LITTER PRODUCTION, NUTRIENT INPUT AND RELEASE DURING DECOMPOSITION IN DEGRADED MOIST DECIDUOUS AND SUBTROPICAL WET HILL FORESTS OF MEGHALAYA

BY

ASHOK KUMAR SINGH

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SHILLONG-793014

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DEDICATED

TO

MY PARENTS

PHONE :
GRAMS : NEHU

North-Eastern Hill University

Mayurbhanj Complex, Nongthymmai, Shillong-793014

Department of Botany

We certify that the thesis entitled **'Litter production, nutrient input and release during decomposition in degraded tropical moist deciduous and subtropical wet hill forests of Meghalaya'**, submitted by **Mr. Ashok Kumar Singh**, M.Sc., for the **Degree of Doctor of Philosophy in Botany** of the North-Eastern Hill University, Shillong, embodies the results of original research work carried out by him under our supervision. Mr Singh has been duly registered and the thesis presented is worthy of being considered for the award of the Ph.D. Degree. The work has not been submitted for any degree of any other University.

R.R. Mishra
(R. R. Mishra)
Joint Supervisor

H.N. Pandey
(H. N. Pandey)
Supervisor

SHILLONG
THE 28 FEBRUARY 1990

Forwarded
Y. S. Chauhan
28.2.90

Head
Department of Botany
School of Life Sciences
N.E.H.U., Shillong-14

CONTENTS

PREFACE

Human interference in the form of shifting agriculture (Jhum) is the major destructive force of vegetation in the entire north-east India. Forested areas after few years of jhumming are left for vegetation regrowth. Some earlier workers have studied the secondary succession on abandoned jhum fallows in Meghalaya. This piece of research work lays emphasis on investigating functional attributes of the seral communities. The study was conducted in the young ($\leqslant$ 5 year old) and old (15 - 20 year old) stands of subtropical wet hill and tropical moist deciduous forests of Meghalaya.

The thesis is divided into six chapters. General introduction and review of relevant work is given in the first chapter. Second chapter describes the study sites and climate of the area. Community composition and tree phenology are dealt with in the third chapter. Data pertaining to litter production and accumulation have been discussed in the fourth chapter. Results of mineral elements (N, P, K) input through litter and their release during decomposition are discussed in the fifth chapter. A general discussion is given in the last chapter followed by a summary. Literature cited is given at the end.

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SHILLONG (ASHOK KUMAR SINGH)

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CHAPTER 1

GENERAL INTRODUCTION AND REVIEW OF LITERATURE

Forests all over the world are exposed to different kinds of natural and human disturbances. Natural disturbances and concommitant recovery mechanism are integrated aspects of normal ecosystem behaviour (White 1979). Human disturbances, on the other hand, differ sharply in kind, scale, intensity and frequency and may or may not be more extensive than natural disturbances. Many kinds of human disturbances have a higher frequency than natural disturbances. This is obvious in shifting cultivation practice followed in humid tropical forests (Reiners 1980). The interaction of man's activities with physiography and climate has led to the extensive degradation of original vegetation and soil in many parts of the world (Rosen 1984).

The structure of plant and animal communities and subsequent development of vegetation is strongly influenced by nature and intensity of disturbance (White 1979, Pandey and Singh 1984). Effects of human intervention on basic ecosystem processes such as energy flow and nutrient and hydrologic cycles are widely prevalent both in temperate and tropical countries of the world (Lamottee 1981). And some amount of quantitative data are now available that permit us to predict: (1) the changing structure of forest through time after massive disturbance, (2) the changing status of nutrient stores in ecosystem, and (3) the changes in water balance of whole ecosystem as they develop following disturbance (Mooney 1977). But still our understanding of the impacts of man's intervention with the structure and function of natural ecosystem is far from complete.

The north-eastern region of India is characterized by luxuriant growth of deciduous, humid evergreen and mixed coniferous types of forest vegetation. Much of the original vegetation, however, have either been totally disappeared or transformed into degraded secondary forests by different kinds of human activities. Two major activities that have contributed to the large scale destruction of the forests in the north-east India are large scale extraction of timber and shifting cultivation, locally called 'Jhum'. Jhumming is the predominant form of agriculture which supports about 1.6 million tribal population, spread over in an area of 0.426 million hectares in the entire north-eastern region. Shortening of jhum cycle (the intervening fallow period before the farmer returns to the same site) during last few decades under increasing pressure of rising population is a major cause of rapid environmental degradation including deforestation in the region.

