



**UNIVERSITI PUTRA MALAYSIA**

**LITTERFALL, THROUGHFALL AND STEMFLOW  
IN ACACIA MANGIUM STANDS ON TIN TAILINGS AND  
THEIR EFFECTS ON SOIL CHEMICAL PROPERTIES**

**INDRESHWAR PRASAD INDU**

**FH 1995 5**



LITTERFALL, THROUGHFALL AND STEMFLOW IN *ACACIA MANGIUM*  
STANDS ON TIN TAILINGS AND THEIR EFFECTS ON  
SOIL CHEMICAL PROPERTIES

By

INDRESHWAR PRASAD INDU

Thesis Submitted in Fulfillment of the Requirements for  
the Degree of Master of Science in the Faculty of  
Forestry, Universiti Pertanian Malaysia

January, 1995



THIS WORK IS DEDICATED TO  
MY LATE FATHER---SREE RAM BILAS PRASAD



## ACKNOWLEDGEMENTS

I would like to express my sincere appreciation and deep gratitude to Associate Professor Dr. Lim Meng Tsai (Chairman of my Supervisory Committee), for his wise counsel, constant guidance, healthy criticism, constant encouragement, persistent inspiration and various logistic support throughout the entire graduate programme. Grateful appreciation is extended to Dr. Lai Food See and Professor Dr. Nik Muhamad Majid for serving on my committee and providing invaluable support, suggestions and comments at the various stages of this study.

My sincere appreciation is also expressed to Mr. Abdul Aziz Bashir, Senior Assistant Registrar, for his comments that improve the manuscript of this thesis.

Sincere gratitude is expressed to the Institute of Forestry (IOF), Nepal for granting study leave and to Institute of Forestry Project (IOFP) for providing financial support. My sincere gratitude is also extended to the Intensification of Research in Priority Areas (IRPA) Project and the International Development Research Centre (IDRC) for financial support.

My special thanks go to fellow graduate students Mr. Bimal, Dr. Shah, Mr. Thakur, and Mr. Neeraj for the stimulating discussions, suggestions and warm friendship.



I am deeply appreciative of my mother, Rukminni Devi and wife, Kaushalya for their sacrifices, devotion and understanding which have always been a source of inspiration throughout the entire period of my graduate study. Finally, I am especially grateful to my loving sons (Avishek & Kishlay), daughter (Pinky) and brother (Shashi), who, with their patience and understanding, were a constant source of inspiration.

Above all, my humble praises to Lord Siva who made this possible.



## TABLE OF CONTENTS

<b>ACKNOWLEDGEMENTS</b> .....		iii
<b>LIST OF TABLES</b> .....		viii
<b>LIST OF FIGURES</b> .....		xii
<b>LIST OF PLATES</b> .....		xiii
<b>ABSTRACT</b> .....		xiv
<b>ABSTRAK</b> .....		xvi
<b>CHAPTER</b>		
<b>I</b>	<b>INTRODUCTION</b> .....	1
<b>II</b>	<b>LITERATURE REVIEW</b> .....	6
	Litter Production .....	6
	Litter Production Measurement in the Tropics .....	7
	Factors Affecting Litterfall .....	8
	Patterns of Litter Production ....	10
	Nutrient Concentration in Litter .	11
	Litter Accumulation .....	11
	Litter Accumulation Measurement in the Tropics .....	15
	Turnover Constant (k) .....	15
	Litter Decomposition .....	16
	Magnitude of Litter Decomposition Methods Used in the Estimation of Rate of Decomposition .....	17
	Factors Affecting Litter Decomposition .....	18
	Throughfall, Stemflow and Interception .	23
	Throughfall .....	23
	Stemflow .....	34
	Interception .....	41
	Nutrient Status of Malaysian Soils .....	43
	Role of Forest Litter Improving Nutrient Status of Soil .....	45



