II. LITERATURE REVIEW

Introduction

Tropical land use change has important implications for biogeochemical cycles both regionally and globally (Scholes and Van Breemen 1997). Much work has focused on the effects of forest conversion to cropland or pasture on carbon storage (Fisher et al. 1994, Nepstad et al. 1994, Van Nordwijk et al. 1997) and soil nutrient availability (Fernandes and Stanford 1995, Neill et al. 1997). The conversion of the tropical forests to other land use (such as, agroforestry systems) generally ruptures ecosystem function.

Forest management which removes the majority of mature trees in a large area may change the forest microclimate drastically (Childs and Flint 1987) often resulting in increased nitrogen mineralization rates (Frazer et al. 1990, Smethurst and Nambiar 1990).

Approximately 81% of the organic carbon that is active in the terrestrial carbon cycle is stored in soils (Paustian et al. 2000, Wattel-Koekkock et al. 2001). Soil is the large pool of terrestrial organic carbon in the biosphere (Jobbagy and Jackson 2000). Beside this, the conversion of the tropical forest will change nitrogen dynamic in ecosystem (Neill et al. 1997).

Research in soil nitrogen availability has important relevance for the understanding of processes in forest ecosystems (Pettersson and Hogbom 2004). Nitrogen availability depends highly on the decomposition of litter material and subsequent release of nitrogen in plant-available forms by mineralization, converting organic nitrogen into inorganic nitrogen compounds (Myrold 1999). Thus, nitrogen availability and the nitrogen cycling in forest can be affected by forest management, as it may alter these factors (Likens and Bormann 1995).

Litterfall production and leaf-litter decomposition

Litter maintains nutrient and energy flow at the soil-plant interface. It also provides habitat for various soil organisms and protects soil from erosion (Sangha et al. 2006). Agren and Bossata (1996) described litter as “the bridge between plant and soil”. The plant litter provides the largest contribution to the formation of the humic layers in the soil, and litter decomposition by soil organisms release mineral nutrients for the plants (Luizão and Schubart 1987). Accumulation of the litter layer on the soil surface depends on many factors, which are, vegetation, climate, management practices, and action of decomposing organisms (Luizão and Luizão 1991, Szott et al. 1991, Fernandes et al. 1997). Leaves are the primarily litter component, which is important in nutrient cycling, because they are faster to decompose than woody components (Herrera et al. 1978, Luizão and Schubart 1987). Tree density, basal area, age structure, altitude, latitude and season are factors that strongly influence litterfall dynamics in natural forest (Sundarapandian and Swamy 1999). However, Kumar and Deepu (1992) in tropical forest ecosystem reported that the litterfall production did not directly relate to stand basal area and density. Litterfall pattern in rain-forest ecosystem is determined by a variety of factors, such as species composition, successional stage in its development and related microclimate differences (Sundarapandian and Swamy 1999).

Decomposition of plant litter involves the physical and chemical processes that reduce litter to CO_2, water, and mineral nutrients (Lambers et al. 1998). The leaves decomposition is recognized as critical pathways of organic matter and nutrient flux in tropical forest. Moreover, leaves decomposition is important factors in forest succession, since they largely form the nutrient status of the forest. Decomposition of leaf-litter, by which organic matter and nutrients are returned to the forest soils, is a primary mechanism and has received considerable attention for sustainable soil fertility (Moretto et al. 2001, Xuluc-Tolosa et al. 2003). In forest ecosystems, a major source of organic matter entering the decomposition subsystem is represented by plant litter, with leaves accounting from 22 to 81% of total litter annual production (Scaracia et al. 2000, Li 2001), or 60-70% of the total fine litterfall in Okinawa forest (Xu et al. 2004). Leaf-litter decomposition is key process in the control of nutrient cycling and formation of soil organic matter (Berg and McClaugherty 2002, Xu and Hirata 2005).

Rate of litter decomposition was controlled by soil organisms' decomposer, physicochemical environment, and litter quality. The rate of decomposition are determined by the quality of litter - particularly carbon and nitrogen content -, the physical environment and the qualitative and quantitative decomposition of decomposer organisms (Swift et al. 1979, Berg and McClaugherty 2003, Kemp et al. 2003). Soil physicochemical environment was controlled by soil humidity, soil organic matter, soil pH, soil C/N ratio. The major factors controlling decomposition in forest ecosystems are soil moisture, temperature and litter quality (Gilliam et al. 2001, Trofymow et al. 2002).

