Sains Malaysiana 45(3)(2016): 355–363

Species Diversity and Stumpage Valuation of Timber Resources at Pasir Tengkorak Forest Reserve, Langkawi, Kedah

(Kepelbagaian Spesies dan Nilai Stumpej Sumber Balak di Hutan Simpan Pasir Tengkorak, Langkawi, Kedah)

HAFIDZ ABDULLAH, A.G. AWANG NOOR* & I. FARIDAH-HANUM

ABSTRACT

Tropical forests are highly diverse and provide a great deal of economic value. They play an important role in providing goods and services which contribute to long-term social benefits in local communities. This study was carried out to examine the tree composition and estimate its economic value of timber resources in a lowland coastal forest. Four one ha plots were established in Pasir Tengkorak Forest Reserve in Langkawi, Kedah and the subplots measuring 10 × 10 m were established in each plot. All trees greater than 1 cm DBH (diameter at breast height) were identified and the parameters measured included tree height and diameter. The species diversity indices obtained for all four plots were relatively high. The Simpson's index of diversity ranges from 0.946 to 0.969, while the Shannon-Weiner index (H') ranges from 3.808 to 5.616. The Simpson's measure of evenness (1/D) ranges from 0.239 to 0.563 suggesting that species evenness in the four ha plots were low. Stumpage value of timber in the study area was quite high with average value of RM33,600.46 per ha. Regression analysis showed that the relationship between stumpage value and species diversity was significant at the 5% level.

Keywords: Economic value of timber; regression analysis; species diversity; stumpage value; tree composition

ABSTRAK

Hutan tropika mempunyai kepelbagaian yang tinggi dan menyumbang kepada nilai ekonomi yang tinggi. Ia memainkan peranan dalam menyediakan produk dan perkhidmatan yang menyumbang kepada faedah sosial jangka masa panjang kepada masyarakat. Objektif kajian ini adalah untuk mengkaji komposisi pokok dan menentukan nilai ekonomi sumber balak di satu kawasan hutan tanah rendah pesisir pantai. Empat plot kajian (100 × 100 m) ditandakan di Hutan Simpan Pasir Tengkorak di Langkawi, Kedah dan subplot berukuran 10 × 10 m ditanda dalam setiap plot. Kesemua pokok berdiameter 1 cm ke atas dikenal pasti dan parameter yang diambil kira termasuk diameter dan tinggi pokok. Indeks kepelbagaian spesies yang diperoleh dalam keempat-empat plot adalah tinggi. Indeks kepelbagaian Simpson mencatatkan nilai antara 0.946 dan 0.969 dengan nilai purata 0.960. Indeks Shannon-Weiner (H') berada antara 3.808 hingga 5.616 dengan nilai purata 5.06. Pengukur kesamaan Simpson (1/D) bernilai antara 0.239 hingga 0.563 menunjukkan kesamaan spesies pada keempat-empat plot adalah rendah. Keputusan menunjukkan nilai stumpej di kawasan ini adalah tinggi dengan nilai purata RM33,600.46 setiap hektar. Analisis regresi menunjukkan hubungan antara nilai stumpej dan kepelbagaian spesies adalah signifikan pada tahap 5%.

Kata kunci: Analisis regresi; kepelbagaian spesies; komposisi pokok; nilai ekonomi kayu; nilai stumpej

INTRODUCTION

Forests in Malaysia are classified as tropical rainforest, which are believed to be among the oldest and most complex ecosystems in the world. Two of the main characteristics of tropical rainforest are the fast growth of plant species and unmatched diversity of species. Malaysia enjoys a diversity of plant species in a sustainable ecological environment with a large forested area and stable climate.

It is estimated that there are more than 14500 of flowering plant species in Malaysian tropical rainforest. These include 5000 tree species, 1000 orchid species, 300 palm species and 1167 fern species. About 677 timber species comprising of 168 genera have commercial value (NRE 2006).

Due to their significant effect to the socio-economic of the country, numerous studies on biodiversity assessment and evaluation of timber resources have been conducted in various types of forests. A study was conducted by The Forestry Administration of Cambodia (2010) to provide a better understanding of the changing relationships between society and forest policy reviews and reforms in national forest sectors. Awang Noor (2010) determined the current economic valuation of forest resources in Malaysia from previous studies under various forest ecosystems, which has been useful in formulating policy and legal frameworks.