Removal of tree canopy either through selective felling or clear cutting of forest and abandonment of land after few years of cultivation provide suitable site for the commencement of secondary succession. Secondary successional pattern subsequent to 'Jhumming' depends upon the weeding practice at the time of agriculture, type of vegetation that is slashed and seed source available to soil (Ramakrishnan et al. 1981). The seral communities on jhum fallows differ from one another in species composition, diversity and dominance and show differences in population structure of the constituent species. Such a variability in the community structure influences the energy and nutrient budgets of the ecosystem by altering the amount and pattern of the litter production and decomposition. Recovery of vegetation is closely associated with the recovery of biogeochemical cycle. Initially, recovery in nutrient cycle during succession was attributed to the increasing capacity of ecosystem to entrap and hold nutrients (Odum 1969). More specifically rapid rate of net primary production, high elemental storage in successional vegetation, faster recovery of evapotranspiration and reduction in mineralisation have been offered as mechanisms for minimising nutrient losses from the ecosystem (Vitousek et al. 1979).

Based on the long history of research and observations of earlier workers on succession, Marglef (1968), Odum (1969) and Whittaker (1975) identified general trends in community development. Their synthetic treatments helped subsequent researchers (Connell and Slatyer 1977, Van Hulst 1978) to examine the empirical and experimental basis of succession theory. Virtually all current discussion on succession considers only secondary succession which may be the result of severe disturbances associated with natural catastrophies, man-induced changes or due to subtle processes. In each instance the individual species in the ecosystem interacts in such a way that disturbance to any one of them or to one part of the system may affect the entire community. White (1979) has pointed out the problems of assessing the impact of disturbance on natural vegetation and has described disturbance as a tripartite continuum of frequency, predictability and magnitude. Depending on the degree of disturbance Connell (1979) has proposed six hypotheses which operate during plant succession.

Succession is characteristically variable both in its environment and species composition. The variability is partly attributed to the climate, geographical location, geomorphological features, site disturbance and the number and kind of species present in the community (Bazzaz 1979). The functional changes such as organic productivity, litter production, rate of decomposition and mineral cycling during progression of succession have been examined by Golley *et* al. (1974). Recent studies (Meentemeyer et al. 1982) show aboveground litter production to be the dominant pathway joining the living biological component to the non-living soil component of the ecosystem through organic matter decomposition cycle. It acts as an input-output system on the soil surface and determines several other functions of the ecosystem. Therefore, recently much emphasis has been placed on determining the nutrient flux accompanying litterfall and decomposition in forest ecosystem.

Forest litter is the layer of residues of leaves, branches, bark, fruits and other parts of plants that accumulate on the surface of soil. The classic work of Ebermayer (1876) on the production and chemical composition of forest litter demonstrated conclusively the importance of litter fall in the nutrient cycling in forest ecosystem. At the same time its significance in soil development was shown by Muller (1887). The studies on the litterfall in forest ecosystems have been reviewed by Lutz and Chandler (1946), Adaltonen (1948) and Bray and Gorham (1964). The role of physical environment in litter production has been discussed by Jordan (1971), Jensen (1974) and Jordan and Murphy (1978). Recently, the importance of forest litter in soil and slope conservation, forest management resistant to anthropogenic and pyrogenic activities and forest productivity have been emphasized by Sapozhnikov (1984).

The early work on litter dynamics in the tropics has been done in Africa by Laudelout and Meyer (1954) in equatorial forest. Greenland and Kowal (1960) and Nye (1961) have determined the litter fall and nutrient content in moist tropical forest of Ghana. In South Central America Jenny et al. (1949) studied the litter dynamics in temperate and tropical forests and Klinge and Rodrigues (1968) in Amazonia Terra. Firma. forest. Ewel (1976) studied litter production in successional forest of eastern Guatemala. Litterfall in relation to climate has been studied by Tanner (1980, 1981) in the montane rain forests of Jamaica. In south east Asia some work has been done in Thailand (Kira et al. 1967), New Guinea (Edwards 1977), Edwards and Grubb 1977) and Malaysia (Gong 1972, Lim 1978, Ogawa 1978, Yoda 1978, Proctor et al. 1983).

