Chapter 10

General Discussion

Micro-environmental variability and soil nutrient dynamics

Effect of land use change on microclimatic variability

Tree cover loss due to land use conversion from forest to different agricultural systems influenced the microclimatic conditions like rise in air temperature, soil temperature, light intensity and decrease in relative humidity. However, better canopy cover in forest ecosystem filtered the solar radiation and thus the microclimate under forest got modified favourably. However, amongst the studied land uses, agroforestry system and horticultural system have some tree population as a component species which acted as wind breaker and provided shade, and consequently the microclimatic parameters showed a positive drift in these ecosystems compared to jhum or terrace cultivation systems where tree component was absent.

Effect of land use change on soil physical properties

Effect on soil texture, water holding capacity and bulk density

The change in the mode of land use brought about changes in soil physical and chemical properties as well. Greater percentage of silt and clay in the forest soil as compared to other land use systems can be attributed to variation in vegetation patterns of different land use systems. Due to lack of tree canopy in the agricultural systems, the soils are exposed to direct rainfall (1800-2000 mm year\(^{-1}\)), causing erosion of top soil (Greacen and Sands, 1980; Scholes et al.,
1994), especially the smaller sized clay particles (Eyre, 1968). Greater bulk density in agricultural systems (particularly in horticultural system at Sagalee and jhum cultivation system in Kheel) may be due to increased mechanical pressure due to various farming activities. On the contrary, low bulk density of forest soil may be due to the fact that the forest soil had highest organic matter and also greater root density (Aweto, 1981). Evidently, a strong negative correlation was found between organic matter and bulk density \((r=-0.782, \text{df}=19, p<0.01)\). Malmer and Grip (1990) recorded that the bulk density in disturbed forest was 41% more than an undisturbed forest. Further, higher percentage of clay and organic matter content in soil of forest and agroforestry systems contributed to greater water holding capacity. Congdon and Herbohn (1993), Scholes et al. (1994) and Lyngdoh (1995) have earlier reported a positive correlation between clay content in soil and water holding capacity. The present study also recorded a significant positive correlation between water holding capacity and clay content \((r=0.569, \text{df}=19, p<0.01)\), and although not significant a positive correlation existed between water holding capacity and organic matter content also \((r=0.151, \text{df}=19, p>0.01)\). This suggests that the conversion of forest land to agricultural land deteriorated the soil physical characteristics.

**Effect of land use change on soil moisture**

Soil moisture varied seasonally due mainly to the rainfall pattern. For instance, the soil moisture was higher during rainy season and lower during winter. The sloping nature of the landscape of the study area had additional effect on the
seasonal pattern in soil moisture content. This seasonal pattern was relatively
more distinct in open-canopied or canopy-less agricultural systems, while in
dense canopied forest better soil physical condition had a resilient effect on this
seasonality of soil moisture. The variation of soil moisture between the
different land use systems was significant (F=29.13, p<0.001 in Sagalee and
F=11.72, p<0.001 in Kheel). The terrace cultivation system had highest mean
moisture content, followed by the forest and lower in the horticultural system.
Nonetheless, greater soil moisture in terrace cultivation system was due to
marshy condition of the soil as a result of stagnant water at the horizontal
terraces particularly during summer and rainy seasons, which provide quite a
different soil conditions as compared to that in the other land use systems under
study.

Effect of land use change on soil pH
The seasonal variation of soil pH can also be attributed to rainfall pattern, as
high rainfall causes greater leaching of cations from the soil and consequently
the pH goes down during the rainy season. On the other hand, low soil moisture
during winter raised the pH (Fuchs, 1989). The seasonal affect on soil pH was
more prominent in the open agricultural fields that registered a low soil pH
(Table 4.4). Higher pH values in the lower soil depths may be due to leaching
and infiltration effects of cation movement from the surface layer to the
subsurface layer as a result of high rainfall (Juo et al., 1995).
Soil nutrient dynamics

