



**UNIVERSITI PUTRA MALAYSIA**

**EVALUATION OF SITE EFFECTS ON FOREST PRODUCTIVITY OF  
PLANTED *Khaya ivorensis* A. CHEV. AND *Hopea odorata* ROXB. ON  
DEGRADED FORESTLAND IN SEGAMAT, JOHOR, MALAYSIA**

**YETTI HERYATI**

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**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in  
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MALAYSIA**

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in partial fulfilment of the requirements for the degree of Master of Science

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By

**YETTI HERYATI**

**December 2011**

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Tropical rainforests play an important role in ameliorating and maintaining global climate. Despite increasing recognition of their importance in the tropics, the amount of natural forests continues to decrease at an alarming rate, mainly due to rapid and extensive forest harvesting that damages soil and vegetation, concomitantly contributing to the degradation of forestland. In Segamat, Johor, Malaysia, there has been an effort by forestry-related local agencies such as the Forest Research Institute of Malaysia (FRIM) to reduce further degradation by rehabilitating forestland through the implementation of forest plantation using high-quality exotic (*Khaya ivorensis* A. Chev.) and indigenous (*Hopea odorata* Roxb.) species.

In order to evaluate the success of forest rehabilitation or plantation forest, one must understand and assess the abiotic factors of soil in relation to weathering and soil fertility

status, as well as biotic factors related to the site suitability of species. However, information on the soil characteristics of degraded forestlands and the suitability of specific exotic and indigenous species to these sites is limited or lacking. The present study of forest plantation of *K. ivorensis* and *H. odorata* was conducted five years after planting in degraded forestland in Segamat, Johor. This study is divided into four parts corresponding to the following objectives: (1) to characterize the soils of plantation forest (*K. ivorensis* and *H. odorata*) and an adjacent secondary forest, (2) to evaluate the growth performance and biomass accumulation of *K. ivorensis* in three different soil series, (3) to evaluate the soil fertility status of *K. ivorensis* in comparison with adjacent secondary forests using the soil fertility index (SFI) and soil evaluation factor (SEF), and (4) to assess the productivity and potential of *K. ivorensis* and *H. odorata* for sequestering the source of greenhouse gas CO<sub>2</sub>.

The focus of the first study is characterizing soil properties in terms of morphology, physico-chemical properties, and sesquioxide properties. For this purpose, two soil profiles were dug at each site for plantings of *K. ivorensis* and *H. odorata*, as well as in adjacent secondary forests. The soil profiles were described, followed by soil sampling according to soil horizon. The soils were moderately to strongly acidic both in plantation forests and secondary forests. The activity ratios of Al (Alo/Ald) and Fe (Feo/Fed) of the soils at all sites were lower than 0.10, indicating that the soils were undergone to intense weathering and eventually reached the ultimately weathered stage. The point of zero salt effect (PZSE) and the residual charge at PZSE ( $\sigma_p$ ) values at all sites were low, and no clear differences in the profiles were associated with low amounts of Al and Fe oxides and hydroxides. In general, the soil fertility status was low due to intense weathering and the acidic nature of the soils.

The second study concerns the growth and biomass accumulation of *K. ivorensis* at five years old in three soil series (Padang Besar, Rengam, and Durian). At each soil site, three plots with a size of 30 x 40 m were demarcated. The height and diameter of five-year-old *K. ivorensis* were measured individually, followed by the calculation of survival rate and growth performance in terms of mean annual increment (MAI) in height and diameter. The destructive sampling method was performed at each stand of *K. ivorensis* where five standing trees were chosen to estimate biomass accumulation. The growth performance of *K. ivorensis* in terms of MAI in diameter, MAI in height, and basal area was highest at Padang Besar, followed by Durian and Rengam. The best fit regression of an allometric equation using D as an independent variable is recommended for estimating tree component biomass and stem volume at sites. The highest stem volume and biomass accumulation values were recorded at Padang Besar ( $77.99 \text{ m}^3 \text{ h}^{-1}$  and  $63.16 \text{ t ha}^{-1}$ , respectively), followed by Durian ( $53.10 \text{ m}^3 \text{ h}^{-1}$  and  $46.33 \text{ t ha}^{-1}$ , respectively) and Rengam ( $43.13 \text{ m}^3 \text{ h}^{-1}$  and  $40.96 \text{ t ha}^{-1}$ , respectively).

