	Manual labour	9	2.2
	No income (Homemaker/Retiree/ Students)	95	23.6

cont'd Table 4

	Undisclosed	33	8.2
Places of origin	West Malaysia	194	47.9
	East Malaysia	199	49.6
	Undisclosed	10	2.5

As apparent from the results, they displayed a 'not so keen' attitude towards accommodations that are located remotely outside the city.

Conceptually, this study contributed towards the strengthening of the characteristics of two contrasting types of ecotourists. The hard domestics and the soft domestics fit into the hard-soft dimensions of ecotourism, as proposed theoretically by Laarman and Durst (1987), on top of the comprehensive-minimalist dimensions and the hard-soft manifestations proposed by Weaver (2005). Hence, as conceptually proposed in this study, the hard domestics and soft domestics adhere to the same variants in their preferences towards the eco-friendly attributes in their accommodation selection.

As demonstrated by the results of this study, the hard domestic ecotourists reflected the characteristics towards the hard end of the ecotourism spectrum. This is revealed in their tendencies to displaying avid nature lover characteristics and low expectations towards services and comfort, concurring with Weaver and Lawton's (2002) identification of hard ecotourists. On the contrary, the soft domestic ecotourists demonstrated affinity towards the end of the soft ecotourism spectrum in their preferences towards the eco-friendly accommodations. Although they displayed the basic traits of ecotourists such as loving nature and having fondness towards a peaceful surrounding, they also portrayed the characteristics of soft ecotourists due to their reluctance in preferring rustic and remote accommodations, as well as having high expectations towards acquiring the comfort of air-conditioner and accommodation with complete facilities.

Future research should consider data collection at two different areas, such as between an area without eco-friendly accommodations and that with eco-friendly accommodations. The two areas can be compared across independent samples for the formulation of strategies which will help ecotourism destinations to foster better eco-friendly programmes and practices. The researchers also suggest that future research concentrate on water management, energy management, promotion and marketing, materials and structure, as well as other relevant ecotourism issues, as stipulated in the ecolodge guidelines. These characteristics will provide invaluable information in assisting relevant authorities in developing eco-friendly accommodations of the future.

Active implementation of eco friendly programmes and practices will become landmark ecotourism areas. Apart from providing information on the importance of conservation through various interpretive products, the accommodations in ecotourism areas should actively adopt environmental-friendly programmes. These programmes must pledge to actively promote the principles of ecotourism. A public environmental policy for future developments of accommodations should also be able to foster green friendly initiatives in and around parks.

We conclude that the results of this study have provided evidence that ecotourists are not homogenous even if the population appears to more likely be similar in many ways. As stated by Wight (2001), ecotourists have differences in terms of their preferences towards the attributes of eco-friendly accommodations. Thus, this study has indeed contributed to the body of knowledge of ecotourists and their preferences towards eco-friendly accommodations, specifically in a Malaysian setting.

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The Effects of Environmental and Soil Fertility Factors on Plant Species Diversity in Kilim Geoforest Park, Langkawi, Malaysia

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ABSTRACT

Mangroves contain significant biodiversity and are highly valuable for coastal communities for their daily life and ecotourism attractions. It was observed that appropriate environmental and soil factors are important for conducive growth of mangroves, which in turn influence species distribution, composition and diversity. This study was carried out to compare soil fertility status among three main riverine systems and to analyze the effects of environmental and soil fertility factors on species richness, evenness and diversity in mangrove forest at Kilim Geoforest Park in Langkawi. A total of one hundred (20 m × 20 m) plots were established along both sides of the three rivers: River Kisap (40 plots), River Ayer Hangat (30 plots) and River Kilim (30 plots). All the species and trees of diameter 1 cm dbh and above found within the plots were enumerated and identified. Species richness was computed based on the Jackknife method and species diversity using Simpson's Index, Shannon-Wiener's Index and Brillouin's Index. The evenness index was measured by Simpson's measure of evenness, Camargo's index of evenness and Smith and Wilson's index of evenness. The composite soil samples of each riverine system were analysed for available P, dry Ph, total N & C and exchangeable (Ca, K, Mg & Na). The Canonical Component Analysis (CCA) method was used to show the relationship between the environmental and soil fertility factors and plant species diversity. Based on the analysis of the current study, soil fertility factors in the study areas were significantly different among the three rivers. Meanwhile, biodiversity indices like Brillouin's index, Shannon-Wiener index, Simpson's index, and Jackknife estimates of species richness were clustered together in River Kisap, as also indicated by the clustering of mangrove species such as *Avicennia marina*, *Acanthus volubilis*, *Bruguiera cylindrica*, *Ceriops decandra*, *Xylocarpus moluccensis*, *Rhizophora apiculata* and *Bruguiera parviflora*. Meanwhile, the ordination diagram of canonical redundancy analysis showed strong correlations between

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environmental and soil fertility factors and species diversity in Kilim Geoforest Park, Langkawi.

Keywords: Mangrove forest, Kilim Geoforest Park Langkawi, species richness, evenness and diversity, Jackknife method, Simpson, Shannon-Wiener, Brillouin, Camargo, Smith and Wilson indices

INTRODUCTION

Mangroves are defined as shrubs, trees, palms or ferns that grow within the inter-tidal region of coastal and estuarine environments throughout the tropical and subtropical areas around the world (Tomlinson, 1986). Mangroves can also include plants, associated forest communities and abiotic factors which form the mangrove ecosystem. The term 'mangrove' is also used to define both the plants that occur in tidal forests and to describe the community itself (Tomlinson, 1986; Wightman, 1989). Coastal ecosystems such as estuaries, wetlands and mangrove forests contain significant biodiversity and are highly valuable for coastal communities for their daily life. Mangrove ecosystem attracts intensive attention among the coastal ecosystems due to not only its peculiar habitat characteristics but also its rich biodiversity.

Mangrove forest in Langkawi is unique because they flourish on limestone formation, which is a rare occurrence and also supports unique flora and fauna species, some of which are endemic to the island, particularly the limestone vegetation. They are usually found on a shallow limestone substratum or Type VI of mangrove setting (Thom, 1984), and it is believed as one of its kinds in the world (Latiff, 2009). However, the anthropogenic pressure often leads to neglect the ecosystem and its surroundings culminate into a critical status of many coastal environments. Mangroves are the most threatened among the coastal ecosystems, more so throughout the tropical developing countries of the world as well as in Langkawi. Mangrove forest in Langkawi was reduced to 3270 ha or 10.6% reduction from 3657.67 ha in 1980 (Latiff, 2009). Knowing the fact that Langkawi is one of the biggest tourist attractions in Malaysia, Kilim Geoforest Park in Langkawi has been rapidly developed since the last 20 years mainly for tourism purposes. The mangrove areas in Kilim Geoforest Park cover approximately 3,142 ha, of which about 1,336 ha belong to Kisap Forest Reserve. There are several threats to Kilim Geoforest Park mangroves, specifically over-exploitation by the local people, such as natural resource development viz. coastal agriculture, salt production, intensive shrimp culture, as well as coastal industrialization and urbanization that completely destroy the mangrove ecosystem; and increasing facilities for yatch parking and activities for ecotourism.

As in other countries, the early attempts at mangrove restoration programmes in Malaysia met with mixed results, with some being successful, while others were doomed from the start. Reports by many experts (Field, 1996; Erftemeijer & Lewis 2000) showed that mangrove restoration programmes conducted before were not based on well-understood ecological principles and well-defined objectives. There are many factors affecting the diversity and composition of mangroves in the world.

In more recent years, attention has turned to the ecological processes that are present in the natural and restored mangrove systems (McKee & Faulkner, 2000; Alongi, 2002; Saenger, 2002; Lewis III, 2005). The relationship between the restored mangrove ecosystem and adjoining ecosystems such as salt marsh (Saintilan & Hashimoto, 1999) and sea grass beds (Hogarth, 2007) has also been a focus of attention. A consensus has also emerged that an understanding of mangrove hydrology is most important for successful restoration (Wolanski *et al.,* 1992). By establishing a new concept aiming at mangrove restoration programmes, degraded mangrove forest would probably be restored.

Of late, however, environmental factors have become the focus of discussion, for example, tidal waters bring nutrients along with other essential minerals to the on-shore region where they become available to mangroves. This tidal water was earlier considered to be the only factor playing a major role in the regeneration and growth of mangroves. Nonetheless, it has been observed that other factors such as rainfall (200cm–300cm), atmospheric humidity (60% - 90%), and moderate temperatures (19°C - 35°C) have also been considered ideal for mangroves' growth (Blasco, 1977; Naskar & Mandal, 1999).

On the contrary, a study in India showed different results; despite having the maximum tidal fluctuations, Bhabnagar estuary did not have high mangrove species diversity because of its low average rainfall (60 cm annum^{-1}) and inadequate upstream freshwater supply (Blasco & Aizpuru, 1997). Venkatesan (1966) argued that mangrove habitats would remain productive as long as they got inundated with tidal water, received high rainfall annually, and benefited from the continuous upstream freshwater which usually carries silt, sediments and organic matter. Mandal (1996) supported the above view while investigating seed germination and seedling development of mangroves. Mangroves initially require fresh water to continue their physiological process until they develop salt secretary organs such as salt glands, corkwart, gall and other related mechanisms (Naskar *et al*., 1997; Naskar & Mandal, 1999).

The objectives of this research were to compare the soil fertility status among the three main riverine systems, to establish interrelationship and relative roles of soil fertility in determining species diversity, as well as to relate environmental factors influencing species distribution, composition and diversity in the three main riverine systems - River Kisap, River Kilim and River Ayer Hangat in the Kilim Geoforest Park, Langkawi, in terms of species richness, evenness and diversity.

MATERIALS AND METHODS

Site Description

Kilim Geoforest Park, Langkawi, features limestone dominating the eastern part of the main Langkawi island and the adjacent small islands of Setul formation. Magnificently formed landscape of nearly vertical to subrounded karstic hills with pinnacles of various shapes and sizes can be viewed. It comprises three rivers, namely; River Kilim, River Ayer Hangat and River Kisap. These rivers have many tributaries, with mangrove forests line both sides of the rivers. Kilim karstic hills bear many beautiful caves, while karstic coastlines are provided with much more varied and colourful karstic features including sea notches, sea tunnels, sea caves, sea arches, sea stacks and remnant islands. The limestone of Kilim is also very rich in fossils, particularly those at Pulau Langgun. The region's highest (23m a.s.l.) Holocene (circa 7000m a.s.l) was also recorded within this Geoforest Park. The ecosystems of the old limestone rock formation, the caves, the mudflats and the seas that surround it have three main vegetations, namely; the mangroves, the vegetation of the limestone hills, and the flora of the mudflats and beaches.

The study area is located between the latitude 6^0 29' 33.20'' to 6^0 23' 6.24'' and between the longitude 99^0 48' 0.34'' to 99^0 55' 30.86'' at the northeast of Langkawi Island (Fig.1). The area is mainly covered by forest, mangroves, agricultural land and sand beaches. The topography varies from flat coastal plains to hilly areas to rugged mountains. All the data for this study were collected from November 2009 to February 2010.

Sampling for Plant Composition

Plots of 20 m × 20 m were established along River Kisap (40 plots), River Kilim (30 plots) and River Ayer Hangat (30 plots) within Kilim Geoforest Park. All the plots were 250 m apart from edge to edge of the plot along these rivers to the shoreline (Fig.2).

Within each plot, all trees ≥1 cm dbh (diameter breast height) were identified, measured and recorded. Other parameters recorded were species name and height. All other woody plants ≤ 1cm dbh, shrubs, climbers, epiphytes and weeds were counted. However, a complete specimen was collected, tagged and recorded if the species were not known. They were brought to the Herbarium at the Faculty of Forestry, Universiti Putra Malaysia (UPM) for drying process and identification.

Soil Sampling

Soil samples were taken from 6 randomly chosen plots from each of the riverine systems. Within each 20 m × 20 m plot, 5 soil samples were taken – one point (3 soil samples/point) in the middle of the plot, the other four points were collected randomly within each quadrant of the plot. Hence, a total of 90 soil samples were collected using soil auger (10 to 20 cm soil layers) from the three riverine systems. The soil samples from each sampling point plot were mixed thoroughly as a composite sample, air dried and passed through a 2 mm mesh sieve to remove the stone pieces and large root particles. The composite soil sample was used for a detailed soil

Fig.1: Location of Kilim Geoforest Park, Langkawi, Malaysia and the sampling site

analysis, as follows: (i) Available P (ppm); (ii) Dry pH; (iii) Total N (%); (iv) Total organic C (%); (v) Exchangeable Ca (cmol/kg); (vi) Exchangeable K (cmol/kg); (vii) Exchangeable Mg (cmol/kg) and (viii) Exchangeable Na (cmol/kg).

Data Analysis

A data matrix X_{ij} was analyzed, where i= 1, 2, 3,.... 98, 99, 100 denote the 100 plots established along the three rivers, and j= 1, 2, 3...., 19, 20, 21 represent 21 indices of soil fertility, measure of plant diversity and

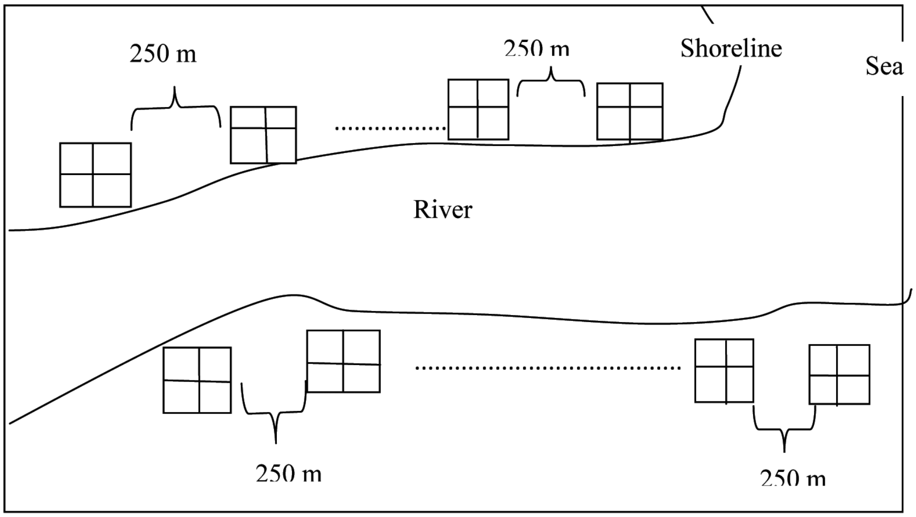

Fig.2: Plot layout at each of the three rivers

environmental factors. The j factors are as follows:

1. Environmental factors: (i) Total amount of rainfall (RF); (ii) Total number of raindays (RD); (iii) Mean temperature (T); (iv) Relative humidity (RH); and (v) Surface wind speed (WS)
2. Soil fertility factors: (i) Available P; (ii) Dry pH; (iii) Total N; (iv) Total organic C; (v) Ex. Ca; (vi) Ex. K; (vii) Ex. Mg; (viii) Ex. Na; (Ex. = Exchangeable).
3. Measures of plant diversity: (i) Total number of individual (NI), (ii) Brillouin's index H (BI), (iii) Shannon-Wiener index of diversity H' (SW); (iv) Simpson's index of diversity (SI); (v) Camargo's index of evenness (CE); (vi) Smith and Wilson's index of evenness (SW); (vii) Simpson's measures of evenness (SE); and (viii) Jackknife estimates of species richness (JR).

