UNIVERSITI PUTRA MALAYSIA

AN ESTIMATE OF PRIMARY PRODUCTIVITY IN AIR HITAM FOREST RESERVE

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Universiti Putra Malaysia

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By

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March 2000

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Natural forest is a mosaic of structural phases. Different growth stages have different productivity level. The main objective of this study is to estimate the net primary productivity (NPP) of three different growth stages in Air Hitam Forest Reserve by using the summation method.

The first study area is a more mature and diverse stand (Biodiversity Plot, BP). The second (Macaranga Plot I, MPI) and third study (Macaranga Plot II, MPII) areas are younger and more homogenous stands.

Trees in Diameter Class 10-20 cm dominated all the study plots accounting for between 56 and 78 % of all the trees in the plots. The basal area for BP was 21.1 m^2/ha, in MPI was 27.9 m^2/ha and MPII was 19.7 m^2/ha. The most common species in BP was *Eugenia griffithii* while in MPI and MPII it was *Macaranga gigantea*.

A modified equation was derived from *Acacia mangium* biomass equations and Kato's *et al.* (1978) equation. The total biomass estimated was 201.7 t/ha in BP,

273.6 t/ha in MPI and 151.8 t/ha in MPII. Biomass was estimated over two consecutive occasions. The estimated annual biomass increment (ΔY) was 0.8 t/ha/yr in BP, 1.3 t/ha/yr in MPI and 2.0 t/ha/yr in MPII.

Litter production was monitored for 14 months by using 0.7 x 0.7 m traps. The estimated mean annual litter production (ΔL) estimated in BP, MPI and MPII were 15.4 t/ha/yr, 8.7 t/ha/yr and 11.4 t/ha/yr respectively.

Grazing was estimated from values obtained in Pasoh Forest. The estimate for grazing (ΔG) for BP was 2.0 t/ha/yr, MPI was 2.7 t/ha/yr and MPII was 1.5 t/ha/yr.

By summing all the productivity components, the estimated NPP was 18.2 t/ha/yr in BP, 12.7 t/ha/yr in MPI and 14.9 t/ha/yr in MPII. The estimated GPP was 60.7 t/ha/yr in BP, 42.3 t/ha/yr in MPI and 49.7 t/ha/yr in MPII.

A carbon model was used to crosscheck the estimated total biomass and litter production. These predicted values are comparable to the values estimated by the summation method. Therefore, the estimated NPP is realistic.

In conclusion, Air Hitam Forest Reserve is a mosaic of different stages of recovery stages or successional sequence and these are reflected by the stands with different forest profiles, species composition, basal areas, total biomass, litter production, estimated NPP and GPP.

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

PENGANGGARAN PENGELUARAN PRIMER DI HUTAN SIMPAN AIR HITAM

Oleh

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Mac 2000

Pengerusi: **Profesor Madya Lim Meng Tsai, Ph.D.**

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Hutan semulajadi adalah suatu mozek fasa hutan. Fasa pertumbuhan yang berbeza akan memberi nilai pergeluaran yang berbeza. Objektif utama dalam kajian ini adalah untuk menganggarkan pengeluaran primer bersih (NPP) di tiga fasa pertumbuhan yang berbeza di Hutan Simpan Air Hitam dengan menggunakan kaedah perjumlahan.

Lokasi kajian pertama adalah dirian yang lebih matang dan pelbagai (Biodiversity Plot, BP). Lokasi kajian kedua (Macaranga Plot I, MPI) dan ketiga (Macaranga Plot II, MPII) adalah dirian yang lebih muda dan seragam di Kompartment 15.

Pokok Diameter Kelas 10-20 cm mendominasi di semua plot kajian dengan julat 56 ke 78 % daripada jumlah pokok di dalam plot. Luas pangkal untuk BP adalah 21.1 m^2/ha, MPI adalah 27.9 m^2/ha dan MPII adalah 19.7 m^2/ha. Spesis yang paling umum dijumpai di BP adalah *Eugenia griffithii* manakala di MPI dan MPII, ia adalah *Macaranga gigantea.*

Satu modifikasi persamaan diperolehi daripada persamaan biojisim *Acacia mangium* dan persamaan Kato *et al.* (1978). Anggaran jumlah biojisim adalah 201.7 t/ha di BP, 273.6 t/ha di MPI dan 151.8 t/ha di MPII Anggaran biojisim dibuat untuk dua kali berturut-turut. Anggaran pengumpulan biojisim tahunan (Δ Y) ialah 0.8 t/ha/thn di BP, 1.3 t/ha/thn di MPI dan 2.0 t/ha/thn di MPII.

Kajian sarap dijalankan selama 14 bulan dengan menggunakan bekas 0.7 x 0.7 m. Jumlah min pengeluaran tahunan sarap (Δ L) yang dianggarkan di BP, MPI dan MPII masing-masing adalah 15.4 t/ha/thn, 8.7 t/ha/thn dan 11.4 t/ha/thn.

