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EFFECT OF FOREST ECOSYSTEMS ON SOIL PROPERTIES - A REVIEW

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ABSTRACT

Forests have been the primary source to rejuvenate productivity of land by improving soil health through the action of root system and addition of organic matter through litter fall. Results of various research studies conducted under different forest ecosystems in India and abroad revealed that the decomposition of forest litter and recycling of nutrients made soil physico-chemical and biological properties favourable for plant growth. The differences in vegetation types imparted differences in soil properties. With fast growing human and livestock population in India, the pressure on limited forest resources is inevitable. Consequently, the area under forests is dwindling and also the forests are getting denuded/ degraded. Hence, fast growing species of short rotation are being advocated for degraded, marginal, sub-marginal and fragile lands to meet the multiple needs of the people and industry. Evaluation of soil properties under different forest covers revealed profound impact on soil health. However, the beneficial effects of tree stands on the magnitude of improvement varied from species to species. Establishment of forest covers of suitable tree species on marginal, sub-marginal, waste/degraded lands could be a very effective and eco-friendly way of improving/reclaiming these scarce and problem land resources and also increasing area under forests.

The forest cover that constituted 22.7 per cent of the total land area in India in 1952 has declined to around 19 per cent as against national objective of 33 per cent. The per capita forest cover is only 0.1 ha against the world average of 1.0 ha. Due to ever increasing human and livestock population and various industrial and other developmental activities, the area under forest is decreasing/dwindling year after year. Despite this, the existing forests are also at various stages of denudation and degradation due to unending human needs and greeds. The forest wealth in India is facing multifarious problems, due to escalating demands for meeting food, fodder, fuel, timber, and wood products required by the people. The good quality lands for the afforestation purposes are almost exhausted. The fast growing species of shorter rotations are being grown on marginal, sub-marginal, waste/ degraded lands with the attempt to achieve the national objective of 33 per cent area under forests and also to ameliorate their health. This warranted the need to review the investigations carried out on the effect of forest covers on physico-chemical properties and site characteristics and to sum up the overall effect of afforestation on soil health of degraded/ wastelands. The evaluation of soil properties under tree cover is also important from research point of view to understand the impact of different tree species on different soil properties.

Many forest species have been found promising in rejuvenating the degraded lands. Tree plantations exert an ameliorative effect on such lands by improving soil friability and permeability through the action of root system and by adding organic matter through litter fall (Szabolcs, 1989; Garg and Jain, 1991; Garg, 1992). It has long been recognized that vegetation exerts a decisive influence on the morphological, physical, chemical and biological properties of soils. Jenny (1941) in his discussion on organisms as a soil-forming factor treated vegetation both as an independent and as a dependent variable. In order to examine the role of vegetation as an independent variable, it should be possible to study the properties of soil as influenced by the vegetation while other soil forming factors such as climate, parent material, topography and time are maintained at any particular constellation. Hence, under natural conditions, it is very difficult to estimate reliably the influence of vegetation on soil properties. But, the magnitude of this influence can be easily evaluated when man controls the vegetational cover as in many silvicultural operations.

Physical and chemical properties of soil changed considerably as a result of tree planting, however, the effect of tree plantations on soil properties differed with the kind of vegetation (Yadav, 1968). In natural forests and man made protected plantations, cycling of nutrient is also an important aspect as considerable amount of nutrients are returned through litter fall and become available for cycling (Pritchett and Fisher, 1987). Litter fall brings about important changes in physical, chemical and biological characteristics of soil (biophysical environment) and balances the nutrient resources of soils. Available evidences (Banerjee *et al.,* 1985; Miles, 1985) suggested that vegetation has a pronounced effect on many soil properties. When a population of one species is replaced by plant of different species, significant changes in dynamic properties of surface and subsurface soils such as pH, organic matter and exchangeable bases can be expected and with time changes in structure, horizon thickness, colour etc. are in offing. An attempt has, therefore, been made to review the effect of forest covers on soil physico-chemical and biological properties.