The nutrient content of the leaves affect the rate of decomposition. Generally high levels of nutrients, notably nitrogen, are expected to be able to accelerate the decomposition process. Several studies have shown a positive correlation between initial nitrogen concentration and the decomposition rate constant (Alhamd et al. 2004) and negatively correlated with both the lignin/nutrient ratio (nitrogen or phosphate) and with the lignin concentration (Lambers et al. 1998). The lignin/nitrogen ratio is a better predictor for litter decomposition, if initial lignin content is 10-28% (BassiriRad 2005).

The 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 rates (Li et al. 2001). Therefore, the C/N ratio in litterfall is a good predictor for the rate of decomposition, and the decomposition rate correlates inversely with the C/N ratio. The high C/N ratio correlates with rich-carbon litter, particularly lignin. Litter decomposition depends on vegetation type litter and soil quality (Schinner et al. 1989, Lambers et al. 1998) in alpine forest has the low decomposition rate due to the high tannin and lignin in litter (Blume et al. 1996, Scheffer and Scfachtschabel 1998). Chemical composition of litter, which changes with type of plant community, influences structure and activity of microbial communities inhabiting soils (Kutsch and Dilly 1999).

Soil organic matter

In the terrestrial ecosystems, soil organic matter (SOM) is an essential reservoir of carbon, nutrients, and energy in the life cycle (Jenkinson 1988). Soil organic matter encompasses the soil biota, plant and animal tissues at varying stages of decomposition. The soil organic matter is the driving force for biological activity as the primary source of energy and nutrients for many soil organisms. A direct effect of this biological activity is seen in the macro structure of soils, through the formation of soil pores as a consequence of faunal activity and root and fungal growth (Craswell and Lefroy 2001). The relative importance of these functions varies with soil type, climate, and farming system (Tiessen and Shang 1998).

Soil organic matter is a key source of nutrients for plant growth. It is essential for maintenance of soil structure, and contributes to the ability of soil to retain nutrients and water (Liu et al. 2003). In North Cameroon, the forest conversion into continuous cultivation causes soil quality degradation. Soil quality degradation is connected with decrease in SOM, particularly in the sand fraction, with negative impacts on soil aggregation and aggregate stability (Obale-Ebanga 2001). According to Bowman et al. (2000) that minimum 2% of SOM would determine soil productivity.

The organic matter content of soils may range from less than 0.1% in desert soils to close to 100% in organic soils. In organic soils, which include most soils used for agriculture, usually contain between 1 and 4% organic matter (Schnitzer 2001). Soil organic matter consist of fresh organic residues (<10 %), active organic fractions (35-50 %), and stable organic matter/humus (33-50 %) (Önemli 2004).

It is largely that SOM increases soil structure stability (Barthès et al. 1999), resistance to rainfall impact (Hudson 1973), increases macroporosity and infiltration rate, and mesofauna activities (Lavelle et al. 1992), increases nutrients holding capacity, constituting a nutrients pool for plants, decreases evapotranspiration, increases water holding capacity (Carter 2002). Forestry and agroforestry can increase biomass production and improve soil fertility through litter on the soil surface (Harmand 1998).

The changes of SOM could be used as an indicator for ecosystems changes, because SOM is the complex interaction product in ecosystem (Pennock and Frick 2001). Beside SOM quality, sum and turnover also represented the impact of land use conversion (Tiessen and Stewart 1983). Thus, SOM are an important indicator for soil quality (Larson and Pierce 1994, Rosell et al. 2001), and soil productivity (Larson and Pierce 1994). Solomon et al. (2000) stated that changes in land use can influence decreasing quality and quantity of SOM. If SOM was well-managed, it can maintain soil fertility and promote sustainable agriculture (Katyal et al. 2001).

Soil organic matter and biota are most importance for maintaining soil structure and fertility (Grimaldi et al. 1993). The content and composition of SOM are important parameter for soil characteristics and any change in the size of soil carbon pool could alter atmospheric CO_2 concentration and affect the global carbon balance (Trumbore et al. 1996). Accumulation and distribution of SOM and its associated nutrients are controlled by residues inputs, decomposition processes and mineralization rates (Isaac et al. 2005). Moreover, SOM content depends upon parameters such as, altitude, exposition, relief, microclimate (temperature and humidity), vegetation type, and land use practices (Seeber and Seeber 2005).

