1.1. Soil - the natural resource

Soil forms the skin of unconsolidated mineral and organic matter on the earths’ surface and maintains the ecosystem upon which all life activities depend. Soil is a dynamic living resource whose condition is vital in crop productivity. Sustainability of life on earth is totally dependent on soil.

1.2. Soil quality and soil health

The quality and health of soil determine the agricultural sustainability and environmental quality and as a consequence, plant, animal and human health. In a broader perspective, soil quality or health can be defined as the capacity of a soil to perform its functions, as a vital living system, within the ecosystem and land use boundaries that determines sustained biological productivity, maintenance of the quality of air and water and promotion of plant, animal and human health. Soil health is commonly used to describe those aspects of soil quality that reflects the conditions of soil as expressed by management sensitive operations (Islam and Weil, 2000). The concept of soil quality refers to the suitability and capability of a soil to perform specific ecosystem functions (Doran and Parkin, 1994; Bezdicek et al., 1996; Karlen et al., 1997; Karlen et al., 2001). In an agriculture ecosystem the major ecosystem processes mediated through soil can be grouped into four fundamental, though somewhat overlapping functions *viz.*., 1) promotion of plant growth; 2) biogeochemical cycling of elements especially carbon and mineral nutrient elements; 3) provision of habitat for soil organisms; and 4) partitioning, storage,
translocation and decontamination of water (Weil and Magdoff, 2004). The only soil component which directly or indirectly influences all these soil functions is soil organic matter (SOM).

1.3. Agriculture and soil health

The health of soil is changing over time, due to human use and management. The vertical rise in population demands for more food and fiber, which has led to intense farming activities in the past few decades. Worldwide, concern for sustainable global development and preservation of soil resources is reflected in the theme of numerous international conferences (Janzen et al., 1992; Doran et al., 1994; Doran and Zeiss, 2000). Cultivation is disturbing the natural system, which may bring changes in soil properties. Proper management of the soil resources is of extreme importance in sustaining crop and land productivity. Also monitoring the changes in soil properties is essential for proper assessment of the impact of cultivation on soil properties and to evolve suitable agro-ecological management policies.

1.4. Soil organic matter (SOM)

SOM is a component that regulates the physical, chemical and biological properties of a soil which in turn largely determines the soil fertility, agricultural productivity and sustainability. It consists of a mixture of plant and animal residues at various stages of decomposition, of substances synthesized chemically and biologically from the break down products and of microorganisms and small animals and their decomposing remains. The precise structure or composition of SOM is not well understood. SOM comprises hundreds of organic compounds that are chemically and structurally different. These compounds vary in quantity in different soils under various crops and management practices. As the extent of
influence of these different compounds on soil physical, chemical or biological properties can differ, soils with varying SOM composition may function differently. SOM is probably the most complex and least understood soil component (Weil and Magdoff, 2004). It is difficult and cumbersome to isolate each and every organic compound in soil and to study their specific influence on various soil properties. However, several pools of organic compounds are defined by their turnover rates and availability to microbial processes.

1.5. Soil organic matter pools

To sustain the health of agricultural lands, it is essential to properly manage SOM in arable soils. Conventionally, humus has been equated with inherent soil fertility and can be efficiently extracted from mineral soils in alkali. The resulting humic or fulvic acid fractions of SOM had been extensively studied. However, recent developments in organic matter research had proved that these fractions are ‘procedural artifacts’ existing only in laboratory and have not proven to be useful guides to adaptive management or contribute significantly in understanding the SOM dynamics or soil quality (Wander, 2004). However, upon renewed interest in soil organic matter research in the past few decades, many had come out with measurable SOM fractions that impart fundamental characteristics to soil (Wander, 2004). SOM can be broadly categorized to labile and recalcitrant pools depending on their decomposition or turnover rates (Six et al., 2002). Labile fraction mainly consists of easily oxidizable components such as carbohydrates, sugars, cellulose etc., which are palatable to microbes whereas lignin and tannin type materials fall under the recalcitrant group, which are resistant to decay. Labile or active pool of SOM is reported to be responsible for building soil aggregate structure, micronutrient chelation and nutrient mineralization and is very sensitive to changes in management practices or cultural operations (Tisdall and Oades,
According to Loveland and Webb (2003), active fraction or labile pool of SOM is more important factor in controlling changes in soil properties than the total SOM. In contrast, the passive pool, with half-life period measured in centuries, is composed of recalcitrant compounds that are resistant to decay and tends to accumulate in soil over time (Weil and Magdoff, 2004).