The third study compares soil fertility status for the Rengam, Padang Besar, and Durian series for *K. ivorensis* plantation in comparison with adjacent secondary forests by using the SFI and SEF. Soil samples were collected at depths of 0-10 cm (surface soils) and 20-30 cm (subsurface soils) in three replicates for each soil series at both sites. The results showed that soil pH both in planted and secondary forests was moderately acidic to slightly acidic, with low content of exchangeable bases and available P but high Al saturation. The SFI result revealed that the fertility status of Rengam soil was significantly higher than the fertility of the other two soil series, whereas no significant difference was observed in the case of SEF. Based on the SFI and SEF values, there were

no significant differences in fertility status between the planted and secondary forests for surface and subsurface soils. In general, planting *K. ivorensis* on degraded forestland seemed to increase soil fertility status, as was seen in secondary forests.

The fourth study assessing the productivity of planted *K. ivorensis* and *H. odorata* in terms of growth performance and biomass accumulation is elucidated for a similar soil series (Rengam series). In the Rengam soil series, the growth performance of *K. ivorensis* in terms of MAID, MAIH, and basal area was higher than that of *H. odorata*. Similarly, the stem volume of the *K. ivorensis* stand was  $43.13 \text{ m}^3 \text{ha}^{-1}$ , significantly higher than *H. odorata* stands volume of  $33.66 \text{ m}^3 \text{ ha}^{-1}$ . Nevertheless, the growth performance for *H. odorata* in this study was higher than in the previous study. *K. ivorensis* and *H. odorata* stands have the potential to absorb CO<sub>2</sub> from the atmosphere for storage in aboveground biomass with values of  $15.90 \text{ Mg C ha}^{-1}$  and  $13.62 \text{ Mg C ha}^{-1}$ , respectively. In addition, the carbon content in the root biomass of the *H. odorata* stand was higher than that in the *K. ivorensis* stand, with values of  $7.67 \text{ Mg C ha}^{-1}$  and  $4.58 \text{ Mg C ha}^{-1}$ , respectively.

In conclusion, rehabilitating degraded forestland by planting high-quality exotic and indigenous species improves the site quality and productivity of degraded forestland. In addition to the suitability of species to a site, soil fertility in situ should be considered when attempting to rehabilitate degraded forestland in the future.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia  
sebagai memenuhi keperluan untuk ijazah Master Sains

**PENILAIAN KESAN TAPAK TERHADAP PRODUKTIVITI HUTAN YANG  
DITANAM DENGAN SPESIS *Khaya ivorensis* A. CHEV. DAN *Hopea odorata*  
ROXB. DI HUTAN TEROSOT NILAI DI SEGAMAT, JOHOR, MALAYSIA**

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Hutan hujan tropika memainkan peranan penting dalam menjaga dan meningkatkan keseimbangan cuaca dunia. Walaupun dengan peningkatan dalam kesedaran kepentingan hutan hujan tropika, hutan asli ini masih diterokai pada kadar yang membimbangkan akibat pengeluaran hasil hutan yang berleluasa dan cepat yang akhirnya menyebabkan tanah dan tumbuhan ternyah-gred. Institut Penyelidikan Perhutanan Malaysia (FRIM) adalah antara agensi berkaitan perhutanan di Malaysia yang menubuhkan hutan ladang yang ditanam dengan spesies pokok eksotik berkualiti tinggi (*Khaya ivorensis* A. Chev.) dan spesies tempatan (*Hopea odorata* Roxb.) di Segamat, Johor, Malaysia dalam usaha untuk mengurangkan ternyah-gred hutan.

