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Relationship between Economic Value and Species Diversity of Timber Resources in a Hill Forest in Peninsular Malaysia

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Abstract

Timber resource is a major component of tropical forest and usually undervalued economically. This paper attempts to examine the relationship between economic value and species diversity of a hill dipterocarp forest in Peninsular Malaysia. The rank-abundance curve described a lognormal distribution pattern, indicating high diversity communities. The species diversity indices obtained were high: Fisher's alpha diversity index ranged from 96.53 to 109.56, Shannon-Weiner index were 5.29 to 5.39, while values of Simpson Index ranged from 134.02 to 151.11. The estimated mean stumpage value per hectare was Malaysian Ringgit RM25 413 and the main contribution was from the family Dipterocarpaceae. The regression analysis showed that the relationship between stumpage value and species diversity was not significant at the 5% level ($p>0.05$). Timber volume, size of trees and the presence of high timber value have great influence on the stumpage value for a given forest area.

Keywords: Economic value, Species diversity index, Regression analysis, Residual value technique

1. Introduction

Malaysia's forest essentially comprise of an evergreen rainforest with sixteen different types of natural climatic and edaphic forests ranging from the coasts to mountains (MOSTE, 1997). Her species diversity is one of the richest in the world and its contribution is very significant for the socio-economic development of the country. The diversity of forest goods and services provides timber and non-timber goods in the forestry sector, food and industrial crops in the agriculture sector and the regulation of good water, air, temperature and carbon sequestration amongst others. The lowland and hill forests provide many valuable timber species and predominate the international tropical timber market.

Numerous descriptive studies of species richness in lowland and hill forests have been used to analyse structure and diversity. Generally, these studies relied on data from various plot sizes ranging from one to four hectares. The economic value of timber resources has also been extensively analysed and has covered many different types of forest ecosystems. Despite numerous studies, there has been little effort to examine the relationship between the economic value measured by stumpage value and species diversity of tropical forests. The aim of this paper was to show the kind of relationship between stumpage value and species diversity in a tropical hill forest. This study is part of an on-going larger project entitled "Economic Valuation and Forest Resource Accounting in Peninsular Malaysia" commissioned by the Forestry Department Peninsular Malaysia in 2006 to the Faculty of Forestry, Universiti Putra Malaysia to determine the economic value of forest resources for six forest ecosystems viz., montane forest, hill forest, lowland forest, peat swamp forest, mangrove forest and coastal forest.

2. Materials and Methods

2.1 Study Area

This study was carried out in Tranum Forest Reserve, Pahang, Peninsular Malaysia during the year 2006. Five plots each of size 1 ha (100m x 100m) were established along a line transect from altitude 350 to 880 m a.s.l. Plots 1, 2, 3, 4 and 5 were further divided into 10m x 10m subplots for enumeration purposes. All trees greater than 1 cm dbh were measured and identified up to the specific level. The details of the plots' establishment are discussed in another paper (Faridah-Hanum *et al.,* 2007).

2.2 Species diversity

Species abundance times quadrat matrices were prepared and then exported for each two combination plots (e.g. plots 1 & 2, plots 1 & 3, etc) in order to calculate the means and variances of the species richness-estimators, based on 50 randomized quadrat orders for each data set. The program EstimateS was used to compute species richness-estimators (Colwell, 2006). The rank-abundance curve was then examined and plotted to describe the community structure based on the lognormal distribution model. The following formula were used to calculate various species richness and diversity indices (Waite, 2000):

a) Margalef's index of species richness: $R = (S_{obs}-1)/\ln N$, where ln N is the natural log of the number of individuals inventoried, S_{obs} is the total number of species recorded

b) Alpha Fisher's index of diversity: $S = \alpha \ln (1+N/\alpha)$

c) Shannon-Wiener index of diversity: $H' = -\Sigma p_i * \ln p_i$, where p is relative percentage cover value of species expressed as a proportion

d) Simpson's (inverse) index of diversity: $S = 1/D$, where D is the sum of relative percentage (i.e. Σp_i, that is the index of dominance), D ranges from $1 - S_{obs}$)

e) Pielou's measure of evenness: $E = H'/\ln S_{obs}$

2.3 Estimating Economic Value of Timber Species

The economic value of timber resources i.e. standing tree is called stumpage value and can be calculated using the residual value technique. Stumpage value is calculated by taking the difference between the selling value of the products made from it and the stump-to-market processing costs (including margin for profit and risk) (Davis & Johnson, 2000; Klemperer, 2003). The following formula is used to calculate stumpage value for each tree inventoried (Awang Noor et al., 1992; Awang Noor & Mohd. Shahwahid, 1995):

