UNIVERSITI PUTRA MALAYSIA

SPECIES-SITE MATCHING AND GROWTH PREDICTION OF THREE FOREST PLANTATION SPECIES AT TAWAU, SABAH, MALAYSIA

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By

RAM NATHAN

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Master of Science Degree

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SPECIES-SITE MATCHING AND GROWTH PREDICTION OF THREE FOREST PLANTATION SPECIES AT TAWAU, SABAH, MALAYSIA

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Chairman : Assoc. Prof. Mohamad Azani Alias, PhD

Faculty : Faculty of Forestry

Sabah Softwoods Berhad venture into forest plantation was initiated in 1974. The trees species introduced were promising, but differences in yield and growth rate within its area continually repeated. Often, the yields were not within the expectation even when their genetic differences were narrowed down silviculturaly. To overcome such problems, study on species-site matching of *Gmelina arborea*, *Paraserianthes falcataria* and *Acacia mangium* were carried out with the aim of minimizing the variability in growth, thus maximizing yield.

The effect of soil series (Paliu, Kumansi, Tanjong Lipat and Kapilit) and climate on tree species growth variables was a priority in the species-site matching and site suitability study. Correlation and regression analysis of growth with climate, site assessment with respect to tree species height growth (site index), formulation of growth and yield equation of each tree species, and the financial analysis to determine the prospect of species-site matching operations prior to forest tree plantation establishment were done in answering the growth variability, in improving silviculture and management of forest plantation, in ensuring future sustainability of its resources, and to secure its forest ecosystem in perpetuity.

The results revealed that temperature, relative humidity, rainfall, sunshine hours, wind run, degree of wetness, rain index, humidity coefficient, and dryness index coefficient of variations were less than 25%. Such findings related that the climate was not extreme. The analysis of soil series data revealed significant differences for the percentages of sand, clay, porosity, moisture content, and cation-exchange capacity. Paliu series was best for *Gmelina arborea* (22.52 $m^3ha^{-1}yr^{-1}$) and *Paraserianthes falcataria* (34.18 $m^3ha^{-1}yr^{-1}$). This soil series was very sandy and porous with moderate cation exchange capacity and moisture content. *Acacia mangium* growth showed no differences between the soil series. It grew equally well on any of the soil series in the area and its mean annual increment ranged between 19.06 $m^3ha^{-1}yr^{-1}$ and 26.42 $m^3ha^{-1}yr^{-1}$. The yields of tree species on their preferred soils were also highly correlated with daily sunshine hours. The climatic variables daily sunshine hours, temperature, rainfall, and raindays explained about 65 to 76% of the variations in their yields (m^3ha^{-1}) depending on tree species. The site assessment and classification based on site index equation derived for each tree species revealed that *Gmelina arborea* was site-specific species and grew best only in areas with site index class I. *Gmelina arborea* and *Paraserianthes falcataria* showed wider differences in height between its site index classes when compared with *Acacia mangium* as the former trees species varied significantly in growth rate between the soil series.

Growth and and yield equations using height of dominant tree and diameter at breast height were derived for *Gmelina arborea* (R^2 = 0.8947), *Paraserianthes falcataria* (R^2 = 0.8961) and *Acacia mangium* (R^2 = 0.7915).

Financial analysis revealed carrying out of species-site matching operation prior to forest trees plantation is financially profitable (IRR = 22.09%). The Net Present Value remains positive and Benefit / Cost ratio is more than 1 at 10% and 15% discounted rate.

Conclusively, the results of this study provided tools for species-site matching, forecasting growth, decision making, and planning of future planting of *Acacia mangium*, *Gmelina arborea*, and *Paraserianthes falcataria*.

Abstrak tesis yang dikemukakan kepada Senate University Putra Malaysia bagi memenuhi keperluan untuk Ijazah Master Sains

KAJIAN PEMADANAN SETEMPAT DAN TAKSIRAN PERTUMBUHAN BAGI TIGA SPESIS PERLADANGAN HUTAN DI TAWAU, SABAH, MALAYSIA

Oleh

RAM NATHAN

Januari 2009

Pengerusi: Assoc. Prof. Mohamad Azani Alias, PhD

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Penglibatan Sabah Softwoods Berhad dalam perladangan hutan dimulakan sejak tahun 1974. Namun, setelah ditanam dengan spesies yang dikenali pasti secara besar-besaran kajian awal menunjukkan keupayaan di kalangan spesies kayu-kayan tersebut amat berbeza, sehinggakan pada sesetengah keadaan ianya berlaku di luar jangkaan terutama ketidakseimbangan pada kadar pertumbuhan walaupun perbezaan genetik didapati terlalu kecil. Bagi mengatasi masaalah tersebut, satu kajian berkaitan pemadanan setempat ke atas spesies-spesies *Gmelina arborea, Paraserianthes falcataria, dan Acacia mangium* telah dilakukan dengan harapan untuk meminimumkan pertumbuhan tak seimbang, sekaligus mencapai perolehan yang maksimum.