Pemakanan oleh haiwan dianggarkan daripada nilai yang diperolehi di Hutan Pasoh Anggaran untuk pemakanan oleh haiwan (Δ G) di BP ialah 2.0 t/ha/thn, MPI ialah 2.7 t/ha/thn dan MPII adalah 1.5 t/ha/thn.

Dengan mencampurkan semua komponen pengeluaran, anggaran NPP ialah 18.2 t/ha/thn di BP, 12.7 t/ha/thn di MPI dan 14.9 t/ha/thn di MPII. Anggaran GPP adalah 60.7 t/ha/thn di BP, 42.3 t/ha/thn di MPI dan 49.7 t/ha/thn di MPII.

Satu model karbon digunakan untuk menyemak semula jumlah biojisim dan pengeluaran sarap. Nilai yang diramalkan adalah sebanding dengan nilai yang dianggarkan dengan kaedah perjumlahan. Maka, NPP yang dianggarkan adalah realistik.

Pada kesimpulannya, Hutan Simpan Air Hitam adalah mozek pelbagai fasa pemulihan atau peringkat sesaran dan ini ditunjukkan daripada dirian yang

mempunyai perbezaan dari segi profil hutan, komposisi spesies, luas pangkal, jumlah biojisim, pengeluaran sarap, NPP dan GPP.

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LIST OF ABBREVIATIONS

asl	Above sea level
BP	Biodiversity Plot
cal/m^2	Calories/square metre
CO_2	Carbon dioxide
$CO_2/m^2/day$	Carbon dioxide/square metre /day
dbh	Diameter at breast height
E (l)	Leaf Efficiency
FAO	Food and Agriculture Organization
g/m^3	gramme/cubic meter
$g/m^2/yr$	gramme/square metre/year
GPP	Gross Primary Productivity
Gt C/yr	Gigatonne Carbon/year
ha	hectare
IBP	International Biological Programme
kg/ha/yr	kilogramme/hectare/year
LAI	Leaf Area Index
MPI	Macaranga Plot I
MPII	Macaranga Plot II
NPP	Net Primary Productivity
PAR	Photosynthetically Active Radiation
t	tonne
t C/ha	tonne Carbon/hectare
t/ha	tonne/hectare
t/ha/yr	tonne/hectare/year
UNESCO	United Nations Educational, Scientific and Cultural Organization
UPM	Universiti Putra Malaysia

CHAPTER I

INTRODUCTION

Background

Forests are important reservoirs of carbon. Currently, the world's forests contain about 75 % of the living carbon held in terrestrial ecosystems (Houghton, 1993). Their destruction contributes about 25 % of the current human mediated emission of atmospheric CO_2. Conversely, reforestation could also remove a significant amount of CO_2 from the atmosphere in a decade (Unruh *et al*., 1993).

Realising the significant role of forests in the global carbon cycle, the Kyoto Protocol was introduced in 1997. It set a target of five percent reduction of the greenhouse gas emissions between 2008 and 2012 (Prebble, 1998). The adoption of the protocol introduced the term carbon trading. Carbon trading is based on the fact that as trees grow, they absorb carbon dioxide from the air, which they use to generate food necessary for their growth. In 1998, the Government of the State of New South Wales (NSW) signed agreements with two energy-producing companies to use the planted forest to offset the greenhouse emission produced by the companies. These agreements involve the purchase of carbon rights by these companies. These carbon rights are issued as carbon credit certificates which are transferable. Under the Kyoto Protocol, tree carbon is tradable (Asumadu, 1998).

It is estimated that 50 % of the tree biomass is carbon. As trees grow, the total amount of carbon stored increases with time, until the trees reach maturity when a natural equilibrium (between CO_2 respired and CO_2 photosynthesised) is achieved

(Brown, 1997; Asumadu, 1998). The forest has the ability to remove carbon dioxide from the atmosphere through the process of photosynthesis. Studies suggest that between 1.1 and 1.8 Gt C/yr can be sequestered in 50 years by the forestry sector (Makundi *et al.*, 1998). In Malaysia, studies suggest that approximately 1.8×10^{-7} Gt C/ha could be sequestered over a 60-year rotation in the Sabah forest under the Enhanced Natural Regeneration/Reforestation Project (Moura-Costa, 1996). Under a reduced-impact-logging project in Sabah, the reduction in carbon emission and enhanced sequestration is estimated at 6.5×10^{-8} Gt C/ha (Makundi *et al.*, 1998). Thus, the possibility of emission reductions in forestry and the potential for increasing carbon sequestration give the sector more important roles in measures to mitigate climate change as envisaged in the Kyoto Protocol.

To understand an ecosystem, we have to understand the ecology of organic matter production, storage at different trophic levels and the ecological determinants of energy transfers between trophic levels (Kimmins, 1997). Productivity is a concept that causes much confusion since it is used in many different senses. At the ecosystem level, the organic matter fixed by photosynthesis occurring in the forest over a period is considered the gross primary productivity (GPP). This is often expressed in tonne/hectare/year (t/ha/yr). Some of the organic matter fixed in photosynthesis is released again during respiration by the green plants for their own growth and maintenance. If respiration is deducted from GPP, it gives the net primary productivity (NPP), which represents the amount of organic matter available to the other trophic levels of the community (Longman and Jenik, 1987).