III	<b>MATERIALS AND METHODS</b> .....	47
	Site Description .....	47
	Climate .....	49
	Soil Characteristics .....	49
	Experimental Layout .....	50
	Data Collection .....	51
	Litter Production .....	51
	Litter Accumulation .....	52
	Litter Decomposition .....	53
	Gross Rainfall Measurement .....	54
	Throughfall Measurement .....	54
	Stemflow Measurement .....	56
	Soil Sampling .....	58
	Soil Analysis .....	58
	Litter Analysis .....	60
	Analysis of Throughfall, Stemflow and Rainfall Samples .....	61
IV	<b>RESULTS AND DISCUSSION I: LITTER PRODUCTION, ACCUMULATION AND DECOMPOSITION</b> .....	63
	Litter Production .....	63
	Leaf Litter Production .....	64
	Twig Litter Production .....	66
	Miscellaneous Litter Production ..	66
	Total Litter Production .....	67
	Nutrient Concentration of Litter Components .....	69
	Nutrient Flux Through the Litter .	79
	Litter Accumulation .....	84
	Ground Leaf Litter .....	84
	Ground Twig Litter .....	85
	Ground Miscellaneous Litter .....	88
	Total Ground Litter .....	88
	Ground Leaf Litter Mineral Nutrients .....	89
	Litter Decomposition .....	98
V	<b>RESULTS AND DISCUSSION II: THROUGHFALL AND STEMFLOW</b> .....	104



	Throughfall, Stemflow and Interception .	104
	Throughfall .....	104
	Stemflow .....	109
	Interception .....	118
	Nutrients in Precipitation Components ..	121
	Nutrient Concentration in Precipitation Components .....	122
	Nitrogen .....	122
	Phosphorous .....	126
	Potassium .....	127
	Calcium .....	128
	Magnesium .....	130
	Nutrient Flux via Throughfall and Stemflow .....	131
VI	RESULTS AND DISCUSSION III: SOIL NUTRIENT STATUS .....	136
	Results.....	136
	Soil Organic Matter .....	136
	Soil pH .....	137
	Soil Nitrogen .....	137
	Soil Phosphorous .....	137
	Exchangeable Potassium .....	139
	Exchangeable Calcium .....	139
	Exchangeable Magnesium .....	140
	Discussion..	140
VII	GENERAL DISCUSSION .....	150
VIII	SUMMARY, CONCLUSIONS AND RECOMMENDATIONS .....	156
	Summary.....	156
	Conclusions. ....	159
	Recommendations .....	160
BIBLIOGRAPHY	.....	162
APPENDIX	Additional Tables .....	176
BIOGRAPHICAL SKETCH.....		192





## LIST OF TABLES

Table		Page
1	Litterfall, Ground Litter and Turnover Coefficient (k) for Various Tropical Forest .....	9
2	Average Nutrient Concentration of Litter in Various Tropical Forest .....	12
3	Return of Nutrients Via Litterfall in Various Tropical Forest .....	13
4	Relative Magnitude of Interception, Throughfall and Stemflow Under Natural and Plantation Forest in Temperate Region .....	25
5	Relative Magnitude of Interception, Throughfall and Stemflow Under Natural and Plantation Forest in Tropical Region .....	26
6	Factors Affecting Throughfall .....	28
7	Return of Nutrients Via Precipitation, Throughfall and Stemflow to the Soil (kg/ha/yr) in Various Forest. ....	35
8	Factors Affecting Stemflow .....	38
9	Factors Affecting Interception .....	43
10	Time Schedule of Data Collection .....	51
11	Monthly Mean of Litterfall in <i>A. mangium</i> Covered Plot at UPM (Site A) and Semenyih (Site B) from January, 1992 to December, 1992 .....	65
12	Mean Concentration of Nutrients in the Different Litter Component in Decreasing Order in <i>A. mangium</i> Covered Plot at UPM (Site A) and Semenyih (Site B) .....	70



13	Mean nutrients Concentrations of Litter and Litter Components in Some Tropical Forest .....	72
14	Comparison of Mean Nutrient Concentration in Different Litter Components in <i>A. mangium</i> Covered Plot at UPM (Site A) and Semenyih (Site B).....	73
15	Monthly Return of Nutrients Through Litterfall in <i>A. mangium</i> Covered Plot at UPM (Site A) and Semenyih (Site B). ....	81
16	Content of N, P, K, Ca and Mg for Total Litter and its Different Components in <i>A. mangium</i> Covered Plot at UPM (Site A) and Semenyih (Site B).....	82
17	Bimonthly Mean Biomass of Litter Layer on Different Six Occasion from February to December 1992, in <i>A. mangium</i> Covered Plot at UPM (Site A) and Semenyih (Site B) .....	86
18	Comparison of Ground Litter Components Mean Biomass, Nutrient Concentration and Mean Nutrient Content in Ground Leaf Litter in <i>A. mangium</i> Covered Plot at UPM (Site A) and Semenyih (Site B) .....	87
19	Bimonthly Nutrient Concentration Mean of Ground Leaf Litter in <i>A. mangium</i> Covered Plot at UPM (Site A) and Semenyih (Site B) .....	91
20	Bimonthly Nutrient Content Mean of Ground Leaf Litter at <i>A. mangium</i> Covered Plot at UPM (Site A) and Semenyih (Site B). ....	92
21	Nutrient Content (N, P, K, Ca and Mg) of Leaf Litter, Mean Ground Leaf Litter and their Turnover Coefficient in Some Tropical Forest.....	96