**Effect of land use change on ammonium-N**

The study of different available forms of nutrients revealed that there were significant spatial and temporal variations of this nutrient pool. The dynamics of the nutrient pool in soil was affected by climatic condition, vegetation type, mode of land use, microbial growth and altitude etc. The ammonium concentration varied significantly through different seasons and land use systems. The higher ammonium concentration in summer could be mainly due to greater ammonification rate (Nadelhoffer *et al.*, 1984) as during this period the weather remains favourable for microbial activity (Maithani *et al.*, 1996). Reduction in ammonium concentration during the rainy season can be attributed to the higher nutrient demand by higher plants and microbes (Arunachalam *et al.*, 1996a). Simultaneously the probability of nutrient loss through soil erosion, runoff and high denitrification during this period can not be overlooked (Arunachalam *et al.*, 1997). However, low ammonium concentration during winter may be due to low ammonification rate. During this period immobilization rate is also higher in the soil microbes (Maithani *et al.*, 1996). According to Jackson *et al.* (1989) the uptake of ammonium-N by microbes is five times more than that by the forest trees. Further, Maithani *et al.* (1996) reported peak microbial biomass nitrogen during winter which also conforms with the present observation. Further seasonality in ammonium concentration in the present study sites is also in concordance with the trends reported by Arunachalam *et al.* (1997) from a subtropical environment.
Effect of land use change on nitrate-N

The seasonal trend in nitrate concentration was slightly different from that of ammonium. This may be due to the fact that during rainy season soil becomes almost saturated with moisture which might create an anaerobic condition in soil (Scholes et al., 1994). Consequently, the aerobic nitrifiers might become less active, which have resulted in low nitrification during this period and ultimately resulted into low nitrate concentration in soil during summer and rainy season. However it is not true for jhum cultivation system in Sagalee and abandoned jhum land in Kheel, where the highest nitrate concentration was recorded during the rainy season. This can be attributed to the openness of the system which made the soil exposed to direct sunlight and consequently rapid nitrification might have taken place due to high soil temperature. In this case moisture content can not limit the nitrification rate as the case in other land use systems mentioned earlier, due to good drainage of these steep sloping lands, low organic matter content and water holding capacity. Nevertheless, there was a strong positive correlation between nitrate concentration and soil pH \((r=0.22, \text{df}=179, p<0.005)\). This is in accordance with Chao et al. (1993) who reported the positive relation of growth and activity of autotrophic nitrifiers with soil pH.

Effect of land use change on phosphate -P

The phosphate concentration in soil was greater during winter and lower during rainy season. Site wise, the terrace cultivation system recorded the highest Phosphate concentration and the horticultural system the lowest. The high
concentration of available phosphorous during winter could be due to high soil pH. Additionally, the nutrient demand of plant and microbes remains low during this period which contributed to high phosphate concentration during the dry winter periods. Conversely, during rainy season, soil was relatively more acidic and consequently the phosphorous mineralization rate goes down and/or the plant demand for nutrient goes high as it is the favourable plant growth period, ultimately resulting in low available phosphorous concentration in soil. The terrace might receive phosphorous from the adjacent upper hill slope through runoff and soil erosion which caused the high available phosphorous concentration in the terrace cultivation system. In the horticultural system the low concentration of available-P may be due to continuous farming of horticultural crops (since about last 15 years) without any fertilizer input in this low soil phosphorous zone resulted in reduction of phosphorous in this particular ecosystem.

**Effect of land use change on organic-C**

Greater percentage of organic C during winter could be due to low decomposition rate coupled with high litter-fall, fine root mortality and low microbial activity (Garcia-Oliva *et al.*, 2003). Several workers have also reported the accumulation of organic C during the dry season (Campo *et al.*, 1998; Eaton, 2001; Luizao *et al.*, 1992; Yang and Insam, 1991). Following the peak during dry winter, the organic C concentration declined gradually through succeeding summer, rainy and autumn season which suggests the break down of organic C during this period. It went further low during rainy season, which
may be because of loss through soil erosion in addition to high decomposition rate of organic matter coupled with low litter fall and fine root mortality (Garcia-Oliva et al., 2003). The lowest organic C concentration during autumn may be due to the cumulative loss of organic C during the preceding summer and rainy season. The variations in organic C content across different land use systems could be mainly due to difference in organic matter input status which is again related with vegetation cover (chapter 6). Thus the organic C content in forest soil was high, obviously due to greater organic matter input through litter-fall and fine root mortality. On the contrary, the agricultural systems particularly jhum cultivation system and horticultural system receive very less amount of organic matter because of scanty vegetation cover of these systems compared to forest (Chapter 6).