Mineralization of SOM is a major source of plant nutrients, but the stock can run out quickly, unless sufficient organic inputs are used. Total SOM content is not very sensitive indicator for soil fertility as it changes relatively slowly under different management regimes, and often has a high spatial variability, linked to variability of soil texture. The SOM is labile and their qualities easily decrease if soil environment change, but it could be recovered by increasing organic matter (Kurniatun et al. 1999). If total SOM was compared with active pool, active pool is a better indicator of soil fertility than total SOM content (Maroko et al. 1999). Carbon and nitrogen are major constituents of SOM and plant. As such, they play a fundamental role as nutrients within the tropic food web. Carbon and nitrogen are released when organic matter is biologically or chemically deconstructed (Sharrow and Ismail 2004).

SOM fractionation can be done with chemical and physical fractionation. Chemical fractionation produced humic acid, fulvic acid, and humin (Yagi et al. 2005), whereas physical fractionation produced light, intermediate, and heavy fractions. Light fractions or active pools are more sensitive indicator for ecosystem changes (Degryze et al. 2004) and SOM quality (Gregorich and Janzen 1996). Light fraction organic matter (LFOM) is components of SOM which have been considered a labile fraction contributing to carbon and nitrogen cycling (Curtin and Wen 1999). In SOM consists of 10-30 % active pool, which is correlated with soil microbe. Thus, active pool is derived from plant residues, microfauna debris, and microbe with its metabolism product (Janzen et al. 1992).

The plant-soil organic matter cycle under agroforestry commences with fixation of carbon from the atmosphere by plants, through the process of photosynthesis. After harvest and losses (e.g. burning), what remains on the soil becomes plant residues (litter and root residues). These are converted into the active fraction by litter decomposition. This decomposition is continued by the action of meso- and microfauna, converting the active fraction into soil humus. During this conversion, more than half of the carbon and nitrogen are lost in the oxidation, an order of 80-90% from above ground plant residues and 50-80% from roots (Young 1997).

Nitrogen Use Efficiency (N NUE)

The concept of nutrient use efficiency (NUE) evolves initially from an agronomic point of view. Nutrient use efficiency is often misunderstood or misrepresented if it is discussed as an isolated issue and not in the context of the efficiency of the total crop production system. Where nutrients are purchased inputs, land is most often the primary limiting resource in terms of its availability. The most effective way of improving the system's efficiency was through continuous increases in yields. By this way the efficiency of the system as a whole would be improved because the primary limiting resource was more productive in terms of yield per unit farmed (Dibb 2000).

Several basic techniques were described to measure nutrient balances, such as (1) *Soil Surface Balance* (measures the difference between the inputs or the application of nutrients and the output or removal of nutrients from the soil), (2) *Farm Gate Balance* (measures the difference between the nutrient content of farm inputs and the nutrient content of farm outputs) and (3) *Soil System Balance* (used where detailed information on inputs, out puts, and internal transformations was available for all the important components). This type of balance required much larger data inputs, requiring the use of relevant computer models. A number of excellent mechanistic models were developed to trace the fate of nutrients. The use of isotopes (e.g. ^{15}N) to trace the behavior of applied fertilizer was very useful in understanding the complex physical/chemical/and microbial transformations after nutrients were added to soil. Nutrient budgets were used to get an estimate of nutrient use efficiency. Nutrient efficiency might be defined in agronomic, economic, or environmental terms. For example economic efficiency occurred when farm income was maximized as a result of nutrient inputs. The nutrient deficit or surplus over the short term was not an indication of undesirable consequences, but in fact may be beneficial and desirable for building overall soil fertility. Again this is a typical agronomist concept, which is more dictated by the availability of nutrients by fertilization for an actual yield of harvestable products (Stewart 2007).

