CHAPTER I

1. INTRODUCTION

Decomposition refers to the physical breakdown of the material (usually measured as mass loss), while mineralization refers to the release of inorganic nutrients available for plant uptake (Berg and McClaugherty, 2008). It is primarily a biological process resulting from enzymatic activities of soil microorganisms and influenced in a variety of ways by activities of the soil fauna (Visser, 1985). Melillo et al., (1989) discussed the decomposition process from litter to humus in two phases. In the early stage, there is rapid loss of water-soluble components followed by rapid loss of cellulose from the litter and there is little loss, or possibly even a gain of insoluble decay products (collectively referred to as "lignin"). During the early phase, carbon is relatively available and nutrients are limiting, and there is immobilization of the limiting nutrient (usually N). Once the litter reaches the late stage of decomposition, it is considered to be humus and it is distinguished by a stabilized content and slow decay of all components. The late stage of decay is characterized by a net loss of lignin and net mineralization of N.

1.1 Litter and Litter Decomposition

Litter, originating from the above and below ground plant is the major pathway of supply of energy and nitrogen to the soil in most of the terrestrial ecosystems. As a gain of decomposition of plant and animal residues, carbon is recirculated to the atmosphere as Carbon dioxide and organic nitrogen is made available as ammonium, ammonia nitrogen, while other essential nutrients appear in plant-available forms. During decomposition, some of the Carbon and Nitrogen are immobilized into microbial tissue and the remaining part is microbiologically converted into resistant humic substances (humus), which constitute the bulk of the soil organic matter (Haynes, 1986).

Litter decomposition is important in terrestrial ecosystems for maintaining productivity because it regulates the availability of nutrients needed for plant growth. Mason (1977) distinguished three basic processes of litter decomposition, namely biological action, weathering and leaching.

The dead organic matter plays a major role in determining the structure and function of an ecosystem by acting as an energy source for heterotrophic organisms and nutrient reservoir for intrasystem cycling and by regulating to a large extent the hydrology of the system. The rate of
decomposition is a complex and often prolonged process, the rate of constants varying with the nature of the substrate and characteristics of the environment. The decomposing rates are markedly higher for tropical forests ranging from 0.45 to 1.5% per day. The values for temperate grassland communities range from 0.050 to 0.14% per day. The lowest rates of decomposition have been reported for Californian pine forests ranging from 1 to 3% per annum. Plant tissues are largely composed of complex organic compounds which include ether soluble fats, oils, waxes and resins, water soluble compounds, cellulose, hemicellulose, crude protein, lignin, and mineral constituents by weight (Haynes, 1986).

Litter fall and decomposition are two primary mechanisms by which the forest ecosystems' nutrient pool is maintained. The litter on the forest floor acts as an input-output system for nutrients (Das and Ramakrishnan, 1985), and the rates at which forest litter falls and subsequently decays regulate energy flow, primary productivity and nutrient cycling in forested ecosystems (Karnas, 1970; Waring and Schlesinger, 1985). It is particularly important in the nutrient budget of tropical forest ecosystems on nutrient-poor soils where vegetation depends on the recycling of nutrients contained in the plant detritus (Singh, 1968; Prichett and Fisher, 1987). In the recent years, there has been an increase in the number of studies concerning litter dynamics, although a majority of these deal with temperate and/or homogenous forests (Das and Ramakrishnan, 1985; Pande and Sharma, 1966; Gill et al., 1987; Harmon et al., 1990). Litter production by individual tree species in a natural forest stand is dependent on their dominance in the stand and the total amount reflects its stocking density (Kotwal and Mall, 1977). Litter decomposition is by and large a substrate-dependent property.

1.2 Factors affecting Leaf Litter Decomposition

The key factors affecting the litter decomposition include (i) the decomposer community and its complex nature (Swift et al., 1979) (ii) litter quality (Berg and McClaughervy, 1989; Hooper and Vitousek, 1998; Kalburjti et al., 1999; Moretto et al., 2001; Ross et al., 2002) and (iii) the physical and chemical characteristics of the environment (Vitousek et al., 1994; Kalburjti et al., 1997, 1999; Koukoura, 1998).

Climate and litter quality are the main determinants of litter decomposition (Swift et al., 1979; Lavelle et al., 1993). Although the activity of soil organisms has been identified as a
controlling factor (Lavelle et al., 1993; Couteaux et al., 1995), the rate of microbial activity should be considered as a mechanism by which the influences of climate and litter quality are realized.