**Effect of land use change on total-N**

The seasonal variation of total-N followed almost similar trend that of organic C. Thus, it was positively correlated with organic C ($r=0.266$, $df=179$, $p<0.001$). This may be due to the fact that the organic matter is the main source of soil organic C and other plant nutrients including N (Solomon et al., 2002). It was highest during winter when plant growth is slow and microbial activity also remains low, but the supply of organic matter increased due to high litter fall and greater root mortality (Garcia-Oliva et al., 2003) and the nutrient loss remains minimum due to scanty rainfall. Eventually combined effects of all these factors resulted in the accumulation of total-N during this particular period. The accumulation of soil nutrient over dry season has also been
reported by Campo et al. (1998), Eaton (2001), Lodge et al. (1994), Luizao et al. (1992) and McDowell (1995). There was a significant variation of total-N among different land use systems ($F=282.21$, $p<0.001$). This kind of difference of total-N in soil is quite understandable because of difference in the input of organic matter which in turn depends on the vegetation status of the particular system. However, in terrace cultivation system, the situation is slightly different where the soil nutrient loss from the adjacent forest must have been trapped in this system which resulted in higher in total-N level compared to other agricultural systems.

**Effect of land use change on C/N ratio**

The higher C/N ratio in agricultural land compared to forest was due to low nitrogen level in the agricultural systems which is evidenced by the results of total-N. This indicates the increased probability of loss of N from the agricultural systems which is obvious due to slopping terrain. Conversely, the low C/N ratio in forest indicates that higher N level is maintained in this system which is a key nutrient in the growth and development of plants. The loss of nitrogen from the forest soil is probably minimised, perhaps, due to the presence of good canopy cover in addition to the regular highest input of organic matter through litter-fall and fine root mortality coupled with atmospheric nitrogen fixation.

**Dynamics of soil microbial biomass**

**Effect of land use changes on microbial population dynamics**

Due to the change in land use and altered microclimatic condition the soil
microbial population varied significantly across the seasons, land use and soil depths. Although land use change did not affect the seasonal variation pattern of microbial population (fungi and bacteria) in general, but it affected the magnitude of microbial population as evidenced by the significant low microbial population ($F=47.56$, $p<0.001$; $F=59.54$, $p<0.001$ for fungi and $F=22.40$, $p<0.001$; $F=18$, $p<0.001$ for bacteria at Sagalee and Kheel, respectively) in the agricultural systems or abandoned jhum land compared to the forest in the present study. Nevertheless, the seasonal variation of microbial population was significant irrespective of land use ($F=26.93$, $p<0.001$; $F=154.45$, $p<0.001$ for fungi and $F=84.40$, $p<0.001$; $F=69.37$, $p<0.001$ for bacteria at Sagalee and Kheel, respectively) mainly attributed to the distinct seasonal variations in environmental factors (particularly temperature, humidity, rainfall etc.). The earlier report of Jha et al. (1992b) on the seasonal variation of microbial population is comparable with the present results. The significant low microbial population in agricultural system may be due to poor substrate quality in those systems where soil nutrients were also poor (chapter 4).

**Effect of land use changes on microbial C and N**

Any change in land management has been promptly reflected in microbial biomass nutrient and therefore it can be used as an index of soil nutrients status (Powlson and Jenkinson, 1981; Carter, 1986; Powlson et al., 1987). Seasonal variations of microbial C and N were similar to that of microbial population. But in the jhum and terrace cultivation systems, the seasonal trend
of MBC was different; in this case highest microbial biomass C was recorded during winter and it declined over summer, and rainy seasons. There was a significant positive correlation of microbial biomass nutrient (C and N) pool with the soil nutrients which suggested a close linkage between microbial growth and soil nutrients (Arunachalam et al., 1997). Thus microbial biomass acts as the quantitative indicator of soil fertility. They are the main labile fraction of soil organic matter and act both as sink and source of plant available nutrients (Singh et al., 1989)

The values of MBC (441.73-1834.40 and 967.20-1768.70 μg g⁻¹ in Sagalee and Kheel respectively) are within the reported range (61-2000 μg g⁻¹) for tropical and temperate forest soils (Vance et al., 1987; Henrot and Robertson, 1994). On the other hand, the values of MBN in Sagalee (57.32-113.65 μg g⁻¹) was within the reported range of evergreen forest (42-242 μg g⁻¹), but lower than the values (132-240 μg g⁻¹) of moist deciduous forest but the range of values of MBN in Kheel (104.26-363.55 μg g⁻¹) are wider than the reported values. This may be due to the steepness of slope of the area where the chances of nutrient loss are very high and that might be the reason why the MBN immobilised larger amount of N in these systems under the truly tropical environment in Kheel.