$SV_{i,j} = (P_{i,j} - C - PM_{i,j}) * V_{i,j}$ where, SV is stumpage value per hectare (RM), P is ex-forest log price (RM/m3), C is logging cost (RM/m3), PM is profit margin (RM/m3), V is volume of standing tree (m3), i is index of species, j is the index of diameter class. The margin for profit and risk (PM) is computed as follows:

$PM_{ij} = (P_{ij} * PR) / (1+PR)$, where PR is profit ratio. The profit ratio used here was 0.3.

The total stumpage value is obtained by summing up the stumpage value for all individual trees in the study area, i.e.

$$\text{Total SV} = \sum_{i=1}^{n}\sum_{j=1}^{k} SV_{i,j} = \sum_{i=1}^{n}\sum_{j=1}^{k}[(P_{i,j} - C - PM_{i,j}) * V_{i,j}]$$

The volume of individual tree inventoried was estimated using local volume table developed by Awang Noor *et al.* (2001) and given as follows:

$V_i = 0.0015086 * DBH_i^{1.882311}$, where V is volume of standing tree (m^3), DBH is tree dbh and *i* is index of tree.

Data on log prices (in Malaysian Ringgit RM) by species and diameter classes were obtained from ASPA (2004) log price report. The ex-forest log prices per cubic meter were reported for individual species and species groups. The average logging cost used was RM120/m^3 and the profit ratio was 0.3.

2.4 Relationship Between Economic Value and Species Diversity

The relationship between stumpage value and species diversity can be written as follows:

$SV_i = \alpha + \beta * SDI_i + \varepsilon_i$, where SV is stumpage value (RM) in each quadrat i (20m x 20m), SDI is Shannon-Wiener diversity index (for all trees above 1 cm), α and β are parameters and ε is random error with mean zero and common variance, $\varepsilon_i \sim N(0, \sigma^2)$. The estimated model was:

$$\hat{SV}_i = \hat{\alpha} + \hat{\beta} * SDI_i$$

The model was estimated using the ordinary least square technique (OLS). Two situations were evaluated: (a) trees greater than 30 cm dbh, and (b) trees above the cutting limit (50 cm for dipterocarps, and 45 cm for the non-dipterocarps). These are the minimum diameter cutting limits for trees to be harvested under the sustainable forest management (SFM) practices in Peninsular Malaysia.

3. Results and Discussion

3.1 Species Diversity

There were 22 374 stems comprising 446 tree species included in 176 genera and 64 families identified from all the plots. Results on the floristic composition, tree families and species dominance were discussed in detail in a separate paper (Faridah-Hanum *et al.,* 2007). The rank-abundance curve in Figure 1 describes a lognormal distribution pattern, indicating how varied the community was. The density dependent measures showed that the study area had high diversity in all plots (Table 1). The Fisher's alpha diversity index (α) range from 96.53 to 109.56 and the average for all plots is 102.27. The Shannon-Weiner index (H') gave a very high value ranging from 5.29 to 5.39; while the average for all five plots gave H' = 5.36. The values of H' increased with species but they rarely exceed 5.0 (Waite, 2000). The Simpson index (D) range from 134.02 to 151.11 and the average is 144.04 which is a measure of index of dominance and gives the probability that two individuals drawn randomly from a sample will belong to the same species. The distribution of the individuals among the species was even in all plots ($E > 0.9$). The significant difference of the Shannon-Wiener index between two plots can be compared using the Student's t-test, which is given by (Waite, 2000) is shown in Table 2. The Shannon-Wiener index were not significantly different among plots 3, 4 and 5 ($p>0.05$). All other comparisons of Shannon-Wiener index were found to be significantly different at the 5% level ($p<0.05$).