22	Weekly Rates of Decomposition of of <i>A. mangium</i> Leaves from March to December, 1992 in <i>A. mangium</i> Covered Plot at UPM (Site A) and Semenyih (Site B). . . . .	100
23	Throughfall (T), Stemflow (S) and Interception (I) on Depth Basis of Gross Rainfall (Re) for Different Sub-plots Under <i>A. mangium</i> Covered Covered Plot at UPM (Site A) and and Semenyih (Site B) from October 1991 to October 1992 . . . . .	107
24	Average Throughfall (T), Stemflow (S) and Interception (I) on Depth Basis (mm) and Percentage (%) of Gross Rainfall (Re) for <i>A. mangium</i> Covered Plot at UPM (Site A) and Semenyih (Site B) . . . . .	107
25	Summary of Regression Equations for <i>A. mangium</i> Covered Plot at UPM (Site A) and Semenyih (Site B) . . . . .	108
26	Some Characteristics of Tree Used for Stemflow Sampling in the <i>A. mangium</i> Study plots at UPM (Site A) and Semenyih (Site B) . . . . .	110
27	Monthly Concentration and Content of Nutrients in Precipitation, Throughfall and Stemflow Under <i>A. mangium</i> Covered Plot at UPM (Site A) . . . . .	124
28	Monthly Concentration and Content of Nutrients in Precipitation, Throughfall and Stemflow Under <i>A. mangium</i> Covered Plot at Semenyih (Site B) . . . . .	125
29	Nutrient Contents of Precipitation, Throughfall and Stemflow with Net Leaching/ Retention and Total Added to the <i>A. mangium</i> Covered Soil at Both Sites (UPM and Semenyih) From July to October 1992 . . . . .	133



30	Comparison of Some Soil Properties of Grass Covered Soil and <i>A. mangium</i> Covered Soil at UPM (Site A) and Semenyih (Site B) .....	138
31	Comparison of Some Soil Properties Under Grass Covered Soil Between UPM (Site A) and Semenyih (Site B) .....	142
32	Comparison of Some Soil Properties Between <i>A. mangium</i> Covered Soil at UPM (Site A) and Grass Covered Soil Semenyih (Site B) .....	144
33	Comparison of Some Soil Properties Between <i>A. mangium</i> Covered Soil at Semenyih (Site B) and Grass Covered Soil UPM (Site A) .....	144
34	Comparison of Some Soil Properties <i>A. mangium</i> Covered Soil at UPM (Site A) and Semenyih (Site B) .....	145
35	Total Nutrients Added to the Soil Via Litter, Throughfall and Stemflow at <i>A. mangium</i> Covered Plot UPM (Site A) and Semenyih (Site B).....	155



## LIST OF FIGURES

Figure	Page
1 Location of the Study Site (a) Universiti Pertanian Malaysia Farm (Site A) and (b) Semenyih, Selangor (Site B) .....	48
2 Litter Production (a) Leaves, (b) Twigs and (c) Miscellaneous .....	68
3 Loss of Original Dry Weight After Time (Week) in (a) UPM (Site A) and (b) Semenyih (Site B) .....	101
4 Regression of Average Throughfall on Gross Rainfall UPM (Site A) and (b) Semenyih (Site B) .....	106
5 Regression of Average Stemflow on Gross Rainfall (a) UPM (Site A) and (b) Semenyih (Site B) .....	113
6 Regression of Average Stemflow Against Intercepting Crown Area (a) UPM (Site A) and (b) Semenyih (Site B).....	114
7 Regression of Average Stemflow Against Crown Diameter (a) UPM (Site A) and (b) Semenyih (Site B) .....	115
8 Regression of Average Stemflow Against Crown Depth (a) UPM (Site A) and (b) Semenyih (Site B) .....	116
9 Regression of Average Stemflow Against Height (a) UPM (Site A) and (b) Semenyih (Site B) .....	117
10 Regression of Average Interception on Gross Rainfall (a) UPM (Site A) and (b) Semenyih (Site B) .....	120



LIST OF PLATES

Plate		Page
1	A Typical Design of Trough Used in Troughfall Measurement .....	55
2	The Stemflow Collar Design Used in Stemflow Measurement .....	55



Abstract of thesis submitted to the Senate of the Universiti  
Pertanian Malaysia in fulfillment of the requirements for the  
degree of Master of Science.