The data of flora in coastal forest provides important information on the type of vegetation and species distribution. Besides, the floristic composition of coastal forest may be compared with different types of forests in Malaysia due to different altitudes, types of soil and climate. The output of such study can provide information on differences of total individuals in an area, specific species distribution and also species growth pattern from the other types of forests.

The objectives of the study were to examine the floristic composition and species diversity in Pasir Tengkorak Forest Reserve, as well as to determine the stumpage value of timber resources in the area and to examine the relationship between the stumpage value of timber and its species diversity. This study was jointly performed with Hayat et al. (2010), who focused on the assessment of species diversity in a one ha plot at Pasir Tengkorak Forest Reserve. The present study was extended to four one ha plots with added data on stumpage value.

MATERIALS AND METHODS

STUDY AREA

The study area was at Pasir Tengkorak Forest Reserve, located in north-west of Langkawi Island (6° 20' N, 99° 50' E), about 40 km from the main town, Pekan Kuah. The area is near to the main tourist attraction Pasir Tengkorak Beach and is not far from Krakatau Island, Thailand. This study was conducted at Compartment 2, which is also a part of Machincang Forest Reserve. The forest type is coastal lowland forest with an elevation of not more than 300 m. The geology in the north-west of Langkawi consists of quartzite sandstone overlain by metamorphosis of Setul limestone, shale and minor sandstone of Signa formation and a dolomitic limestone sequence of Chuping Formation (Hussin et al. 2005).

The Machincang Forest Reserve is predominantly Burmese and Thai in species composition. The climate in north-west of Langkawi is warm tropical and the annual average temperature range is 24-33ºC. The monthly rainfall can reach as high as 342 mm in December and range as low as zero in January. Since the 1950s, the forest area has been logged several times, thus, it is classified as a secondary forest. There is minimal use of the forest by local communities, who collect forest products such as rattan, wild fruits and plants (Hymeir et al. 1998).

DATA COLLECTION

Four plots of one ha (100 × 100 m) each were established along a line transect at an elevation of 130-300 m above sea level. Each plot was divided into 10 × 10 m subplots for specimen and data collection. The plots were separated by a gap of 50 m along the line.

The data collection was conducted from January 2008 to December 2009. All trees greater than 1 cm DBH and above were identified and the parameters measured include tree height and diameter. Other main works were the specimen collection, preservation, arrangement of specimen and species identification.

DATA ANALYSIS

Diversity index was used to determine the diversity of species in the study area. In this study, the non-parametric measures of diversity used were the Simpson's diversity of index and the Shannon-Wiener index. These diversity indices were the major methods to calculate various species richness and the diversity indices that showed the probability of picking two trees at random from different species (Waite 2000).

The equations for the indices are as follows:

(i) Simpson's diversity of index

$$D = -\Sigma P_i^2,$$

where Σ is the total number of species in the community; and P_i is the relative percentage cover value of species expressed as a proportion.

However, this equation can be converted to a measure of diversity by using the original of Simpson's measure:

D is the probability of picking two trees at random from different species; and 1 is the probability of picking two trees of the same species.

Therefore, the equation is:

$$1 - D = 1 - \Sigma P_i^2,$$

where (1 - D) is the Simpson's index of diversity.

(ii) Shannon-Wiener index

$$H' = -\Sigma (P_i * \ln P_i),$$

where H' is the Shannon Wiener diversity index; and ln is the natural logarithm.

Species evenness measures the relative abundance of the various populations present in an ecosystem. Krebs (1989) stated that for continuous data or data with large number of records, the maximum value for Simpson's (D_{max}) is:

$$D_{max} = 1 / S,$$

where D_{max} is the maximum possible value for Simpson's; and S is the number of species.

Therefore, for the Simpson's measure of evenness, this index is based on the Simpson's diversity index, D and is defined as:

$$E_{1/D} = \frac{1/D}{S},$$

where $E_{1/D}$ is the Simpson's measure of evenness; and D is the Simpson's diversity index.

STUMPAGE VALUATION

The stumpage valuation was calculated only for trees with a DBH of 15 cm and above. The residual value method was used to calculate the stumpage value of timber. The stumpage value was calculated as a residual by taking the difference between the selling value of the products and processing costs, including margins for profit and risk (Davis & Johnson 2000). The formula for calculating the stumpage value of a tree is given as:

$$SV= (P - C - PM) * V,$$

where SV is the stumpage value for each species and diameter classes (RM/m^3); V is the volume for each species and diameter classes (m^3); P is the timber price for each species and diameter classes (RM/m^3); C is the average logging cost (RM/m^3); and PM is the profit margin (RM/m^3).

