UNIVERSITI PUTRA MALAYSIA

EFFECTS OF DIFFERENT REHABILITATION METHODS AND SOIL PARAMETERS ON THE ESTABLISHMENT OF FOREST TREE SEEDLINGS IN A DEGRADED FOREST

MASWAR

EFFECTS OF DIFFERENT REHABILITATION METHODS AND SOIL PARAMETERS ON THE ESTABLISHMENT OF FOREST TREE SEEDLINGS IN A DEGRADED FOREST

By

M A S W A R

Thesis Submitted in Fulfilment of the Requirement for the Degree of Master of Agricultural Science in the Faculty of Agriculture Universiti Putra Malaysia

December 2000

بسم الله الرحمن الرحيم

In the Name of Allah, Most Gracious, Most Merciful

Dedicated to my:

Parents *Bahar Dj* **&** *Rosna*

mother-in-law *Hasanur*

wife *Helfianty*

and children *Alvin Al Asyraf Maswar* **&** *Arifin Al Amiri Maswar*

Abstract of the thesis submitted to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Agriculture Science.

EFFECTS OF DIFFERENT REHABILITATION METHODS AND SOIL PARAMETERS ON THE ESTABLISHMENT OF FOREST TREE SEEDLINGS IN A DEGRADED FOREST

By

M A S W A R

December 2000

Chairman: Assoc. Prof. Dr. Mohd. Mokhtaruddin Abd. Manan

Faculty: Agriculture

The degradation of forests not only results in the loss of productive timber but also many other socio-economic and ecological problems. Thus, rapid forest recovery of the logged-over forest is important. Amongst the strategies that can be used to establish productive forest are selection of plant species, methods of establishment and subsequent vegetation management techniques. Therefore, the objectives of this study are: 1) to identify suitable methods for rehabilitation of logged-over forest and 2) to identify the most important soil parameters affecting seedling growth.

The study was carried out on a degraded logged-over lowland tropical forest, located in Pasoh Forest Reserve, Negeri Sembilan, Peninsular Malaysia. Four rehabilitation methods tested were: T1 for line planting, with lines set from west to east with a width of 3m, 5m and 10m and distance between lines was 10m; T2 for gap planting of 10m x 10m x 5/ha; T3 for gap planting of 20m x 20m x 5/ha; and T4 for gap planting of 10m x 10m x 9/ha. The lines and gaps were planted with three timber species namely *Azadirachta excelsa, Hopea odorata,* and *Vitex pubescens*. The suitability of the methods was evaluated by measuring seedlings survival, biomass production, changes in soil properties and cost establishment.

One year after planting, height increment of seedlings of *Azadirachta excelsa* and *Hopea odorata* was measured. *Vitex pubescens* was not included because there was no visible growth increment during the one-year period. Soil samples from the surface soil were collected from the vicinity of the seedlings for the determination of physical and chemical properties. Statistical analysis was conducted in order to establish relationships between soil parameters and seedlings growth.

The results showed that there were no significant difference in the survival of the seedlings of all species one-year after planting and they adapted quite well to degraded soil conditions. This implies that all the rehabilitation methods and species are suitable for rehabilitation of degraded logged-over forest in this area. However, in term of biomass production T1 was found to be the best method of rehabilitation but in term of cost T2 was found to be the cheapest.

The simple regression equations between soil parameters and height increment showed that the soil parameters limiting the growth of *Azadirachta excelsa* are thickness of A-horizon, texture, penetration resistance, available water capacity, organic matter, and exchangeable Ca and Mg. For *Hopea odorata,* the limiting

growth factors are thickness of A-horizon, macro-pore space and penetration resistance. However, the multiple linear regressions showed that the growth of young seedlings *Azadirachta excelsa*, and *Hopea odorata* is affected not only by single soil parameters but also by an interaction of several soil parameters.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi syarat keperluan untuk mendapatkan Ijazah Master Sains Pertanian.