The mean contribution of MBC to soil organic C in different land use systems (3.48-12.75%) is higher than the reported range (1.5-5.3%) by Teng et al. (1989) and Luizao et al. (1992) in tropical forest soils and (1.8-2.9%) by Vance et al. (1987). However, mean contribution of microbial biomass N to TKN in different land use system are (1.97-8.90) within the reported range (2.8-9.8%,
Brookes et al., 1985) for agricultural soil, but wider than the range (3.4-5.9%, Martikainen and Palojarvi, 1990) reported for forest soils. Percentage contribution of MBC to soil organic C was higher in the systems where soil organic C was low e.g. abandoned jhum lands and was least in either jhum or terrace cultivation system. The lower contribution of MBC to soil organic C and the abnormal seasonal variation of MBC as discussed above suggests that the agricultural activities disturbed the overall microbial growth and dynamics in these systems. Similarly, the contribution of MBN to total soil N was highest in horticultural system and in abandoned jhum land and lowest contribution was observed in forest and agroforestry systems at Sagalee and Kheel, respectively. This suggests that the land use systems with low soil N had higher microbial contribution to total soil N and vice-versa. From this result, it can be perceived that the land use systems with low soil organic C or TKN perhaps developed a nutrient conservation strategy through microbial immobilization.

**Effect of land use change on microbial biomass C/N ratio**

The mean C/N ratio (2.73-21.11) in soil microbial biomass of different land use systems was wider than the range reported by Martikainen and Palojarvi (1990) for various soil types (6-9) and by Fenn et al. (1993) for chaparral soils (7-13). This is due to higher MBC compared to microbial biomass N in soil in general. The higher microbial biomass C/N ratio in the surface soil of abandoned jhum land can be attributed to the low N in microbial biomass which is again due to low soil N status in the system. The higher microbial biomass C/N ratio in
lower depths can be due to low N in soil and also less microbial activities in lower soil depths.

The results on microbial biomass revealed that the land use change tremendously affected the microbial properties of soil in general although the environmental factors like temperature, humidity, physiological water conditions etc. affected the seasonal variation of microbial growth irrespective of land use. However, it is recorded that some agricultural systems with low soil nutrient status (e.g. horticulture and abandoned jhum land) perhaps developed a nutrient conservation strategy through microbial C and/or N immobilization.

**Impact of land use change on floristic composition**

The study of vegetation characteristics revealed that the study area is quite rich in plant diversity across all the taxonomic level of species (153), genera (123) and family (54). This is quite in accordance with the fact that the study area falls in the region which is one of the 25 mega biodiversity hotspots of the world (Myers *et al.*, 2000). The species richness (153 species) recorded in the present study is closer to the other tropical forests in India *e.g.* in Western Ghats (173 in Kalakad Mundanthurai Tiger Reserve, Ganesh *et al.*, 1996; 92 species in Kadamakal Reserve, Elouard *et al.*, 1997). The total number of species encountered belonged to 54 families is well within the range of 16-58 family found in tropical forests (Gentry, 1998; Campbell *et al.*, 1992). The highest diversity and dominance of tree species in forest compared to different agricultural systems and abandoned jhum land is obvious, because the tree
population was destroyed during the initiation of agriculture which caused only a few trees in abandoned jhum land and almost no trees in terrace or jhum cultivation systems. On the contrary, the shrub species dominated the vegetation community in abandoned jhum land which can be considered as a secondary forest at an early successional stage. However, the herbaceous plant diversity and density was higher in abandoned jhum land and jhum cultivation system compared to forest, horticultural system, agroforestry system and terrace cultivation system. This can be attributed to the fact that the agricultural systems under continuous stress condition due to weeding and other agricultural activities including ploughing (in terrace cultivation system) and in forest due to dense canopy only few shade loving herbs are favoured. In jhum cultivation system however, the weed seed bank in the soil may be rich (Saxena and Ramakrishnan, 1984) due to the lesser agricultural activities like zero tillage etc. which resulted in high weed population. Saxena and Ramakrishnan (1984) also found higher weed density in jhum plots with short jhum cycle. The density and diversity of grasses were highest in horticultural system which corroborates with the result obtained under *Citrus reticulata* plantation by Sidhu (1989). This can be attributed to the openess of canopy of the system and at the same time it is a permanent system which encouraged the growth of invasive species, particularly the grasses. Compared to the horticultural system, the agroforestry system had higher plant diversity because of introduced plant species to meet various requirements of the farmers.

