

**MICROBIAL NUTRIENT DYNAMICS AND MINERALIZATION
IN DEGRADED SUBTROPICAL FOREST ECOSYSTEMS
UNDERGOING RECOVERY**



By
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CERTIFICATE

I certify that the thesis entitled "*Microbial nutrient dynamics and mineralization in degraded subtropical forest ecosystems undergoing recovery*" submitted by Miss Kusum Maithani, for the degree of Doctor of Philosophy in Botany of the North-Eastern Hill University, Shillong, embodies the record of original investigation by her under my supervision. She 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.

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CHAPTER 1

INTRODUCTION

Forest provides a critical pathway for exchange of carbon dioxide between the atmosphere and land, and covers about one-third of world's total land area. Forests are also responsible for about two-third of global photosynthesis on land surface. Besides, forests have been intimately linked with human society and its socio-economic development. Due to explosion in human population in recent years, there has been tremendous pressure on forest resources. The over-exploitation of forest resources has led to forest degradation and depletion in forest cover.

Ecological implications of land degradation and deforestation in the tropics are far reaching. At the global scale, degradation of natural resources leads to loss of gene pools and biological diversity, exacerbation of climatic change through the increase of green-house gases in the atmosphere and altered hydrological cycles. At the local scale, natural resource degradation leads to lack of economic growth, increased impoverishment of the population and urban migration. Forest cutting has been reported to cause a net loss of soil organic carbon. This loss affects the soil fertility level of the highly weathered tropical soils and plant regeneration in the degraded sites. Soil organic matter is an important regulator of numerous environmental constraints to productivity. Mineralization of decomposing residue is a major source of plant nutrition in highly weathered soils with little inherent mineral fertility (Sanchez *et al.* 1989).

The activities of microorganisms and soil fauna serve to promote soil aggregation (Oades 1984), leading to reduced erosion (Lai 1986) and greater moisture infiltration (Lavelle 1988). Other important benefits resulting from the maintenance of the soil organic matter include nutrient retention and storage (Russell 1973), increased buffering capacity in low activity clay soils (Swift & Sanchez 1984) and an increase in their water holding capacity. However, a decrease in total soil organic matter as a result of land management and increased soil aeration is an universal phenomenon in both temperate and tropical regions. Degradation of the soil system through soil organic matter loss results from soil tillage (Follett & Schimel 1989) and clearing of natural vegetation (Srivastava & Singh 1989). Even simple land perturbations are associated with a decline in soil organic matter (Nye & Greenland 1960). However, the carbon loss from the system is gradual and is not easily detectable. One of the current models of SOM dynamics *viz.*, CENTURY, divides SOM into three fractions with different turnover times; the active (0.14 yr), slow (5 yrs) and passive (150 yrs) fractions (Parton *et al.* 1989). The active fraction with short turnover time appears to contain primarily the living soil microbial biomass and microbial products.

Information on changes in microbial biomass following vegetation removal is valuable not only because it provides an indication on slower, less easily detectable SOM changes but also because the microbial biomass contributes to soil fertility. The microbial biomass represents an important labile pool of soil nutrients and plays an active role through immobilization in preventing nutrient leaching (Vitousek & Matson 1984). The microbial biomass accounts for only 1-3% of soil organic-C but it acts as medium through which all organic material that enters the soil must pass (Jenkinson 1977). From the

viewpoint of soil productivity, the soil biomass controls the major processes involved in nutrient transformation and cycling, soil organic matter maintenance and macroaggregation for favourable water and aeration characteristics. Changes in microbial population in response to variation in soil conditions have important implications for nutrient cycling in forest ecosystems. According to Luizao *et al.* (1992), the amounts of SOM and microbial biomass in the humid tropical rain forest soils are substantial. Soil microbial biomass C and N fluxes are far greater than the cycling of C and N through litterfall (Arunachalam *et al.* 1996b). Slashing and burning reduces microbial biomass and mineralization in the top soil and is associated with a shift in forms of mineral-N in favour of nitrate.

Studies on soil biological processes including soil microbial biomass have engaged considerable attention in recent years and numerous methods have been proposed to estimate soil microbial biomass. Physiological and biochemical methods are most frequently used, although these methods have their particular limitation and significance. Chloroform-fumigation (a physiological method) has been widely accepted for soil microbial biomass estimation; the fumigation is either followed by incubation or direct extraction depending upon the soil pH and humic nature.