The volume of each species was determined using the local volume table developed by Awang Noor et al. (2008):

$$V = 0.001586 \times DBH^{1.882311}.$$

The volume equation was not available as the data from pre-F was underestimated. Local volume table from other site from previous study was used. Even though the site of study was different, the tree species available between the two sites were relatively similar.

The profit margin was calculated by using the formula as follow:

$$PM = P \times PR / (1 + PR),$$

where PR is the profit ratio.

The logging cost for the area was estimated at RM200/m^3. This cost value excluded royalty, premium and tax. This cost was derived from the average logging cost in the past studies of various forest areas in Peninsular Malaysia (Ahmad Fauzi et al. 2002; Awang Noor et al. 2007; Badrul Hisham 2004; Mohd Shahwahid et al. 1999). The profit ratio used was 30% or 0.3. Data on the log prices were obtained from MASKAYU, an official bulletin published by Malaysian Timber Industrial Board (MTIB 2010, 2009, 2008).

SENSITIVITY ANALYSIS

Sensitivity analysis is an analytical method used to evaluate the effects of risk and uncertainty of a market analyses. The usual approach is to test the values within plus and minus, for example 10% of the expected value while keeping all other factors constant (BC Ministry of Forests 1999). In this study, sensitivity analysis was carried out to determine the effect of two parameters, which were log price and logging cost on stumpage value for two classes of trees both below cutting limit (15 cm and above) and above the cutting limit (45 cm and above). The log price and logging cost were reduced and increased to 10 and 20% from the current price and normal logging cost, respectively.

THE RELATIONSHIP BETWEEN STUMPAGE VALUE AND SPECIES DIVERSITY

The relationship between stumpage value and species diversity (Awang Noor et al. 2008) is given as follow:

$$SV = \alpha + \beta * SDI + \varepsilon,$$

where SV is stumpage value (RM); SDI is Shannon-Wiener diversity index (for all trees above 1 cm), α and β are parameters; and ε is the random error with mean zero and common variance $\varepsilon_1 \sim N(0, \sigma^2)$.

The relationship between the stumpage value and species diversity was determined using regression analysis. The estimated model was $SV= \alpha + \beta * SDI$, using the ordinary least square (OLS).

RESULTS AND DISCUSSION

FLORISTIC COMPOSITION AND SPECIES DIVERSITY

A total of 13543 tree individuals with a diameter above 1 cm had been identified and classified into their respective families, genera and species. From this total, the composition of flora in the study area comprised of 50 families, 113 genera and 236 species. The largest family in terms of stem numbers was Guttiferae with 2457 stems or 18.1% from the total. This was followed by Anacardiaceae family with 1854 stems (13.7%), Myrtaceae with 1150 stems (8.6%) and Rubiaceae with 1114 stems (8.3%) (Table 1). Rubiaceae was the largest family with 10 genera, followed by Euphorbiaceae and Lauraceae with eight genera and seven genera, respectively. Meanwhile genus which had the most species was *Syzygium* with 21 species and followed by *Garcinia* with 12 species. The family Guttiferae had the most species distributed across the study area with 19 species and Rubiaceae, Euphorbiaceae and Lauraceae with 16 species each (Table 3). The most abundant species recorded was *Swintonia floribunda* from Anacardiaceae with 801 stems followed by *Garcinia eugenifolia* (Guttiferae) with 704 stems and *Syzygium nigricans* (Myrtaceae) with 599 stems (Table 2).

The species diversity indices for trees with DBH 15 cm and above obtained for all four plots were relatively high (Table 4). The Simpson's index of diversity ranged from 0.946 to 0.968 with an average of 0.96, while the Shannon-Weiner index (H') ranged from 3.808 to 5.207 with an average value of 5.06.

For species evenness, the results showed that Simpson's measure of evenness (1/D) was ranged from 0.239 to 0.364. The results suggested that species evenness in the four one ha plots was low. Overall, only the value of species diversity index in Plot 1 was lower compared to the other plots. However, the evenness index showed that the evenness at Plot 1 was higher than the other plots.