SAS (Statistical Analysis System) package was used to compare the soil fertility status among the three rivers. In order to investigate complex relationships, the multivariate statistical analysis techniques - Principal Component Analysis (PCA) and Canonical Correlation Analysis (CCA) were used. PCA was used to compute the Eigenvalues using Conoco 4.5 software. The CCA method was used to illustrate the interrelationships between the environmental factors, soil fertility and plant diversity groups.

Principle Component Analysis (PCA)

PCA is a useful statistical technique that is used to obtain a small number of linear combinations of the many factors (the 21 factors), which account for the most of the variability in the data. The components with Eigenvalues ≥ 1 and their cumulative percentages of variance are considered as the one accounted for the most of the variability.

Canonical Correlation Analysis (CCA)

CCA is a method to help identify the associations between two sets of variables. It does so by finding linear combinations of the variables in the two sets that exhibit strong correlations. The pair of the linear combinations with the strongest correlation forms the first set of canonical variables. The second set of the canonical variables is the pair of linear combinations that shows the next strongest correlation among all the combinations that are uncorrelated with the first set. Often, a small number of pairs can be used to quantify the relationship of the two sets.

Data for computing species richness, evenness and diversity indices were analyzed using Ecological Methodology Software (Krebbs 1998), as follows:

Species Richness

i. Jackknife Estimate

$$\hat{S} = s + \left(\frac{n-1}{n}k\right)$$

Where,

$\hat{S}$ = jackknife estimate of species richness

s = total number of species present in quadrates

n = total number of quadrates samples

k = number of unique species (species which occur in only one quadrate)

Species Diversity

i. Simpson's Index

$$\hat{D} = 1 - \sum Pi^2$$

Where,

$\hat{D}$ = Simpson's index

Pi = proportion of species i in the community

ii. Shannon-Weiner measure

$$H` = \sum (Pi)(\log Pi)$$

Where,

H ' = information content of the sample (bits/individual) and index of diversity

s = number of species

Pi = proportion of the total sample belonging to i species

iii. Brillouin's index

$$HB = \frac{\ln(N!) - \Sigma\ln(ni!)}{N}$$

Where,

HB = the Brillouin index,

N = total number of individuals in the sample

ni = number of individual of species i

ln(x) = natural logarithm of x (or logarithm base e)

N! means the factorial of N = 1 * 2 * 3 * 4... * N

Species Evenness

i. Simpson's measure of evenness

$$E_{\frac{1}{\hat{D}}} = \frac{\frac{1}{\hat{D}}}{s}$$

Where,

$E_{1/D}$ = Simpson measure of evenness

S = number of species in the sample

$\hat{D}$ = Simpson index

ii. Smith and Wilson's index of evenness

E_{var}=1-[2/(πarctan{}^{2}/s)}

E_{var}=1-[2/(πarctan{$\Sigma\downarrow(i = 1)^{\uparrow}\varepsilon$ 【(log↓e ($n\downarrow i$) − $\Sigma\downarrow(j = 1)^{\uparrow}\varepsilon$(】 (log↓e ($n\downarrow j$))/s)^2/s)}

Where,

E_{var} = Smith and Wilson's index of evenness

n_i = Number of individuals in species i in the sample (i = 1, 2, ..., s)

n_j = Number of individuals in species j in the sample (j = 1, 2, ..., s)

s = Number of species in the entire sample

iii. Camargo's index of evenness

$$E' = 1 - \left(\sum_{i=1}^{s} \sum_{j=i+1}^{s} \left(\frac{|P_i - P_j|}{S} \right) \right)$$

Where,

p_i = proportion of individuals of a species at site i

p_j= proportion at site j;

s = total number of sites in the sample.

TABLE 1
Floristic composition and dominant tree species ≥1 cm dbh at Kilim Geoforest Park, Langkawi, Malaysia

Area	Family	Species	No. of Stem
	1. Avicenniaceae	1. *Avicennia officinalis*	20
	2. Rhizophoraceae	2. *Bruguiera gymnorhiza*	17
		3. *Bruguiera parviflora*	424
		4. *Bruguiera sexangula*	465
		5. *Ceriops tagal*	1264
		6. *Rhizophora apiculata*	1226
		7. *Rhizophora mucronata*	455
	3. Cycadaceae	8. *Cycas siamensis*	3
Sungai Kilim	4. Lythraceae	9. *Memecylon edule* Roxb. var. *ovatum*	1
		10. *Memecylon pauciflorum*	1
	5. Rutaceae	11. *Murraya paniculata*	2
	6. Anacardiaceae	12. *Pentaspadon curtisii*	3
	8. Moraceae	13. *Streblus ilicifolius*	19
		14. *Streblus laxiflorus*	1
	9. Polygalaceae	15. *Xanthophyllum discolor*	8
	10. Meliaceae	16. *Xylocarpus granatum*	124
		17. *Xylocarpus moluccensis*	18
		Total	**4051**

cont'd Table 1

Sungai Kisap	1. Avicenniaceae	1. *Avicennia marina*	55
	2. Rhizophoraceae	2. *Bruguiera cylindrica*	1110
		3. *Bruguiera parviflora*	311
		4. *Ceriops decandra*	1
		5. *Ceriops tagal*	367
		6. *Rhizophora apiculata*	1114
		7. Rhizophora mucronata	244
	3. Lauraceae	8. *Cinnamomun* sp.	4
	4. Ebenaceae	9. *Diospyros ismailii*	21
	5. Elaeocarpaceae	10. *Elaeocarpus griffithii*	1
	6. Erythroxylaceae	11. *Erythroxylum cuneatum*	9
	7. Euphorbiaceae	12. *Excoecaria agallocha*	4
	8. Loganiaceae	13. *Fagraea curtisii*	7
	9. Bignoniaceae	14. *Fernando adenophylla*	10
	10. Moraceae	15. *Ficus deltoidea*	5
		16. *Ficus rumpii*	2
		17. *Ficus superb*	4
	11. Flacourtiaceae	18. *Flacourtia rukam*	3
	12. Sterculiaceae	19. *Heritiera littoralis*	4
	13. Flacourtiaceae	20. *Hydnocarpus ilicifolia*	4
	14. Lythraceae	21. *Lagerstroemia floribunda*	9
	15. Euphorbiaceae	22. *Macaranga* sp.	1
		23. *Mallotus brevipetiolatus*	4
		24. *Mallotus dispar*	2
		25. *Phyllanthus pulcher*	15
	16. Lythraceae	26. *Memecylon edule* Roxb. var. *ovatum*	18
		27. *Memecylon pauciflorum*	35
	17. Tiliaceae	28. *Microcos* sp.	1
		29. *Pentace* sp.	3
	18. Anacardiaceae	30. *Pentaspandon curtisii*	9
		31. *Pentaspandon velutinis*	1
	19. Rubiaceae	32. *Psychotria angulata*	1

cont'd Table 1

Sungai Kisap	20. Sterculiaceae	33. *Pterospermum lanceaefolium*	5
	21. Bignoniaceae	34. *Radermachera pinnata*	11
		35. *Radermachera stricta*	3
	22. Araliaceae	36. *Schefflera heterophylla*	2
	23. Bignoniaceae	37. *Spatodea companulata*	9
	24. Anacardiaceae	38. *Spondias pinnata*	2
	25. Sterculiaceae	39. *Sterculia augustifolia*	17
		40. *Sterculia lancaviensis*	19
	26. Moraceae	41. *Streblus ilicifolius*	41
	27.Myrtaceae	42. *Syzgium* sp.	3
	28. Combretaceae	43. *Terminalia triptera*	5
	29. Verbenaceae	44. *Vitex pinnata*	1
	30. Polygalaceae	45. *Xanthophyllum affine*	3
		46. *Xantophyllum discolor*	3
	31. Meliaceae	47. *Xylocarpus granatum*	253
		48. *Xylocarpus moluccensis*	76
		Total	**3832**
Sungai Ayer Hangat	1. Avicenniaceae	1. *Avicennia marina*	37
	2. Rhizophoraceae	2. *Bruguiera cylindrical*	62
		3. *Bruguiera parviflora*	91
		4. Ceriops tagal	429
		5. Rhizophora apiculata	1109
		6. Rhizophora mucronata	265
	3. Ebenaceae	7. *Diospyros ferrea*	1
	4. Euphorbiaceae	8. *Excoecaria agallocha*	1
	5. Moraceae	9. *Ficus superb*	1
	6. Anacardiaceae	10. *Pentaspadon motley*	1
	8. Lythraceae	11. *Sonneratia alba*	1
	9. Moraceae	12. *Streblus ilicifolius*	5
	10. Polygalaceae	13. *Xanthophyllum affine*	4
	11. Meliaceae	14. *Xylocarpus granatum*	1517
		15. *Xylocarpus moluccensis*	27
		16. *Xylocarpus rumphii*	54
		Total	3605
		Grand Total	11488

RESULTS AND DISCUSSION

Overall Species Composition and Dominance

In this study, a total of 11,488 and 14,820 individual species of trees ≥1 cm dbh and other woody plants ≤ 1cm dbh, shrubs, climbers, epiphytes and weeds were identified, measured and recorded, respectively. All the species were enumerated to determine species composition and dominance in the 4 hectares study plot at Kilim Geoforest Park, Langkawi. The identified species were further classified according to their family and number of stems. For each riverine system, at least 24 families, 37 genera and 58 species of all trees (Table 1) were identified, apart from 43 families, 88 genera and 114 species of non-trees (e.g., orchids, shrubs, climbers, epiphytes, grasses, bamboos, and weeds (Table 2).

TABLE 2
The floristic composition and dominant species of woody plants ≤ 1cm dbh, shrubs, climbers, epiphytes and weeds at Kilim Geoforest Park, Langkawi, Malaysia

Area	Family	Species	No. of Stem
Sungai Kilim	1. Acanthaceae	1. *Acanthus volubilis*	40
	2. Euphorbiaceae	2. *Euphorbia antiquorum*	23
	3. Meliaceae	3. *Xylocarpus granatum*	66
		4. *Xylocarpus moluccensis*	27
	4. Moraceae	5. *Streblus ilicifolius*	45
	5. Polygalaceae	6. *Xanthophyllum discolor*	4
	6. Rhamnaceae	7. *Ziziphus affinis*	13
	7. Rhizophoraceae	8. *Bruguiera parviflora*	127
		9. *Bruguiera sexangula*	256
		10. *Ceriops tagal*	439
		11. *Rhizophora apiculata*	759
		12. *Rhizophora mucronata*	118
		Total	1917
Sungai Kisap	1. Acanthaceae	1. *Acanthus ebracteatus*	3
		2. *Acanthus ilicifolius*	68
		3. *Acanthus volubilis*	679
		4. *Justicia sp*.	6
		5. *Pseuderanthemum crenulatum*	6
	2. Aizoaceae	6. *Sesuvium portulacastrum*	5
	3. Anacardiaceae	7. *Pentaspadon curtisii*	1
		8. *Pentaspadon motleyi*	7
	4. Annonaceae	9. *Fissistigma fulgen*	63
	5. Apocynaceae	10. *Parameria* sp.	30

cont'd Table 2

	6. Araliaceae	11. *Schefflera heterophylla*	5
		12. *Scindapsus scortechinii*	3
	7. Araceae	13. *Alocasia denudate*	79
		14. *Amorphophallus haematospadix*	12
		15. *Amorphophallus variabilis*	60
		16. *Arisaema fimbriatum*	286
	8. Asclepiadaceae	17. *Hoya coronaria*	4
		18. *Hoya diversifolia*	73
		19. *Pentasacme caudatum*	15
	9. Asteracae	20. *Chromolaena odorata*	37
		21. *Pluchea indica*	1
	10. Avicenniaceae	22. *Avicennia marina*	85
	11. Begoniaceae	23. *Begonia curtisii*	169
		24. *Begonia phoeniogramma*	3
	12. Cycadaceae	25. *Cycas siamensis*	1
	13. Cyperaceae	26. *Fimbristylis calcicola*	6
	14. Davalliaceae	27. *Davallia denticulate*	44
	15. Dioscoreaceae	28. *Dioscorea calcicola*	53
		29. *Dioscorea tamarisciflora*	185
	16. Dryopteridaceae	30. *Dryopteris anneaphylla*	36
Sungai Kisap		31. *Dryopteris ludens*	51
		32. *Tectaria coadunata*	8
		33. *Tectaria keckii*	19
	17. Ebenaceae	34. *Diospyros ferrea*	33
		35. *Diospyros ismailii*	8
	18. Euphorbiaceae	36. *Croton cascarilloides*	58
		37. *Excoecaria agallocha*	6
		38. *Macaranga* sp.	3
		39. *Mallotus brevipetiolatus*	2
		40. *Mallotus dispar*	11
		41. *Phyllanthus columnaris*	5
		42. *Phyllanthus pulcher*	9
	19. Flacourtiaceae	43. *Flacourtia rukam*	1
	20. Gesneriaceae	44. *Boea acutifolia*	52
		45. *Didymocarpus lacunosus*	12
		46. *Henklia* sp.	146
		47. *Monophyllaea glabra*	33
		48. *Paraboea ferruginea*	128
	21. Gramineae	49. *Dendrocalamus elegans*	5
	22. Labiatae	50. *Orthosiphon aristatus*	14
	23. Leguminosae	51. *Bauhinia curtisii*	40

cont'd Table 2

		52. *Bauhinia flava*	22
		53. *Caesalpinia crista*	26
		54. *Derris trifoliata*	13
		55. *Mucuna gigantea*	15
	24. Loganiaceae	56. *Fagraea curtisii*	60
Sungai Kisap	25. Lythraceae	57. *Lagerstroemia floribunda*	3
		58. *Memecylon edule*	130
		59. *Memecylon pauciflorum*	2
	26. Meliaceae	60. *Xylocarpus granatum*	605
		61. *Xylocarpus moluccensis*	108
	27. Menispermaceae	62. *Stephania venosa*	3
		63. *Tinospora crispa*	9
	28. Moraceae	64. *Ficus deltoidea*	14
		65. *Streblus ilicifolius*	155
		66. *Streblus laxiflorus*	54
	29. Oleaceae	67. *Jasminum insularum*	75
	30. Orchidaceae	68. *Bulbophyllum vaginatum*	14
		69. *Bulbophyllum xanthum*	5
		70. *Dendrobium gemellum*	3
		71. *Dendrobium pachyglossum*	6
		72. *Eria bractescens*	25
		73. *Eulophia keithii*	12
		74. *Flickingeria fimbriata*	42
		75. *Geodorum citrinum*	3
Sungai Kisap		76. *Liparis elegans*	17
		77. *Nervilia calcicola*	428
		78. *Vandopsis gigantea*	16
	31. Polypodiaceae	79. *Drynaria quercifollia*	55
		80. *Drynaria sparsisora*	43
		81. *Microsorum punctatum*	80
		82. *Microsorum zippelii*	20
		83. *Phymatosorus nigrescens*	6
		84. *Pyrrosia lanceolata*	2
		85. *Pyrrosia piloselloides*	10
		86. *Selliguea* sp.	100
	32. Pteridaceae	87. *Acrostichum aureum*	11
	33. Rhamnaceae	88. *Ventilago oblongifolia*	8