Values of microbial biomass can provide one of the most satisfactory estimates of the restoration of soil microbial populations. Several workers argue that soil biomass measurements are not uniform across systems and may only be relative, however, as an ecological marker, relative biomass change over time should be sufficient for predicting the ecosystem recovery after disturbance.

The microbial biomass measurements may provide the information needed for ecosystem level monitoring of disturbance and recovery

(Smith & Paul 1990). Srivastava *et al.* (1989) found a direct relationship between coal-mine spoil age and microbial biomass and suggested that microbial biomass is a critical factor in the recovery of the mine spoils and can be taken as a functional index for soil redevelopment.

Improving soil fertility is one of the most common tactics to increase agricultural and forest productivity. Maintaining high level of available N and P, the two most limiting nutrients in soil, remains a major challenge to ecologists and land managers. The availability of N and P in soil is largely controlled by biologically mediated processes such as mineralization and immobilization.

Mineralization is a process of nutrient release from the organically bound materials into inorganic or plant-available forms. Mineralization, is therefore, an important factor regulating production in non-fertilized forest ecosystems. Many studies have reported increased loss of N and other elements from forest ecosystem following tree felling. It has been suggested that these losses are caused either by increased N mineralization rate or reduced N uptake by plants after disturbance (Vitousek & Melillo 1979). Increased N mineralization following disturbance has been attributed to changes in microclimate, substrate quality or both. Matson & Vitousek (1981) reported that microclimate was more important in controlling mineral-N flux in a one-year old clear-cut site, and substrate quality was more important in 4-year old site.

Wide variations occur in N mineralization among soils of different vegetational types, even when they are in close proximity and develop from similar parent material. It has also been suggested by Rice & Panchoy (1972) that the ionic form of mineral-N in soil may indicate the stage of secondary succession.

A better understanding of nutrient transformation within forest ecosystem requires data on microbial nutrient immobilization and mineralization patterns. A survey of available literature reveals that although microbial nutrient studies have engaged the attention of a large number of researchers in other countries, studies on these aspects from India are limited. Though some studies relating to microbial nutrients (Singh *et al.* 1989, 1991, Srivastava & Singh 1989) are reported from Indian subcontinent, they are restricted to dry tropical deciduous forests and savanna. Studies relating to microbial nutrient dynamics and mineralization in disturbed humid subtropical forests undergoing natural recovery have not been undertaken so far.

OBJECTIVES

The objective of the present research was to study microbial immobilization and mineralization patterns in an aggrading human-impacted humid subtropical forest ecosystem. The specific objectives of the study were as follows:

1. To study the changes in chemical and biological properties of soil and diversity and dominance patterns of fungi during revegetation of the disturbed forest.
2. To study the relative changes in microbial biomass C, N and P in forest stands undergoing recovery after tree cutting.
3. To study the N mineralization pattern during forest regrowth.
4. To study the influence of resource quality (litter and roots) on mineral-N dynamics in regrowing forest communities.

5 To evaluate the relative influence of soil pH, temperature and moisture on N mineralization.

To achieve the above-mentioned objectives, data on microbial population, microbial biomass C, N and P dynamics and mineral-N flux as influenced by season, soil characteristics, stand age, and resource quality were collected on a seasonal basis in forest regrowths of three different ages in a humid subtropical forest of Meghalaya. The data obtained on these aspects have been analysed to characterize the pattern of nutrient restoration during revegetation of the tree-cut sites, and the role of microbial biomass in soil organic matter and nutrient dynamics during the recovery of degraded forests.

The thesis is divided in to 10 chapters. The data collected on various aspects such as soil, vegetation, microbial population, microbial C, N and P, N mineralization, etc. are presented in Chapters 3-9. Chapter 1 gives a general introduction to the whole study. Chapter 2 presents the review of literature published on the subject matter of the thesis and related aspects. Chapter 3 includes the details pertaining to location, geology, climate, soil, species richness and diversity of the selected study sites. Soil and microbial population dynamics have been discussed critically in Chapter 4. The details relating to microbial biomass C, N and P dynamics and *in situ* N mineralization pattern have been given in Chapters 5 and 6. Influence of leaf litter and fine and coarse roots on N mineralization has been detailed in Chapters 7 and 8. Results of *in vivo* studies on the effects of soil pH, temperature and moisture on N mineralization have been discussed in Chapter 9. The results presented in chapters 4-9 have been critically discussed in detail in the individual chapters. However, the major findings of the whole study have also been briefly discussed in an integrated manner in chapter 10 (General discussion). This is followed by a brief summary and references.