The forest plant community is characterized by the dominance of tropical
evergreen species like *Duabanga grandiflora, Litsaea monopetala, Cinnamomum bejolghota* etc. among the trees. The dominance of tree species in the forest at Kheel is distributed among five or six tree species but in Sagalee single tree species dominance indicates past disturbance of the forest vegetation. According to Keel and Prance (1979), dominance increases as a function of stress, while Jacobs (1987) holds the view that in tropical forests dominance by single species often indicates past damage. *C. reticulata* exerted mono-dominance in the horticultural system. But in agroforestry system the dominance of tree community is contributed by more than three species, namely *D. grandiflora, C. indica, G. arborea,* and *T. grandis* etc. where most dominant species were *D. grandiflora and C. indica.* Besides, the other land use systems namely abandoned jhum land, jhum cultivation system and terrace cultivation system are dominated by shrub or herbs as these land use systems are lacking in tree population due to agricultural land use. Among these systems the abandoned jhum land had higher herb and shrub density and diversity compared the other land use systems, which are still in agricultural use, can be due to the lack of disturbance after abandonment of the agricultural land.

Tree density varied from 145 to 859 plants per hectare in tropical forests (Richards, 1952; Ashton, 1964; Campbell, *et al.* 1992). The tree density found in the present study at Sagalee (870 no. ha\(^{-1}\)) is within the range but the value obtained in Kheel (915 no. ha\(^{-1}\)) is higher than the reported range. This variation in density may be due to the altitudinal differences between Sagalee and Kheel.
The altitudinal variation might be due to variation in temperature, relative humidity, radiation values, wind movements and edaphic factors (Nakashizuka et al., 1992). The values are well within the reported range for tropical forest (Gentry et al., 1988; Chandrasekhara and Swamy, 1997; Parthasarathy and Karthikeyan, 1997 a, b; Ghate et al., 1998). The basal area of trees (40.17 to 42.07 m$^2$ ha$^{-1}$) in forest in the present study is well within the reported range by others, but lower than the values reported by Singh et al. (102.7 m$^2$ ha$^{-1}$; 1981), Parthasarathy et al. (94.6 m$^2$ ha$^{-1}$; 1992); Burgess (73.6 m$^2$ ha$^{-1}$; 1961) and Sundarapandian and Swamy (81.38 m$^2$ ha$^{-1}$; 2000). The differences in density and basal area may, however, be attributed to altitudinal variations (Rai and Proctor, 1986), species composition, age structure, successional stage of the forest and degree of disturbance (Sundarapandian, 1997).

Over all this study revealed that the diversion of forest with rich plant diversity to different agricultural system caused drastic changes in vegetation structure and composition that might take considerably longer time to recover even after abandonment. The dense weed population in the open-canopied agricultural systems particularly the jhum and/or terrace cultivation system in this sloping land might play a greater role to conserve the nutrient and soil from runoff loss through weed biomass and by covering the soil surface. While tree-based agricultural system namely the agroforestry system can be an ideal agricultural system to conserve the biodiversity to some extent and at the same time to harvest a sustainable agricultural produce, upon a few ecological and socio-economic considerations (Arunachalam et al., 2002).
Effect of land use changes on crop/weed biomass

There was substantial variation of biomass production during different months of a year. It appears from the results that the biomass fluctuation in agricultural system is ruled mainly by agricultural activities and the crop biomass was as important component in those systems where biological interactions are too important than the edapho-climatic factors. But in non-agricultural systems the environmental factors played important role than any other factors like temperature, humidity, rainfall, soil fertility and species composition etc.

During the seed formation period of the crop plant, most of the photosynthetic resources are allocated towards the crop biomass which resulted in the peak in biomass accumulation during this period. This may be due to the genetic setup of annual crops to grow at a faster rate to complete the life cycle within a short period and also to compete with the weeds. In the present study, crop growth was much faster than the weed which is in agreement with Pandey et al. (1969, 1971) and Govil and Pandey (1985). The standing dead biomass however increased steadily with the age of crop plants where the age of the plant was the main reason of transfer of live biomass to standing dead biomass. However, standing live biomass of weed accumulation is mainly affected by climatic factors in addition to the age effect. It was higher during rainy months and least during winter and standing dead biomass increased during winter period and gradually diminished during the rainy months. But in the agricultural system, weed biomass accumulation is mostly affected by weeding, ploughing and other human activities that altered the normal biomass allocation pattern due to
repeated disturbance (Toky and Ramakrishnan, 1981b; Mishra and Ramakrishnan, 1983a) and this may be the reason for abnormal peaks in weed biomass accumulation in the agricultural systems, where the weed biomass could not reach its potential peak in appropriate time. However, the values of standing crop biomass of different land use systems are comparable with that reported by Piper and Gernes (1989) for prairie ecosystem.