cont'd Table 2

Sungai Kisap		89. *Ziziphus affinis*	16
		90. *Ziziphus oenoplia*	100
	34. Rhizophoraceae	91. B*ruguiera cylindrica*	809
		92. *Bruguiera parviflora*	273
		93. *Ceriops tagal*	455
		94. *Rhizophora apiculata*	1316
		95. *Rhizophora mucronata*	121
	35. Rubiaceae	96. *Antirhea atropurpurea*	61
		97. *Argostemma pictum*	137
		98. *Psychotria angulata*	18
		99. *Psydrax* sp.	47
	36. Rutaceae	100. *Micromelum minutum*	71
		101. *Murraya koenigii*	27
		102. *Murraya paniculata*	9
	37. Sapindaceae	103. *Allophylus ternatus*	26
	38. Selaginellaceae	104. *Selaginella* sp.	580
	39. Tiliaceae	105. *Microcos* sp.	32
	40. Verbenaceae	106. *Cissus repens*	71
		107. *Clerodendrum nutans*	8
	41. Vitaceae	108. *Tetrastigma leucostaphylum*	4
		109. *Vitex siamica*	4
	42. Zingiberaceae	110. *Kaempferia pulchra*	15
		Total	9069
Sungai Ayer Hangat	1. Acanthaceae	1. *Acanthus ebracteatus*	78
		2. *Acanthus ilicifolius*	162
		3. *Acanthus volubilis*	660
	2. Avicenniaceae	4. *Avicennia marina*	29
	3. Lythraceae	5. *Memecylon edule*	4
	4. Meliaceae	6. *Xylocarpus granatum*	702
		7. *Xylocarpus moluccensis*	77
		8. *Xylocarpus rumphii*	76
	5. Moraceae	9. *Ficus deltoidea*	3
	6. Rhamnaceae	10. *Ziziphus affinis*	2
	7. Rhizophoraceae	11. *Bruguiera cylindrica*	24
		12. *Bruguiera parviflora*	69
		13. *Ceriops tagal*	713
		14. *Rhizophora apiculata*	1174
		15. *Rhizophora mucronata*	56
	8. Rubiaceae	16. *Psydrax* sp.	5
		Total	3834
		Grand Total	14820

For trees ≥1 cm dbh as in Table 1, five most dominant species at each riverine system in terms of the number of stems are as follows:

Sg. Kilim: *Ceriops tagal* (1264 stems), *Rhizophora apiculata* (1226), *Bruguiera sexangula* (465), *Rhizophora mucronata* (455 stems), and *Bruguiera parviflora* (424 stems);

Sg. Kisap: *Rhizophora apiculata* (1114 stems), *Bruguiera cylindrical* (1110 stems); *Ceriops tagal* (367 stems), *Bruguiera parviflora* (311 stems); and *Rhizophora mucronata* (244 stems); and

Sg. Ayer Hangat: *Xylocarpus granatum* (1517 stems), *Rhizophora apiculata* (1109 stems), *Ceriops tagal* (429 stems), *Rhizophora mucronata* (265 stems); and *Bruguiera parviflora* (91 stems).

Meanwhile, the two most dominant families for trees ≥1 cm in the three riverine systems combined are Rhizophoraceae (8954 stems or 77.94% of the total stems) and Meliaceae (2069 stems or 18.01%). Rhizophoraceae has 8 species in 3 genera (8954 stems or 77.94%), the highest, and therefore, the most diverse among the trees ≥1 cm in the three riverine systems. This is followed by Moraceae (5 species in 1 genus: 78 stems or 0.68%) and Euphorbiaceae (5 species in 4 genera: 27 stems or 0.24%). On the other hand, the least diverse plant species were those with only one genus and one species in various families, while the most were with less that 10 individual stems.

For woody plants ≤ 1cm dbh, shrubs, climbers, epiphytes and weeds, five most dominant species at each riverine system in terms of the number of stems are as follows (Table 2):

Sg. Kilim: *Rhizophora apiculata* (759), *Ceriops tagal* (439 stems), *Bruguiera sexangula* (256), *Bruguiera parviflora* (127 stems) and *Rhizophora mucronata* (118 stems);

Sg. Kisap: *Rhizophora apiculata* (1316 stems), *Bruguiera cylindrical* (809 stems); *Acanthus volubilis* (679 stems), *Ceriops tagal* (455 stems), and *Bruguiera parviflora* (311 stems); and

Sg. Ayer Hangat: *Rhizophora apiculata* (1174 stems), *Ceriops tagal* (713 stems), *Xylocarpus granatum* (702 stems), *Acanthus volubilis* (660 stems), and *Xylocarpus moluccensis* (77 stems).

The three most dominant families for plants ≤ 1cm dbh, shrubs, climbers, epiphytes and weeds in the three riverine systems combined were Rhizophoraceae (6709 stems or 45.27% of the total stems), Acanthaceae (1702 stems or 11.48%) and Meliaceae (1661 stems or 11.21%). Orchidaceae has 11 species in 9 genera (571 stems or 3.85%), the highest and therefore, the most diverse for plants ≤ 1cm dbh in the three riverine systems. This is followed by Euphorbiaceae (9 species in 7 genera: 124 stems or 0.84%), Polypodiaceae (8 species in 5 genera: 316 stems or 2.13%), Rhizophoraceae (6 species in 3 genera: 6709 stems or 45.27%) and Gesneriaceae (5 species in 5 genera: 371 stems or 2.5%). On the other hand, the least diverse plant species are those with only one genus and one species in various families and the majority is with less 75 stems.

The Effect of Soil Fertility and Environmental Factors on Plant Species Diversity

Environmental factors for the year 2010, such as RF, RD, T, RH collected from a nearby meteorological station, are similar for all the study areas, namely; RF= 2398.2 mm, RD=180 days, T= 28.4 ^{0}C, RH= 78.8 % and WS=1.9 m/second, as the rivers are adjacent to each other.

The soil fertility factors in the three study areas (River Kisap, River Kilim and River Ayer Hangat) were also determined in this study. Many previous studies have shown that soil fertility is one of the key factors determining the species diversity in certain areas (Zack *et al*., 2003). Based on our analysis, some soil fertility factors in the study areas are significantly different among the three rivers (Table 3).

The soil fertility factors are closely related to soil organic matter (SOM) content and its mineralization. The extent of C mineralization determines soil nutrient release and therefore nutrient availability. In the study area, soil properties showed a slight heterogeneity among the study sites. The test results in Table 3 show that River Kisap has higher available P, total N and organic C contents as compared to River Kilim and River Ayer Hangat.

Analysis of the Plant Species Diversity

Interestingly, species richness, species heterogeneity and species evenness for both mangrove and woody plants ≤ 1cm dbh, shrubs, climbers, epiphytes and weeds for the three locations showed that they are significantly diverse (Tables 4 and 5). Based on Jackknife's index, River Kisap, with an index equals to 53.32 and 126.85, is the richest area with mangrove and woody plants ≤ 1cm dbh, shrubs, climbers, epiphytes and weeds, respectively as compared to River Ayer Hangat and River Kilim. In the River Kisap area, 15 mangrove species were identified, whereas only 8 species were identified at the other two rivers.

TABLE 3
Soil fertility factors at the three riverine systems at Kilim Geoforest Park, Langakwi, Malaysia (statistics sharing the same superscripts $^{(a \text{ or } b)}$ are not significantly different at P > 5%)

Soil Fertility Factors	Locations		
	River Ayer Hangat	River Kilim	River Kisap
Available P (ppm)	153.94^{a}	148.59^{a}	166.07^{b}
Total N (%)	0.27^{a}	0.28^{a}	0.29^{a}
Total 0rganic C (%)	4.14^{a}	6.21^{a}	6.93^{b}
Ex. Ca (cmol/kg)	8.22^{a}	11.48^{a}	8.80^{a}
Ex. K (cmol/kg)	2.30^{a}	2.61^{a}	2.60^{a}
Ex. Mg (cmol/kg)	21.53^{a}	30.91^{b}	22.70^{a}
Ex. Na (cmol/kg)	54.34^{a}	79.23^{b}	57.62^{a}
Soil pH	5.83	5.28	6.04

TABLE 4
Species diversity of mangrove at three riverine systems in Kilim Geoforest Park, Langkawi

A. Measure of Species Richness			
Diversity Index	River Kilim	River Kisap	River Ayer Hangat
Jackknife estimates of species richness	19.48	53.32	18.32
B. Measure of Species Heterogeneity			
Diversity Index	River Kilim	River Kisap	River Ayer Hangat
Simpson's index of diversity (1-D)	0.77	0.81	0.70
Shannon-Wiener index of diversity H'	2.44	3.00	2.08
Brillouin index of diversity	2.43	2.97	2.07
C. Measure of Species Evenness			
Diversity Index	River Kilim	River Kisap	River Ayer Hangat
Simpson's measure of evenness	0.26	0.11	0.21
Camargo's index of evenness	0.25	0.14	0.22
Smith and Wilson's Index of Evenness	0.10	0.18	0.10

TABLE 5
Species diversity of woody plants ≤ 1cm dbh, shrubs, climbers, epiphytes and weeds at three riverine systems in Geoforest Park, Langkawi, Malaysia

A. Measure of Species Richness			
Diversity Index	River Kilim	River Kisap	River Ayer Hangat
Jackknife estimates of species richness	13. 57	126.85	17.76
B. Measure of Species Heterogeneity			
Diversity Index	River Kilim	River Kisap	River Ayer Hangat
Simpson's index of diversity (1-D)	0.76	0.95	0.81
Shannon-Wiener index of diversity H'	2.55	5.11	2.72
Brillouin index of diversity	2.53	5.07	2.71
C. Measure of Species Evenness			
Diversity Index	River Kilim	River Kisap	River Ayer Hangat
Simpson's measure of evenness	0.35	0.17	0.32
Camargo's index of evenness	0.37	0.25	0.32
Smith and Wilson's Index of Evenness	0.29	0.23	0.16

TABLE 6
A summary of RDA ordination for mangrove tree species and their relationship with environmental factors in the Kilim Geoforest Park, Langkawi, Malaysia

Term	Axis				Total inertia
	1	2	3	4	
Eigenvalues:	0 .317	0.228	0.000	0.000	0.546
Species-environment correlations:	.000	1.000	0.000	0.000	
Cumulative percentage variance					
of species data :	58.2%	100%	0.0	0.0	
of species-environment relation:	58.2%	100%	0.0	0.0	
Sum of all eigenvalues:					0.546
Sum of all canonical eigenvalues :					0.546

TABLE 7
A summary of the RDA ordination for woody plants ≤ 1cm dbh, shrubs, climbers, epiphytes and weeds and their relationship with environmental factors in the Kilim Geoforest Park, Langkawi, Malaysia

Term	Axes				Total inertia
	1	2	3	4	
Eigenvalues	: 0.418	0.152	0.000	0.000	0.570
Species-environment correlations:	1.000	1.000	0.000	0.000	
Cumulative percentage variance					
of species data	: 73.3%	100%	0.0	0.0	
of species-environment relation:	73.3%	100%	0.0	0.0	
Sum of all eigenvalues					0.570
Sum of all canonical eigenvalues					0.570

Based on the recorded data, all the indices showed that Sungai Kisap is the most diverse area in Kilim Geoforest Park, followed by Sungai Kilim and Sungai Ayer Hangat. As for woody plants ≤ 1cm dbh, shrubs, climbers, epiphytes and weeds, the ranking is as follows: Sungai Kisap > Sungai Ayer Hangat > Sungai Kilim. Sungai Kilim showed the most evenness area for both mangroves and woody plants ≤ 1cm dbh, shrubs, climbers, epiphytes and weeds, followed by Sungai Ayer Hangat and Sungai Kisap.

The Relationships between Environmental Factors and Measures of Plant Diversity

Tables 6 and 7 summarize the Eigenvalues, species-environment correlation and cumulative percentage variance of the species data and species-environment relation obtained through CCA. The results of the interaction of mangrove species with the environmental factors are explained at the first and second axis of canonical correlation. High Eigenvalues (0.317) and species-environment correlations (r =1.00) were obtained at the first axis. At the second axis, however, the Eigenvalues decreased (0.228), with species-environment correlation value was maintained. These values proved that the environmental factors strongly influenced species diversity in the study areas.

The ordination diagrams of canonical redundancy analysis (RDA) shown in Fig.3 and Fig.4 indicate a strong correlation between environmental factors and species diversity in Kilim Geoforest Park, Langkawi. Mangrove species such as AM, AV, BC, CD, XM, RA and BP were clustered together in the River Kisap area. This is due to the best soil fertility factors such as soil pH, available P (AP), total N (N), total organic C (OC), ex. K (eK), ex. Ca (eCa), ex. Mg (eMg), and ex. Na (eNa) induced by favourable environmental factors such as RF, RD, T, RH. Moreover, plant vigour variables such as dbh (DBH), height, basal area (BA) and the number of individual (N) also showed a strong correlation with soil fertility in the study areas (Fig.3).