Physical Properties

Soil texture: Mechanical composition (soil texture) is very important fundamental and stable property. The finer soil particles help to conserve water and plant nutrients in addition to binding soil particles together as structural aggregates, whereas, the coarse particles serve as a skeleton to the soil, to make the soil permeable and well aerated. Yadav (1963) studied the soil profiles in Chakrata forest division of Uttar Pradesh and noted that the soils developed under pure plantation of deodar had the highest proportion of coarse sand and the lowest amount of silt through out the depth. Mechanical eluviation of clay from top soil and its deposition in the subsoil were well marked in certain profiles and accounted for, however, well marked differentiation in A and B horizons. Another study on the same site revealed that soils under deodar were fine textured and the contents of clay, silt and sand varied with depth but did not show any definite trend (Banerjee and Badola, 1980). The profiles under various teak plantations showed a slightly higher amount of clay in 30-90 cm layer (Jose and Koshy, 1972). The results of another study showed a slight increase in clay and silt content and decrease in the sand content in the sites under vegetation (Mathur *et al.,* 1982). This was attributed this to enhanced weathering in the sites under vegetation because of decomposition of added organic matter and root penetration. Pal *et al.* (1984) reported that soils developed under conifer and broad-leaved species had a finer texture than loamy fine sand.

Observations of a study on morphological and physical properties of soils under three types of forest vegetation revealed highest percentage of clay in the natural forests throughout the profile. The translocation of clay with depth was highest in teak plantation followed by mixed plantation and natural forests. Highest percentage of clay and lower percentage of sand under mixed vegetation and pure teak was due to deforestation and afforestation activities on the site. The clay migration process was more (eluviation and illuviation) under pure plantation of teak than in mixed plantation and natural forests (Prasad *et al.,* 1985). Minhas (1986) studied soils of wet temperate region of Himachal Pradesh having forest vegetation and found that soil textural class to vary from sandy loam to clay loam. The textural class of soils under chir pine forests in Solan forest Division (H.P.) varied from loam to silt loam (Malik, 1992).

Bulk density: Physical properties like bulk density (BD) and porosity improved under vegetation and the effects were limited to surface soil layer only (Ohta, 1990). Jain and Garg (1996) compared the influence of one-decade-old plantations of *Eucalyptus hybrid, Prosopis juliflora* and *Terminalia arjuna* on the physico-chemical properties of soils while revegetating sodic wastelands at Lucknow (UP). They noted that the BD in 0-15 cm soil layer was decreased and water-holding capacity increased over unplanted site. BD density decreased significantly under *P. juliflora* followed by *T. arjuna*, whereas its reduction under *E. hybrid* was insignificant. Higher BD under control site (unplanted site) was due to increasing amount of compaction and nodulation of $CaCO_3$. Similarly, Balamurugan *et al.* (2000) observed a slight decrease in bulk density under *E. citrodora* plantation than under open space. Improvement in the physical parameters of sodic soils is a good indicator of amelioration of such soils by forests (Martin, 1979).

Influence of tree plantations (*Tectona grandis, Dalbergia sisoo* and *Acacia catechu*) on soil properties at Dharwad (AP) exhibited reduction in BD of soils under plantation as compared with control (Hosur and Dasog, 1995). However, among the three species, the reduction was only under *D. sisoo* and *A. catechu* and soils under teak had almost similar BD to that under control. They attributed this to higher annual litter return by *D. sisoo.* Similarly, the BD was lowest and the pore paces were highest in surface soil (0-30 cm) under brushwood followed by eucalyptus and than under sal forest due to higher organic matter contents (Pratap Narain *et al.*, 1995). The relationship between OC and pore space was also found significant and positive (r = 0.81) but significant and negative between bulk density and organic carbon (r = -0.83). Similar studies conducted by different workers also recorded reduction in bulk density under forest trees due to high organic matter content and good soil structure as compared with cultivated (control site) land (Biswas and Ali, 1969; Biswas and Khosla, 1971; Hosur and Dasog, 1995; Contractor and Badanur, 1996).