Over all, the biomass accumulation by crop and weed together in agricultural systems were less than the abandoned jhum land which is a natural ecosystem in contrast to the managed ecosystem represented by agricultural system in the present study. This may be due to the fact that in agricultural system the active growth period is occupied by crop and in addition to that, the annual crops are grown for 3 to 4 months in a year, which is again managed for higher economic yield and the weed biomass accumulation is discouraged simultaneously. Consequently, the total biomass accumulation by annual plants in agricultural system was less than the abandoned jhum land at least in Kheel.

Higher crop productivity in agricultural system during their maturation period indicates that resources are allocated to the reproductive function of the crop plants (Govil and Pandey, 1985). On the other hand, the weed biomass productivity was higher when the crops are absent in the field or during the rainy or summer months and the productivity was invariably low during winter months in almost all the land use systems. This may be due to the competition between the crops and weed species for resources. The annual NPP was higher in the agricultural crops compared to the weeds in both the study areas. In
general, the productivity of the crop and weeds together were higher in agricultural systems where species diversity was lower in contrast to abandoned jhum land or forest where the productivity was less and the weed diversity was higher (Chapter 6) compared to the agricultural systems that envisage the role of species composition in biomass productivity. Piper and Gernes (1989) also reported the inverse relationship between productivity and species diversity of a site. The study of biomass accumulation pattern and productivity of crop/weed biomass in different land use systems suggest that it is affected by land use practice, environmental factors, and type of vegetation. The crop plants are adjusted for rapid growth during its favourable growing period and also to compete with the weed communities whereas the weed biomass accumulation and productivity is affected by biological activities particularly in the agricultural systems. However, in the non-agricultural system, the weed productivity is mainly ruled by edaphic and climatic parameters and may also be due to dominant weed species composition.

**Crop residue quality, decay and nutrient mineralization patterns**

*Residue quality*

The range of C content (29.55-44.56 % and 30.09-43.31 % in weed and crop residues, respectively) was within the upper (50%) limit but below the lower most value (40%) of the reported range (Kumar and Goh, 2000). According to Parr and Papendick (1978) the N content in crop residues varies considerably. This is in agreement with the present results of N content of different crop/plant
residues which ranged from 0.24 to 4.06% in the present study. However, the reported range of initial N concentration for various tree leaf litters in tropics was 0.36-3.90% (Das and Ramakrishnan, 1985; Laishram and Yadava, 1988; Okeke and Omaliko, 1992; Sankaran, 1993 and Bloomfield et al., 1993) and the present results are comparable to it.

The lignin content of crop/plant residues ranged from 9.00 to 28.52 (%) which are very close to the reported range for plants (5-30%) (Paul and Clark, 1989). The cellulose content ranged from 11.00 to 43.21 was mostly within the reported range (15-60%) in plant as reported by Paul and Clark (1989), except that the present result exceeds the lower limit that have been reported from elsewhere. Nevertheless, the reported range of cellulose content in fresh leaf litter of tropical tree species (21.3-31.7%; Bloomfield et al., 1993) is narrower than the range in crop/plant residues (11.00-43.21 %) in the present study.

**Effect of initial litter chemistry on decomposition**

Some crop and even weed residues are fairly good in quality pertaining to their N contents, C/N and lignin/N ratios. According to Myers et al. (1994) substrates with C/N<25 is of high quality and release mineral N at a faster rate compared to low quality residues (C/N>25). Usually, threshold C/N ratio is 20 to 30 beyond which the decomposition is suppressed (Kumar and Goh, 2000).

In the present study there was a strong positive correlation between initial N content of crop residues and decomposition rate (r=0.53, p<0.05). This is in concordance with the report by Janzen and Kucey (1988) and Douglas and Richkman (1992) that indicates further decomposition of plant residues with
high N content and also release N rapidly. Highly significant correlations among N content, N release and biomass loss have been reported by several workers (Frankenberger and Abdelmagid, 1985; Mellilo et al., 1982; Neely et al., 1991; Giller and Cadisch, 1997). High lignin content and/or lignin/N ratio in crop residues reduces the decomposition rate. There was a strong negative correlation of lignin content and lignin/N ratio with decomposition rate ($r=0.68$, $p<0.005$; $r=0.77$, $p<0.001$) in the present study that corroborates with the above results.