3.2 Economic Value

It was found that the average stumpage value per ha for commercial trees above the cutting limit (trees above cutting limit: ≥ 50 cm for dipterocarps and ≥ 45 cm for non-dipterocarps) was RM 25 413 per ha (Table 3). More than half (57%) of the stumpage values was contributed by the family Dipterocarpaceae followed by Myristicaceae (11.1 %), Sapotaceae (7.7%), Guttiferae (5.8%) and Myrtaceae (4.1%). This was due to the contribution by larger sized trees of three major species of the family Dipterocarpaceae which were *Shorea platyclados*, *S. ovata* and *S. parvifolia* which contributed about 47% of the total stumpage value per hectare (Table 4). For trees ≥ 30 cm the dipterocarps present contributed an average per ha of 66% of the total stumpage value (Table 5). The stumpage value also varied by diameter class. About half (47%) of the total stumpage was from the diameter class 50-80 cm. The results also indicated that higher diameter class had contributed the large proportion of stumpage value. This shows that in terms of economic value of timber resources, its contribution depends on the extent of the timber volume, the size of trees and the presence of high value timber. When compared to the stumpage value estimated from previous studies, the stumpage value estimated in this study site was relatively high and in most cases greater than the other forest areas (Table 6). This study hence proved that commercial sized trees gave a higher stumpage value.

3.3 Relationship Between Economic Value and Species Diversity

The scatter plot of stumpage value and one of the species diversity indices is shown in Figure 2. It can be seen that the relationship is positive but it is observed that a large variation of stumpage value exists as the diversity index increases. The large variation of stumpage value at higher values of diversity index might indicate the presence of heteroskedasticity in the sample (Gujarti, 2003). Using the Breusch-Pagan-Godfrey heteroskedasticity test of software STATA 8.0, we obtained the χ^2 value of 0.92 at 5% level of significance. Therefore, we conclude that there was no heteroskedasticty of error variance ($p > 0.05$) and the parameter estimates were done using the ordinary least square (OLS) method.

The results of the regression analysis for OLS are presented in Table 7. There is a positive relationship between stumpage value and species diversity in the study area for trees above 30cm dbh and above the cutting limit. However, the variation of stumpage value is explained as a small percentage of species diversity (3 percent for trees greater than 30 cm and less than 1 percent for trees above the cutting limit). The coefficients of the regression indicate that an increase of one point of diversity index increases the stumpage value by Malaysian Ringgit RM456 and RM956 for trees ≥ 30 cm dbh and 45 cm dbh, respectively. However, the regression coefficients in the two dbh situations are not significantly different at 5% level ($p > 0.05$). Therefore, the results of the study showed that the economic value of timber resources did not depend on species diversity in a hill forest. As mentioned in the preceding section, stumpage value depends on the extent of timber volume, the size of trees and the presence of high value timber not on whether the forest is highly diverse or has high species richness.

4. Conclusion

The Tranum Forest Reserve, Pahang shows both high species diversity and economic value. However, the results of regression analysis suggest stumpage value was not affected by species diversity. The low variation of this relationship is attributed to different factors affecting stumpage value and species diversity. While the stumpage value is affected by timber volume and market condition of log, species diversity is affected by many related factors such as historical factors of the area, spatial heterogeneity, competition, climatic, productivity and disturbance of the area. Further analysis is required to examine the relationship between economic value and species diversity under various market conditions. Incorporating economic and ecological perspectives in forest management will enhance sustainable forest management.