KESAN DARIPADA KAEDAH PEMULIHAN YANG BERBEZA DAN CIRI-CIRI TANAH KE ATAS PERTUMBUHAN ANAK POKOK DI HUTAN TERDEGRADASI

Oleh

M A S W A R

Disember 2000

Pengerusi: Prof. Madya Dr. Mohd. Mokhtaruddin Abd. Manan

Fakulti: Pertanian

Degradasi hutan tidak hanya menyebabkan kehilangan hasil kayu yang produktif tetapi juga menyebabkan masalah sosio-ekonomi dan ekologi. Pemulihan segera hutan yang telah diteroka adalah penting. Antara strategi yang boleh digunakan untuk menghasilkan hutan yang produktif kembali adalah pemilihan spesies pokok, kaedah yang digunakan dan teknik pengurusan tnaman. Objektif kajian ini adalah 1) mengenal pasti kaedah pemulihan hutan yang sesuai 2) mengenal pasti ciri-ciri tanah yang penting dalam mmpengaruhi tumbesaran anak pokok.

Kajian telah dijalankan di kawasan hutan terdegradasi, terletak di Hutan Simpan Pasoh, Negeri Sembilan, Semenanjung Malaysia. Empat kaedah yang dikaji adalah: T1 untuk tanam mengikut jaluran, dimana jaluran penanaman dibuat dari barat ke timur, dengan lebar 3m, 5m dan 10m, dan jarak antara jalur tanaman 10m; T2 untuk tanam secara kelompok 10m x 10m x 5/ha,; T3 untuk tanam secara

kelompok 20m x 20m x 5/ha; dan T4 untuk tanam secara kelompok 10m x 10m x 9/ha. Jaluran dan kelompok ditanam dengan tiga spesies pokok iaitu *Azadirachta excelsa*, *Hopea odorata* dan *Vitex pubescens.* Kesesuaian kaedah dinilai dengan jumlah anak pokok yang hidup, penghasilan biomas, perubahan ciri-ciri tanah dan kos yang digunakan.

Setahun selepas penanaman penambahan tinggi anak pokok *Azadirachta excelsa*, dan *Hopea odorata* disukat. *Vitex pubescens* tidak dimasukkan dalam pengiraan data kerana tidak ada penambahan tinggi yang nyata dilihat dalam jangkamasa tersebut. Sampel tanah dari permukaan tanah disekitar anak pokok yang dipilih diambil untuk penentuan ciri-ciri fizik dan kimia. Analisis statistik digunakan untuk menentukan perhubungan antara pertumbuhan anak pokok dan cirri-ciri tanah.

Keputusan menunjukkan bahawa satu tahun selepas ditanam tidak ada perbezaan bererti dalam kadar hidup kesemua spesies. Semua spesies menunjukkan kesesuaian dengan keadaan tanah yang telah terdegradasi. Kenyataan ini menunjukkan semua kaedah pemulihan hutan dan spesies adalah sesuai untuk pemulihan hutan yang telah diteroka untuk kawasan ini. Namun begitu, dalam penghasilan biomas T1 didapati adalah yang terbaik sementara T2 pula adalah terbaik dari segi ekonomi atau kos yang digunakan.

Pengiraan regresi ringkas antara ciri ciri tanah dan pertambaan tinggi tanaman, menunjukkan bahawa ciri-ciri tanah yang menghadkan pertumbuhan *Azadirachta* *excelsa* adalah ketebalan dari A-horizon, tektur, air tersedia, kepadatan tanah, bahan organan, dan Mg dan Ca dapat ditukar. Sifat tanah yang menghadkan pertumbuhan *Hopea odorata* adalah ketebalan dari A-horizon, kepadatan tanah, dan rongga pori makro. Regresi (multiple linear) menunjukkan bahawa pertumbuhan dari anak pokok tidak hanya dipengaruhi oleh satu ciri tanah sahaja tetapi oleh interaksi beberapa ciri-ciri tanah.

ACKNOWLEDGEMENTS

I would like to express my appreciation and most sincere gratitude to Associate Professor Dr Mohd. Mokhtaruddin bin Abdul Manan, chairman of my advisory committee for his constant guidance, helpful advice, encouragement and constructive criticism throughout the study.

Thanks are also due to my co-supervisors, Associate Professor Dr Faridah Hanum Ibrahim, Faculty of Forestry and Associate Professor Dr. Mohd. Kamil Yusoff, Faculty of Science and Environmental Studies, Universiti Putra Malaysia, for their valuable suggestions and comments. Special thanks are due to Profesor Dato' Dr. Nik Muhamad Nik Abd. Majid, Coordinator of UPM-CIFOR Project, for supporting my study at Universiti Putra Malaysia.