**Decay pattern**

The initial phase (0 to 30 or 60 days) of faster rate of decomposition can be attributed to the combined effect of high nutrient availability, leaching or faster release of easily decomposable materials in the initial phase. On the other hand, the relatively slow rate of decomposition in the second phase (90 to 120 days) can be attributed to the increase of recalcitrant materials like lignin, cellulose, and hemicellulose etc. and reduction of N content as it has already been used by the microbes in the initial phase. Berg and Agren (1984) and Janzen Kucey (1988) also observed two phased decomposition of plant residues where the phase I was relatively rapid and is dependent on the initial N content (Jama and Nair, 1996), whereas phase II decomposition was relatively slower and is regulated by lignin and polyphenol decomposition (Bert, 1986; Jama and Nair, 1996) which shows little differences in the residue decomposition rate regardless of initial N content because soluble, easily decomposable components might already have been utilized by the microbes and/or lost by
leaching (Reinstem et al., 1984; Christensen, 1986; Smith and Peckenpaugh, 1986; Collins et al., 1990a and Douglas et al., 1990). Thus the variation of decomposition rate among the crop, weed residues and tree leaf litter can be attributed to the initial litter chemistry.

**N mineralization pattern in decomposing litter**

Initial slow rate of N mineralization (up to 60 days) in *A. conyzoides* leaf, stem and root and *G. max* stem could be the result of slow microbial colonisation in the residues, may be due to lack of moisture in the litter and unfavourable climatic condition. Initial immobilization of N in other residues could be due to the low N availability in soil which led the micro-organisms to consume N from the decomposing residues to compensate the low availability in soil for their metabolic activities. There was an increase (after 60 days) in N concentration in decomposing mass in some residues (with high C/N ratio) during initial period, which may be due to microbial immobilization (Anderson, 1973; Maithani et al., 1996), nutrient inputs from through fall and atmospheric precipitation (Bocock, 1963), and/or atmospheric N₂ fixation (Wood, 1974). The results of the present study was slightly different from that reported by Arunachalam et al. (1998) that the initial rapid N release has been followed by slow release. However, except the difference in the initial phase (up to 60 days) the N mineralization in the later phase is comparable with the present study. After the initial phase of slow rate of N mineralization up to 30 days in most of the cases the rate increased in the next phase after 30 to 60 days and continued up to 90 days, followed by a gradual decline in N mineralization. The increase
of N mineralization in the second phase can be due to the lysis of microbial cells as a result of the lack in food material in the residues after an initial boom in microbial population during the initial phase of decomposition which consumed most of the food materials available in the residues (Reinstern et al., 1984; Christensen, 1986; Smith and Peckenpaugh, 1986; Collins et al., 1990a; Douglas et al., 1990)

**Effect of soil organic amendment on plant productivity**

Organic amendment to soil affected the plant growth and soil fertility that varied quantitatively depending on the quality of organic residues added to soil. Mulching effects on seed germination of different plant species. It influenced the *P. vulgaris* most favourably, whereas it moderately affected the germination of *Z. mays* and *A. esculentus*. This may be due to the allelopathic effect of crop/weed residue mulch. Elliott *et al.* (1978) and Putnum (1994) reported adverse allelopathic effects of crop residues on seed germination, seedling and crop growth. However, Facelli and Pickett (1991) reported that use of residue in the crop field can reduce temperature and evapotranspiration, release leachate that can be source of mineral nutrients and can influence germination factors such as moisture, temperature, and light fluctuation (Carson and Peterson, 1990). The effect of soil amendment on plant height was significantly higher compared to control and was most prominent in vermicompost treated plots. This may be due to the increase in soil fertility level in the amended plots which is evidenced by the higher available N. However, the root length did not show any particular trend. The plant growth in terms of basal cover, shoot and
root length of *Z. mays*, in the compost treatment was better, whereas vermicompost treatment was suitable for *P. vulgaris* and *A. esculentus*. This may be due to the difference in nutrient release patterns under different treatments and also difference in nutrient uptake pattern of different crop. Consequently, appropriate treatments are to be screened and applied for different plant species to reap a better harvest.