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Table 1. Diversity dependent measures for each 1-ha plot calculated based on tree density, Tranum Forest Reserve, Pahang (trees ≥ 1 cm dbh)

Diversity dependent measure	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Average All Plots
N	3924	3577	4952	5002	4919	4475
S_{obs}	360	355	388	421	417	388
Basal Area	70.45	56.30	130.13	126.89	99.83	96.72
R	43.38	43.26	45.49	49.31	48.94	46.08
α	96.53 (2.89)	97.93 (3.02)	98.56 (2.74)	109.56 (2.97)	108.78 (2.97)	102.27
H’	5.29 (0.01)	5.33 (0.01)	5.4 (0.01)	5.38 (0.01)	5.39 (0.01)	5.36
S	134.02 (0.61)	148.04 (0.58)	151.11 (0.74)	143.45 (0.70)	143.58 (0.69)	144.04
E	0.90	0.91	0.91	0.89	0.89	0.90

Table 2. Results of t-tests for comparison of Shannon-Wiener Index among plots in Tranum Forest Reserve, Pahang (** significant at the 5% level; ns not significant at the 5% level)

	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5
Plot 1	-	-2.0**	-5.5**	-4.5**	-5**
Plot 2		-	-3.5**	-2.5**	-3**
Plot 3			-	1.0ns	0.50ns
Plot 4				-	-0.50ns
Plot 5					-

Table 3. Average stumpage value per hectare (RM/ha) by families in Tranum Forest Reserve, Pahang (trees above cutting limit: ≥ 50 cm for dipterocarp; ≥ 45 cm for non-dipterocarp)

Family	Stumpage Value (RM)	Percentage
Dipterocarpaceae	14485	57.00%
Myristicaceae	2812	11.07%
Sapotaceae	1947	7.66%
Guttiferae	1453	5.72%
Myrtaceae	1041	4.10%
Lauraceae	462	1.82%
Tiliaceae	408	1.61%
Thymelaeaceae	307	1.21%
Moraceae	241	0.95%
Polygalaceae	241	0.95%
Meliaceae	192	0.75%
Ebenaceae	181	0.71%
Anacardiaceae	153	0.60%
Burseraceae	141	0.55%
Fagaceae	118	0.46%
Rubiaceae	102	0.40%
Flacourtiaceae	89	0.35%
Icacinaceae	86	0.34%
Apocynaceae	82	0.32%
Leguminosae	82	0.32%
Euphorbiaceae	78	0.31%
Ulmaceae	77	0.30%
Rosaceae	74	0.29%
Proteaceae	60	0.24%
Verbenaceae	57	0.23%
Juglandaceae	51	0.20%
Araucariaceae	45	0.18%
Sapindaceae	45	0.18%
Elaeocarpaceae	44	0.17%
Podocarpaceae	38	0.15%
Symplocaceae	36	0.12%
Sterculiaceae	28	0.11%
Rhizophoraceae	21	0.08%
Ochnaceae	21	0.08%
Theaceae	20	0.08%
Myrsinaceae	20	0.08%
Magnoliaceae	17	0.07%
Pandanaceae	14	0.05%
Meliosmaceae	10	0.04%
Ericaceae	10	0.04%
Melastomataceae	7	0.03%

Lecythidaceae	6	0.02%
Staphyleaceae	6	0.02%
Annonaceae	6	0.02%
Actinidiaceae	3	0.01%
Celastraceae	3	0.01%
Total	RM 25413	100.00%

Table 4. Top 20 Most High Stumpage Value Timber Species (RM/ha), Tranum Forest Reserve, Pahang (trees above cutting limit: ≥ 50 cm dbh for dipterocarp; ≥ 45 cm dbh for non-dipterocarp)

Species	Family	Stumpage Value Per ha	Percentage
Shorea platyclados	Dipterocarp	8254	32.5%
Shorea ovata	Dipterocarp	1905	7.5%
Shorea parvifolia	Dipterocarp	1807	7.1%
Knema intermedia	Non-Dipterocarp	1394	5.5%
Dipterocarpus crinitus	Dipterocarp	1303	5.1%
Shorea maxima	Dipterocarp	951	3.7%
Payena dasyphylla	Non-Dipterocarp	642	2.5%
Calophyllum fraseri	Non-Dipterocarp	557	2.2%
Calophyllum symingtonianum	Non-Dipterocarp	452	1.8%
Pouteria malaccensis	Non-Dipterocarp	418	1.6%
Pentace curtisii	Non-Dipterocarp	408	1.6%
Knema scortechinii	Non-Dipterocarp	368	1.4%
Gonystylus maingayi	Non-Dipterocarp	307	1.2%
Horsfieldia crassifolia	Non-Dipterocarp	279	1.1%
Syzygium sp.12	Non-Dipterocarp	242	1.0%
Palaquium sp.	Non-Dipterocarp	231	0.9%
Palaquium rostratum	Non-Dipterocarp	195	0.8%
Palaquium obovatum	Non-Dipterocarp	161	0.6%
Cratoxylum arborescens	Non-Dipterocarp	155	0.6%
Xanthophyllum palembanicum	Non-Dipterocarp	143	0.6%
Subtotal	All groups	20,173	79%
	Dipterocarp	(14,221)	(70%)
	Non-dipterocarp	(5,951)	(30%)
Remaining species		5,241	21%
Total		RM 25,413	100%