According to Shannon-Wiener index of diversity (H'), Plot 4 was more diverse than the other plots. This may be related to the large number of abundant species in the

TABLE 1. Ten largest families with most number of stems

No.	Family	Individuals				
		Plot 1	Plot 2	Plot 3	Plot 4	Total
1	Guttiferae	614	439	711	692	2457
2	Anacardiaceae	522	614	398	320	1854
3	Myrtaceae	329	62	190	571	1150
4	Rubiaceae	166	255	354	258	1114
5	Lecythidaceae	149	178	129	120	576
6	Verbenaceae	36	0	110	404	550
7	Myristicaceae	230	241	48	24	543
8	Melastomataceae	86	89	171	156	500
9	Ebenaceae	93	167	127	104	491
10	Lauraceae	122	64	136	174	487
11	Others					3821

TABLE 2. Ten largest species in four one ha plots

No.	Family	Species	Individuals
1	Anacardiaceae	*Swintonia floribunda*	801
2	Guttiferae	*Garcinia eugeniifolia* Wall. ex T. Anderson	704
3	Myrtaceae	*Syzygium nigricans* (King) Merr. & L.M. Perry	599
4	Anacardiaceae	*Swintonia schwenkii*	586
5	Lecythideceae	*Barringtonia pendula* (Griff.) Kurz	575
6	Guttiferae	*Calophylum symingtonianum* M.R. Hend. & Wyatt-Sm.	442
7	Myrsinaceae	*Ardisia lanceolata* Roxb.	420
8	Guttiferae	*Mesua ferrea*	184
9	Euphorbiaceae	*Antidesma coriaceum*	135
10	Pentaceae	*Pentace curtisii*	114

plot. The flora composition and the species diversity were comparable to that of Hayat et al. (2010) in Plot 1.

STUMPAGE VALUE

In this study, the total stumpage value was estimated at RM33,600 per ha with a total volume of 289.17 m^3 per ha. The total volume and stumpage value included the trees with 15 cm DBH and above, for a total of 1184 of trees from 32 families. Table 5 shows the number of stems, total volume, and total stumpage value for each family in all four one ha plots.

Anacardiaceae was the main contributor of the total stumpage value calculated at RM14,379.00 per ha comprising of 302 stems enumerated and also the largest total volume estimated at 96.61 m^3 per ha. This was followed by Myrtaceae with RM7,078.83 per ha (161 stems, 52.50 m^3 per ha) and the Guttiferae which contributed RM2,508.56 per ha (200 stems and total volume of 32.28 m^3 per ha).

Table 6 shows the highest stumpage value timber species in the four one-ha plots at Pasir Tengkorak Forest Reserve. *Swintonia floribunda* (Anacardiaceae) was the species with the highest stumpage value estimated at RM8,373.58 per ha. This was followed by *Swintonia schwenkii* (Anacardiaceae) calculated at RM5,895.39 per ha and *Syzygium nigricans* (Myrtaceae) at RM3,295.75 per ha.

SENSITIVITY ANALYSIS

Table 7 shows that when the log prices were increased to 10 and 20% and logging cost remained the same, the estimated stumpage value was increased to RM9,989.36 and RM13,790.41 per ha for trees with DBH from 15 to 45 cm. In contrast, when the logging cost was increased to 10 and 20% while the log price remained the same, the stumpage values were reduced to -RM176.11 and RM 3,006.10 per ha.

Meanwhile when the log prices were reduced to 10 and 20% while the logging costs remained the same, the estimated stumpage values were reduced to RM2,387.27 and -RM1,413.78 per ha, respectively. When the logging cost was reduced to 10 and 20% while log prices remained the same, the stumpage values were estimated at RM9,370.53 and RM12,552.75 per ha. The negative stumpage value indicated that the selling value of the products is lower than the processing costs thus the concessionaires were making a loss instead of gaining profit.

For trees above the cutting limit (45 cm DBH and above), the results showed that the estimated stumpage value was increased to RM24,406.35 and RM30,009.23 per ha when the log prices were increased by 10 and 20% while the logging costs remained the same. On the other hand, when the logging cost was increased by 10% and 20% while log prices remained the same, the stumpage values were reduced to RM15,558.02 and RM11,358.39 per ha, respectively.