Very few reports are available on the effect of organic amendment to soil on the total crop biomass. In the present study, vermicompost treatment increased the biomass accumulation for all the test plants, followed by the conventional compost treatment. This may be due to better synchrony of nutrient release and uptake as evidenced by the significant positive correlation between biomass accumulation and nutrient mineralisation pattern and also the highest amount of available nutrient supply in the vermicompost treated plots compared to other plots. The data on plant growth and soil N mineralization suggests that during initial period of plant growth and at fruiting stage, the available N reduced considerably, despite the simultaneous increased mineralization rate, perhaps supported the high demand of plant for nutrients during those periods at least in case of *P. vulgaris and A. esculentus*.

Ghoshal and Singh (1995) reported that total crop biomass enhancements of 36, 33 and 67% over control in fertilizer, farmyard manure and farmyard manure + fertilizer treatments, respectively, in rice and 28, 41 and 78%, respectively, in lentil. Mukherjee and Gaur (1984) reported that various mulched treatments increased ammoniacal and nitrate nitrogen, available P, humus content and
microbial population over control. Paddy straw used as mulch significantly increased the grain yields of different crops such as wheat, pea, green chickpea and maize over control (Gaur, 1978; Gaur and Mukherjee, 1980).

The higher quantity of available N in all the amended plots compared to control is due to the addition of extra nutrient source in the form of organic residues or manures which through mineralization contributed to the available-N pool in those plots. The maximum availability of N in vermicompost treated soil may be due to the low C/N ratio (5.59) and high N content (5.80%) of the manure, which accelerated the N mineralization process. Singh and Kumar (1996) reported that Sesbania sp. with C/N ratio of 19.50 showed higher N-mineralization than in cluster bean with C/N ratio of 24.80 in sandy loam soil at Hissaer.

Thus, soil organic amendments increased the nutrient supply and plant productivity at different magnitude depending on the quality of residue used and mode of its application. It appears from the experiment that not a single crop residue management practice is suitable in all the situations (Murata and Goh, 1997). Different forms and dosages of organic amendment to soil can be useful for different crops. The quality of residue used is an important parameter in view of agricultural management and crop productivity. The adverse allelopathic effect of organic inputs can be reduced by composting or vermicomposting before using it in the field and direct use of crop/weed residues can reduce the germination of seed and growth of seedlings by releasing the biochemical substances.
Conclusions

The conversion of forest into agricultural land resulted in vast differences in microclimatic conditions which reflected in soil chemical properties like pH, ammonium, nitrate and phosphate concentration. Moreover, the difference in substrate quality (nutrient level) also may have had a direct relation with the variation of available and total soil nutrient concentration in different land use systems.

The soil microbial properties are observed to be closely related with soil physico-chemical properties. Some agricultural systems e.g. horticulture and abandoned jhum land perhaps develop a nutrient conservation strategy through microbial immobilization due to low soil nutrient status. Therefore, soil microbes are an important component in the management of an ecosystem.

Furthermore, the vegetation type has a major role in determining the microenvironment and also nutrient input/conservation status through plant biomass in any type of land use system. The dense weed population in the open canopied agricultural systems particularly jhum cultivation system or terrace cultivation system in this sloping land might play a great role to conserve the nutrient and soil from runoff loss though weed biomass and covering the soil surface. While tree based agricultural system namely agroforestry system can be an ideal agricultural system to conserve the biodiversity and have good agricultural produce simultaneously.

Although major part of the crop/plant residues produced in the agricultural system is recycled back to the system which might improve the soil nutrient
status but there is a possibility of great loss of nutrients from the system due to lack of synchrony between nutrient release from residues and uptake by the plant. Nevertheless, the nutrient content and lignin in the plant residues regulate decay and nutrient mineralization rates. Therefore, it is required to develop a residue management strategy to minimise the nutrient loss and optimal use of the natural resources for which further research and field trials are necessary. However, it can be concluded from the present study that some weed residues e.g. *Ageratum conyzoides* and also some crop residues like *Glycine max* and paddy residues can be used for recycling purpose. Crop residue recycling is important for maintaining the soil nutrients available for sustainable crop growth in an organic farming system and could well be a viable alternative strategy to soil nutrient management, perhaps with some technological interventions such as vermicomposting.

The organic amendments to soil increases the nutrient supply and plant productivity at different magnitude depending on the quality of residue used and the mode of its application. It appears from the experiment that not any single crop residue management practice is suitable in all the situations. Different forms of organic amendment of soil could be useful for different crops. However, the vermicomposting seems to be a favourable technique for soil nutrient enrichment and enhanced productivity.