Table 5. Average stumpage value per hectare by diameter class and species group (RM/ha), Tranum Forest Reserve, Pahang (trees ≥ 30 cm dbh)

	Dipterocarp		Non-dipterocarp		Total	
Diameter Class	Stumpage Value	Percentage	Stumpage Value	Percentage	Stumpage Value	Percentage
30-40	1741	9.1%	-	-	1741	6.0%
40-50	2893	15.2%	53	0.5%	2946	10.2%
50-60	3586	18.8%	1752	17.6%	5338	18.4%
60-70	2559	13.4%	1975	19.8%	4534	15.6%
70-80	2105	11.0%	1810	18.2%	3915	13.5%
80-90	941	4.9%	1165	11.7%	2106	7.3%
90-100	524	2.8%	638	6.4%	1162	4.0%
100-110	1774	9.3%	104	1.0%	1878	6.5%
110>	2934	15.4%	2454	24.7%	5389	18.6%
Total	19058	100.0%	9951	100.0%	29009	100.0%

Table 6. Estimated total stumpage value from previous studies in Peninsular Malaysia (RM/ha) (trees ≥ 30 cm dbh)

Forest Type	State	Forest Reserve/ Compartment	Year of study	Average stumpage value per ha (RM/ha)	Source
Hill Forest	Pahang	Lesong FR/ C88 &89	1989	25,235	Awang Noor *et al.* (1992)
Hill Forest	Pahang	Bencah FR/C15	1989	11,200	Awang Noor *et al.* (1992)
Hill Forest	Pahang	Berkelah FR/C50	1999	12106	Nur Hajar (1999)
Hill Forest	Pahang	Tekai Tembeling FR/C77	2003	13,992	Awang Noor & Mohd. Shahwahid (2003)
Hill Forest	Pahang	Lesong FR	2003	42,532	Awang Noor & Mohd. Shahwahid (2003)
Hill Forest	Kelantan	Balah FR/Block 95	1996	26,271	Che Roslan (1996)
Hill Forest	Terengganu	Jengai FR/C86	1989	17,172	Awang Noor *et al*. (1992)
Hill Forest	Kedah	Ulu Muda FR/C27	1994	26,710	Faridah-Hanum *et al.* (1999a)
Hill Forest	Johor	Lenggor FR/C225	1994	23,038	Dominic (1995)
Lowland Forest	Selangor	Ayer Hitam FR/	1995	26,362	Faridah-Hanum *et al.* (1999b)
Hill Forest	**Pahang**	**Tranum Forest Reserve**	**2006**	**28,962**	**This study**

Table 7. Results of regression analysis for stumpage value (SV) and Shannon diversity index (SDI)
(ns – not significant at the 5% level)

Variable	Parameter	Trees ≥ 30 cm dbh	Trees above cutting limit
(constant)	$\hat{\alpha}$	-3419.766ns (2555.561)	-1309.244ns (2057.498)
SDI	$\hat{\beta}$	954.503ns (574.312)	455.856ns (462.761)
N		93	110
R square		0.029	0.009
F value		2.762ns	0.928ns