Nutrient availability in the soil-plant system is dictated by complex interactions (or competition) between plant roots, soil microorganisms, chemical reactions and pathways of losses. The concentration dependents of most of the processes that nutrients undergo in soil include transformations induced by microbes (N_2 fixation, nitrification, denitrification, immobilization etc.), chemical processes (exchange, fixation, precipitation, hydrolysis, etc.) and physical processes (leaching, runoff, volatilization, etc.). The extent by which the added nutrients removed from soil solution by these processes, which compete with plant uptake, can thus affect both nutrient use efficiency and the environment (Jagadeeswaran et al. 2005).

Nutrient deficits occur in many places and as crop yields and nutrient removal increase, there is a greater need to be efficient with nutrient inputs. One of the largest input costs in agriculture is fertilizer. Because nitrogen fertilizer is made via an energy intensive process the costs are expected to rise sharply as the price of energy continues to rise. The use of fertilizers also poses an environmental problem because substantial proportions of fertilizer become mobilized by rain or irrigation and may cause damage to nearby lakes and streams where the nutrients cause eutrophication. This situation forces researchers to see the concept from a different angle mainly efficiency considered from nutrient uptake instead of nutrient availability through fertilization. A balanced fertility program is essential for optimizing yields, increasing profit, and improving the efficiency of fertilizer applications (Johnson et al. 1997). Nitrogen deficiency in agricultural systems is a world-wide problem. For non-legumes, nitrogen may be the most common limiting nutrient. The utilization efficiency of nitrogenous fertilizers under field conditions is poor. For example, for rice, the utilization efficiency of nitrogenous fertilizers under field conditions is around 50 and 25-30 %, respectively. However, without balanced nutrition, fertilizer nitrogen applications may be less efficient, and part of the fertilizer investment is wasted. This results in loss of a costly input and accentuates the environmental degradation (Johnson et al. 1997; Abrol et al. 1999).

Using classic crop response curve showed how NUE could be misrepresented or misinterpreted if the values and objectives of the system were ignored or forgotten. When Y-axis represented yield potentials (the value reaches 100% when all components existed in optimum level) and X-axis represented increasing applied nutrients, assuming all other inputs were not limiting then the relationship between the yield potential and the nutrient applied was hyperbolic. If any of the input was less then optimum the curve peak would not reach 100%, on the other hand when an input was at toxic level, the curve would turn down soon after reaching a peak. The target situation was just below the 100% level, B where the land use efficiency (LUE) was the highest as the interacting inputs and resources were at optimum level. In this range the optimum economic gain could be achieved (Figure 2.1) (Dibb 2000).

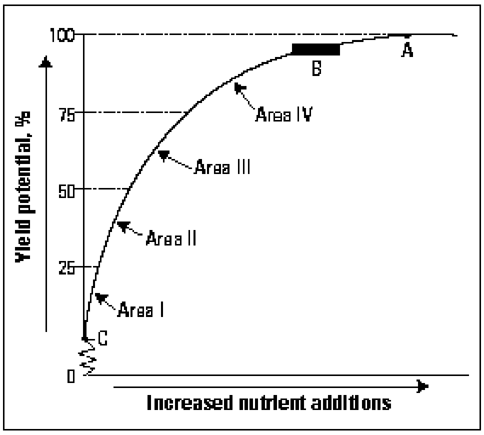

Figure 2.1. Nutrient use efficiency (NUE) and land use efficiency (LUE) are compatible (Dibb 2000).

Dividing the curve (Figure 2.1) arbitrarily into 4 areas, starting from the bottom to the top we discussed developmental changes from Area I to IV. Area I was at the bottom of the curve, representing agricultural production systems characterized by low yield, as nutrient available was low, and any fertilization would give a very high response, therefore, NUE was high. However, LUE was low, because the yield was still low. Therefore if NUE was the only goal, it could be achieved here, but people still starved because of low yield. Agricultural production areas in Saharan-Africa could describe this area. Area II, little higher than Area I in the response curve, described agricultural production systems already utilizing modern varieties responsive to fertilization, the crop yield in general and LUE were higher than that in Area I, but surprisingly NUE was lower mainly due to problems of nutrient imbalance. Some states under farmer Soviet Union fell under this category. Area III of the curve represented conditions where there was still a good response to added fertilizer; NUE was improved with a higher crop yield. In this area because soils were usually fertile and farmers paid less attention to replacing harvested nutrients, the yield slipped back to that of Area II. Agricultural production systems in Argentine and probably our agricultural production systems are in this category. Area IV was at the top of the response curve. The problems of imbalance were corrected, NUE as well as LUE were high, here crops grew vigorously producing a considerable residues and with proper management could help to reduce soil erosion. Agricultural production systems in USA, Europe, and probably also Australia are under this category. The developmental changes from Area I to IV of the response curve could improve NUE for sustainable agricultural production systems that provided adequate food, feed, fiber and fuels to the world. So it is only NUE in area IV, and not in area I, II, or III that is true NUE (Dibb 2000).