In India, litter production studies have been confined mainly to the tropical deciduous forest (Champion 1936, Puri 1953). Litter production, its nutrient content and turnover in dry deciduous forest at Varanasi were determined by Singh (1968, 1969). Subsequently, information on this aspect was added by Gaur and Pandey (1978), Vyas and Garg (1984) and Kapur et al. (1986). The litter production in the forests of north-east India has been investigated by Singh and Ramakrishnan (1982) and Boojh and Ramakrishnan (1981).

The importance of litterfall, particularly leaffall during early stages of succession has been reviewed by Golley _et al_. (1974). The rate of litterfall and nutrient input has been investigated in very few successional communities of the tropics. Gomez Pompa (1974) has carried out a number of studies on litter dynamics in successional communities in the tropics. He emphasized the importance of mineral turnover in community development during succession. Van Cleve and Viereck (1981) have examined the role of standing dead biomass on the forest floor during succession in the boreal forest of Alaska.

A large number of factors affect litter production and composition in forest ecosystem. Effects of climate, soil, forest type and physiography have been discussed in great depth by Bray and Gorham (1964), Swift (1977), Turnbull (1983) and Meentemeyer (1984). Bray and Gorham (1964) have shown the influence of climate on litter production. The mean annual litter production averages 1 t/ha for Arctic-Alpine Zone, 11 t/ha for equatorial forests and 3.5 and 5.5 t/ha for cool and warm temperate forests, respectively. It ranges from 5.5 to 15.3 t/ha in tropical forests (Madge 1965, Muller and Neilsen 1965, Hopkins 1966, Kira and Shidei 1967, Hains and Foster 1977, Brassel _et al_. 1980, Tanner 1980). The rate of litterfall decreases with decrease in availability of light during the growing season along a world wide gradient (Jordan 1971). Bray and Gorham (1964) have shown the role of temperature in controlling total litterfall at different latitudes. The maximum amount was observed at the equator, declining steadily at 65° N latitude in Europe where forest grades into Tundra. The litterfall pattern may vary even at the same latitude in coastal and montane forests due to difference in total amount of light available for growth during growing season (Jordan and Murphy 1978).

Jorgensen et al. (1975) noted that water and nutrient availability also limits litter production.

Physical effects of rain have also been considered in litterfall. The increased weight of senesced material in the canopy due to wetting caused them to fall (Brassel et al. 1980). But, Tanner (1980) has observed that litterfall per day during the dry season was about two times and during the hurricane period it was about 4 times more than during the wet period. Ovington (1957) was first to quantify the dry matter production in Pinus sylvestris plantation from early stage of development to fully mature stage and concluded that it is a function of stand development. However, Bray and Gorham (1964) have shown that there is no inherent tendency towards higher or lower litterfall with increasing age from 30 to more than 100 years of age; the variation may be encountered at lower age where canopy is underdeveloped.

The litter which falls seasonally or continuously is attacked by a variety of microorganisms and is decomposed to such a degree that it becomes an inseparable ingredient of the soil system (Swift 1983). The relationship between litterfall and litter standing crop on the forest floor has been used to measure turnover (k) of forest floor material (Jenny et al. 1949, Greenland and Nye 1959). Olson (1963) has reviewed the studies carried out in different types of forests both in tropical and temperate climates. The litter turnover coefficient has been estimated in few tropical lowland forests of Nigeria by Madge (1965), Hopkins (1966) and Swift et al. (1981). In dipterocarp forest of Malaya, the turnover of leaves and small litter was calculated by Ogawa (1978), Yoda (1978), Andersen et al. (1983) and Gong and Ong (1983). Similar studies in temperate deciduous forest were conducted by Reiners and Reiners (1970) at Minnesota, Harris et al. (1975) at Tennessee, Rochow (1975) at Missouri and Lang and Forman (1978) at New Jersey. The tropical rain forests have the values greater than 1 suggesting complete turnover within a year while values less than one indicate turnover time ranging from few years to several decades, generally reported from temperate and alpine forests.

The weight loss from litter bags has been widely used to measure the rate of decomposition of plant litter in different climatic zones (Edwards and Heath 1963, Wiegert and Evans 1964).