Structural index: Different forest species are known to exert varied influence on the structural indices such as water stable aggregates, mean weight diameter of aggregate etc. Plants have deep and ramified root system and have capacity to mechanically bind soil particles. Further, the root exudates and high organic matter content due to litter fall also help in the process of binding soil particles and increasing aggregate stability. The resultant effect of forest cover is that it improves the water stable aggregates of the soil, more particularly in degraded lands. Variation in degree of aggregation among plantations could be attributed to intensive microbial activities, root development and organic matter incorporation (Yadav and Banerjee, 1968). The maximum percentage of total water stable aggregates (>0.1mm) was 76.3 per cent in top layer under teak plantation, 78.7 and 70.9 per cent in 8.23 cm layer under sal and chir plantation, respectively and 74.9 per cent in 23-46 cm layer under khair (Yadav and Singh, 1976). Many workers have found significant correlation of soil aggregates with OM and clay contents (Chesters *et al.*, 1957; Biswas *et al.*, 1961; Singh and Chaterjee, 1966; Yadav and Banerjee, 1968).

Hosur and Dasog (1995) evaluated the influence of tree species on soil properties and observed higher aggregate stability, aggregates of 2.5 mm size and mean weight diameter of aggregates under forest plantations compared to control site. Among the three plantations, soil aggregation was better under *Dalbergia sisoo*. A similar study conducted by Contractor and Badanur (1996) under eight different forest covers and cultivated field (control) also exhibited good structural index i.e., eucalyptus recorded the highest water stable aggregates (WSA) (51.3%) followed by teak (49.81%) and the lowest under control (cultivated field) (40.6%). They ascribed this to higher OC content under teak (0.68%) and eucalyptus (0.65%). Yadav and Singh (1976) and Singh and Banerjee (1980) also recorded higher percentage of WSA in the surface layer of forest soil. Correlation between the 1-2 mm size WSA and Ca was also found to be significant in teak and chir plantations. They also concluded that exchangeable Ca is of importance in influencing the development of large sized WSA to a certain extent. On the whole, they found that the development of large sized WSA in the surface soil was influenced by both OM and exchangeable Ca under teak, sal and chir and by clay content under khair. The small size aggregates in the subsoil were also influenced by clay content under teak and sal plantations.

Infiltration: The soil water storage which is of utmost importance for the tree growth and development, governed by the infiltration rate, water holding capacity (WHC) etc. of soil and land use further govern the runoff quantitatively and is also of considerable importance in checking the soil erosion. Soil erosion is one of the serious problems in India and the forests play an important role in checking this problem. Trees intercept rain water through their canopy to the maximum thereby lowering down the erosive velocity of runoff water in slopes, increasing the time of concentration for rain water and providing more opportunity for infiltration. Experimental evidences have shown that runoff is one tenth in grassy land than that in cultivated fields. It is also well known that different cover types affect the infiltration rates in different ways and forest covers generally enhanced infiltration (Megahan and Satterland 1962; Nazarov, 1969). At Bellary in India, infiltration studies were conducted under different vegetative covers and it was observed that infiltration rate was lower under agricultural land than the woodland (Mathur *et al.*, 1971). Under similar conditions, infiltration rate was highest in the forest land in comparison to bare, grass and agricultural soils (Annon, 1962). Kittredge (1948) concluded that the difference in infiltration between forested and cropped soils was in the ratio of 100 to 2 in the surface soils. Wood (1977) also recorded higher infiltration rates on 14 out of 15 forest sites than in the adjacent sites used for agriculture.

Mathur *et al.* (1982) assessed and quantified the effect of different land covers i.e. forest land and agricultural land on infiltration behaviour and found that forest soils had higher infiltration rate than in adjacent agricultural soils subjected to continued cultivation. The forest land had higher initial infiltration rate due to thick layer of humus, higher organic matter (7.27%), moisture equivalent (39.80%), pore space and water holding capacity (60.26 %) of soils. In a similar study under three land uses *viz.*, cultivated, orchard and forest, the forest soil had higher infiltration rate (5.91 cm/hr) as compared to the cultivated lands (1.08 cm/hr) and orchards (2.90 cm/hr) (Sharma *et al.*, 2001). The profiles under forest lands also had well aggregated top soil layer resulting in higher infiltration, less detachment and migration of soil particles through runoff (Mathan and Kannan, 1993).