TABLE 3. Species importance value (IV)

Species	D (tree/ha)	F	R_d	R_f	BA (m^2)	RBA (%)	IV
Plot 1							
Swintonia floribunda	411	83	12.04	10.63	7.34	24.13	46.80
Syzygium wrayi	180	69	5.27	8.83	6.75	22.22	36.33
Garcinia eugeniifolia	299	88	8.76	11.27	1.56	5.14	25.17
Pentace triptera	111	52	3.25	6.66	1.92	6.30	16.21
Mesua ferrea	85	61	2.49	7.81	1.08	3.56	13.86
Barringtonia macrostachya	149	62	4.36	7.94	0.36	1.19	13.49
Knema furfuracea	124	57	3.63	7.30	0.45	1.47	12.40
Calophyllum ferrugineum	124	40	3.63	5.12	0.76	2.49	11.24
Diospyros styraciformis	81	46	2.37	5.89	0.38	1.26	9.52
Memecylon minutifolium	71	43	2.08	5.51	0.46	1.51	9.10
Others	1602	100	46.92	12.80	9.07	29.84	89.57
Total	3414	781	100	100	30.39	100	300.00
Plot 2							
Swintonia floribunda	411	90	14.66	5.49	8.53	31.07	51.22
Mesua racemosa	106	44	3.78	2.69	2.13	7.76	14.22
Barringtonia pendula	177	73	6.31	4.45	0.35	1.27	12.04
Garcinia parvifolia	119	58	4.25	3.54	0.88	3.20	10.99
Knema malayana	108	61	3.85	3.72	0.65	2.38	9.95
Swintonia spicifera	48	26	1.71	1.59	1.60	5.84	9.17
Diospyros bibracteata	93	52	3.32	3.17	0.25	0.89	7.38
Dacryodes longifolia	67	46	2.39	2.81	0.46	1.67	6.87
Timonius corneri	53	35	1.89	2.14	0.31	1.12	5.14
Horsfieldia wallichii	64	34	2.28	2.07	0.19	0.70	5.06
Others	1557	1120	55.56	68.33	12.12	44.1	167.96
Total	2803	1639	100.00	100.00	27.47	100.00	300.00
Plot 3							
Swintonia schwenkii	118	63	3.69	2.97	4.70	15.90	22.56
Swintonia floribunda	136	64	4.25	3.02	4.30	14.55	21.82
Garcinia eugenifolia	188	75	5.88	3.54	0.50	1.71	11.12
Memecylon paniculatum	123	52	3.85	2.45	0.50	1.68	7.98
Barringtonia pendula	128	65	4.00	3.07	0.25	0.85	7.92
Ardisia lanceolata	128	66	4.00	3.11	0.09	0.31	7.42
Teijsmanniodendron coriaceum	109	39	3.41	1.84	0.57	1.91	7.16
Rhodamnia cinerea	80	48	2.50	2.26	0.47	1.60	6.37
Mesua ferrea	55	36	1.72	1.70	0.83	2.82	6.24
Aidia densiflora	74	45	2.31	2.12	0.46	1.55	5.99
Others	2058	1567	64.39	73.92	16.86	57.12	195.42
Total	3196	2120	100.00	100.00	29.53	100.00	300.00
Plot 4							
Teijsmanniodendron coriaceum	423	93	10.23	4.17	2.13	8.08	22.49
Swintonia spicifera	161	43	3.89	1.93	2.45	9.29	15.12
Garcinia eugeniifolia	187	74	4.52	3.32	0.31	1.17	9.01
Garcinia rostrata	184	69	4.45	3.09	0.21	0.78	8.32
Syzygium nigricans	111	25	2.69	1.12	1.08	4.08	7.89
Rhodamnia cinerea	128	65	3.10	2.91	0.46	1.73	7.74
Ardisia crenata	172	70	3.89	3.14	0.10	0.39	7.43
Brackenridgea hookeri	108	60	2.61	2.69	0.40	1.51	6.82
Barringtonia macrostachya	118	68	2.85	3.05	0.23	0.89	6.79
Syzygium wrayi	89	33	2.15	1.48	0.71	2.68	6.32
Others	2453	1630	59.32	73.10	18.32	69.38	219.41
Total	4134	2230	99.70	100.00	26.40	99.98	317.34

TABLE 4. Diversity dependent measures for each plot

Diversity dependent measures	Plot 1	Plot 2	Plot 3	Plot 4	Average
For trees > 1 cm dbh:					
N	3410	2803	3196	4134	3386
Simpson's index of diversity	0.962	0.962	0.979	0.976	0.970
Shannon-Wiener index of diversity (H')	5.607	5.808	6.257	6.192	5.966
Simpson's measure of evenness (1/D)	0.219	0.168	0.262	0.229	0.220
For trees > 15 cm dbh:					
N	307	253	297	327	284
Simpson's index of diversity	0.958	0.946	0.969	0.968	0.96
Shannon-Wiener index of diversity (H')	3.808	5.207	5.591	5.616	5.06
Simpson's measure of evenness (1/D)	0.563	0.239	0.364	0.341	0.38