Pemadanan setempat spesies-spesies *Acacia mangium, Gmelina arborea dan Paraserianthes falcataria* masing-masing mengikut kategori tanah (Paliu, Kumansi, Tanjong Lipat, dan Kapilit) yang telah dikenalpasti melalui kajian tanah dijalankan berpandukan kepada data-data iklim, tanah, dan pertumbuhan. Analisis

berkaitan '*Correlation and Regression*' kadar pertumbuhan dengan iklim, penilaian/taksiran setempat bersabit dengan pertumbuhan (indeks setempat), rumusan persamaan perolehan dan pertumbuhan setiap spesies, dan keupayaan nilai kepulangan (*financial analysis*) spesies-spesies berkenaan sebagai tanaman ladang telah dijalankan dengan anggapan ia amat penting sebagai jawapan kepada ketidakseimbangan pertumbuhan, penambahbaikan amalan silbikultural dan pengurusan perladangan hutan demi menjamin pemeliharaan sumber-sumber hasil, dan menyelamatkan ekosistem hutan secara berkekalan.

Dalam kajian pemadanan setempat spesies, data iklim menunjukkan perbezaan tahunan yang tidak keterlaluan. Perbezaan purata suhu, purata kelembapan, sukatan hujan, masa pancaran cahaya matahari harian, kelajuan angin, tahap kebasahan (*degree of wetness*), indek hujan (*rain index*), koefisien kelembapan (*humidity coefficient*), dan indek kekeringan (*dryness index*) untuk setiap satu data iklim didapati kurang daripada 25%. Ini menunjukkan perbezaan yang tidak keterlaluan semasa pertumbuhan spesies kayu yang dikaji. Data ciri-ciri tanah menunjukkan perbezaan amat ketara di antara peratusan kandungan pasir, tanah liat, peratusan poros (serapan), lembapan kandungan, dan kapasiti pertukaran kation. Tanah jenis Paliu dianggap terbaik untuk pertumbuhan *Gmelina arborea* (22.52 $m^3ha^{-1}tahun^{-1}$) dan *Paraserianthes falcataria* (34.18 $m^3ha^{-1}tahun^{-1}$) kerana mempunyai peratusan serapan, lembapan kandungan, dan kapasiti pertukaran kation yang baik. Berbeza dengan spesies *Acacia mangium* yang berupaya tumbuh di sebarang jenis tanah di satu-satu kawasan dengan kadar pertumbuhan di antara 19.06 $m^3ha^{-1}tahun^{-1}$ and 26.42 $m^3ha^{-1}tahun^{-1}$ Analisis "*Correlation*" di antara data isi padu spesies dengan iklim menunjukkan tahap isi padu spesies bergantung pada sukatan masa pancaran matahari harian. Perlaksanaan "*regression*" pula

menunjukkan ciri-ciri iklim iaitu purata suhu, sukatan hujan, bilangan hari hujan, dan sukatan masa pancaran matahari harian mempengaruhi tahap isi padu spesies (m^3ha^{-1}) di antara 65 hingga 76%, bergantung pada spesies. Rumusan indek setempat dan penghasilan kelas-kelas rumusan indek setempat mengikut spesies menunjukkan spesies *Gmelina arborea* hanya sesuai di kawasan rumusan indek kelas I. Perbezaan tahap ketinggian tertinggi yang ketara didapati di antara kelas-kelas rumusan indek setempat *Gmelina arborea* dan *Paraserianthes falcataria* jika dibandingkan dengan *Acacia mangium.*

Penghasilan persamaan pertumbuhan dan perolehan dengan mengunakan faktor tahap ketinggian tertinggi dirian dan garis pusat aras dada juga dihasilkan untuk *Gmelina arborea* (R^2 = 0.8947), *Paraserianthes falcataria* (R^2 = 0.8961) dan *Acacia mangium* (R^2 = 0.7915).