By using the ordination diagram, it clearly shows that River Kisap is the most diverse area in the Kilim Geoforest Park, Langkawi. Many biodiversity indices such

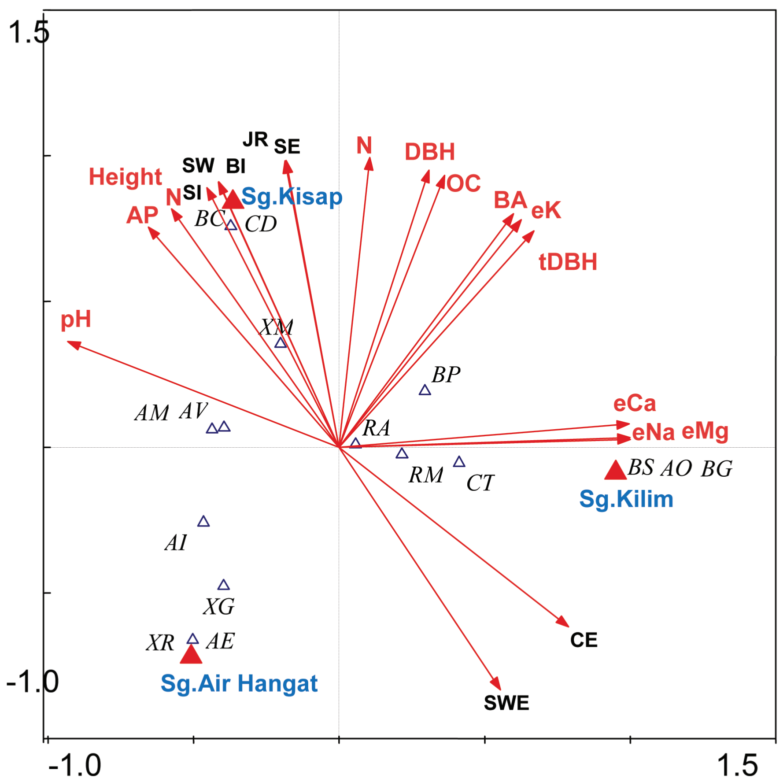

Fig.3: Ordination diagram of the first two axes of RDA for the mangrove species and their relationship with environmental factors in the Kilim Geoforest Park, Langkawi, Malaysia (see Appendix 1 for list of acronyms)

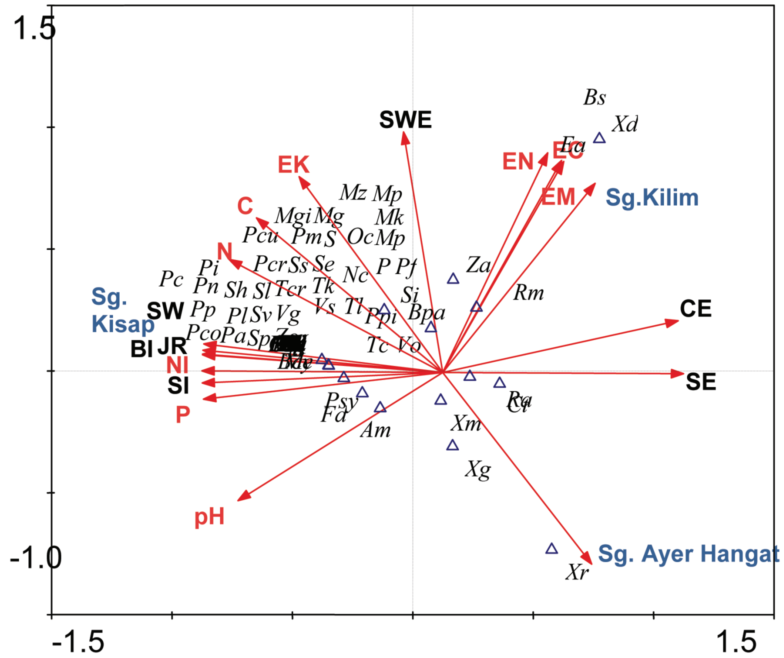

Fig.4: Ordination diagram of the first two axes of RDA for woody plants ≤ 1cm dbh, shrubs, climbers, epiphytes and weeds and their relationship with environmental factors in the Kilim Geoforest Park, Langkawi, Malaysia (see Appendix 1 for list of acronyms)

as Brillouin's index H (BI), Shannon-Wiener index of diversity H' (SW), Simpson's index of diversity (SI), and Jackknife estimates of species richness (JR) were clustered together in River Kisap (Fig.3 and Fig.4).

CONCLUSION

Plant biodiversity provides a buffer against environmental fluctuations, because different species respond differently to these fluctuations, leading to more predictable aggregate community or ecosystem properties (Loreau *et al*., 2001). In the present study, the interrelationship and relative roles of soil fertility and environmental factors have been investigated to determine the effect to which they influence species distribution, composition and diversity in the three main rivers, namely; River Kisap, River Kilim and River Ayer Hangat in Kilim Geoforest Park, Langkawi. Multivariate statistical analysis techniques (PCA and its RDA ordination, CCA) were used to understand their relationships. The study area is also characterized by complex topography and heterogeneous vegetation.

Results from RDA and CCA indicate that soil fertility and environmental factors should be considered in explaining variability in plant diversity. It is a fact that organic matter is a critical factor in determining the status of soil fertility in a certain area. In the present study, River Kisap is found to be more fertile than River Kilim and River Ayer Hangat because it has higher content of organic C and available P, as well as suitable soil pH for the growth of vegetation. Hence, River Kisap is the most diverse area in terms of floristic composition as compared to River Kilim and River Ayer Hangat. Meanwhile, variation in diversity is often correlated with productivity, and also with many other factors that influence productivity such as soil fertility, climate, disturbance regime or herbivory (Loreau *et al*., 2001). Understanding how these atmospheric and climatic change factors may interact with one another is important because their interactions may affect individual, community and ecosystem level processes in previously unpredicted ways (Long, 1991; Morrison & Lawlor, 1999; Poorter & Pe´rez-Soba, 2001). The response of plant communities to the changes in resource availability is often mediated by species composition, particularly given the range of growth strategies, demography and productivity possessed by diverse plant communities (Niklaus *et al.,* 2001; Reich *et al.,* 2004).

Kilim Geoforest Park, Langkawi, is very sensitive, and it is also a protected area because it has been declared by UNESCO as one of the world heritage (UNESCO 2000). The diversity of the biological resources of this area provides direct economic benefits to the local people. This biological diversity provides timber and non-timber goods in the forestry sector, food and industrial crops in the agricultural sector, as well as food in the fisheries sector and for tourism attraction.

According to Malaysia's National Policy on Biological Diversity (2010) report, agriculture, forestry and fisheries have been major contributors to national wealth creation. The tourism industry relies on the country's diverse and unspoilt natural beauty including unique species of plants and animals in national parks, wildlife reserves, bird parks and in marine parks and the adjacent coral reefs. Kilim Geoforest Park, Langkawi, stands to gain due to the diversity of its biological resources.

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APPENDIX I
List of Acronyms

Acronym	Mangrove Species ≥1 cm dbh	Acronym	Environmental/ Metereological Data
AE	*Acanthus ebracteatus*	RF	Total Amount of rainfall
AI	*Acanthus ilicifolius*	RD	Total number of rainy days
AM	*Avicennia marina*	T	24 hour mean temperature
AO	*Avicennia officinalis*	RH	24 hour mean relative humidity (%)
AV	*Acanthus volubilis*	WS	Mean surface wind speed
BC	*Bruguiera cylindrica*		
BG	*Bruguiera gymnorrhiza*		**Soil FertilityFactors**
BP	*Bruguiera parviflora*	P	Available P
BS	*Brugueira sexangula*	pH	Dry pH
CD	*Ceriops decandra*	N (%)	Nitrogen
CT	*Ceriops tagal*	C (%)	Organic Carbon
RA	*Rhizophora apiculata*	EC	Exchangeable Calcium
RM	*Rhizophora mucronata*	EK	Exchangeable Potassium
XG	*Xylocarpus granatum*	EM	Exchangeable Magnesium
XM	*Xylocarpus moluccensis*	EN	Exchangeable Natrium
XR	*Xylocarpus rumphii*		
Woody plants ≤ 1cm dbh, shrubs, climbers, epiphytes and weeds		Measures of Plant Species Diversity	
AC	*Acrostichum aureum*	NI	Total number of individual
At	*Allophylus ternatus*	BI	Brillouin's index H
Ad	*Alocasia denudata*	SW	Shannon-Wiener index of diversity
Ah	*Amorphophallus haematospadix*	SI	Simpson's index of diversity (1-D)
Av	*Amorphophallus variabilis*	CE	Camargo's index of evenness E'
Aa	*Antirhea atropurpurea*	SWE	Smith and Wilson's index of evenness
Ap	*Argostemma pictum*	SE	Simpson's measures of evenness E1/D
Af	*Arisaema fimbriatum*	JR	Jackknife estimates of species richness
Am	*Avicennia marina*		
Bc	*Bauhinia curtisii*		Other parameters
Bf	*Bauhinia flava*	DBH	Total DBH (cm)
Bc	*Begonia curtisii*	tDBH	Mean total DBH (cm)
Bp	*Begonia phoeniogramma*	BA	Total Basal Area (m^2)
Bs	*Boea acutifolia*		
Cc	*Caesalpinia crista*		
Cr	*Cissus repens*		
Cn	*Clerodendrum nutans*		

Co	*Chromolaena odorata*	*Md*	*Mallotus dispar*
Cca	*Croton cascarilloides*	*Me*	*Memecylon edule*
Cs	*Cycas siamensis*	*Mp*	*Memecylon pauciflorum*
Dd	*Davallia denticulata*	*M*	*Microcos* sp.
Dg	*Dendrobium gemellum*	*Mm*	*Micromelum minutum*
Dp	*Dendrobium pachyglossum*	*Mp*	*Microsorum punctatum*
De	*Dendrocalamus elegans*	*Mz*	*Microsorum zippelii*
Dt	*Derris trifoliata*	*Mg*	*Monophyllaea glabra*
Dl	*Didymocarpus lacunosus*	*Mgi*	*Mucuna gigantea*
Dc	*Dioscorea calcicola*	*Mk*	*Murraya koenigii*
Dt	*Dioscorea tamarisciflora*	*Mp*	*Murraya paniculata*
Df	*Diopsyros ferrea*	*Nc*	*Nervillia calcicola*
Di	*Diopsyros ismailli*	*Oa*	*Orthosiphon aristatus*
Dq	*Drynaria quercifolia*	*Pf*	*Paraboea ferruginea*
Ds	*Drynaria sparsisora*	*P*	*Parameria* sp.
Da	*Dryopteris anneaphylla*	*Pc*	*Pentasacme caudatum*
Dl	*Dryopteris ludens*	*Pcu*	*Pentaspadon curtisii*
Eb	*Eria bractescens*	*Pm*	*Pentaspadon motleyi*
Ek	*Eulophia keithii*	*Pc*	*Phyllanthus columnaris*
Ea	*Euphorbia antiquorum*	*Pp*	*Pyllanthus pulcher*
Eag	*Excoecaria agallocha*	*Pi*	*Pluchea indica*
Fc	*Fagraea curtisii*	*Pc*	*Pseuderanthemum crenulatum*
Fd	*Ficus deltoidea*	*Pa*	*Psychotria angulata*
Fc	*Fimbristylis calcicola*	*Psy*	*Psyndrax* sp.
Ff	*Fissistigma fulgen*	*Pl*	*Pyrrosia lanceolata*
Fr	*Flacourtia rukam*	*Ppi*	*Pyrrosia piloselloides*
Ff	*Flickingeria fimbriata*	*Sh*	*Schefflera heterophylla*
Gc	*Geodorum citrinum*	*Ss*	*Scindapsus scortechinii*
H	*Henklia* sp.	*S*	*Selaginella* sp.
Hc	*Hoya coronaria*	*Se*	*Selligue* sp.
Hd	*Hoya diversifolia*	*Sp*	*Sesuvium portulacastrum*
Ji	*Jasminum insularum*	*Sv*	*Stephania venosa*
Js	*Justicia* sp.	*Si*	*Streblus ilicifolius*
Kp	*Kaempferia pulchra*	*Sl*	*Streblus laxiflorus*
Lf	*Lagerstroemia floribunda*	*Tc*	*Tectaria coadunata*
Le	*Liparis elegans*	*Tk*	*Tectaria keckii*
M	*Macaranga* sp.	*Tl*	*Tetrastigma leucostaphylum*
Mb	*Mallotus brevipetiolatus*	*Tc*	*Tinospora crispa*

Vg	*Vandopsis gigantea*
Vo	*Ventilago oblongifolia*
Vs	*Vitex siamica*
Xd	*Xanthophyllum discolor*
Xg	*Xylocarpus granatum*
Za	*Ziziphus affinis*
Zo	*Ziziphus oenoplia*

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Vegetative Description of Three *Aquilaria* (Thymelaeaceae) Saplings in Malaysia

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ABSTRACT

Plants' reproductive parts are most important for species identification. However, trees such as *Aquilaria* species take many years to mature and produce flowers and fruits. Inconsistent and infrequent flowering periods may cause additional hindrance to classical identification. In this study, descriptions were made based on vegetative parts such as leaf, branch and bark for saplings of three *Aquilaria* species found in Malaysia. It was found that *A. hirta* sapling can be recognized through the densely hairy twigs, young shoots and axillary buds, undersurface of leaf, margin, petiole and midrib besides the strongly raised midrib, and usually unbranched habit; *A. malaccensis* through the many branches and white spots along main axis, entire leaf margin, slightly hairy leaf undersurface and midrib, and glabrous petiole; *Aquilaria* sp.1 from the lower branches that are nearly perpendicular to the stem and wavy leaf margin. These vegetative characters can serve as a basis for the correct identification of *Aquilaria* saplings when growers need to confirm their planting materials.

Keywords: Aquilaria, identification, sapling, vegetative characteristics

INTRODUCTION

Aquilaria Lam., a genus from the family Thymelaeaceae, is endangered tree taxa endemic to the Indo-Malesia regions (Mabberley, 2008). *Aquilaria* produces 'gaharu', a valuable forest product that is sought for its uses in perfumery, incense and religious purposes (Barden *et al*., 2000). *Aquilaria* species are listed in the IUCN Red List Appendix II, and regarded as highly endangered (IUCN 2011). Demand for conservation is increasing to restore their diversity in nature. In Malaysia, *Aquilaria* has attracted a great number of local planters, entrepreneurs, and individuals who planted the trees on a large scale (Lok *et al.,* 1999). Many of these plantations cultivated

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Aquilaria species of foreign origins because they are believed to be of better in producing quality 'gaharu' (Nor Azah *et al.,* 2008; Rompoei *et al.,* 2009). The genetic diversity of *Aquilaria* species in the country at present has been greatly multiplied with cultivated *Aquilaria* trees. With the introduction of foreign species from the neighbouring countries, there is a risk of losing the native genetic diversity (Adams, 1997).

Information on the taxonomy and morphology of mature *Aquilaria* trees in the wild is currently available. However, descriptions of saplings are lacking. Tropical trees are usually identified together with their reproductive parts, which are the flowers and fruits. *Aquilaria,* however, takes several years to bear flowers and fruits (Kumeto & Ito, 2011). Hence, in the absence of their reproductive parts, identification of saplings can only be done through their vegetative parts, including leaves, branches and bark (Whitmore, 1973; Keller, 2004). The first description of the genus *Aquilaria* was done by Lamarck in 1783 based on *A. malaccensis*. Following works on *Aquilaria* include Ridley and Hutchinson (1924), and the revision by Hou (1960). To date, five *Aquilaria* species have been found in Malaysia, viz., *A. malaccensis* Lam., *A. hirta* Ridl., *A. beccariana* Van Teigh., *A. rostrata* Ridl. and *A. microcarpa* Baill (Chua, 2008), and *Aquilaria* sp.1 (Tawan, 2004). The two former species are vulnerable to over-exploitation and habitat loss while the remaining species are known from single herbarium specimens (Lau & Chua, 2012). The distribution and ecology of different *Aquilaria* species in Malaysia were also undertaken by Faridah-Hanum *et al*. (2009), while Lau and Chua (2012) carried out conservation assessments of *Aquilaria* for Peninsular Malaysia.

This work was undertaken to provide a vegetative description of three *Aquilaria* saplings, which is deemed necessary for individuals or growers to confirm their planting materials before establishing *Aquilaria* plantations.