Climate is the primary determinant of decay rate over broad geographical scales (Meentemeyer, 1978; Berg et al., 1993; Aerts, 1997). Decay will be uniformly slow in climates that are too cold, dry or wet to support a community of decomposers to operate at or near optimum (Couteaux et al., 1995). As a result, decay rates are generally high in the humid tropics and decline with increasing latitude or elevation, and are low in Mediterranean ecosystems, deserts and bogs (Swift et al., 1979). These differences are related to both climate and litter quality, as litter tends to be more recalcitrant in cold or dry environments (Aerts, 1997). The relationship might best be described as climate determining the general range of decay rates, and litter quality determining the relative rates of litters within the range set by climate.

1.2.1 Moisture

In general, litter moisture contents in excess of 150% or below 30% (dry weight basis) tend to slow down the rate of litter decomposition (Haynes, 1986). Within this range, decomposition rates will increase with increasing moisture if temperature is adequate (Bunnell et al., 1977). Substantially greater rates of decay have been reported at moist sites compared to dry sites having similar elevation and temperature (Vitousek et al., 1994) and following irrigation of dry forests (Raison et al., 1990). Very high moisture will also severely constrain the activity of microbial communities (Bunnell et al., 1977; Couteaux et al., 1995).

Schuur et al., (2001) reported a reduction in litter decomposition rates across a gradient of annual precipitation ranging from 2,200 to >5,000 mm, with a corresponding reduction in soil reduction–oxidation potentials. Improved aeration associated with the drainage of peat bogs has been shown to increase the rates of decomposition of litter (Lieffers, 1988).

1.2.2 Temperature

It is very difficult to separate the effects of temperature on decomposition from that of many other environmental factors, because soil temperature often co-varies with other factors that also affect decomposition. Moreover, decomposer organisms have a wide range of temperature optima (0–45 °C; Paul and Clark, 1996), even though their activities often show a positive correlation with increased temperature (Swift et al., 1979). Vitousek et al., (1994) reported increased rates of decomposition along a decreasing elevation gradient in Mauna Loa, Hawaii, which was most strongly associated with temperature as opposed to precipitation or substrate.
quality. They found that a change of 10 °C in mean annual temperature was associated with a 4- to 11-fold increase in the decomposition of leaf litter of a dominant species at that site. Numerous manipulative experiments, including artificial warming of litter layers, have also shown that increased temperature resulted in higher rates of CO₂ evolution and mass loss (Peter John et al., 1993; Hobbie, 1996; Winkler et al., 1996).

Actual evapotranspiration, which incorporates both temperature and moisture, is usually the best predictor of decomposition rates across a range of climates. AET was correlated with mass loss of Scots pine needles along a climatic transect in Scandinavia (Meentemeyer and Berg, 1986). AET was also correlated with first-year mass loss of a broad range of climatic conditions and leaf litters (Dyer et al., 1990), and with Scots pine needle litter along a transect from the sub-Arctic to the subtropics (Berg et al., 1993). In contrast, annual mean temperature best predicted first-year mass loss of root litter along a climatic transect from the Arctic circle to Germany (Berg et al., 1998). The lack of effect of moisture was attributed to these sites all being moist. Three-year mass loss across Canada was also best correlated with mean annual temperature (Moore et al., 1999). Inclusion of mean annual precipitation further improved the relationship, but AET was no better, indicating that summer moisture levels may not significantly constrain decomposition rates of litter in Canada.

1.2.3. Nitrogen Availability

The generally faster decay of N-rich litters suggests that litter decay rates would increase if their N content were increased through N fertilization or deposition, or would decrease if the N content declined as a result of elevated atmospheric CO₂ levels. In contrast, rates of decay have not been consistently altered by changes in the C:N ratio of litter resulting from N additions (Berg et al., 1987; Titus and Malcolm, 1987; Hunt et al., 1988; Prescott et al., 1992; Cotrufo and Ineson, 1995; Prescott, 1995) or elevated CO₂ (Couteaux et al., 1991, 2000; Cotrufo et al., 1994; Kemp et al., 1994; Hirschel et al., 1997; Finzi et al., 2001). For example, mass loss rates of pine needle litter from fertilized plots were the same as those for unfertilized litter, and much slower than those for green needles, despite having N concentrations similar to that of green needles (Prescott, 1995). Thus, additional N should stimulate the decomposition of low-lignin litters, but at the same time could suppress the decomposition of high-lignin litters.
1.2.4 Indicators of Litter Decay Rates