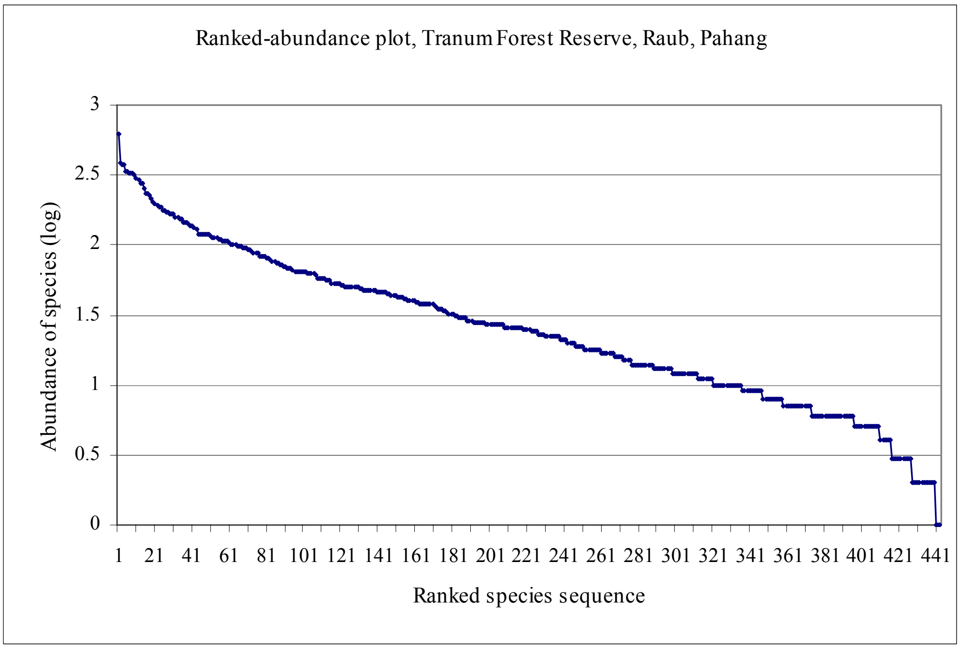

Figure 1. Ranked-abundance plot, Tranum Forest Reserve, Pahang (trees ≥ 1 cm dbh)

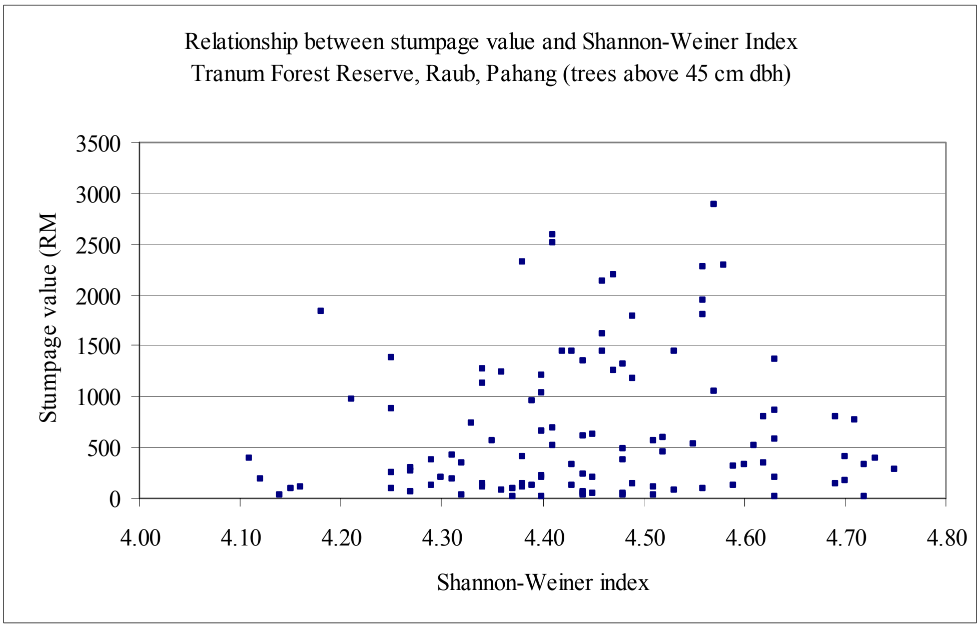

Figure 2. Relationship between stumpage value and Shannon-Wiener Index, Tranum Forest Reserve, Pahang (trees ≥ 45 cm dbh)