MATERIALS AND METHODS

Plant Materials

Three selected local *Aquilaria* species were brought back as wildings from the following places viz. *A. malaccensis* (Lentang Seed Centre, Karak, Pahang), *A. hirta* (forest near Ladang Merchang, Terengganu) and *Aquilaria* sp. 1 from Semenggoh Forest, Sarawak. They were planted in polybags in a mixture of soil forest and red soil (1:1) and grown in the shade house at the Faculty of Forestry, Universiti Putra Malaysia (UPM). Saplings were watered and fertilized periodically with organic compound fertilizer (HumicFert+) to ensure the growth of leaves and branches.

Herbarium Specimens

Two specimens were taken after the saplings were planted for one year. All the specimens were pressed, dried and mounted, and kept as voucher specimens in the Herbarium, Faculty of Forestry, Universiti Putra Malaysia. Comparisons were made with the following specimens from matured trees:

Aquilaria malaccensis UPM 8871, UPM 8872, UPM 8873, UPM 17460, KEP 37142, KEP 40707, KEP 37045, KEP 34553, KEP 31387; *A. hirta* KEP1679, KEP 71521, KEP 1188, KEP 26898, KEP 23836, KEP 69910, KEP 10542, KEP 2397, KEP 16972, KEP 8298, KEP10673, KEP 8330, KEP 25030, KEP 59689, KEP 59692, KEP 59675, KEP 59602, KEP 58682, KEP 59691, KEP 59601; *Aquilaria* sp. 1 S34204.

The vegetative parts of the saplings were photographed using Leitz MZ8 Low-range Microscope (Leica, Germany). A scale was then added into the photo to provide measurement references. The software Leica QWin Standard Y 2.8 was used to operate the microscope and to analyze the images.

RESULTS AND DISCUSSION

The saplings of the *Aquilaria* species examined are herein described by distinguishing the characters highlighted in **bold** as follows:

Aquilaria sp.1 (Fig.1a, Fig.2a-f)

Sapling with **lower branches nearly perpendicular to the stem**. Twigs slender, slightly hairy. Leaves oblong-oblanceolate, 6.0-10.4 x 2.2-3.4 cm, base obtuse, apex acuminate, acumen 0.9-1.6 cm; texture chartaceous, slightly hairy below; midrib channelled above, raised and hairy below; lateral veins conspicuous, 12-20 pairs; **leaf margin wavy.** Petiole hairy, 0.3cm long**.** Young shoots and axillary buds hairy, light green, 0.4-1.0 cm long.

Fig.1: Representatives of *Aquilaria* saplings used in this study; (a) *Aquilaria* sp.1 sapling from Semenggoh, Sarawak, (b) *A. hirta* sapling from Merchang, Terengganu, and (c) *A. malaccensis* sapling from Karak, Pahang.

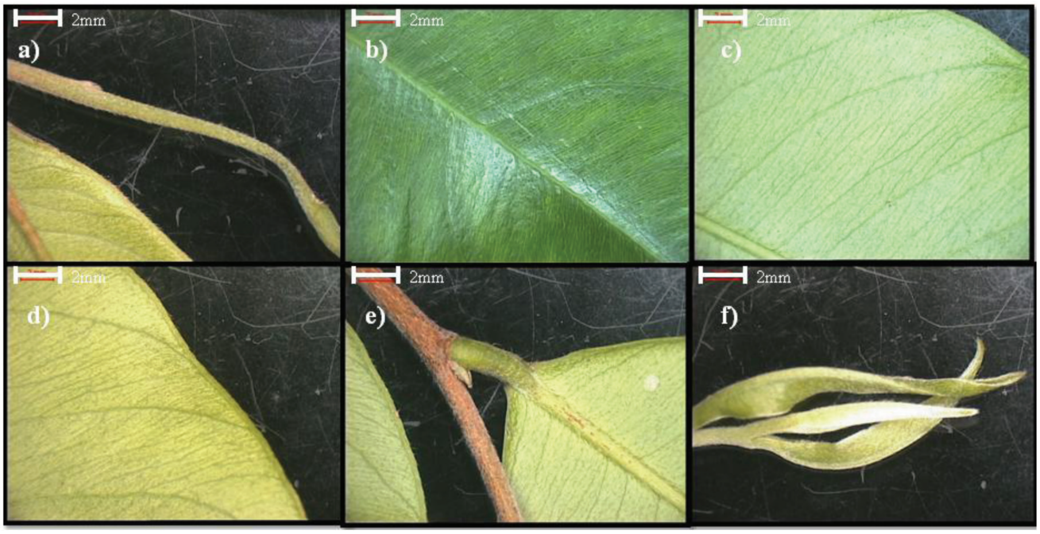

Fig.2: Vegetative characteristics of *Aquilaria* sp.1.; (a) young branch, (b) leaf surface, (c) lateral veins, (d) margin, (e) petiole and (f) young shoot. Reference scale as provided.

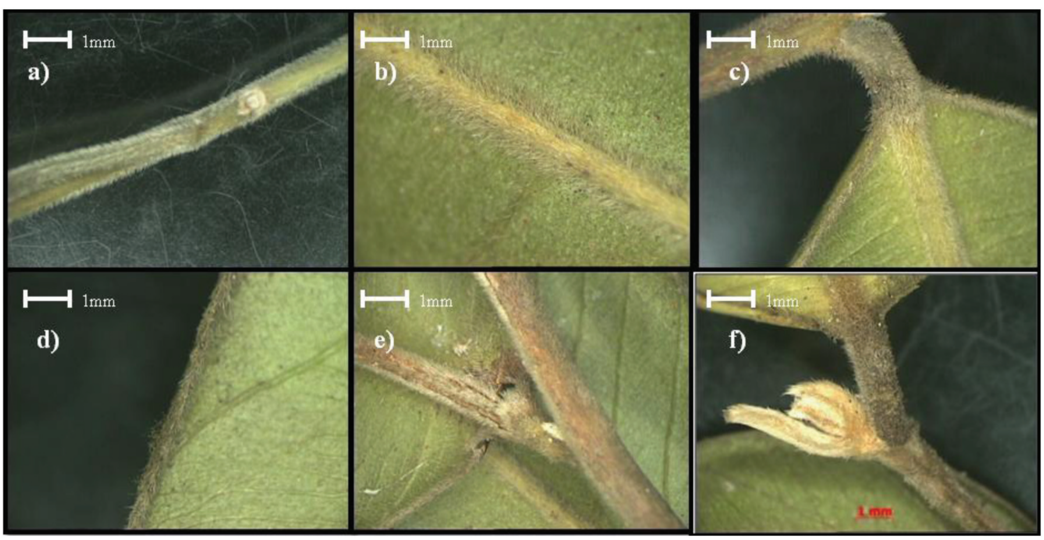

Fig.3: Vegetative characteristics of *Aquilaria hirta*: (a) young branch, (b) midrib, (c) petiole, (d) margin, (e) young shoot and (f) axillary bud. Reference scale as provided.

Aquilaria hirta Ridl (Fig.1b, Fig.3 a-f)

Sapling **rarely branching**. **Twigs densely hairy**. Leaves acuminate-lanceolate, 8.5-13.8 x 3.7-6.5 cm, base acute, apex acuminate, acumen of 1.5cm long; texture coriaceous, glabrous above**, densely hairy below; midrib strongly raised, densely hairy below**. Lateral veins conspicuous below, 14-23 pairs; **leaf margin entire, densely hairy**. **Petiole densely hairy**, 0.4-

Fig.4: Vegetative characteristics of *Aquilaria malaccensis:* (a) leaf surface, (b) leaf bottom, (c) midrib, (d) petiole, (e) young shoot and (f) axillary bud. Reference scale as provided.

0.7cm long. **Young shoots and axillary buds densely hairy**, light green, 1.5-3.0 cm long.

Aquilaria malaccensis Lam. (Fig.1c, Fig. 4a-f)

Sapling **often branching with white spots along the main axis**. Twigs greenish, glabrous. Leaf elliptic-lanceolate, 8.5-11.5 x 3.0-4.1cm, base acute, apex acuminate, acumen of 1.8-1.9cm long; texture thinly coriaceous, shiny green above, **slightly hairy below**; **midrib slightly hairy;** lateral veins conspicuous, 19-26 pairs; **leaf margin entire. Petiole glabrous**, 0.3-0.4cm long. Young shoots and axillary buds hairy, light green, 0.5-0.7cm long.

From the above descriptions, the distinguishing characters were tabulated (Table 1). The easiest sapling to identify is *A. hirta* due to the nearly unbranched habit, densely hairy throughout the plant besides the strongly raised leaf midrib. These characters differ remarkably from the saplings of the two other species. Meanwhile, the observations showed that matured *A. hirta* specimens differ from the saplings by having soft velvety hairs on the leaf undersurface, margin, petiole and midrib. *Aquilaria* sp.1 was reported as an incomplete species by Tawan (2004), who noted that it closely resembles *A. beccariana* through its vegetative characteristics. However, its taxonomic status is not confirmed as the reproductive characteristics of *Aquilaria* sp.1 tree do not match the reproductive characteristics of *A. beccariana* tree. Despite this, the *Aquilaria* sp. 1 sapling is easily recognisable from the wavy leaves and lower branches that are nearly perpendicular to the stem, unlike the branches of *A. malaccensis* sapling. The sapling of *A. malaccensis* has many branches

TABLE 1
A comparison of the sapling characteristics between three *Aquilaria* species

Leaf Characteristics	*Aquilaria* sp.1	A. hirta	*A. malaccensis*
Lower branches	Nearly perpendicular to stem	Rarely branching	Often branching with white spots along the main axis
Leaf Texture	Chartaceous	Coriaceous	Thinly coriaceous
Leaf Undersurface	Slightly hairy	Densely hairy	Slightly hairy
Midrib	Raised below and channelled above	Strongly raised below	Raised below
	Slightly hairy below	Densely hairy below	Slightly hairy below
Lateral veins	Conspicuous	Raised and prominent below	Conspicuous
Margin	Wavy	Entire and densely hairy	Entire
Petiole	Slightly hairy	Densely hairy	Glabrous
Young shoots and axillary buds	Slightly hairy	Densely hairy	Slightly hairy

and white spots along the main axis, entire leaf margin, slightly hairy leaf undersurface and midrib, and glabrous petiole. However, adult trees of *A. malaccensis* have glabrous plant parts, with conspicuous shiny leaf upper surface, sunken midrib above but raised beneath.

CONCLUSION

Generally, identification of plant taxa relies more on the reproductive parts due to their inherent hence stable characters. However, in this study, young saplings were identified by observing their vegetative parts in the absence of reproductive parts. Like many other tree species, it is difficult to determine the identity of the saplings of *Aquilaria*, especially to inexperienced individuals. In this research work, it was demonstrated that by looking at vegetative parts, saplings could be identified correctly. This could be a quick solution for the general public to help determine the species identity of young saplings, especially when planning to plant the three *Aquilaria* species on plantations.

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Recreational Economic Value of the Perlis State Park, Malaysia: An Application of Zonal Travel Cost Model

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ABSTRACT

Perlis State Park is known for recreational activities. Since there is no significant income from timber production for the state of Perlis, outdoor recreation provides the alternative source of income. Since managing a state park costs substantially, assessment of recreational uses justifies the initial cost. This paper, using the semi-aggregated travel cost method, estimates the recreational value of Perlis State Park for Malaysian domestic visitors. The recreational value of the park is estimated at RM5,340,642.48. The value derived from the study contributes to the stakeholders' assessment of the intangible value of the park to justify the ecotourism developmental cost. The valuation of the recreational activities in public parks reveals the non-market economic value of the park under certain type of management. This paper also emphasises on the importance of maintaining visitor arrivals as a means to sustain the recreational value.

Keywords: Recreation demand model, Travel Cost Model (TCM), functional forms, heteroscedasticity, recreation benefit

INTRODUCTION

Natural environments, such as forests, mountains, rivers, streams, and others, have been the venues for various kinds of recreational pursuits like camping, hunting, trekking, biking, boating, climbing, and many more. The existence of these activities is what makes a particular area has its recreational value (Freeman, 2003) from direct visitor spendings or embedded in various types of expenditure. Nevertheless,

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managers of these areas need to balance the utilisation of these recreational activities and conservation. This concern has prompted managers of natural areas to quantify the possible alternative earnings, which may be generated from recreational activities in these areas.

In Malaysia, most natural areas, such as national parks, state parks, are public lands and managed by governmental departments. One good example, in the state of Perlis, the Perlis State Forestry Department (PSFD) is a governmental department that manages the Perlis State Park (PSP). Due to its status as a protected area, PSP is restricted from any kind of forest resource extractions, thus, limiting the income to the state government. As the governing agency of the area, PSFD needs to assess the alternative value generated from non-extractive forest-based product and this information may give PSFD some ideas on the value of the PSP in terms of recreational products.

Source: Perlis State Forestry Department (2006)

Fig.1 Location Map of the Perlis State Perak

The purpose of this paper is to demonstrate that a commonly used non-market valuation approach, i.e. the Travel Cost Method (TCM), can be used to generate a proxy estimate of the benefits by using PSP as the study area. To the researchers' knowledge, this is the first study carried out to estimate the recreational value of PSP.

Perlis State Park

Perlis State Park (PSP) is located in the northernmost area of Peninsular Malaysia, along the western border of Perlis, where Peninsular Malaysia meets Thailand (Fig.1). The park is situated on the longest continuous range of limestone hills in the country, called the Nakawan Range, which lies from Kuala Perlis to Thaleban National Park in Thailand. The purpose of its establishment is for the conservation of the unique limestone of the Nakawan Range. Apart from its conservation purposes, the park is also popular for outdoor recreational activities such as trekking, mountain climbing, camping, bird watching, and the like.

The park covers an area of 5,015 ha comprising of Mata Ayer Forest Reserve (2,156 ha) and Wang Mu Forest Reserve (2,859 ha). Next to PSP, is the Thaleban National Park in Southern Thailand. The park is currently administered by PSFD, handed over after the establishment project by Danish International Development Agency (DANIDA), World Wide Fund for Nature (WWF) and the Forestry Department of Peninsular Malaysia. It is the first state park in the country that is administered by a state Forestry Department.

Based on these attributes, the recreational experience of PSP can be categorised as caves, trails, lakes, and cross-border shopping experiences (Syamsul *et al*., 2006). Generally, these recreational products can be enjoyed at three main locations, namely, the Wang Burma Recreational Complex (WBRC), Gua Kelam Recreational Area (GKRA) and Wang Kelian Sunday Market (WKSM).

WBRC is equipped with man-made facilities such as chalets, hostels, and campsites. The second location, GKRA, is a former mining area but now it is the main tourism destination of the northern part of Peninsular Malaysia. Meanwhile, WKSM is known for its cross-border tourism and shopping experience and it is included as one of the attraction spots of the state park. The uniqueness of the market is that visitors are allowed to cross the Thailand-Malaysia border, by up to 2km without any travelling documents.

PSP has received an increasing number of visitors since its establishment in 1996. Up to 2003, there were 7,755 overnight visitors in 2003 compared to merely 937 overnight visitors in 1996. However, the trend shows a fluctuation in the visitor arrivals in the subsequent years (Table 1). PSP has been included as one of the main tourism destinations since the state government announced 2003 as the Visit Perlis Year (Government of Malaysia, 2006). This also included the WKSM as an attraction in PSP (Azyyati *et al*., 2007).