LITTERFALL, THROUGHFALL AND STEMFLOW IN *ACACIA MANGIUM*  
STANDS ON TIN TAILINGS AND THEIR EFFECTS  
ON SOIL CHEMICAL PROPERTIES

by

INDRESHWAR PRASAD INDU

January, 1995

Chairman: Associate Professor Dr. Lim Meng Tsai  
Faculty: Forestry

*Acacia mangium* has been planted on ex-tin tailing areas to improve soil fertility. The return of macro nutrients from *A. mangium* and their effects on the soil chemical properties is however not well understood. The main objective of this study is to compare the effects of macro nutrient input via *A. mangium* litter, throughfall and stemflow on soil chemical properties of mineral and ex-tin mining soils.

The first study area located in mineral soil situated in Universiti Pertanian Malaysia farm consists of an *A. mangium* covered plot (AMA) and a grass covered plot (GCA). The second study area on ex-tin mine soil located in Semenyih, Selangor, consists of an *A. mangium* covered plot (AMB) and a grass covered plot (GCB).

The total annual litter production for AMA is 872.51 g/m<sup>2</sup> and 741.18 g/m<sup>2</sup> for AMB. The litter production of AMA is



significantly ( $P < 0.01$ ) higher than that of AMB. At AMA, the annual return of nutrients through litterfall are  $9.48 \text{ g/m}^2$  N,  $0.33 \text{ g/m}^2$  P,  $3.13 \text{ g/m}^2$  K,  $6.27 \text{ g/m}^2$  Ca and  $1.90 \text{ g/m}^2$  Mg. At AMB, it is  $8.09 \text{ g/m}^2$  N,  $0.28 \text{ g/m}^2$  P,  $2.71 \text{ g/m}^2$  K,  $5.38 \text{ g/m}^2$  Ca and  $1.62 \text{ g/m}^2$  Mg.

The mean ground leaf litter biomass is  $516 \text{ g/m}^2$  for AMA and  $458.68 \text{ g/m}^2$  for AMB.

The mean weekly decomposition rate of leaf litter is 1.6% at AMA and 1.5% at AMB.

Throughfall, stemflow and interception average 59.7%, 2.9%, and 39.7% of gross rainfall at AMA, while at AMB, the corresponding percentages are 57.6%, 2.7% and 39.8%. The total quantity of nutrients added annually to each hectare of the soil through precipitation, throughfall and stemflow is 6.68 kg of N, 0.42 kg of P, 10.26 kg of K, 1.19 kg of Ca and 0.59 kg of Mg for AMA, while for AMB, it is 5.95 kg of N, 0.28 kg of P, 9.14 kg of K, 0.91 kg of Ca and 0.52 kg of Mg.

The litter produced and crown leaching nutrients also improved the soil nutrient status in AMA compared to GCA by the following changes in mean concentrations: organic matter, 1.3% ; N, 0.64 mg/g; P, 4.50 ppm; K, 0.51 ppm; Ca, 0.10 ppm and Mg, 0.09 ppm. In AMB, the improvement in organic matter is 0.3% ; N, 0.27 mg/g; P, 0.65 ppm; K, 0.03 ppm; Ca, 0.03 ppm and Mg, 0.01 ppm.





Abstrak tesis yang dikemukakan kepada Senat Universiti Pertanian Malaysia untuk memenuhi syarat ijazah Master Sains.

GUGURAN-SARAP, CURAHAN-TERUS DAN ALIRAN-BATANG DALAM DIRIAN  
*ACACIA MANGIUM* DI ATAS BEKAS LOMBONG BIJIH TIMAH  
SERTA KESANNYA TERHADAP SIFAT KIMIA TANAH

OLEH

INDRESHWAR PRASAD INDU

January, 1995

Pengerusi:           Profesor Madya Dr. Lim Meng Tsai  
Faculti:             Perhutanan

*A. mangium* telah ditanam di kawasan bekas lombong bijih timah untuk memperbaiki kesuburan tanah. Pulangan nutrien makro daripada *A. mangium* dan kesan mereka terhadap sifat kimia tanah bagaimanapun tidaklah diketahui secara mendalam. Objektif utama kajian ini ialah untuk membandingkan kesan input nutrien makro melalui sarap, curahan-terus dan aliran-batang *A. mangium* terhadap sifat kimia tanah bagi tanah mineral dan bekas lombong bijih-timah.