Analisis kewangan menunjukkan dengan melaksanakan pemadanan setempat untuk spesies kayu-kayan sebelum penubuhan ladang hutan tahap kadar pulangan dalaman adalah sebanyak 22.09% pada kadar 10% diskaun. Tambahan, senario perolehan semasa (*Net Presnt Value*) adalah positive dan '*ratio*' nilai hasil hutan ladang (keuntunggan yang diperolehi dari jualan hasil) dengan perbelanjaan membentuk hutan ladang untuk ketiga-tiga species kayu tersebut adalah lebih dari 1 pada kadar diskaun 10% dan 15%.

Justeru itu, aktiviti penyelidikan ini menghasilkan cara membuat kesimpulan tahap isi padu yang akan dicapai di masa hadapan, membuat keputusan, dan merancang penanaman bagi menentukan penghasilan optimum.

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APPROVAL

I certify that an Examination Committee has met on January 30, 2009 to conduct the final examnination of Ram Nathan on his thesis entitled "Species-Site Matching and Growth Prediction of Three Forest Plantation Species at Tawau , Sabah, Malaysia" in accordance with Universities and University Colleges Act 1971 and the Constitution of the University Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Master of Science.

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DECLARATION

I hereby declare that the thesis is based on my original work, except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Putra Malaysia or other institutions.

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RAM NATHAN

Date: 14 April 2009

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LIST OF ABBREVIATIONS

FAO	Food and Agriculture Organization
ITTO	International Tropical Timber Organization
SSB	Sabah Softwoods Berhad
SFM	Sustainable Forest Management
SFMLA	Sustainable Forest Management License Agreement
A.	*Acacia*
G.	*Gmelina*
P.	*Paraserianthes*
ANOVA	analysis of variance
CO_2	carbon dioxide
DBH	diameter at breast height
Hdom	height of dominant tree
MAI	mean annual increment
PSP	permanent sample plot
s.e.d	small end diameter
C/N ratio	carbon / nitrogen ratio
C	carbon
CEC	cation-exchange capacity
N	nitrogen
P	phosphorous

K	potassium
B/C ratio	Benefit / Cost ratio
IRR	Internal Rate of Return
NPV	Net Present Value
m^3	cubic meters
m^3yr^{-1}	cubic meters per year
$m^3ha^{-1}yr^{-1}$	cubic meters per hectare per year
m^3ha^{-1}	cubic meters per hectare
ha	hectare

CHAPTER 1

INTRODUCTION

1.1 General Background

Globally, the supply of valuable timber from the natural tropical forests is rapidly diminishing. The extensive harvesting and utilization of natural tropical forests to meet the world's demand of tropical timbers, is depleting such forests at an alarming rate. This inhibits the success of forest rehabilitation through natural regeneration. The insatiable demand and the race for development has also reduced forested areas and resulted in unsustainable logging. Such activity is due to various economic, political, and technical reasons especially for the generation of national revenue.

Future shortage of natural tropical timber is imminent both domestically and globally. Myers (1992) stated that the annual deforestation rate seems set to accelerate. According to the Food and Agricultural Organization (FAO), annually the conversion of the world's forest to other land uses and the non-rehabilitated logged areas constitute about 0.38% and 0.22%, respectively (Anon., 2001). In Malaysia, the harvesting and conversion of forested areas into other uses such as for agriculture, housing, and highways have reduced the area under forests.

The International Tropical Timber Organization's (ITTO) statistics on forested area in Malaysia for 2005 revealed that Malaysia with its total land area of 32.86 million ha has 60% of the country under forest (Anon., 2005). Table 1 shows the details.

Table 1: Forested area in Malaysia

Regions	Land area (million ha)	Natural forest area (million ha)	Plantation forest area (million ha)	Total area under forest (million ha)	% of forest to land area
Peninsular Malaysia	13.16	6.12	0.05	6.17	47
Sabah	7.37	4.21	0.17	4.38	59
Sarawak	12.33	8.70	0.40	9.10	74
Total	32.86	19.03	0.62	19.65	60

Source: Anon. (2005).

As this existing forest will be subjected to further agricultural and other non-forestry uses, a total of 14.6 million ha were earmarked as permanent forest estate. Of this, 3.2 million ha were under protection forest that is for both flora and fauna, and another 4.7 million ha delineated as production forest under Sustainable Forest Management (SFM) practices.

Malaysia now faces the growing depletion of timber supply from the natural forest. Though forecasts vary, ITTO documented (Table 2) that the total log production and log export showed a downward trend from 1990 to 2003 (Anon., 2005 and Zaini, 2008).

Table 2: Statistics on Malaysia's log production and export

Year	Log production (million m^3)	Log export (million m^3)
1990	39.10	20.30
1999	22.20	6.74
2003	21.50	5.47
2006	21.74	Not available

Source: Anon. (2005) and Zaini (2008).