1.6. SOM – Significance of labile pool

Knowledge about the nature and turnover of SOM is a prerequisite for understanding the structure, chemical reactivity and inherent fertility of soils and for predicting the fate of mineral fertilizers, animal manures and crop residues added to the soil. SOM is highly sensitive and susceptible to changes depending on the land use pattern and associated management practices (Wander, 2004). Changes in total organic matter content in response to changes in land use or soil management practices that occur over relatively short periods are difficult to detect because of high background carbon content and natural soil variability (Haynes and Beare, 1996). Identifying and quantifying the suitable indicators that are sensitive enough to reflect the changes in SOM quality and quantity is very important to develop suitable nutrient management strategies for a sustainable nutrient management system. The labile fractions of organic matter such as particulate organic matter, soluble organic matter or microbial biomass can respond more quickly to land use or soil management changes and are suggested as early indicators of SOM changes (Gregorich et al., 1994).

It has been reported that higher quantity of organic matter need not necessarily maintain or increase crop yield (Ladha et al., 2003). According to Brinson et al., (1998) the nutrient availability in a system is more influenced by the size of the labile or active SOM
fraction rather than the total quantity of SOM. Parton and Rasmussen (1994) also reported that the labile component of SOM plays the most important role in the short-term turnover of nutrients.

1.7. Plant litter and crop residues as SOM sources

Major sources of organic matter in natural as well as many of the cultivated soil systems such as that of plantation crops are plant litter and crop residues (Chadwick et al., 1998; Fioretto et al., 2001; Santa Regina and Tarazona, 2001; Kogel-Knabner, 2002). The decomposition and nutrient release patterns of organic materials are determined by the resource quality, decomposing organisms and environmental conditions (Berg et al., 2000). Since litter quality influences the decomposition process of soil organic matter, the quality of SOM vary in different land use systems (Giller and Cadisch, 1997; Pankhurst et al., 1997; Krull et al., 2003).

1.8. SOM quality and decomposition

Chan et al., (2001) observed that different organic carbon fractions vary in their decomposition pattern. Mineralization of soil organic matter has a key role in the availability of nutrients. With changes in the quality and quantity of SOM, the potential of a soil to supply or sequester carbon and nutrients is altered through changes in mineralization–immobilization rates (Janssen and Persson, 1982). Decomposition of organic matter in a soil is mainly governed by soil microbes. However, the decomposition rate varies with the quality and physical availability of substrate, which are the energy sources to soil microbes (Raich and Tulekcioglu, 2000). Thus the organic matter decomposition or organic carbon mineralization pattern may vary with the land use type and soil management. Understanding the decomposition kinetics of soil organic matter under different land use systems or
management practices can provide useful information on the carbon stabilization potential of the systems as well.

1.9. Rubber based land use systems

Rubber (*Hevea brasiliensis*), the prime source of natural rubber, has been commercially cultivated in India since, 1902. Major portion of the rubber area in India is confined to the west coast of the country extending from Kanyakumari district of Tamilnadu in the south to Coorg district of Karnataka in the north. Most of the rubber plantations in the traditional rubber growing tract in India are now in the second or third planting cycle (Krishnakumar and Potty, 1992; Karthikakuttyamma, 1997) and majority of these are to be replanted again. Because of the tropical climate of the traditional belt with heavy rainfall and high temperature, the soil in these regions are highly weathered and mostly laterite and lateritic types. In general, organic carbon (OC) content of traditional rubber growing soils is medium to high (NBSS & LUP, 1999). However, a decline in OC status occurs with replanting (Karthikakuttyamma *et al.*, 2000).

The rubber tree, a native of the Amazon river basin has a defoliation cycle by which large quantities of litter is added to the soil. In mature rubber plantation about 5 t ha$^{-1}$ year$^{-1}$ of litter is added through annual leaf fall (Philip *et al.*, 2003) which is the main source of organic matter.

Establishment of leguminous cover crop in immature phase of rubber is a recommended and commonly followed agro-management practice. The leguminous cover crops, *Pueraria phaseoloides* or *Mucuna bracteata* is usually established in the immature rubber fields. Huge turnover of organic matter (5 to 7 t ha$^{-1}$) additions are reported from these cover crops (Kothandaraman *et al.*, 1989; Philip *et al.*, 2005).
Since rubber has a long gestation period of about seven years, intercropping with banana or pineapple is also a common practice in the initial years of immature phase of rubber. The quantity and quality of crop residues generated and incorporated in these systems are different and since the plant residues are the primary source of SOM, the relative size and composition of SOM pools in these rubber based systems may vary. The management practices such as tillage operation, fertilizer and organic matter input etc., are also different in these rubber based systems which may also contribute to varying organic matter composition and soil quality.

**Objectives**

Though many reports are available on the effect of cover crop and intercrop on soil properties in rubber growing soils, information on litter quality, labile fractions of organic carbon and soil carbon mineralization in different rubber based systems is limited. Hence the present investigation was carried out with the following objectives;

1. To determine the quality and decomposition pattern of the three major litter species *viz.*, *Hevea*, *Pueraria* and *Mucuna* in rubber plantations
2. To characterize soil organic matter and soil properties in different rubber based systems and
3. To study the carbon mineralization in soils under different rubber based systems