Kawasan kajian yang pertama terletak di tanah mineral di ladang Universiti Pertanian Malaysia, mengandungi petak diliputi *A. mangium* (AMA) dan petak dilitupi rumput sahaja (GCA). Kawasan kajian kedua di tanah bekas lombong bijih timah di Semenyih, Selangor, mengandungi petak diliputi *A. mangim* (AMB) dan petak diliputi rumput sahaja (GCB).



Jumlah penghasilan tahunan guguran sarap bagi AMA ialah 872.51 g/m<sup>2</sup> dan 741.18 g/m<sup>2</sup> bagi AMB. Penghasilan sarap bagi AMA adalah lebih tinggi (bererti pada P<0.01) berbanding dengan AMB. Pada AMA, pulangan tahunan nutrien melalui guguran sarap ialah 9.48 g/m<sup>2</sup> N, 0.33 g/m<sup>2</sup> P, 3.13 g/m<sup>2</sup> K, 6.27 g/m<sup>2</sup> Ca dan 1.90 g/m<sup>2</sup> Mg. Pada AMB, ianya adalah 8.09 g/m<sup>2</sup> N, 0.28 g/m<sup>2</sup> P, 2.71 g/m<sup>2</sup> K, 5.38 g/m<sup>2</sup> Ca dan 1.62 g/m<sup>2</sup> Mg.

Purata biojisim sarap daun di tanah ialah 516.13 g/m<sup>2</sup> bagi AMA dan 458.68 g/m<sup>2</sup> bagi AMB.

Purata penguraian mingguan bagi sarap daun ialah 1.6% di AMA dan 1.5% di AMB.

Purata curahan-terus, aliran-batang dan pemintasan ialah 59.7%, 2.9%, and 39.7% daripada hujan secara kasar pada AMA, manakala pada AMB, peratusan yang sepadan ialah 57.6%, 2.7% dan 39.8% . Jumlah kuantiti nutrien bertambah pada setiap hektar tanah setahun melalui curahan hujan, curahan-terus dan aliran-batang ialah 6.68 kg N, 0.42 kg P, 10.26 kg K, 1.19 kg Ca dan 0.59 kg Mg di AMA, manakala di AMB, ianya adalah 5.95 kg N, 0.28 kg P, 9.14 kg K, 0.91 kg Ca dan 0.52 kg Mg.

Sarap yang dihasilkan dan larutanlesap nutrien dari silara juga memperbaiki status nutrien tanah pada AMA berbanding dengan GCA pada perubahan purata kepekatan seperti berikut: bahan organik, 1.3% ; N, 0.64 mg/g; P, 4.50 ppm; K, 0.51 ppm; Ca,



0.10 ppm dan Mg, 0.09 ppm. Pada AMB, perbaikan bahan organik ialah 0.3%; N, 0.27 mg/g; P, 0.65 ppm; K, 0.03 ppm; Ca, 0.03 ppm dan Mg, 0.01.



## CHAPTER I

### INTRODUCTION

Green plants are the primary producers of organic matter through the process of photosynthesis. All forms of life are dependent upon these primary organic materials which are used for various metabolic activities (George, 1982). A substantial portion of the accumulated nutrients in the plant biomass is returned to the soil primarily through litterfall and rainfall by way of stemflow and throughfall. Addition of N, P, and K to the soil mainly occur through litterfall while throughfall, however, accounts for most of K and Mg inputs to the soil (Parker, 1983). Nutrients in litterfall are more slowly released into the soil from organic matter than those from throughfall and stemflow which are in ionic form and are either easily absorbed by plant or quickly leached away in the soil (Parker, 1983). Rapid decomposition of plant litter at the onset of the rainy season, however, usually enhances major increases in nutrient accumulation over a relatively short period (Swift *et al.*, 1981). Hence, litterfall and canopy leaching are important in that they are the two principal routes by which mineral nutrients are cycled rapidly within the forest ecosystem. The study of the quantitative aspect of nutrient status of litter, litter production, litter accumulation, litter decomposition and nutrient leaching from canopy via stemflow and throughfall is



therefore an important one, as these processes are the major pathways for nutrient transfer in forest ecosystem (Parker, 1983).