The Dibb's argument was typical of an agronomist, and supported by Mikkelson from Potash and Phosphate Institute using nutrient budget approach. The accepted approach to nutrient balance measured the difference between nutrient inputs and outputs in an agricultural system. Nutrient budgets described nutrient flows within farming systems and assisted in the planning of the complex spatial and temporal managements within rotational cropping and mixed farming systems. Budgets were the outcome of a nutrient accounting process, ranging from simple to complex, which detailed all the inputs and outputs to a given system over a fixed period of time. The underlying assumption of a nutrient budget was that of mass balance (i.e. nutrient inputs to the system minus any nutrient exports equal the change in storage within the system) (Dibb 2000).

Nutrient or fertilizer use efficiency concepts generally describe how well plants or a production system use nutrients (Stewart 2007). The ratio of dry weight gain to net nutrient uptake is one definition of nutrient use efficiency (NUE). The other definition is given by the ratio of dry weight gain to nutrient content and for some tissues such as leaves. NUE is the reciprocal of nutrient concentration since leaf dry weight is the dry weight gain, and the nutrient content is the net nutrient uptake (Luxmoore 1989), or, is the ratio of biomass production to nutrient uptake (Hiremath et al. 2002). When nitrogen fertilizer efficiency was measured as nitrogen use efficiency (NUE), by considering two components: (1) recovery of fertilizer nitrogen, either in grain or in total above ground biomass in the current crop, and (2) a part of the applied nitrogen that was left behind (immobilized) in the soil and becomes available to subsequent crops, NUE value was of about 50-70%, and those of potassium and phosphate were 50-60% and 10-20%, respectively (Isherwood 1999).

Nitrogen use efficiency in ecosystem (N $\mathrm{NUE}_{\mathrm{Es}}$) measured by litterfall production and occurs primarily because nitrogen circulation in litterfall is a reliable indicator of nitrogen availability in the ecosystems. This suggestion is logical if forests are very often nitrogen limited; both nitrogen uptake and circulation should then be a function of nitrogen availability. Vitousek (1982) offer four lines of evidence in support of this suggestion: (1) the sites where potential symbiotic nitrogen fixers are dominants or codominants (which include many of the tropical forests) have a relatively high nitrogen circulation and a relatively low efficiency of litter production, (2) the temperate sites with relatively large amounts of nitrogen in litterfall and low efficiencies are in regions receiving high levels of anthropogenic fixed nitrogen in rain and snow, (3) forest fertilization show that the application of nitrogen increases both the foliar nitrogen concentrations and forest production The increase in nitrogen availability resulting from fertilization progressively increased the amount of nitrogen in litterfall and decreased the nitrogen use efficiency of litter production, (4) the combination of low nitrogen circulation and low N NUE should be possible if the site has a adequate available nitrogen but some other factor strongly limits production. The mechanisms could cause increased N NUE in low forests: (1) increased nutrients use efficiency in active leaves, (2) increase reabsorption of nutrients from leaves to stems prior to leaf abscission. Nitrogen use efficiency in ecosystem (N NUE_{Es}) which is the ratio of litterfall production to nitrogen content in litterfall, or the inverse of litter nitrogen concentration (Vitousek 1982). The NUE_{Es} was influenced by forest types and climate (Yin 1993). According to Smith et al. (1998), in forest ecosystem worldwide, NUE_{Es} have been used as indices of nitrogen availability and soil fertility. Nitrogen use efficiency increases with decreasing availability of soil nitrogen (Vitousek 1982, Birk and Vitousek 1986, Aerts and De Caluwe 1994). This increase in NUE may be partly the result of lower concentration of nitrogen in living tissues and partly the result of greater resorption of nitrogen (Tateno and Kawaguchi 2002). Therefore plants may not have adapted to nitrogen-poor environments simply by enhancing their NUE (Yasamura et al. 2002).