TABLE 5. Total volume and total stumpage value for each family in all plots (>15 cm DBH)

No.	Family	Individuals	Volume (m^3/ ha)	Total Stumpage Value (RM/ ha)
1	Anacardiaceae	302	96.61	14,379.00
2	Annonaceae	5	0.49	7.89
3	Burseraceae	19	3.42	112.89
4	Celastraceae	19	4.80	430.63
5	Cupressaceae	1	1.42	272.47
6	Dipterocarpaceae	35	8.13	2436.09
7	Ebenaceae	30	3.53	160.17
8	Elaeocarpaceae	43	8.78	511.38
9	Euphorbiaceae	6	0.59	11.83
10	Fagaceae	44	11.38	1085.68
11	Guttifereae	200	8.07	2508.56
12	Ixonanthaceae	6	3.93	585.48
13	Juglandaceae	1	0.20	3.15
14	Lauraceae	30	6.17	450.20
15	Lecythidaceae	1	0.18	2.95
16	Melastomataceae	26	3.24	52.38
17	Meliaceae	21	10.04	1574.06
18	Myristicaceae	36	7.09	163.22
19	Myrtaceae	163	13.13	7078.83
20	Ochnaceae	24	2.71	43.82
21	Podocarpaceae	6	1.68	27.17
22	Rubiaceae	45	6.33	264.96
23	Salicaceae	1	0.14	2.21
24	Sapindaceae	4	0.97	15.61
25	Sapotaceae	10	1.46	138.75
26	Simaroubaceae	1	0.07	1.13
27	Stemonuraceae	8	1.36	21.88
28	Theaceae	16	4.57	416.81
29	Thymelaeaceae	3	1.22	162.22
30	Tiliaceae	26	8.12	580.96
31	Ulmaceae	5	0.70	11.35
32	Verbenaceae	47	5.09	86.73
	Total	1184	289.17	33600.46

In contrast, when the log prices were reduced to 10 and 20% while the logging cost remained the same, the estimated stumpage value was increased to RM7,597.69 and RM13,200.58 per ha. When the logging cost was reduced to 10 and 20% while log prices remained the same, the stumpage values were estimated at RM22,526.00 and RM26,248.54 per ha.

The results showed that the changes of log prices and the logging cost have effect to the stumpage value of the study site. The calculation of stumpage valuation using the sensitivity analysis provides loggers and state authorities with information that at some point of the market price conditions, whether a certain forest area is worth logging. This decision making tool was similar to that of a study

TABLE 6. Ten families and among species with highest stumpage value

Family	Stumpage value (RM/ha)	Percentage (%)
Anacardiaceae	14,379	42.79
Myrtaceae	7,079	21.07
Gutiiferae	2,509	7.47
Dipterocarpaceae	2,436	7.25
Meliaceae	1,574	4.68
Fagaceae	1,086	3.23
Ixonanthaceae	585	1.74
Tiliaceae	581	1.73
Elaeocarpaceae	511	1.52
Lauraceae	450	1.34

Species	Stumpage value (RM/ha)
Swintonia floribunda Griff.	8373.58
Swintonia schwenkii (Teijsm. & Binn.)	5895.39
Syzygium nigricans (King) Merr. & L.M. Perry	3295.75
Syzygium glaucum (King) P. Chantaranothai & J. Parn.	1377.77
Mesua ferrea	1187.97

TABLE 7. Sensitivity analysis (RM/ ha)

Percentage change of logging cost	Percentage change of log price				
	-20 %	-10%	0	10%	+20%
for trees below cutting limit (15-45 cm DBH)					
+20%	-7,778.21	-3,977.16	-176.11	3,612.43	8,566.29
+10%	-4,595.99	-794.95	3,006.10	6,807.15	10,608.19
0	-1,413.78	2,387.27	6188.32	9,989.36	13,790.41
-10%	1,768.44	5569.49	9,370.53	13,171.58	16,972.62
-20%	4,950.65	8751.70	12,552.75	16,353.79	20,154.84
for trees above cutting limit (45 cm DBH and above)					
+20%	152.62	5755.51	11,358.39	16,961.27	22564.16
+10%	3,875.16	9478.05	15,558.02	20,638.81	26,286.70
0	7,597.69	13,200.58	18,803.47	24,406.35	30,009.23
-10%	11,320.24	16,923.12	22,526.00	28,128.89	33,731.77
-20%	15,042.77	20,64.66	26,248.54	31,851.42	37,454.31