TABLE 1
Number of Visitors to Perlis State Park from 1996 to 2010

Year	Total	Local*	Foreigners*
1996	937		-
1997	982		-
1998	1,260		-
1999	1,787		-
2000	2,945		-
2001	5,672		-
2002	4,260		-
2003	7,755	7,273	482
2004	5,591	5,418	173
2005	2,706	2,493	213
2006	3,741	3,672	69
2007	3,891	3,891	66
2008	3290	3145	144
2009	4869	4792	77
2010	2005	1906	99

Source: Perlis State Park Office (2011)
*Note: The breakdown of visitors is not available for the years before 2003

PSP is located in a small Malaysian state of Perlis (80,302 ha). In spite of its size, it has a significant forest cover. From the total area, 11,555 ha are forested lands. Even though the forest area covers 14.39% of the total land areas, there has been no production of timber (except in 1998) compared to other states in Malaysia (Table 2). At the moment, the alternative uses for these forested areas are listed in terms of non-consumptive use such as conservation, education research, and recreational use.

On the other hand, the amount the state of Perlis receives in economic return from recreational and touristic activities at the park is ambiguous and remains unknown. Information on the economic value is important for the state government in order to understand any source of income from the forested areas. This knowledge is crucial, especially as the area has been gazetted for its protection from any form of logging and harvesting of other forest goods.

Hence, an alternative utilisation of the site could be in the form of non-consumptive use such as recreation and conservation. In order to justify the alternative usage of the forest, an assessment of the estimated value of the benefits from recreation and conservation must be made. It is therefore of great interest to determine if the allocation and expenditure for ecotourism in the park is worth the effort by the managing agency.

This paper demonstrates the alternative value derived from outdoor recreation as an alternative to forest extraction in protected areas. The economic value, as estimated from this study, can help PSFD to justify the presence of recreation and government allocation on the development and maintenance of recreational infrastructure in the park.

METHODOLOGY

Travel Cost Method

Over the years, recreation demand has been associated with the estimation of services of forest areas and other recreational use values. The travel cost approach is a popular methodology for assessing many recreational demand studies in natural areas. Since its establishment, various studies have encountered issues theoretically and empirically, and these lead to improvements

TABLE 2
Production of Logs by State (cubic meters, m3)

Year State	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Johor	296,179	211,295	179,217	193,700	181,927	198,342	142,846	159,152	96,419	213,816
Kedah	221,257	113,276	228,138	164,183	157,005	141,622	138,246	147,042	109,480	179,453
Kelantan	1,757,492	1,146,382	1,081,987	1,339,501	944,700	873,026	919,466	694,256	815,585	1,066,479
Melaka	72,565	16,223	10,767	4,310	1,610	2,830	-	4,407	111	1,508
Negeri Sembilan	114,814	64,497	149,234	119,443	68,241	103,823	102,661	102,646	80,956	73,860
Pahang	2,862,507	2,114,889	2,326,912	1,706,176	1,462,046	1,629,796	1,604,859	1,826,066	1,953,273	1,782,523
Perak	939,243	721,469	653,384	878,000	606,264	723,599	757,884	887,454	787,548	833,802
Perlis	-	26	-	-	-	-	-	-	-	-
Pulau Pinang	768	60	100	-	-	-	-	-	-	-
Selangor	109,807	42,694	56,625	69,994	65,015	44,388	71,288	40,492	38,981	48,142
Terengganu	1,005,791	669,004	669,694	596,843	668,322	640,864	682,146	711,403	522,738	493,864
W. Persekutuan	-	-	-	-	-	-	-	-	-	-

Source: Forestry Department Peninsular Malaysia (2006) of the model in terms of econometrics, survey sampling and utility-theoretic derived welfare estimators (Starbuck, 2003).

There are two types of TCM; Zonal TCM (ZTCM) and Individual TCM (ITCM). Early applications of TCM studies were typically based on aggregate zonal, where zones are defined as the concentric areas of increasing distance from the study site (Walsh *et al*., 1989; Freeman, 1993). The price (or travelling cost) is the cost of travelling from the average distance from the zones to the study site. As the distance of the zones gets further away, the prices increase. By this, the variation in price depends on the distance and the number identified zones. Price, and other explanatory variables, is regressed against the per capita visit rates from each zone. ITCM, on the other hand, uses individual data obtained from each respondent rather than zones. Due to the aggregated nature of the dependent variable data, ZTCM was applied as it is more suitable in comparison to ITCM.

There are limitations associated with the traditional zonal travel cost model (ZTCM). Aggregation is always associated with ZTCM. The distance variable in the traditional ZTCM varies due to the difference in the distance of the zones of origin, which means that ZTCM relies on highly aggregated data. Although the respondents are from different zones of residence, the measurement of distance is merely a straight line across region from the respondent's origin to the study site in question. The nature of ZTCM, where the dependent variable is highly aggregated in zones, leads to heteroscedasticity problem. A consequence of heteroscedasticity is an inefficient estimator. The effects of heteroscedasticity on OLS coefficient are discussed in the following section.

Heteroscedasticity, Model Transformation and Model Selection

Studies using cross sectional data often encounter heteroscedasticity problem. The heteroscedasticity problem is often associated with ZTCM (Rosenthal & Anderson, 1984). Since the variance is not homogenous across the zones (observations), the OLS estimators are statistically inefficient, increasing the size of confidence interval (Diamantedes, 2000). In the presence of heteroscedasticity, the ordinary least square (OLS) estimator no longer the best unbiased efficient estimator since the disturbance covariance matrix is non-scalar (Gujarati & Porter, 2009). While detecting heteroscedasticity can be done visually, a more formal approach can be conducted by Goldfeld Quandt test or White test and/or Breush-Pagan-Godfrey test.

One way in working out heteroscedasticity is by model transformation. Model transformation can be carried out in several methods and the logarithm transformation is the most commonly used (Ward & Beal, 2000). The heteroscedasticity problem, that arises from the aggregation of the zones and also application of cross sectional data, is resolved by having a semi-log model.

Studies using semi-log and log-log functional forms include those by Allen *et al*. (1981), Ahmad (1994), Christiansen (1997), Lansdell and Gangadharan (2003), and Poor and Smith (2004), to name a few. The advantages of using semi-log functional form include minimizing the problem of heteroscedasticity as well as eliminating the potential problem of negative trip prediction (Loomis & Cooper, 1990). In comparing different functional forms, Chotikapanich and Griffiths (1998) suggested the use of maximized log-likelihood function value as preferable instead of the R^2 as a descriptive of goodness of fit measure, particularly for the models with different dependent variables. In many studies, the log-likelihood values and Akaike Information Criteria (AIC)[1] are used as the primary means in determining the functional form that best fits the data.

Survey and Sampling Procedure

Surveys were conducted between February 2007 and December 2009. Since the objective of the study was to estimate recreational value of the whole PSP, the respondents were selected among those who came for recreational purposes and the locations where recreational activities were conducted. Personal interviews were conducted at WBRC, WKSM, and GKRA.

The respondents were selected from the leaders of the groups. If the group was a family, the respondent chosen was either the father, mother, or the eldest brother. On the other hand, if it was a non-relative group member, the respondent was the person in charge of the trip. Only one member was interviewed as the respondent. It was assumed that the information given by the leader of the group reflected the information for the entire family or group and not merely his/her own (Ahmad, 1994).

In order to ensure a full return and quality data, the respondents were interviewed personally. Following Kuosmanen *et al*. (2004), only the respondents with the purpose of recreation are interviewed to resolve multi-destination trip visitors[2]. To avoid overestimated consumer surplus, foreign visitors were not included in the survey as they might be visiting other destinations in the country other than a single trip made solely to PSP.

Socio-economic Characteristics of the Respondents

The survey managed to collect 653 usable questionnaires, out of 700 used in the interview sessions. A summary statistics of respondents is presented in Table 3. The median and average ages of the respondents are 35 and 35.11 respectively, older than the median (26.2) of the Malaysian population (Department of Statistics Malaysia, 2010). The sample is educated, with 98.3% have

[1]Akaike Information Criteria are the commonly used criteria to determine alternative regression model, where it lies on the sum of squares. A lower value indicates a better performance of the model. Refer to Gujarati (1988).

[2]In resolving multi-destination trip (MDT), Kuosmanen *et al.* (2004) suggested to ignore MDT visitors by either excluding them from the analysis, or by treating them as if they were single-destination visitors.

attended formal education at school and/or university level (Table 4). Meanwhile, the average income of the respondents is RM1,624[3] per month, as compared to 47% of the national population in middle-income (RM1,200-3,499 per month) household (Pricewaterhouse Cooper, 2006).

TABLE 3
Statistic Summary of the respondents

Variables [a]	Percentage
Gender proportion of sample male	67.7%
Mean age	35.11 (11.66)
Monthly income (RM)	1,624.66 (1,396.65)

[a] Figures in the parenthesis denote standard deviation

TABLE 4
Respondents' Education Level

Education Level	Number	% of total
Higher degree	2	0.30
First degree	226	34.60
Secondary school	278	42.50
Primary school	134	20.50
No formal education	11	1.70
Missing	3	0.5
Total	651	100.00

Applications of the Travel Cost Method

Syamsul *et al*.'s (2012) compiled study applied TCM for valuation studies in Malaysia for the past 30 years. These studies had applied both ZTCM and ITCM approaches. The majority of these studies focused on the valuation of recreational and tourism resources in the country. Many of these studies used visit per capita as the dependent variable.

In this study, visit per capita was used as the dependent variable for the study, as suggested in many previous studies (Syamsul *et al*., 2012). Nevertheless, Brown and Nawas (1973) cautioned that the zonal method is unable to separate the influence of the almost similar variables such as travel cost and travel time. Based on this, the semi-aggregated model was used, with aggregated visit per capita as the dependent variable, whereas individual observations as the independent variables. This particular approach combines the best features of the zonal and individual observation approaches (Brown *et al*., 1983; Ahmad, 1993; Syamsul, 2010).

Definitions of the Dependent Variable

The dependent variable for a zonal TCM is the visitation per capita from the zones of the respondent's origin, which is determined by researcher (Fleming & Cook, 2008). Zones are often based on statistical division[4] system in a country (Stoeckl & Mules, 2006; Ward & Beal, 2000; Fleming & Cook, 2008). In this study, zones were determined according to the local municipality council, where visitors are currently (during the study) residing. Meanwhile, the zones are based on the Population and Housing Census 2000, Malaysia's report.

[3]All figures are in Malaysian Ringgit; RM1 = USD 0.3314, EURO 0.256 (31 July, 2012)

[4]A statistical division is a defined area that represents large, general purpose, regional type geographic area (Fleming & Cook, 2008).

The visitation rate per capita is given by:

$$VC_i=(V_i \, x \, VY_i) / P_i \qquad \text{[Eq. 1]}$$

Where,

VC_i is the visit per capita for the respondents from zone *i*, V_i is the respondents sampled from zone *i*, VY_i is the frequency of visits per year by the respondents sampled from zone *I*, and P_i is the population of zone, *i*.

Definition of Travel Cost Variable

Travelling cost measures the mileage cost in terms of distance, multiplied by vehicle maintenance cost per kilometre. The study only collected samples from motorised road vehicles. This means travel costs for rail and air were excluded, since distance measurements were only taken for personal vehicles or taxis. However, the travelling costs to and from airports and train stations were included. The travelling costs per person were then calculated by dividing with the number of persons travelling together in the same vehicle. The total travel cost per person was then calculated by including all out-of-pocket personal expenditures during travelling to the site for recreation[5]. The calculation is given by:

$$\text{RITC} = \left(\frac{\text{Travelling cost + individual cost}}{\text{Number of person in the same vehicle}} \right) \text{X 2 trips (to and fro)}$$

where:

RITC = Return individual travel cost

The travelling cost was calculated by multiplying the cost per kilometre by the distance from the respondent's residence to the study location (see Fig.2). The unit of measurement is RM per kilometre.

Distances were measured using Mapsource Version 4.09 software on a Garmin Global Positioning System (GPS) by measuring the distance from the nearest township of the respondents' residence to N6 41.873 E100 11.472, which is the GPS coordinate for PSP headquarters in Wang Burma. The town's geographical location is identified via the *mukim*[6] of the township, in addition to its postcode. It was assumed that the respondents took the shortest and the most convenient route available in making their trips.

The cost per kilometre is based on the rates provided by the Highway Planning Unit (HPU), the Ministry of Public Works, Malaysia[7]. These 'cost per kilometre rates' vary depending on the type of vehicle used by the respondents. Other personal expenditures (, such as food and drinks, bus ticket, and lodging) during the travelling phase were also included as parts of the travelling cost. All the expenditure was measured in the Malaysian currency, Ringgit Malaysia (RM). In addition, the travelling cost included personal expenditures made for the journey, such as petrol, toll charges, meal

[5] It was assumed that children and teenager under the age 16 did not contribute to the trip expenditure, Hence, the expenditures were only sustained by adults in the same group.

[6] Mukim is a sub-district geographical administration unit practiced by the local municipality in Malaysia.

[7] Through the Highway Planning Unit, the Ministry of Public Works, Malaysia, conducted studies on the cost per kilometer on personal and commercial vehicles in Malaysia. The cost for sedan was estimated at RM0.28 per km, and motorcycles at RM0.07 per km.

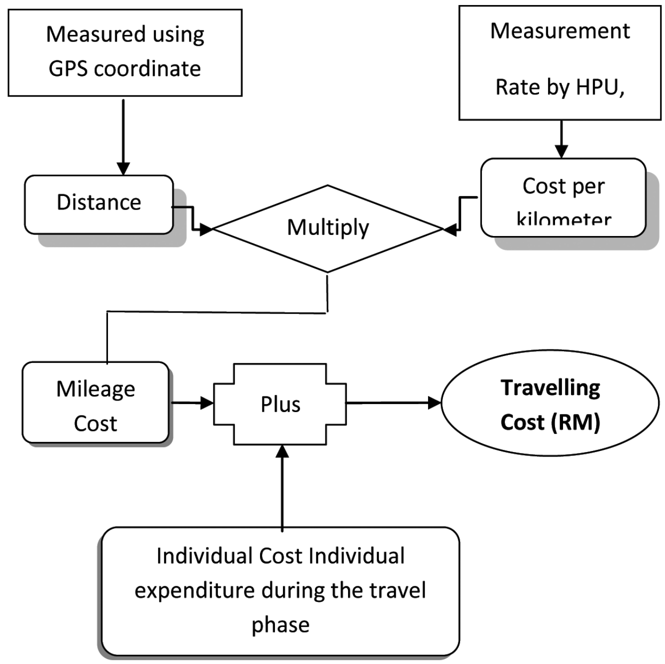

Fig.2: The Measurement of Travel Cost

and also if there was any accommodation cost. There is no entry and/or recreational fee to the park. The total travelling cost was then multiplied by 2 to reflect a return trip.