There are many factors which influence NPP. Generally, they are the physical factors, biological factors and disturbances. The physical factors that affect primary productivity are soil nutrient, climate and quantity of photosynthetically active radiation (PAR). Warmer climates are generally characterized by greater production than cooler ones, wetter climates are also more productive than dry ones (Clapham, 1989).

The biological factors that affect primary productivity are species composition, leaf characteristics such as leaf area index (LAI), leaf efficiency (E (l)), leaf arrangement, leaf structure and adaptation to water stress, nutrient conserving mechanisms, canopy structure and primary consumer. It is a common knowledge that a natural forest is a mosaic of structural phases (gaps, building and mature phase) of different floristic compositions. As a consequence, it is difficult to obtain one single figure for its biomass or productivity (Whitmore, 1986).

Disturbances in the forest can be natural and man made. These disturbances affect NPP. However, these depend on the degree of disturbances and soil degradation. Silvicultural treatments such as thinning and enrichment planting normally help to improve the productivity of the forest. Secondary succession after these disturbances depends on the response of the tree species to these changes. With different species regenerating the area, NPP will also be different.

Many tropical countries have extensively logged their forest and these areas are in various stages of recovery. Their role in sequestering carbon from atmosphere is believed to be important in influencing climate change. However, the actual

productivity and its dynamics of these forests are not clearly known. Moreover, forest planning requires ecological information such as primary productivity which forms the basis for landuse planning and forest activities such as for harvesting, cutting cycle and silvicultural treatments.

Realising the importance of NPP, this study attempted to estimate the NPP of forest stands at different ages. Air Hitam Forest Reserve has been logged over a number of decades and has stands at different stages of recovery. To compare the productivity of the forest stands at different stages of recovery, plots were established in stands of different successional stages.

Objective

This project attempted to estimate the NPP of stands at different growth or recovery stages. Realising that different phases in the growth cycle give different values of NPP, it is interesting to compare how well the stands recovered from the past disturbances. The overall objective of the study was to estimate the NPP of three different forest stands with different characters indicative of different age sequences. NPP was estimated by using the summation method, in which annual biomass increment, litter production and grazing were summed. Biomass was estimated by using a modified allometric equation. It was estimated over two consecutive years. The difference is taken as the biomass increment. Litter production was estimated using randomly placed litter traps in the study plots. Litter was collected regularly over 14 months. The estimate for grazing was not estimated directly and the figure used is adopted from other researchers after a review. Specifically, the study aimed:

i) To compare the forest structure and species composition at different recovery stages of the lowland forest, and

ii) To estimate and compare the NPP at different recovery stages of the lowland forest.

CHAPTER II

LITERATURE REVIEW

This chapter will review the literature related to this study. They are the net primary productivity (NPP), biomass and litter production. As the NPP is the increase of plant biomass in an area over a period minus the losses of net production such as the death of plants, biomass and litter production will also be reviewed in this chapter. The final section deals with the forest dynamics.

Primary Productivity

Introduction

Biologists have been interested in plant productivity for a long time. There are three major periods of research in plant primary productivity. These are (1) before Leibig (384 B.C.-1840), (2) from Liebig to the International Biological Programme (IBP) (1840-1964) and (3) the post IBP (1964 onwards) (Lieth, 1975). However, it is only during the last few decades that studies of primary production of forest ecosystems have been conducted worldwide by many scientists (Satoo and Madgwick, 1982). One of the pioneer studies was done by Ebermeyer in 1876. He measured the amount of leaf and branch litter in forest of important tree species in Germany, determined their inorganic composition and analysed the effects of litter removal on the properties of forest soil and growth of forest trees. The results of his work constitute what we now call nutrient cycling in forest ecosystems.

Biologists have concentrated on physiological processes of plants and not on the processes of production of organic matter in the ecosystem while agronomists and forest scientists studied the yield of what could be harvested and neglected the total production of organic matter as the basis of determining yield (Satoo and Madgwick, 1982).

In general, productivity is the accrual of matter and energy in biomass. The first step in this process is termed primary productivity. It is expressed in units of biomass per unit area per unit time (example: kg/ha/yr). This is performed by green plants, which are the only organisms capable of capturing the electromagnetic energy of the sun and converting it into chemical energy in the form of reduced carbon compounds-photosynthates or carbohydrates (Perry, 1994).

The total fixation of organic matter by photosynthesis is called gross primary productivity (GPP). It is not easy to measure GPP because some of the carbohydrate is lost through respiration. If we measure the total organic material present in the plant, we are measuring net primary productivity (NPP) (Clapham, 1989; Jackson and Jackson, 1997). NPP is the rate of production of organic matter minus respiration but including all losses due to litter fall, root sloughing, grazing, fruits and seed fall (Egunjobi, 1969; Kimmins, 1997).

Importance of Primary Productivity Studies

Rational forest planning requires ecological information such as primary productivity. This is because people either use tropical forests for products such as firewood, food and fibre or convert them into agricultural land or other land use