IV. LITTERFALL, LEAF-LITTER DECOMPOSITION AND FINE ROOT PRODUCTION, IN NATURAL FOREST AND CACAO AGROFORESTRY

INTRODUCTION

Large-scale plantation forests have been established in the world to meet the demands for forest products as a result of increased pressure on natural resources caused by increasing human population. However, land deterioration (such as loss of surface soils, depletion of soil nutrients, and soil compaction) may occur when natural forests are converted to plantation of trees (Fleming and Freedman 1998, Okoro et al. 2000, Laurance et al. 2001, Schroth et al. 2002), such as, cacao plantations.

Forest litter acts as an input of nutrients and the rates at which forest litterfall and, subsequent decays contribute to the regulation of nutrients cycling, as well as to soil fertility and primary productivity in forest ecosystem (Martin et al. 1996, Martin et al. 1997, Bubb et al. 1998, Jamaludheen and Kumar 1999, Lin et al. 1999, Berg 2000, Lebret et al. 2001, Ranger et al. 2003). Litter production from plants, particularly trees, is a major source of organic matter and energy to soil, and is important for nutrient cycling in ecosystem. Both the species and age plantation largely determine the amount of litter production (Lugo and Brown 1993). Litterfall and litter decomposition from trees in agroforestry systems are considered to be an important factor contributing to soil quality. Litterfall has the biggest contribution in humus layer formation in the soil. It is releases mineral nutrients through litterfall decomposition process by soil organisms (Herrera et al. 1978, Luizão and Schubart 1987). Accumulation of litterfall layers on the topsoil depends on several factors i.e. plant species, climate, land use types, decomposers population and their activities (Luizão and Luizão 1991, Szott et al. 1991, Fernandes et al. 1997). Soil surface litter (SSL) in forest can be defined as a layer of accumulated organic materials including freshly, fragmented and humified litters on the soil surface. Leaves and other organic material fall to the ground and decompose, they also form an ‘organic layer’. Organic layer consists of all dead organic matter on the surface of the mineral soil, which derived from litterfall and all kinds of disturbance (e.g. tree harvesting, wind throw) including dead leaves, twigs, branches, fruits and roots, and small material of dead animals, fungi or bacteria. Soil organic matter (SOM) derived from litter input, including leaves, twigs, branches, woody debris, fruits and roots, and small material (< 1 mm) of dead animals, fungi or bacteria in the mineral soil (Mund 2004).

Decomposition in agroforestry systems differs from that of in the natural forest and in the agricultural system, because of differences in the types and quality of organic inputs. Litter is a general term for senescent plant parts. Litter differs from green foliage in that much of the soluble carbon compounds and nutrients are translocated out from leaves during senescence, prior to abscission and leaf fall. As a result, the quality and decomposition rates of litter and foliage from the same plant can be quite different (Mafongoya et al. 1998).

The leaf-litter deposition and decomposition are recognized as critical pathways of organic matter and nutrient flux in the tropical forest. The production and decomposition of leaf-litter in the tropical forest are influenced by the seasonality of precipitation and plant composition. During the wet season, conditions for growth and activity of soil microorganisms are improved, thus increasing decomposition rate. The product of litterfall decomposition is facilitating the formation of SOM and return of nutrient into soil (Xuluc-Tolosa et al. 2003). Decomposition of litterfall involves the chemical and physical processes that reduce litter to CO_2, water and mineral nutrients (Lambers et al. 1998).

Only about 20% of the nitrogen released from tree pruning or litter is taken up by the current crop (Palm 1995). Much of the remaining 40% to 80% of the applied organic nitrogen is incorporated into SOM (Haggar et al. 1993). Because of the slow release of nitrogen from SOM, organic inputs have a greater residual effect on soil fertility than do inorganic fertilizers (Palm 1995).

Decomposition processes are regulated by a number of abiotic and biotic factors (Lavelle et al. 1993). These comprise: (1) microclimate, mainly temperature and humidity (Meentemeyer 1995, Fioretto et al. 2001), (2) vegetation type (Lambers et al. 1998) and litter quality, in particular nitrogen, lignin and polyphenol concentrations (Sariyildiz and Anderson 2003), (3) soil nutrient content (Verhoeven and Toth 1995), (4) the qualitative and quantitative composition of decomposer communities (Knoepp et al. 2000), and (5) soil nutrient availability (Fioretto et al. 2005). Nitrogen and C/N ratio often have a direct impact on the decomposition process and nitrogen mineralization, indicating that litters with different nitrogen content decompose at different rate (Li et al. 2001). Thus, C/N ratio of litter is a good predictor for rate of decomposition, because rate of decomposition often correlates inversely with C/N ratio. Moreover, because of the different decomposition rates of its various compounds, litter quality changes over time, continuously affecting and changing the decomposition process. Therefore, decomposition in alpine forest has the low rate due to high tannin and lignin in litterfall (Blume et al. 1996, Scheffer and Scfachtschabel 1998).

Mean annual decomposition rate constants or decay rate coefficient (k) for temperate and tropical forests have been estimated at k = 0.9 and k = 1.8, respectively (Torreta and Takeda 1999). Within the tropics, there is some evidence of regionality in decay rates coefficient with $k > 2$ (high) for most African forests and k = 1-2 (medium to high) for forests in Southeast Asia and the Neotropics (Anderson and Swift 1983). Very high ($k \approx 4$) rates are observed mainly in African tropical forests (Olson 1963), indicating rapid nutrient cycling. However, decay rates coefficient can be low ($k < 1$) even in tropical areas, depending on litter type, season and altitude (Verhoef and Gunadi 2001). The higher decomposition rates facilitate more rapid nutrient cycling in ecosystems (Sariyildiz et al. 2005).

The fine roots (diameter < 2 mm) are component of belowground production in forest (Nadelhoffer 2000). Root distribution was found to be confined to the surface soil with up to 50% of the fine roots occurring in a thick organic layer. This is typical for nutrient-poor environment (Priess et al. 1999). On the other hand, the capacity of a tree to absorb water and nutrients will depend upon, among other factors, fine roots dynamics; i.e. rates of mortality and regrowth of fine roots, and how these vary in time. Fine roots biomass (live fine root) in cacao plantation shaded by *Cordia alliodora* was always higher over a 15 year period than it was in plantation shaded by *Erythrina poeppigiana* (Muňoz and Beer 2001). Although there have been several studies on litter and fine roots dynamics in tropical forest ecosystems, information on litter and fine roots production in natural forest and cacao agroforestry systems in Central Sulawesi is limited.

In the buffer zone of Lore Lindu National Park (LLNP), there are many different land-use types ranging from natural forest to agroforestry systems with cacao and shade trees. There are six different land-use types: (1) Natural forest with traditional use only - NF, (2) Natural forest with rattan extraction, (3) Natural forest with canopy gaps from selecting logging or local forest gardening, (4) Cacao agroforestry under a remaining forest cover – CF1, (5) Cacao agroforestry under local shade trees – CF2, (6) Cacao agroforestry without forest cover but with planted shade trees - CP. In this work only type (1 - NF), (4 – CF1), (5 – CF2), and (6 - CP) were studied.

The objectives of this study were to determine (1) litterfall dynamics, (2) leaf-litter decomposition, (3) N and C released, and (4) fine roots biomass in the natural forest and cacao agroforestry systems.