Definition of Socio-Economic Variables

The survey asked the respondents to identify their age, the highest level of educational attainment and household income. Age was measured in years. The income variable in this study measures the gross monthly salary (RM), and/or wage, as reported by the respondents. For self-employed respondents, the measurement was based on their average monthly profit. Meanwhile, the education level was determined in the number of years attended in formal education. During the on-site data collection, education level was coded in terms of categorical data. Visitors stated only their highest education level attained based on the different levels of education practiced in Malaysia (see Table 5). The data were later transformed into a continuous measurement of years of education. The years of education reflected the highest education level based on Table 5. Thus, the variable for education was in terms of continuous data (i.e., years of education) representing education level, rather than categorical data.

TABLE 5
Categories of Education Level

Category	Education Level	Years of education
1	No formal education	0
2	Primary school	6
3	Secondary school	12
4	Tertiary education level	16
5	Postgraduate study	18

RESULTS AND DISCUSSION

Model Specifications

In order to obtain the recreational demand function, the zonal visitation rate was regressed against the round individual travel cost (RITC), and three socio-demographic variables, namely; age (Age), education years (EduYr) and monthly income (Inc). The empirical modified model derived is shown in *Eq. 2*.

$$VisCap_{ij} = \beta_0 + \beta_1 RITC_{ij} + \beta_2 EduYr_{ij} + \beta_3 Age_{ij} + \beta_4 Inc_{ij} + \varepsilon \quad [Eq.\ 2]$$

Where,

$VisCap_{ij}$: The visit rate per capita of individual *i* from zone *j*

$RITC_{ij}$: The total round trip travel cost of individual *i* to site *j*

$EduYr_{ij}$: Level of education of an individual*i*, in years

Age_{ij} : Age of the individual*i* from zone *j*

Inc_{ij} : The monthly income of individual *i* from zone *j*

$\beta_0 - \beta_4$: Coefficient to be estimated

In the study, heteroscedasticity was detected by performing the Goldfield-Quandt test. Following the steps explained by Gujarati and Porter (2009), the sample ($n = 653$) was ordered according to *RITC* and the sample was split into three sub-samples ($n\text{-}p/2 = 300$). The central ($p = 53$) was then omitted. The OLS regression then yielded σ_1 = 3698.44 and σ_2 = 463.08. Hence,

$$G = \frac{\sigma_2}{\sigma_1} = \frac{3698.44}{463.08} = 7.98661$$

Using a one tail test with 5% critical value, $F_{(0.95,\ 298,\ 298)} = 1.21$. The test showed that $G>F$ (7.98661 >1.21), therefore, a null hypothesis of homoscedasticity was rejected. Thus, it can be stated that heteroscedasticity existed in the observation. This suggests that the coefficient estimator is inefficient.

Comparing and Selecting the Functional Forms of the Transformed Models

In resolving for heteroscedasticity, the model was then transformed into two functional forms; log-linear (LL) and double-log (DL). The result for all transformed models is shown in Table 6. As a comparison, the linear model (LM) is also presented in the same table. All the models have the same number of observations (*N=653*). The ANOVA test shows that the *F* value is significant at 0.05% confidence level in all the models, indicating rejection of the null hypothesis that all the coefficients are zero.

TABLE 6
A Comparison of the Selected Functional Forms

	LM	LL	DL
R^2	0.053	0.218	0.413
Adj. R^2	0.029	0.199	0.399
Log-likelihood	1122.910	-853.336	-759.613
Akaike info Criteria	-3.387	2.666	2.379
F value	2.22	11.09	27.99

All the selected models (linear and transformed) were then compared to select the best model fit, which was later used to estimate the consumer surplus. The foundation of comparing among the models is by the measure of R^2 and the adjusted R^2. In this study, however, the maximum log-likelihood and AIC were used as the primary means of determining the best functional form that fit the data. The value of the maximised log-likelihood function is preferable over the R^2 value, as a descriptive adequacy of fit measure, particularly for models with different dependent variables (Chotikapanich & Griffiths, 1998). The result demonstrates that the DL model has the highest R^2 (0.4132) and adjusted R^2 (0.3985) value. This is supported by the log-likelihood value that reveals the DL model has the highest value (-759.613)[8]. Meanwhile, the AIC value confirms the consistency in result, where DL model has the lowest value (2.379). Against all the criteria, the functional form of the preferred equation is found to be:

$$\text{Ln}VisCap_{ij} = \beta_0 + \beta_1 \text{Ln}RITC_{ij} + \beta_2 LnEduYr_{ij} + \beta_3 LnAge_{ij} + \beta_4 LnInc_{ij} + \varepsilon \quad [Eq.\ 3]$$

Thus, the DL model is chosen for further analysis and discussion.

Estimation of the Consumer Surplus

The estimation of the recreational value and users' welfare could be done once the demand function had been specified. Comparing R^2, the adjusted R^2 and verified by the log-likelihood value and AIC value, the analysis pointed out that the DL model is the best fit. Therefore, the DL equation was chosen as the best model consumer surplus calculation. Derivation of the demand model yielded the consumer surplus, which is shown below.

Following Stoeckl and Mules (2006) and Graham-Tomasi *et al*. (1990), the calculation of consumer surplus for DL model is as follows:

For $\beta_{TC} > -1$

$$CS_i = \sum [\ (Max\ TC)(Min\ V) - TC_i V_i / \beta_{TC} + 1]\ X\ Pop_i \quad [Eq.\ 4]$$

Where,

CS_i: Consumer surplus for the zone i–th
V_i: Average visit from the zone i–th
β_{TC}: Coefficient of the travel cost
Max TC: Actual maximum total travelling cost from the sample

[8]The negative sign in the AIC scores is the difference between the best model (i.e. the smallest AIC) and each model; therefore, the best model has an AIC difference of zero or approaching zero (Burnham & Anderson, 2002). The AIC scores are shown as changes in the AIC scores or the differences between the best model (the smallest AIC) and the other models. Therefore, the best model has the smallest changes. Hence in the study, the selected model is the model with the highest log-likelihood and the lowest AIC value (Burnham & Anderson, 2002).

Min V: Actual minimum visit per capita from the sample

Pop_i: Population for the zone *i*–th

Adding up the *CSi* from each individual zone yielded the total measure of the consumer surplus from the entire zones included in the study. The aggregated consumer surplus of all the zones represents the total estimated net recreational benefit for the site.

From the sample, there were 148 different zones identified from all the states in Malaysia. The total *CSi* for the surveyed visitors (*N=653*) was estimated at RM57,842.11. Dividing the *CSi* with the total visits yielded the CS per trip or the willingness to pay for outdoor recreation. The calculated value was RM39.24 per trip.

In the study, the statistics of the visitor arrivals was compiled for the three survey locations; WBRC, GKRA and WKSM. The statistics for WBRC was supplied by the PSP Park Warden Office, while the statistics for GKRA was supplied by the Department of Agriculture, Malaysia[9], and WKSM was provided by the Department of Immigration, Malaysia, through its Wang Kelian Post office[10]. Only the data for the WBRC and WKSM visitations for the year 2007 were available for this study, hence, the value was estimated for the same year.

However, the statistics presented by the Department of Immigration, Malaysia, Wang Kelian Post office does not reflect the actual recreation visitors to WKSM. Instead of giving statistics for the specific WKSM visitors, it represents the number of people passing through the Malaysia-Thailand border for the whole year. Using such a number might overestimate the total value. Since WKSM only operates on Sundays, only Sunday visitor statistics of 2007 was included in the calculation, which was 52 days (14.25% of 365 days) or approximately 11,367 visits (Table 7).

TABLE 7
The Estimated Total Recreational Value for PSP

	Visitors Arrival		Estimated Value
	Actual	Adjusted	
WKRC[a]	3,930	3,930	154,213.20
GKRA[b]	120,805	120,805	4,740,388.20
WKSM[c]	79,770	11,367	446,041.08
Total	204,505	136,102	5,340,642.48

[a]Perlis State Park Office, 2009
[b]Department of Agriculture, Perlis, 2009
[c]Department of Immigration, Perlis, 2009

Assuming the total number of visitor arrivals in 2007 as equivalent to the number of the actual visits to PSP (each visitor made one visit), the calculation for the total net recreation value for PSP was then measured by multiplying the *CS* per trip to the total visitation to PSP. Using the adjusted visit rate for WKSM, the total net recreational benefits for the site was then estimated at RM5,340,642.48 for the year 2007.

CONCLUSIONS

Under the current management's strategies, the recreational value estimates found from

[9]Visitor arrival at GKRA is recorded by the admission ticket at the cave entrance. The fee collection is being managed the Department of Agriculture, Malaysia.

[10]The Wang Kelian Post Office located at the Malaysia-Thailand border handles all day-to-day immigration documents of visitors upon exist and entry. The office keep records of visitor statistics entering and/or leaving the country.

this study confirm that there is a substantial economic value in terms of the recreational use of PSP. This economic value seems to justify the efforts to make PSP a venue for outdoor recreational experience opportunity, not only in Perlis, but also for the entire northern region. Even though the study was conducted after the development of the park, the valuation of PSP has direct implications, whereby the recreational value indicates the type of management system in practice and the level of use of the resource.

In general, the economic valuation of recreational activities in public parks reveals the non-market value of the park under certain type of management. If the park management approaches change in a way that will reduce funding for maintenance, operations, or even new development, it will also have impacts on the benefits or even the welfare of the park itself. The knowledge of such changes can be justified since the present level of use and benefits can be assessed, as has been shown in this study. However, under the present conditions, if the park management wishes to request additional allocations for maintenance and new development, it is more justifiable now because the present benefits or recreational utilization can be estimated.

Another important point, in regards to value, is that the estimated recreational use value is associated with the visitation rates. The total economic value is determined by multiplying CS with the visitation rates for a particular year. In addition, changes in visitation will also affect the associated recreational value. However, for the past seven years, the trend has indicated declining visitation rates. If the trend continues to decrease, it would also reduce the recreational value. Therefore, there is a need for the management to have strategies to increase visitations, as this will improve the economic value. Nevertheless, a special study is still needed to consider the likely impacts of these measures, not only on the total visitation but also the physical impact of the recreational activities in the state parks. In more specific, the benefits need to be evaluated against the expected benefits of the increasing number of visitors while maintaining the limits of recreational usage in the protected areas.

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Evaluation of Selected Physical and Mechanical Properties of Multiple Leader *Acacia crassicarpa* A. Cunn. Ex. Benth. Genotypes

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ABSTRACT

A study on the evaluation of the selected physical and mechanical properties of multiple leadered *Acacia crassicarpa* A. Cunn. Ex. Benth, genotype was carried out to maximize its utilization. The study involved two classes of multiple leaders (ML), namely; ML2 (two leadered stems) and ML3 more than two leadered stems and 4 provenances: Claudie River, and Chillie Beach from Queensland (QLD) and Bensbach WP and Bimadebum WP from Papua New Guinea (PNG). ML classes showed significant difference at P<0.05 for physical properties but not between provenances. ML2 produced better mean values of specific gravity, radial and tangential shrinkage, with the values of 0.48%, 1.4% and 2.89% respectively compared to ML3 with values of 0.45, 3.56%, and 5.83%, respectively. Similarly, the ML classes were found to be significantly different at P<0.05 for Modulus of Elasticity (MOE) and Modulus of Rupture (MOR). Once again, ML2 produced higher mean values of 9858.4 N/mm^2 and 89.63 N/mm^2 for MOE and MOR, respectively, than ML3 (7557.7 N/mm^2 and 60.4 N/mm^2 respectively). Based on the physical and mechanical properties, it can be concluded that ML2 is more superior in terms of strength and stiffness than ML3.

Keywords: *Acacia crassicarpa*, multiple leaders, genotypes, physical and mechanical properties

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INTRODUCTION

The national forest plantation project in Malaysia was launched in 1992 and it is aimed to supply the insufficient raw materials required by the wood-based industries (Thai *et al*., 1997). The species selected for this purpose are fast growing, multipurpose and with good attributes to supply merchantable timbers within fifteen years rotation (National Academy of Sciences, 1980; National Research Council, 1983; Turnbull, 1986; 1991; Chung, 1992; Pinyopusarerk, 1992; Ahmed & Kamis, 1999; Rimbawanto, 2002). Forest plantation in Malaysia is mainly planted with *Acacia spp*. especially *A. mangium* and *A. auriculiformis*. This is due to their good growth performance, multipurpose, well adaptability to our country's humid climate and able to improve degraded soil. The growing demand on wood has made *Acacia* as a valuable fast-growing resource in catering for local demand whilst venturing for global market potential. In addition, the toughness of *Acacia* wood makes it a good material in making items that require certain degree of ruggedness (Sharma, 2011). *Acacia crassicarpa* A. Cunn. Ex. Benth. is one of the candidate species that has been proven to grow better than other fast growing *Acacia* spp. in terms of diameter, height, volume production and wood biomass (Kindo *et al*., 2010).

Despite being fast growing with other positive attributes, this species is also without exception, as it has some limitation in its growth habit. In particular, it produces multiple leaders (ML), mainly of epicormic branches (Turnbull, 1986; Doran *et al.,* 1997). Cooper (1931) defines ML as the formation of more than one stem from the base of a planted tree which is possibly caused by genetic and environmental factors. Trees in many genera such as *Acacia* spp, *Eucalyptus* spp and *Tilia* spp tend to produce multiple stems varying in numbers, which usually originate from the basal part of the main stem (Fewles, 2002). A trunk that forked at a height of less than 1.37 m from the ground is considered as multiple stemmed individual (Faber & Tester, 1997). Formation of multiple leaders is undesirable as they reduce the quality of timber. However, there is no report to support such postulation based on their wood properties. Thus, this study aimed to evaluate selected mechanical and physical properties of the multiple-leadered trees from different genotypes of *A. crassicarpa*.

MATERIALS AND METHODS

Sample Sources

The wood samples were obtained from five year-old stems of multiple-leadered (ML) trees, which were removed from the singling operation of a progeny trial, established in Kampung Aur Gading, Pahang, Malaysia. They were from two classes of ML: (i) ML2 (with two leaders – Fig.1(a)), and (ii) ML3 (with more than two leaders – Fig.1(b) with three leaders and 1(c) with four leaders). The study utilized trees of four provenances from two geographic regions, namely, Papua New Guinea (PNG) and Queensland Australia (QLD). Details of these provenances are given in Table 1.