Further, at the 19th "Mesyuarat Majlis Perhutanan Negara" held in August, 2005 and chaired by Y.A.B. Dato' Seri Mohd Najib bin Tun Abdul Razak, it was decided that the annual allowable cut for native forest in Peninsular Malaysia to be reduced by 38%. Based on the 9th Malaysian Plan, the estimated hectarage for harvesting by regions are 36,940 ha for Peninsular Malaysia, 60,000 ha for Sabah, and 170,000 ha for Sarawak. The export value of major timber products decreased from 2006 (RM23.4 billion) to 2007 (RM22.7 billion) by 3% even with the production of value-added products due to shortfalls of raw material supply.

In view of the above problems, the only solution is the establishment and development of forest tree plantations. These forests will help to reduce the pressure and promote the sustainable management of the native forest, and overcome the present decline in production of native timbers.

In Malaysia, initiation of forest tree plantation on experimental basis goes as far back as 1880. In the 1930s, Malaysian foresters noted that future timber supply of commercial trees species from natural forest faces shortfalls especially due to the uneven distribution of well-known species and the slow recouping growth rate of species that is 0.5 to 3.5 $m^3ha^{-1}yr^{-1}$ (Appanah and Weinland, 1993).

It was only in 1954-58 that researchers established experimental large-scale planting of teak and pines in both lowlands and mountains to gauge details of costs in both lowlands and mountains (Appanah and Weinland, 1993). Not long after 1970s, the slow growth rate became the main constraints responsible for the drop in the supply of native timbers in order to manage the productive forest under sustained yield

management system. Then, the Malaysian Government gave high priority to the establishment of forest tree plantations for the production of pulp due to its plan to establish pulp and paper mill. With the assistance of FAO and United Nation Development Program, it initiated large-scale planting of *Pinus caribaea* var *hondurensis*. Most of the planting of pines were at Ulu Sedili, Johore; Kemasul, Pahang; and Tawau, Sabah. However, the planting was discontinued due to shortage of available seedlings that resulted in slow rate of establishment, site-specific species, poor growth rate, and other technical problems.

Later, the Malaysian Government launched a Compensatory Forest Plantation Project funded by the Asian Development Bank in the early 1980s (Appanah and Weinland, 1993). The species for the project were exotics, namely, *Acacia mangium*, *Gmelina arborea* and *Paraserianthes falcataria*. However, only *A. mangium* was widely planted in most of the areas (Appanah and Weinland, 1993) except for Sabah where all the three trees species were planted.

Upon realization on the important roles and contributions of forest tree plantations to both the economy and the environment, the Malaysian Government underlined its seriousness on forest tree plantations in 1996, via a "Study on Baseline Information on Land in Malaysia for Conversion into Forest Plantations" (Anon., 1996). It provided comprehensive information on land availability and land issue that were regarded the most crucial elements of forest tree plantations investments to encourage the private sectors participation. The involvement of private sectors was not encouraging as the incentive provided based on Promotion of Investment Act,

1986 that is Pioneer Status and Investment Tax Allowance (Anon., 1997) were inadequate for forest tree plantations development.

In Sarawak, even though it has large area of natural productive forests, the State Government identified approximately one million ha of marginal land for conversion to forest tree plantations in the next 20 years. The State Government also formulated "The Forest (Planted Forests) Rules 1997" to serve as specific procedures and conditions for orderly establishment, maintenance and harvesting of existing natural marginal forest areas especially for purpose of planted forests (Shaharudin, 2005).

Currently, Sabah is not self-sufficient in its log production. The manufacturers are relying on imported raw materials and plantation timbers. In fact, in Sabah the involvement of private agencies in the establishment of forest tree plantations is encouraging. Large scale planting of exotic trees species began as early as 1974 with the formation of Sabah Softwood Sdn Bhd, presently known as Sabah Softwood Berhad (SSB), as it became evident that not all forest areas are suitable for agriculture development. Not long after, a few more major forest tree plantations agencies were also set up. These are Sabah Forestry Development Authority formed in 1976, with the aim to afforest 61,000 ha of degraded land; Sabah Forest Industries established in 1982 with 268,000 ha of forests land to be planted in order to supply raw materials for its pulp and paper mill; and Kebun Rimau Sendirian Berhad.

In 1997, to accelerate the forest restoration and reforestation activities, Sabah's State Government signed the Sustainable Forest Management License Agreement (SFMLA) with 10 companies (Figure 1).