A number of studies have been conducted on litter production, accumulation and decomposition (Anderson *et al.*, 1983; Lim, 1988; and Scott *et al.*, 1992) and the leaching of nutrients via throughfall and stemflow (Manokaran, 1980; Parker, 1983; Bellot and Escarre, 1991). However, there is little information of such studies conducted in ex-tin-mining areas. Work on nutrient cycling of vegetation planted in tin-tailing areas is also relatively new.

Panton (1964), Wong (1970) and Kho (1979) estimated that there were 120,000, 180,000, and 200,000 hectares of tin-tailings in Peninsular Malaysia. Based on these estimates, it was assumed that the tin-tailing areas in the country during the 1980's increased at an average rate of more than 4,000 hectares per year (Lim and Maesschalck, 1980).

*Acacia mangium* Willd., a fast-growing leguminous tree species, has a wide edaphic tolerance (NRC, 1983). It has been reported to have great potential as a plantation crop in sand, loamy sand or coarse sandy loam (such as in degraded areas) (NRC, 1983). It is also one of the most widely planted fast-growing exotic tree throughout Peninsular Malaysia (Yong, 1984).

*Acacia mangium* is indigenous to Australia, Papua New Guinea and Indonesia. This species grows rapidly and has a high productivity of 18.3 tonnes/ha/yr (Lim, 1986). It is also capable of overcoming strong competition from the common grass, *Imperata cylindrica* and flourishes on degraded areas (NRC, 1983). It can grow up to 23 m after nine years with stem diameter up to 23 cm (Tham, 1976). It is a multipurpose tree, suitable for timber, molding, furniture, fire wood and pulp (NRC, 1983).

The area of forest plantations in the tropics is increasing rapidly following population growth and the associated rising demands for fuel, construction and pulp wood, (Bruijnzeel, 1989). However, recently, concern has been expressed about the effects that fast-growing tree plantations with their often high nutrient demands may have upon soil nutrient reserves and therefore on future productivity, especially when grown on poor soils and in short rotation (Bruijnzeel, 1989). The question of how the forests survive in the nutrient-poor environment has interested ecologists for many years, and it has been hypothesized that nutrient conserving mechanisms have evolved in these ecosystems to enable these forests to survive and grow in this nutrient-poor environment (Richard, 1952).

Despite the growing significance of tropical plantations as ecosystems, the water and nutrient dynamics of forest plantations have received little attention as compared to



natural forests in the tropics (Jordan, 1985). Similarly, less emphasis has been given to nutrient dynamics in *Acacia mangium* plantations in Malaysia. In view of the importance of nutrient dynamics in the tropics, this study attempts to evaluate the nutrient status of litter, litter production, litter accumulation, the rate of decomposition, throughfall, stemflow, nutrients in throughfall and stemflow and their effects on both ex-tin-tailing and ordinary mineral soil planted with *Acacia mangium* trees.

The specific objective is :

To compare the effects of macro nutrient elements input via *Acacia mangium* litter, throughfall and stemflow on soil chemical properties of mineral soil and ex-tin-tailing soil.

The general objectives are:

i. To compare litter production, accumulation, litter decomposition rate and the percentage of throughfall and stemflow between sites.

ii. To compare the quantity of macro nutrients released from *Acacia mangium* stands via litterfall, throughfall and stemflow to the forest floor.

It is hoped that, with this study, the nutrient conserving mechanism, especially transfer of nutrients from *A. mangium* stand via litterfall, throughfall and stemflow to the forest

floor could be understood better and improvements to the soil and the productivity of the stands be made.



## CHAPTER II

### LITERATURE REVIEW

This chapter deals with literature related to this study. These are: litter production, accumulation, decomposition and return of nutrients via litterfall. Including pattern of forest influence on the rainfall interception, throughfall, stemflow components through the forest canopy and their nutrient return.

#### Litter Production

Plant litter is often defined as dead material lying on the soil surface comprising of dead plants and shed organs, but not standing dead matter (Medwecka-Kornas, 1971). Rodin and Bazillevitch (1967) included all dead organic matter from above- and below-ground plant parts as including flowers, leaves, seeds, fruits and small twigs. Roots are generally disregarded and this can cause some problems especially in desert environment where the underground litter from aerial plants could be an important component of desert ecosystem (Holmgren and Brewster, 1972).

Litter can be divided into two types, fine and coarse litter. Leaves, twigs, branches (less than 2 cm diameter) and other fine/small miscellaneous components are regraded as fine litter while coarse litter includes big branch and stems. In