First, C:N ratio (Taylor et al., 1989a; Enriquez et al., 1993; Seneviratne, 2000) and followed by Lignin:N ratio appears to be a good predictor of decay rate in litters with initial lignin contents between 10 and 28% (Taylor et al., 1989a, 1991). In litters with lignin contents <10%, other factors limit decomposition; in litters with lignin contents >28%, decay is limited by the high lignin content but a correlation may not be apparent, because decay rates will be uniformly low. Second, decay rates depend on the length of the study. For example, Aerts and de Caluwe (1997) found that decay during the first 3 months was strongly related to P concentrations, whereas decay after 1 year was related more to concentrations of lignin and phenolics. Third, physical and chemical characteristics of litter that determine decay rate.

1.3 Litter Decomposition and Microorganisms

Microorganisms play an important role in the functioning of forest ecosystems, since their vital activity provides for a substantial part of mineralization in the carbon cycle and mediates humification of plant residues. Nutrients of plant residues should be transformed to become available for plants, and this transformation is realized by the microbial complex. The microbial complex is a heterogeneous component of the ecosystem by both taxonomic composition and functions. It can be described by microbial biomass as well as by the qualitative and quantitative composition of the microbiocenosis. Microbial biomass is the pool of labile organic matter on the one hand and describes the quantities of the agent processing organic matter of plant residues into labile organic matter on the other hand. In most forest ecosystems, organic matter is accumulated in litter. The stock, annual and seasonal dynamic thickness and composition of litter corresponds to pronounced variations in microbial abundance as against soil horizons.

The major groups of litter decomposing organisms are bacteria, actinomycetes, fungi, protozoa, nematodes, microarthropods, enchytraeid worms and lumbricid worms. Fungi are well adapted to their role as primary decomposers since they possess a filamentous, mycelial network that can permeate the relatively massive structure of the recently deposited litter. Furthermore, many of the bacterial decomposer organisms are in fact mycolytic and exert considerable enzyme activity in the breakdown of fungal mycelia (Alexander, 1977). Through the actions of a number of secreted extracellular enzymes, the fungi and some bacteria are active decomposers of plant
proteins, aminoacids and other nitrogenous organic compounds resulting in the eventual release of NH4\(^+\) (as ammonification).

Fungi play a crucial role in leaf litter decomposition and contribute to soil respiration, nutrient recycling, and build-up of soil organic matter (Swift et al., 1979). This is because they decompose the lignocellulose matrix in litter that other organisms are rarely able to decompose (Cooke and Rayner, 1984). Tropical forests have been investigated for the diversity and species composition of litter-inhabiting macro and microfungi (Bills and Polishook, 1994; Lodge and Cantrell, 1995; Lodge, 1996 & 1997; Sharma et al., 1995; Paulus et al., 2003 & 2006b; Rambelli et al., 2004; Santana et al., 2005) and the succession of fungal assemblages during leaf litter decomposition (Promputtha et al., 2002; Tokumasu and Aoki, 2002; Tang et al., 2005; Paulus et al., 2006a).

The functional roles of fungi in the decomposition of lignin in tropical leaf litter (Osono, 2007) is characterized by more rapid removal of lignin (Muvoto et al., 2000; Hirobe et al., 2004b), which leads to faster decomposition of leaf litter and lower accumulation of soil organic carbon than in temperate soils (Takeda, 1998). Osono (2006) developed an approach to examine the abundance and activity of ligninolytic fungi in tropical and temperate forests with reference to the occurrence of bleached portions on leaves of broadleaved woody species. The presence of bleached portions is associated with fungal colonization of leaf tissues and decomposition of lignin (Osono and Takeda 2001; Koide et al., 2005a, b). Osono (2006) showed in a preliminary survey that the bleached area on the leaf surfaces was generally greater in tropical forests than in temperate forests. The bleaching agents in temperate forests included some ascomycetous genera and their anamorphs and basidiomycetes, but the agents in tropical forests were yet to be identified. More studies are necessary to explain the occurrence of the bleached area and fungal populations responsible for lignin decomposition in leaf litter on tropical forest soils.

Keeping these points in view, the present investigation was planned to study the leaf litter decomposition and the associated microfungi over the leaves and litter of Manilkara hexandra (Roxb.) Dub., a dominant tree species in the tropical dry evergreen forest at Point Calimere, Nagapattinam district of Tamil Nadu, India. The findings of the investigation are presented in the thesis, which embodies six Chapters including Introduction, Review of Literature, Materials and Methods, Results, Discussion, Summary with References and Appendix.