My thanks also go to the support staff of the soil physics laboratory, En. Mokhtar Mustapar, En. Ab. Aziz Abdullah, En. Arifin Abu Hassan and En. Mohd. Hanif Arshad for their cooperation and help in laboratory work. I am also thankful to En. Muzamal Johan, En. Ibrahim Edham and En. Abbas Alias from The Faculty of Forestry who helped me in the field. Especially to my colleague, Adrinal thanks for the assistance. I am also grateful to Mr. Muhammad Naseer from The Faculty of Modern Language who was kind enough to edit the whole text of the thesis.

Last but not least, heartfelt appreciation is due to my wife, Helfianty, for her understanding, constant encouragement and sacrifices, and to my children Alvin

Al Asyraf Maswar and Arifin Al Amiri Maswar for being an everlasting source of inspiration. To my father Bahar Dj, mother Rosna, mother-in-law Hasanur, brothers and sister, I wish them every success in this world and hereafter under the guidance and in the path of Allah.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

APO	Asian Productivity Organization
AW	available water
BD	bulk density
Ca	calcium
CEC	cation exchange capacity
FAO	Food and Agriculture Organization
K	potassium
MWD	mean weight diameter
MPa	mega Pascal
Mg	magnesium
N	nitrogen
Na	natrium
P	phosphorous
Pg	petagrams (peta = 10^{15})
p	probability
SOM	soil organic matter
SI	stability index
USDA	United States Department of Agriculture
%WSA>0.5	percentage of water stable aggregate larger than 0.5 mm

CHAPTER I

INTRODUCTION

One of the most serious problems facing tropical countries today is the severe degradation of their natural resources and the resource base it self. It is reported that tropical forest is disappearing increasingly each year. According to FAO (1998) between 1980 and 1995 the extent of world's forest decreased by some 180 million ha representing an annual loss of 12 million ha. Lamb (1994) reported that tropical forests are subjected to disturbance and change. The main reason of this degradation is unsustainably high harvesting levels (Kashio, 1994).

In Malaysia, large-scale agricultural schemes, exploitation logging and shifting cultivation have been cited as the main causes of forest destruction or degradation (Udarbe, 1994). While in Indonesia and Thailand, the expanding population, the demand for economic growth, shifting cultivation and expanding agricultural land as the major cause of deforestation (APO, 1990).

The loss and degradation of forest gave rise to not only the loss of production of timber but also led to many others socio-economic and ecological problems such as intensified seasonal flooding with loss of lives and property, water shortages in dry season, accelerated erosion of agriculture land, siltation of rivers and coastal waters, greenhouse gas emission, watershed instability and the disappearance of certain species of plants and animals (Kobayashi *et al*., 1996a; Kumar, 1994).

Plant succession is a natural process by which the forest ecosystem undergoes changes in structure and composition in response to its environment. It is also the mechanism by which the system heals itself from disturbances. However, natural succession is a slow process. Therefore, in degraded logged-over forest, some forms of additional input are needed to assist the system to recover faster.

Numerous strategies can be used to establish productive forest on degraded logged-over forestland; these include selection of plant species, methods of establishment and subsequent vegetation management techniques. According to Lamb (1994) various terms, such as “restoration”, “reclamation” and ”rehabilitation” have been used to describe a range of mitigation activities to counter the effects of environmental degradation.

In any of the methods employed, the important criteria is to achieve a rapid forest recovery. In this context, replanting tree species is often considered as one of the most effective rehabilitation approach, mainly through more efficient nutrient cycling (Sakurai *et al.,* 1994). Therefore, selection of suitable seedlings and planting methods are crucial to ensure the success of rehabilitation of degraded logged-over forestland.

Beside seedling type and rehabilitation technique, the fertility of soils can have a marked influenced on the establishment and in the type and quality of the natural growth of the young seedlings. Therefore, the ability to recognize the most important soil fertility parameters affecting growth can be invaluable to the agriculturist as well as the forester (Panton, 1995). Seedlings growth on degraded forestland may be limited by factors such as compaction, erosion, nutrient displacement, unsuitable moisture, thermal, and aeration regime and dysfunctional nutrient cycles. These factors may also interact with each other in various ways to produce favorable conditions for seedlings growth. Bulmer (1998) reported that the understanding on how the soil processes affect forest productivity has improved substantially in the past decade, and much of this information could be used to solve problems in rehabilitation of degraded forestland.