After the influential work of Vitousek (1982), NUE emerged as a core concept for analysis of the relationship between carbon gain and the flux of nutrients through plants. Vitousek (1982) reviewed NUE concepts from literature, noticed that a review done by Chapin (1980) who summarized that plants from infertile habitats had higher nutrient concentrations than plants from fertile habitats grown under the same controlled low-nutrient conditions. Chapin further suggested that NUE (grams of organic matter produced per unit of nutrient taken up) is simply the inverse of nutrient concentration in plant tissue, and that consequently plants from nutrient – poor habitats appear to be less efficient than plants from nutrient-rich habitats.

Whole-plant NUE considers processes related to carbon gain and loss, whereas photosynthetic nutrient-use efficiency (NUE_{Ph}) considers only the instantaneous use of nutrients for photosynthetic carbon gain or carbon gain per unit leaf nutrient. The demand for nutrients from growing tissues may drive nutrient resorption and senescence of older leaves. The photosynthetic nitrogen use efficiency tends to decline as the leaves age. The photosynthetic capacity rises with increasing nitrogen content in linear proportion, until limitation by other factors. The photosynthetic nitrogen use efficiency is defined a photosynthetic capacity per unit leaf nitrogen (Larchner 1995, Hikosaka et al. 2002).

Nitrogen and phosphorus are largely withdrawn from senescing leaves before abscission, and use for new growth or stored in plant tissue. At species level, it has been postulated that low rates of nutrient loss can increase the fitness of plants in nutrient-poor environments. While at the ecosystem level, nutrient resorption from senescing leaves has important implications for element cycling (Aerts 1996, Aerts and Chapin 2000). Nutrients which are not resorbed will be circulated through litterfall and must be remineralized to become available again for plant uptake (Nardoto et al. 2006).

When nutrient supply declines relative to plant demand, most plants show the following sequence of events: (1) decrease in vacuolar reserves with little effect on growth, (2) continued reduction in tissue nutrient concentration, especially in older leaves and stems, reduced rates of leaf growth and photosynthesis, increased nonstructural carbohydrate concentrations, senescence of older leaves, and reallocation of reserves to compensate for reduced nutrient status (increased root mass ratio and increased root absorption capacity), (3) greatly reduced photosynthesis and nutrient absorption, dormancy or death of meristems (Lambers et al. 1998).

Translocation or resorption of nitrogen is associated with aging and senescing in tissues. Resorption from senescent leaves reduces nitrogen loss from a whole plant and increases the mean residence time of nitrogen (Hikosaka and

Hirose 2001), although there are no general patterns between nitrogen resorption from senescent leaves and soil nitrogen availability (Tateno and Kawaguchi 2002).

In 1995, coffee (*Coffea* spp.) and cacao (*Theobroma cacao*) plantations world-wide totaled 16,700,700 ha (FAO 1996). Plantations of these perennial crops are one of the most important forms of land use and are enormous economic importance for developing countries in the humid tropics (Wood and Lass 1985, Graaff 1986).

As mentioned before that agroforestry systems were a type of land use, the land use change may affect soil quality degradation. Subsequently, soil quality degradation may affect to decrease SOM. On the other hand, SOM content may increase during the time under agroforestry systems of coffee and cacao. For example, over a 10-year period of conversion of sugar cane fields to cacao plantations, SOM increased by 21% under pruned leguminous *Erythrina poeppogiana* and by 9% under unpruned nonleguminous *Cordia alliodora* (Beer et al. 1998).

Management practices will affect N_2 fixation by leguminous shade trees in cacao plantations. Plantations may be heavily fertilized with nitrogen and other elements, or not fertilized at all (Wood and Lass 1985). Pruning residues may be left around the trees, chopped and spread on the ground, or exported for fodder and firewood. The ability of shade species to produce large quantities of organic material, as litter and pruning residues, can be more important than N_2 fixation because of the positive effects on soil chemical and physical properties, especially in plantations that are fertilized. Therefore, all of these practices will affect levels of N_2 fixation and nitrogen availability in plantation (Nygren and Ramirez 1995, Beer et al. 1998).