TABLE 8. Regression analysis for stumpage value (SV) and Shannon diversity index (SDI) for trees 15 cm DBH and above

Variable	Parameter	OLS coefficients
(constant)	$\hat{A}$	6.502
(0.048)		
SDI	B	0.679
(0.008)		
n		400
R square		0.952
F value		7963.946
Log likehood function		4694.718

Note: Figures in parentheses are standard errors

TABLE 9. Regression analysis for stumpage value (SV) and Shannon diversity index (SDI) for trees 15 cm DBH and above

Variable	Parameter	OLS Coefficients (Loglinear)
(constant)	α	1.960
		(0.013)
SDI	β	0.227
		(0.007)
n		400
R square		0.952
F value		7963.946

Note: Figures in parentheses are standard errors

by Abdul Rahim et al. (2009) using the sensitivity analysis to analyse the conventional logging and reduced impact logging by using the same parameters, which were harvesting cost and timber prices with a constant value for other factors. The results showed that in the long run, the reduced impact practice system were more profitable with the net profit value (NPV) of RM9302 per ha than the conventional practice (NPV= RM8497 per ha).

RELATIONSHIP BETWEEN ECONOMIC VALUE AND SPECIES DIVERSITY

Table 8 shows that regression was significant at the 5% level with an F value of 7963.946. The R^2 value was 0.952 indicating that 95% of the variance in the stumpage value was explained by species diversity.

The relationship between stumpage value and its diversity index is shown in Figure 1. The graph showed that the relationship was positive but the variance was not homogenous as the variation of stumpage value was high when the species diversity increased. Therefore, the presence of heteroskedasticity was determined using the White test (Gujarati 2003). The result showed that the χ^2 value was 386.4 indicating the presence of heteroskedasticity at the 5% level.

Therefore, the model was estimated using the log linear model, which is specified as follows:

$$\text{In SV}_i = \text{In } \alpha * \beta * \text{In SDI}_i + \mu_i.$$

The original specification of the model is in the form of nonlinear, which is given as:

$$\text{SV}_i = \alpha * \text{SDI}_i^{\beta} * e^{\mu i}.$$

The estimated model is given as:

$$\text{In SV}_i\hat{} = \text{In } \alpha\hat{} * \beta\hat{} * \text{SDI}_i.$$

The results of the regression analysis are presented in Table 9. The coefficient was estimated at 0.227 and was significant at the 5% level, which indicated that in 1% increase in species diversity will result in 0.227% increase in stumpage value. The value of the coefficient of the relationship was estimated at 1.960 and was significant at the 5% level. The value was incomparable to the previous study by Awang Noor et al. (2008) in a hill forest where the coefficient was estimated at 954.503 for trees with DBH 30 cm and above and 455.856 for trees with DBH 45 cm and above. The results from Awang Noor et al. (2008) demonstrated that the economic value of timber resources did not depend on species diversity in a hill forest.

CONCLUSION

The most abundant and dominant species in the study area was *Swintonia floribunda (Anacardiaceae)*. The species diversity indices for trees in calculation of stumpage value obtained in the study area were relatively high, but species evenness was low. The results from the study showed that

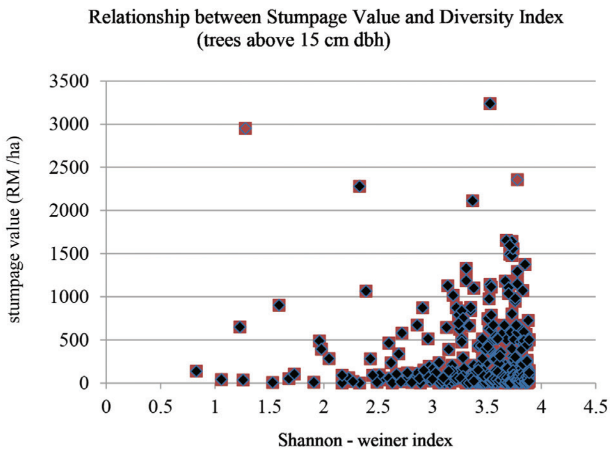

FIGURE 1. Relationship between stumpage value and diversity index (trees above 15 cm DBH)

higher diameter classes contribute a large proportion of stumpage value. The percentage of trees which form a part of timber value contribution depends on the extent of the timber volume, the size of trees and the presence of high value timber. The results from this study suggested that the stumpage value was positively related with the diversity of trees in the forest. Recommendations for further studies should consider economic value under various markets and the factors affecting the species diversity, such as geographical factors and disturbance of the area.