Therefore, the hypotheses for this study are:

i. Different methods of rehabilitation may affect on the survival and growth of seedlings.
ii. Different tree species may adapt differently to local conditions and
iii. Variation in tree growth may be the result of variability in soil parameters.

The objectives of the study are:

i. to identify suitable methods for rehabilitation of logged-over forest in tropical forest ecosystems.
ii. to identify the most important soil parameters affecting seedling growth under the logged-over tropical forest ecosystems.

CHAPTER II

LITERATURE REVIEW

Forest Ecosystems

Forest ecosystems are open systems in the sense that they exchange energy and material with other systems, including adjacent forest downstream ecosystem, and the atmosphere. The exchange is essential for the continued persistence of the ecosystem. Forest ecosystem does not consist of the forests only but the whole complex including the atmosphere, the climate, the soil and its living organisms, which influence the environmental quality (Shafi, 1992).

Forests have the following functions in the landscape: timber and wood production, water conservation, maintaining microclimatic and hygienic conditions, soil conservation and improvement, providing conditions for recreation, medicinal, aesthetic values and other functions (Mabberley, 1992). It also has a prominent role in the conservation of genetic diversity as these habitats contain a majority of the diverse species of the world (Balakrishnan, 1994).

On a larger dimension, forests offer protective roles against environmental changes. The complex roles-played by forests in the heat and water balance of the earth is undeniable (Idris, 1986). Forests are important carbon sinks and climatic stabilizers, store large quantities of carbon and prevent rapid changes in atmospheric carbon dioxide content. The ratio between the atmospheric and terrestrial carbon pools, in natural state, is globally balanced due to the opposing processes of photosynthesis and respiration of the forest vegetation (Raza, 1992).

Tropical Forest Ecosystems

Tropical forests are a complex, self-supporting and stable ecosystem. In this closed ecosystem, trees and other plant species are in equilibrium with soil and their environment (Lal, 1981). The tropical rain forest is the greatest storehouse of plant and animal species capable of providing many useful products. For example, in Malaysian tropical forest there are over 8,000 species of flowering plants of which 2,500 are tree species (Yong, 1987). Besides, there are well over 200 species of mammals, 600 species of birds, 130 species of snakes, 80 species of lizards and thousands of species of insects.

Forest in tropical regions varies widely in composition, structure, function and productivity because of the diversity of climates, soil types and biogeographic conditions where they grow. According to FAO (1998) tropical forest comprise of (a) *Evergreen Tropical Rainforest*: Occur where the annual rainfall is greater than 2,500 mm and where forest grows mostly at low elevation. They are evergreen, luxuriant, predominantly of hardwood species, have a complex structure and are rich in both plants and animals, and (b*) Moist Deciduous Tropical Forest*: Occur where the annual rainfall is between 1,000 and 2,500 mm. The composition and structure vary greatly depending on rainfall distribution, temperature and soil types.

Lal (1981) reported that if the rainfall is adequate, tropical rainforest occurs in a region approximately 10 degrees north and south of the equator. Tropical rain forest is found throughout Southeast Asia (excluding the easternmost island of Indonesia and the eastern coast of the Philippines) Peninsular Malaysia and southernmost Thailand has equatorial climates with little seasonality of rainfall.

In tropical rain forest, most plant nutrients are tied up in the vegetation, and there is an effective nutrient cycling. Rainfall interception, surface detention, evapotranspiration, and soil-water storage effectively decrease water run off to a minimum. Multi-storey canopy and leaf-litter protect the soil against raindrop impact and prevent soil detachment. Leaf litter and other organic residues rapidly decompose thereby enhancing the activities of soil fauna (Lal, 1981).

Current Situation of Tropical Forest Ecosystems

The amount of tropical forestland being disturbed each year as a result of forest harvesting is increasing. According to Udarbe (1994) the main cause of tropical forest loss and degradation are: poverty, over–population, shifting cultivation, extensive farming and over grazing, industrialization, uncontrolled logging, seasonal bushfires and the lack of funds and management technology. O'Hare (1992) reported that tropical rain forest are being cleared at a rate of about 110,000 – 120,000 km^2 per year.