Untuk menilai kejayaan pemulihan hutan atau ladang hutan, pemahaman dan penilaian faktor abiotik ciri-ciri tanah berhubung dengan cuaca dan status kesuburan tanah ditambah faktor biotik dari segi kesesuaian spesies dengan tapak perlu diambil kira. Walau bagaimanapun, maklumat mengenai ciri-ciri tanah dan kesesuaian

spesifik spesies eksotik dan tempatan yang ditanam atas hutan ternyah-gred adalah terhad atau kurang. Penyelidikan ini telah dijalankan di dalam ladang hutan *K. ivorensis* dan *H. odorata* di tapak kajian berumur lima tahun di hutan ternyah-gred di Segamat, Johor. Penyelidikan ini terdiri daripada empat topik kajian dan objektif kajian ini adalah untuk (1) mengenalpasti ciri-ciri tanah dalam hutan ladang (*K. ivorensis* dan *H. odorata*) dan hutan sekunder yang bersebelahan, (2) menilai prestasi pertumbuhan dan pengumpulan biojisim *K. ivorensis* dalam tiga siri tanah yang berbeza, (3) menilai status kesuburan tanah di bawah *K. ivorensis* dan dibandingkan dengan hutan sekunder bersebelahan dengan menggunakan Indeks Kesuburan Tanah (SFI) dan Penilaian Faktor Tanah (SEF) dan (4) menilai produktiviti dan potensi *K. ivorensis* dan *H. odorata* menyimpan gas rumah hijau CO<sub>2</sub>.

Fokus kajian pertama adalah untuk mencirikan sifat-sifat tanah dari segi morfologi, fizik-kimia dan sifat-sifat seskuoksida. Dua profil tanah digali pada setiap tapak hutan ladang *K. ivorensis* dan *H. odorata* dan hutan sekunder bersebelahan. Profil tanah telah dicirikan dan diikuti dengan pensampelan tanah mengikut horizon tanah. Tanah didapati sederhana ke berasid tinggi dalam kedua-dua hutan ladang dan hutan sekunder bersebelahan. Nisbah aktiviti Al (Alo/Ald) dan Fe (Feo/Fed) tanah di semua tapak adalah kurang dari 0.10, menunjukkan bahawa tanah telah sampai ke peringkat tahap luluhan yang tinggi. Nilai point zero salt effect (PZSE) dan  $\sigma_p$  di semua tapak didapati rendah dan tiada perbezaan yang jelas di seluruh profil yang dikaitkan dengan jumlah Al dan Fe oksida dan hidroksida yang rendah. Secara umumnya, status kesuburan tanah adalah rendah disebabkan oleh luluhan tinggi dan keasidan tanah.

Kajian kedua menekankan pertumbuhan dan pengumpulan biojisim *K. ivorensis* pada tiga siri tanah yang berbeza (Padang Besar, Rengam, Durian). Pada setiap siri tanah, tiga plot dengan saiz 30 m x 40 m telah ditentukan dengan jelas. Ketinggian dan diameter setiap *K. ivorensis* yang berumur lima tahun diukur dan diikuti dengan pengiraan kadar kemandirian dan prestasi pertumbuhan dari segi kenaikan tahunan purata ketinggian dan diameter. Kaedah pensampelan secara tebangan dilakukan dalam setiap tapak *K. ivorensis* di mana lima pokok dipilih untuk ditentukan prestasi pertambahan biojisim. Kadar pertumbuhan di tapak *K. ivorensis* dari segi purata pertumbuhan tahunan (MAI) diameter, ketinggian dan luas kawasan pangkal adalah lebih tinggi di tanah bersiri Padang Besar, diikuti oleh Durian dan Rengam. Regresi alometrik terbaik menggunakan D sebagai pembolehubah bebas yang disyorkan untuk mengangarkan biojisim komponen pokok dan isipadu batang dalam setiap tapak. Isipadu batang tertinggi dan pengumpulan biojisim dicatatkan tertinggi di Padang Besar (masing-masing  $77.99 \text{ m}^3 \text{ h}^{-1}$  dan  $63.16 \text{ t ha}^{-1}$ ), diikuti siri Durian (masing-masing  $53.10 \text{ m}^3 \text{ h}^{-1}$  dan  $46.33 \text{ t ha}^{-1}$ ) dan siri Rengam (masing-masing  $43.13 \text{ m}^3 \text{ h}^{-1}$  and  $40.96 \text{ t ha}^{-1}$ ).