The wood sample was evaluated for their moisture content, specific gravity, shrinkage and static bending test. Wood sample was cut into specimens of three sizes,

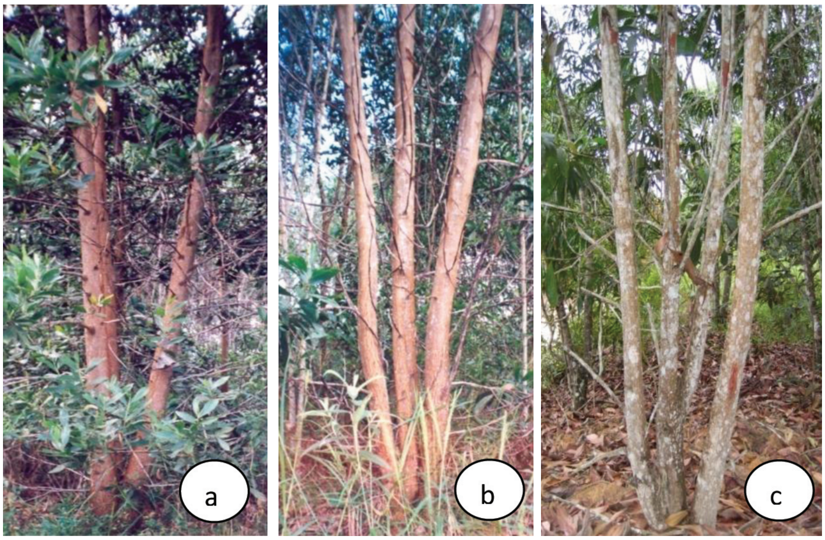

Fig.1: 60-month-old *Acacia crassicarpa* showing a) ML 2 with two-leadered stems, b) ML 3 with three-leadered stems, and c) ML3 with four-leadered stems at the base.

TABLE 1
Details of the sources used in this study

Multiple Leader	Region	Provenance	Latitude	Longitude	Altitude	No. of Trees	No. of Samples
2	PNG	Bensbach WP	05° 03’	141° 17’	25m	4	10
		Bimadebum WP	03° 08’	142° 03’	40m	3	10
	QLD	Claudie River	12° 48’	143° 18’	20m	7	10
		Chillie Beach	12° 38’	143° 24’	03m	3	10
3	PNG	Bensbach WP	05° 03’	141° 17’	25m	1	10
		Bimadebum WP	03° 08’	142° 03’	40m	1	10
	QLD	Claudie River	12° 48’	143° 18’	20m	1	10
		Chillie Beach	12° 38’	143° 24’	03m	1	10

Note: PNG-Papua New Guinea, QLD-Queensland

in dimensions of i) 20 mm (Longitudinal; L) x 20 mm (Radial; R) x 20 mm (Tangential; T), ii) 100 mm (L) x 20 mm (R) x 20 mm (T) and iii) 300 mm (L) x 20 mm (R) x 20 mm (T). All the testing carried out in this study were based on the British Standard (BS 373:1957-Testing small Clear Specimen of Timber).

Moisture Content Test

The moisture content (MC) test was performed by measuring the difference in the weights of the specimens using the following formula after being kept in an oven at 103±2°C for 48 hours.

$$MC\,\% = \frac{\text{Initial weight} - \text{Final weight}}{\text{Final weight}} \times 100$$

Specific Gravity Test

The most accurate method in determining the specific gravity of wood is to weigh the sample in liquid of known density. Paraffin wax was used in this study to coat the specimen from water absorption. The Specific Gravity (SG) test was conducted by placing the specimens in an oven at 103±2°C and immersing in hot paraffin wax while they were still warm. Then, the specimens were quickly removed from the paraffin wax to ensure that only a thin layer of wax was left on the surface of the specimens. Later, the specimens were immersed in water. Then, SG was determined using the following formula:

$$SG = \frac{\text{Oven-dry mass}}{\text{Density of water}}$$

Shrinkage Test

The percentage of shrinkage was determined by measuring the dimensional changes of the specimens which had reached equilibrium moisture content (EMC) of 12%, before and after oven drying at 103±2°C for 24 hours. The dimensions of the changes were measured by using a digital calliper with 0.1 mm accuracy level. The radial and tangential shrinkage was determined according to the following equation:

$$\text{Shrinkage}\,\% = \frac{\text{Initial dimension} - \text{Final dimension}}{\text{Initial measurement}} \times 100$$

Static Bending Test

The static bending test was performed using Universal Testing machine in 3-point bending configuration. The specimens were placed between two supporting pins over a span of 300 mm. The inelastic response of the specimen to apply uniaxial loading was measured in the tangential direction of the specimen. The cross-head speed was maintained at 1.25 mm/min until the sample fails. The maximum load of each specimen was recorded and the values of MOE and MOR were calculated as follows:

$MOE\ (N/mm^2) = PL^3$

Where, Δ = deflection at proportional limit (mm)

P = maximum load (N)

L = span length (mm)

b = width of specimen (mm)

d = depth of specimen (mm)

$MOR\ (N/mm^2) = 3PL^3$

Where, P = maximum load (N)

L = span length (mm)

b = width of specimen (mm)

d = depth of specimen (mm)

DATA ANALYSIS

The data were analyzed for variance using SAS Statistical Analysis System package (ANOVA procedures, SAS Institute, Inc

2000). Least Significant Difference (LSD) was calculated following the ANOVA test to compare the means of each ML class and provenance. The statistical analysis was conducted at the probability of 0.05. If the data were considered as highly significant, the P-value would indicate less than 0.05. Meanwhile, the ANOVA output, which exceeded p-value > 0.05, would signify that the population means are regarded as identical.

RESULTS AND DISCUSSION

The results of the analysis of variance showed that there were significant differences at $P<0.05$ for both the physical and mechanical properties between the ML classes but not between the provenances (Table 2). Generally, ML2 produced better mean values of 0.48%, 1.4% and 2.89% for specific gravity, radial and tangential shrinkage as compared to those produced by ML3. Similarly, the ML classes also differed significantly at $P<0.05$ in their Modulus of Elasticity (MOE) and Modulus of Rupture (MOR). Once again, ML2 produced higher mean values of 9858.4 N/mm^2 and 89.63 N/mm^2 for MOE and MOR, respectively than ML3 (Fig.2).

It is evident that ML formation reduces the overall wood strength of a tree. Results of the mechanical properties from this study verified that ML2 trees were stronger than ML3 trees. Obviously, trees with many stems tend to have weaker physical strength when compared to those with a few stems. This is in line with the energy allocation theory where the energy or nutrient has to be distributed equally to all development tissues for growth and development purposes. Having multiple stems would mean less energy/nutrient being allocated to the respective stems as it has to be shared equally among these stems. Thus, in this study, ML2 tree was expected to experience a better growth than ML3 tree. This is because ML3 tree has to share its nutrient or energy among more stems, thus resulting in lesser energy/ nutrient being allocated to every stem it has. The insufficient nutrient supply in ML3 tree may have resulted in a poorer growth in terms of diameter size. Field observation also revealed and supported this postulation and ML3 tree generally had smaller average diameter than ML2 tree. Such a variation could also be associated with the anatomical differences depicted by the distribution and formation of heartwood, sapwood and cell wall of this ML tree. On the other hand, ML2 tree which normally has bigger diameter tends to have higher portion of heartwood constituting higher amount of wood substances to cell cavity ratio. This in turn has an implication on the physical properties of a wood such as on its specific gravity. On the other hand, Zhang (1997) and Kang *et al*. (2005) also reported that specific gravity is highly correlated with the strength and stiffness of wood. Similarly, the results of this study also revealed that ML2 tree produced higher MOE and MOR values than the ones recorded by ML3 tree; thus, this is in agreement with what has been reported Zaidon *et al.* (2004).

TABLE 2
Analysis of Variance of the Physical and Mechanical Properties of Multiple Leadered A. *crassicarpa* Provenances

Source of Variation	df	Physical			Mechanical	
		Specific Gravity	Radial Shrinkage	Tangential Shrinkage	Static Bending MOE (N/mm^2)	Static Bending MOR (N/mm^2)
		F Value	F Value	F Value	F Value	F Value
Multiple Leader	1	367.57*	732.63*	1002.47*	482.02*	630.2*
Provenance	3	0.73^{ns}	0.15^{ns}	0.41^{ns}	1.73^{ns}	1.12^{ns}
CV (%)		1.37	14.38	9.52	5.38	6.94

Note:* - significant at $p \leq 0.05$, ^{ns} - not significant

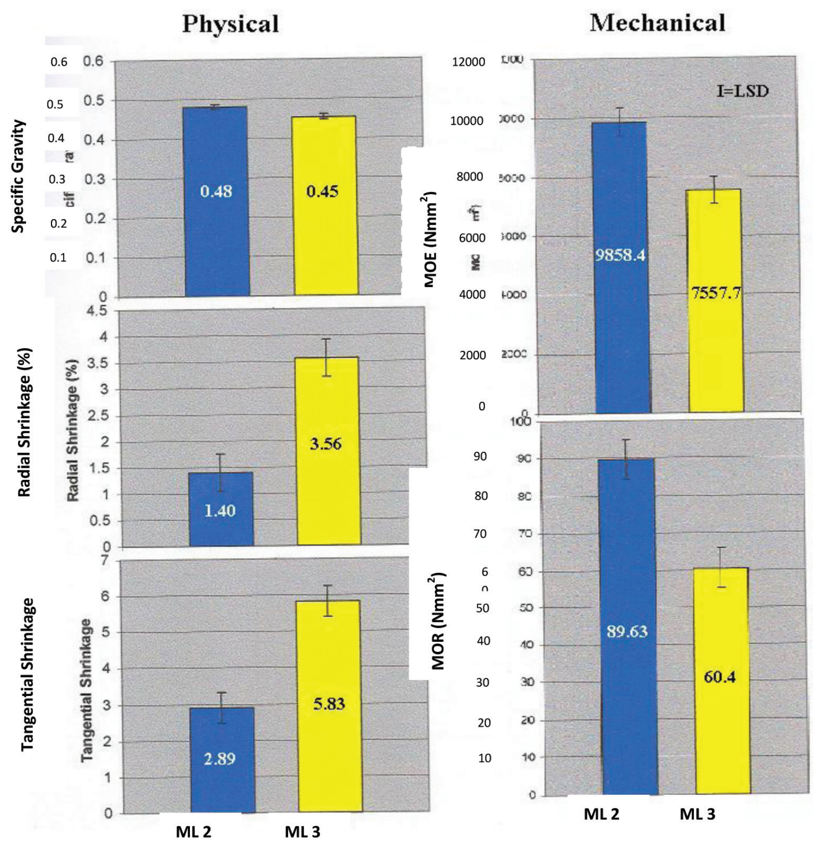

Fig.2: The mean values of physical properties: Specific Gravity (SG), Radial and Tangential Shrinkages and Mechanical Properties: Modulus of Elasticity (MOE) and Module of Rupture (MOR) of Multiple Leader Class 2 (ML 2) and Class 3 (ML 3)

One interesting point that needs to be highlighted in this study is the stem formation of multiple-leadered stems. Compared to a single-stem tree which stands upright and vertical, multiple-leadered stems tend to lean sideways from the base. This mechanism is likely due to the inherent behaviour of each stem to space out in order to supports its crown development. There is a possibility that the angle of stem displacement is directly related to the number of stem. This subsequently leads to the development of reaction wood within multiple-leadered stems. The reaction was formed as a result of induced stress in order for the stem to recover to vertical position. Alfred (2007) and Shmulsky and Jones (2011) indicate on the sensitivity of the stem with regards to the angle of lean and the formation of reaction wood. In hardwood species such as *Acacia*, tension wood normally occurs on the upper (tension) side of leaning stem. It was also stated that mechanical stress and formation of reaction wood are most conspicuous in fast growing species as has been presented in numerous studies (see Isebrands & Parham, 1972; Timel, 1986; Balatinecz & Kretschman, 2001). Meanwhile, studies by Jourez *et al.* (2001), Coutand *et al.* (2004) and Zaidon *et al*. (2004) have indicated the unfavourable properties of tension wood which include inferior mechanical strength, high shrinkages and poor machining properties. A study on microscopic evaluation by Scurfield (1973) revealed that tension wood consists of smaller and fewer vessels and ray cells compared to normal wood. Fewer ray cells would means lesser cell composition in restraining radial shrinkages. Tension wood fibres are thick walled with small lumen. Secondary wall of tension wood is normally loosely connected to the cell wall due to the cells low lignin content. Unlike normal wood which has stiff wall layer, the cell wall of tension wood consists of a gelatine-like cell layer (G layer). The G layer does not provide restraint during shrinkage due to the absence of S2 layer within the secondary wall layer. This observation supports the finding of this study which indicates inferior mechanical properties and high shrinkage of multiple-leadered stems. Due to its high cellulose and low lignin content, tension wood is considered as highly suitable for dissolving and mechanical pulping, as well as for non-structural applications (Razali & Hamami, 1992; Haslett *et al*., 1999; Raor *et al*., 2011).

The analysis of variance of the physical and mechanical properties of this study however did not show any significant differences among provenances (see Table 2). According to John (1999), Nor Aini and John (2003) and John and Nor Aini (2005), who conducted a study on genetic diversity of *A. crassicarpa* plus trees of a provenance trial in Serdang, Selangor, Malaysia, a strong genetic similarity was reported among eight provenances from two geographic regions, namely, Papua New Guinea (PNG) and Queensland (QLD). Those provenances involved are Bimadebum WP, Bensbach WP, and Claudie River, Jardine River, Old Zim, Limal-Malam, Samlleberr and Olive River, whereby the first three are actually the same provenances used in this study. John and Nor Aini (2005) reported that a cluster analysis based on unbiased genetic distance (Nei, 1978) and the UPGMA dendrogram revealed that all eight provenances in their study showed high level of genetic similarities or close relatedness to each other with the mean values ranging between 0.8878 and 0.9736 as well as between 0.8263 and 0.9429, based on biochemical isozyme and molecular Random Amplified Polymorphic DNAs (RAPDs) analyses, respectively. Two clusters were formed based on isozyme data but no clustering was observed according to the geographic regions. On the other hand, only one cluster was formed using RAPD, and similarly, there was no specific grouping according to the geographic regions. Thus, all the provenances were assumed to be genetically related to each other and possibly shared the same ancestor. In addition, similar findings were also reported by Wickneswari and Norwati (1993) on *Acacia auriculiformis*; this further suggested that the provenances of Queensland are genetically related to Papua New Guinea provenances, which are in the same landmass. This result could help to explain the small genetic distance between the provenances obtained in this study. Furthermore, Boland *et al.* (1984) indicated the land connection of PNG and Australia about 10,000 years ago. However such an assumption can also be biased due to the small sample size of mother trees being represented by each provenance as well as the insufficient data available in the present study.

CONCLUSION

The present study indicated that ML2 trees produced better physical and mechanical properties compared to ML3. In particular, strength and stiffness are affected by the number of leaders but not in terms of provenances. Thus, suitable applications of fibre resources from multiple-leadered trees of *Acacia crassicarpa* are for pulp and paper and non-structural purposes. ML2 can be used specifically for furniture making, panelling and flooring, whereas ML3 for special wood ware manufacturing.

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VOL. 36(S) DEC. 2013

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Journal of Tropical Agricultural Science

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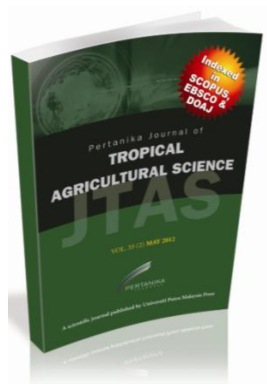

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- Pertanika JTAS aims to provide a forum for high-quality research related to **tropical agricultural research** dealing with issues of worldwide relevance.
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  - methodology/ approach
  - research design (if applicable)
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  - main findings
  - overall contribution
  - conclusions & suggestion for further research
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