ACKNOWLEDGEMENTS

The authors wish to extend their appreciation to the Forestry Department Peninsular Malaysia for their cooperation and provision of research data and information for this study.

REFERENCES

Abdul Rahim, A.S., Mohd Shahwahid, H.O. & Zariyawati, M.A. 2009. Financial and economic analyses of conventional and reduced impact harvesting systems. *Journal of Sustainable Development* 2(3): 113-121.

Ahmad Fauzi, P., Salleh, M., Mohd Shahwahid, H.O., Abdul Rahim, N., Awang Noor, A.G. & Muhamad Farid, A.R. 2002. *Cost of Harvesting Operations in Compliance with ITTO Guideline*s. Main Report Volume 2. Kuala Lumpur: FRIM/ITTO.

Awang Noor, A.G. 2010. Economic valuation of forest resources: Current status and the way forward. *National Conference on Economic Valuation of Forest Resources*. Kuala Lumpur.

Awang Noor, A.G., Faridah Hanum, I. & Tuan Marina, T.I. 2008. Relationship between economic value and species diversity of timber resources in a hill forest in Peninsular Malaysia. *Journal of Sustainable Development* 1(2): 17-26.

Awang Noor, A.G., Mohd Syauke, M.S. & Tuan Marina, T.I. 2007. Analysis of logging cost in Pahang. Paper presented at the *Seminar on Economic Valuation of Forest Goods and Services*. Kuala Terengganu, Terengganu, Malaysia.

Badrul Hisham, K. 2004. Cost and Earning Structure of Logging Industry in the State of Sabah. M.Sc. Project Report. Faculty of Forestry, University Putra Malaysia, Serdang, Selangor, Malaysia (Unpublished).

BC Ministry of Forests. 1999. *Guidelines for Developing Stand Density Management Regimes*. BC Ministry of Forests, Forest Practice Branch, Victoria, British Columbia.

Davis, L.S. & Johnson, K.N. 2000. *Forest Management*. 4th ed. New York: McGraw Hill.

Gujarati, D.N. 2003. *Basic Econometrics*. 4th ed. New York: McGraw Hill.

Hayat, M.S., Kudus, K.A., Hanum, I., Awang Noor, A.G. & Nazre, M. 2010. Assessment of plant species diversity at Pasir Tengkorak Forest Reserve, Langkawi Island, Malaysia. *Journal of Agricultural Science* 2(1): 31-38.

Hussin, A., Dorall, R., Meor, H.H. & Gokilan, S. 2005. The physical geography and geology of Northeast Langkawi. *Malaysian Journal of Science* 24: 1.

Hymeir, K., Daria, M. & Chitra, N. 1998. Biodiversity conservation gap. Analysis activity: Perlis and Kedah. *WWF Project Report*. World Wildlife Fund.

Krebs, C.J. 1989. *Ecological Methodology*. New York: Harper Collins.

Mohd Shahwahid, H.O., Awang Noor, A.G., Abdul Rahman, M.D. & Shaharuddin, A. 1999. Cost and earning structure of logging industry in Peninsular Malaysia. *The Malayan Forester* 62: 107-117.

MTIB. 2010. *MASKAYU*. Vol.1-12. Kuala Lumpur: Malaysian Timber Industrial Board.

MTIB. 2009. *MASKAYU*. Vol.1-12. Kuala Lumpur: Malaysian Timber Industrial Board.

MTIB. 2008. *MASKAYU*. Vol.1-12. Kuala Lumpur: Malaysian Timber Industrial Board.

NRE. 2006. *Biodiversity in Malaysia*. Kuala Lumpur: Economic Planning Unit, Prime Minister's Department.

The Forestry Administration of Cambodia. 2010. *Asia-Pacific Forestry Sector Outlook Study*. Working Paper. Bangkok: The Forestry Administration Phnom Penh.

Waite, S. 2000. *Statistical Ecology in Practice*. Harlow: Pearson Education Limited.

Faculty of Forestry
Universiti Putra Malaysia
43400 Serdang, Selangor Darul Ehsan
Malaysia

*Corresponding author; email: awangnoor@gmail.com

Received: 31 July 2014
Accepted: 24 September 2015