Litter forms an important nutrient pool and plays a significant role in regulating structure and function of forest ecosystem in a variety of ways. The large volume of information on this aspect has been reviewed by Ovington (1962), Olson (1963), Rodin and Bazilevish (1967), Swift et al. (1979) and Singh (1967). In the tropical forests nutrient content of litterfall was determined by Laudelout and Meyer (1954), Nye (1961), Hopkins (1966), Bernhard (1970), Egunjobi (1974), Haines (1977) and Lamb (1985). Litterfall is an important process through which major amount of mineral elements is transferred to the soil in forest ecosystem. Intensive studies on nutrient cycling incorporating litter production and decomposition aspects have been carried out by Likens and Bormann (1972), Fogel and Cromai (1977), Meentemeyer (1978), Birk and Simpson (1980), Cooper (1982), Lindsay (1988) and Staaf (1988). In India, similar studies are available from Central Himalaya and dry deciduous forests (Rai and Srivastava 1982, Mehra et al. 1985, Upadhyay 1988, and Singh 1968, 1969). Some studies on litter decomposition in the tropical moist deciduous forest of Meghalaya have been carried out by Singh (1984).

Decomposition of organic material is the vital aspect of overall nutrient cycling within the forest ecosystem (Reichle 1981). One of the variable influencing the rate and extent of decomposition of biodegradable materials is the supply of mineral nutrients, especially of nitrogenous materials, since microorganisms have a relatively high requirement of nitrogen and nitrogenous compounds which are often limiting in the decomposers' habitats (Park 1976). The importance of mineral supply to microorganisms during decomposition was recognised early in the present century. Hutchinson and Richards (1921) introduced the term 'nitrogen factor' to quantify the relationship between available N and decomposition. The C/N ratio of the decomposable material was later used by Waksman and Tenney (1928), Tenney and Waksman (1929) and Jensen (1931) to quantify the nitrogen release to discuss the variation in decomposition rate. ~~and nitrogen release.~~ Since different elements have different patterns of release over time and the elements are retained with different strength in the litter structure, attempts have been made to explain the dynamics of a single element and its status as a limiting or non-limiting nutrient for microbial growth

(Gosz *et al*. 1973, Parnas 1975, Swift *et al*. 1979). The element in non-limiting concentrations are released during the whole decomposition period, while the limiting ones may be immobilized for a short period (Berg and Staaf 1981). In its general features, carbon : element ratio has gained support from litter decomposition studies concerning several elements in forest ecosystem (Lousier and Parkinson 1976, MacLean and Wein 1976, Berg and Staaf 1980).

The closed nutrient cycling within the forest ecosystem is often disrupted by human intervention and leads to nutrient losses from the system. Deforestation of an experimental watershed in New England increased nitrogen export in streams and decreased organic matter increment within the ecosystem (Likens *et al*. 1969, 1970; Marks and Bormann 1972). The cutting of tropical forests also leads to increased litter breakdown, mineralization and subsequent nutrient loss (Edmiston 1970, Witkamp 1970, Gonzalo de las salas 1973). Bernhard - Reversat (1975) also recorded increased nitrogen loss following the clearance of tropical rain forest in Brazil and Africa.

Forest ecosystem exhibits mechanisms for capture, distribution and conservation of elements essential to system persistence (Witkamp 1971, Dommerques and Mangenot 1970, Gose *et al*. 1972, Likens *et al*. 1972, Satchell 1974). Nutrient immobilization, mineralisation and release have been postulated as the conservation mechanisms which are controlled by decomposer-plant interactions (Parkinson 1967, Witkamp 1971, Henderson and Harris 1974, Harris *et al*. 1975). Indirect measurements of microbial immobilization and release of elements have shown microbial influence on element leaching and root uptake (Witkamp and Frank 1970, Witkamp 1971). The information on inputs (through litterfall), exports, substrates and decomposer organisms are essential for an understanding of elemental conservation mechanisms of forest ecosystem (Mitchell 1974, Jensen 1974, Levilt 1972, Reichle *et al*. 1981) and its recovery process following disturbance.

The objective of the present study were to collect data on some of the above mentioned aspects in the moist deciduous and wet hill mixed coniferous forests of Meghalaya, to understand the structural and functional changes particularly nutrient dynamics through litter production and decomposition during their regrowth after jhumming. Community structure, phenology, litter production, decomposition, Nitrogen (N), Phosphorus (P) and Potassium (K) return through litter, their accumulation on forest floor and release from decaying litter were studied for a period of two years during 1987-88. The results have been discussed in five chapters of the dissertation.