Kajian ketiga memberi tumpuan kepada membandingkan status kesuburan tanah di siri tanah Rengam, Padang Besar dan Durian yang ditanam dengan *K. ivorensis* dengan hutan sekunder bersebelahan menggunakan indeks kesuburan tanah (SFI) dan faktor penilaian tanah (SEF). Sampel tanah diambil pada kedalaman 0-10 cm (tanah permukaan) dan 20-30 cm (bawah permukaan tanah) dalam tiga replikasi untuk setiap siri tanah di kedua-dua tapak. Hasil kajian menunjukkan bahawa pH tanah di kedua-dua tapak hutan ladang dan hutan sekunder adalah berasid sederhana ke rendah dengan kandungan pertukaran bases dan kebolehdapatan P yang rendah tetapi tinggi

dalam kandungan ketepuan Al. Keputusan SFI menunjukkan bahawa status kesuburan tanah Rengam adalah jauh lebih tinggi daripada dua siri tanah yang lain manakala tiada perbezaan ketara yang diperhatikan untuk SEF. Berdasarkan nilai-nilai SFI dan SEF, tidak ada perbezaan yang ketara dalam status kesuburan antara hutan ladang dan hutan sekunder bagi tanah permukaan dan bawah permukaan. Secara umum, penanaman *K. ivorensis* di tanah ternyah-gred dapat meningkatkan status kesuburan tanah seperti yang dilihat dalam hutan sekunder.

Kajian keempat menilai produktiviti tanaman *K. ivorensis* dan *H. odorata* dari segi prestasi pertumbuhan dan pengumpulan biojisim telah dibuktikan pada siri tanah yang sama (siri Rengam). Dalam siri tanah Rengam, prestasi pertumbuhan *K. ivorensis* dari segi ketinggian purata diameter MAI dan ketinggian, dan kawasan pangkal lebih tinggi daripada *H. odorata*. Begitu juga dengan isipadu batang *K. ivorensis*,  $43.13 \text{ m}^3 \text{ha}^{-1}$  dan *H. odorata* adalah  $33.66 \text{ m}^3 \text{ ha}^{-1}$ . Walau bagaimanapun, prestasi pertumbuhan *H. odorata* dalam kajian ini adalah lebih tinggi berbanding dengan kajian sebelumnya. Dirian *K. ivorensis* dan *H. odorata* mempunyai potensi untuk menyerap  $\text{CO}_2$  dari atmosfera yang disimpan dalam biojisim atas tanah dengan nilai masing-masing  $15.90 \text{ Mg C ha}^{-1}$  and  $13.62 \text{ Mg C ha}^{-1}$ . Di samping itu, kandungan karbon dalam biojisim akar di dirian *H. odorata* adalah lebih tinggi daripada *K. ivorensis* dengan nilai masing-masing  $7.67 \text{ Mg C ha}^{-1}$  dan  $4.58 \text{ Mg C ha}^{-1}$ . Kesimpulannya, pemulihan tanah hutan ternyah-gred dengan penanaman spesies eksotik dan tempatan yang berkualiti tinggi dapat meningkatkan kualiti dan produktiviti tapak ternyah-gred. Tambahan juga kepada spesies di tapak tertentu, kesuburan tanah secara in-situ juga perlu dipertimbangkan apabila memulihkan kawasan ternyah-gred sedemikian pada masa akan datang.

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I certify that a Thesis Examination Committee has met on 15<sup>th</sup> December 2011 to conduct the final examination of Yetti Heryati on her thesis entitled "**Evaluation of Site Effects on Forest Productivity of Planted *Khaya ivorensis* A. Chev. and *Hopea odorata* Roxb. on Degraded Forestland in Segamat, Johor, Malaysia**" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the degree of Master of Science.

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## **DECLARATION**

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

**YETTI HERYATI**

**Date: 15 December 2011**



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