A study by Hosur and Dasog (1995) exhibited a wide variation in infiltration rate under different forest plantations. The initial and terminal infiltration rates were highest under *D. sisoo* and lowest under teak plantation and attributed this to good soil structure, lower bulk density and higher organic matter content under former. There was inverse relation of infiltration rate with bulk density. Similarly, both steady state and cumulative infiltration were highest in brushwood, followed by eucalyptus and were lowest in sal forest (Pratap Narain *et al.*, 1990) and ascribed this to presence of dense forest litter and high OM in surface layer under brushwood. Significant improvement in infiltration rate under forests of different species as compared with agricultural land has also been observed by other workers (Wooldridge, 1970; Wood, 1977; Soni *et al* 1985; Contractor and Badanur, 1996). They attributed this to good soil structure and higher organic matter contents of forest soils.

Soil water: Soil water content were higher in soils under forest plantation as compared to agricultural soils (control site)/ unplanted site. This was attributed to more addition of organic matter and its subsequent decomposition in surface soils and improvement in soil structure (Salter and William, 1963; Abrol *et al.*, 1968; Bhavnarayana *et al.*, 1968; Gupta *et al.*, 1977; Gupta and Larson, 1979; Ravender Singh, *et al.*, 1990; Contractor and Badanur, 1996). The maximum water holding capacity and the status of available water (0.03-1.5 MPa) were higher in brushwood followed by eucalyptus and lowest under sal forest (Pratap Narain *et al.*, 1990). The higher organic matter status of brushwood and eucalyptus might be the reason for higher available water. Similarly, the water holding capacity in the open spaces and vegetated areas ranged from 34.25 to 42.53 and 38.55 to 43.36 per cent, respectively and attributed this to increase in finer fractions and organic matter content under vegetated areas.

From the studies discussed above it appeared that physical properties of soils are appreciably affected by the forest species. However, the magnitude of amelioration depends upon the type of species and its population, climate, microbial activities, degree of weathering, nutrient bearing minerals etc.

Chemical Properties

Several studies of soil differences related to the vegetation changes have been carried out. It has been observed that soil properties under different vegetation but underlying almost similar soil material in the tarai region of Kurseong Division in West Bengal revealed considerable differences among pedons primarily due to rooting and litter fall characteristics of the perennial vegetation they support (Banerjee *et al.*, 1986). Each species ultimately each community has got its own requirement during younger growth stages. Total bases in the surface soils under teak were highest but under mixed vegetation much lower and they attributed this to differential recycling of elements under different species. The fast growing short rotational plants deplete soil more as compared to slow growing and long rotational ones. Further, each species and ultimately each community has got its own requirement and capacity for utilizing the soil materials and also for returning to the soil (Seth *et al.*, 1963; Yadav and Sharma, 1968; Jose and Koshy, 1972; Jacques *et al.*, 1975). Therefore, the differences in vegetation type reflect the differences of soil properties.

pH: Soil pH is an important parameter for evaluating degree/magnitude of amelioration of sodic/acidic soils by vegetation types. It declined more at the surface than at lower depths and the maximum reduction was reflected in *Prosopis juliflora* which had larger root area and minimum under *Eucalyptus hybrid*, and *T. arjuna* in comparison to initial values (Jain and Garg, 1996). They also concluded that pattern of root growth synchronized with the depth of improvement in sodic wastelands and helped in accumulation, retranslocation and retardation of soil nutrients for developing soil-vegetation system on such soils. Similar observations in respect of soil reaction have also been made on sodic soils by other workers (Yadav and Singh, 1970; Shukla and Mishra, 1983; Gill *et al.,* 1987; Garg and Jain, 1992). In 13-15 years old forest plantations (*Tectona grandis, Dalbergia sisoo* and *Acacia catechu*), there was reduction in soil pH under *D. sisoo* (5.8) as compared to control (6.1) and this was attributed to better litter fall which on decomposition is known to produce weak acids (Vadiraj and Rudrappa, 1990; Nandi *et al.,* 1991; Chavan *et al.,* 1995; Hosur and Dasog, 1995; Contractor and Badanur, 1996). But, there was significant increase in pH and per cent base saturation in the soils under teak and attributed this to the higher content of the basic ions present in the litter of this species (Nath *et al.,* 1988). Similarly, Pratap Narain *et al.* (1990) recorded higher pH in sal forest soils (5.93) than in brushwood (5.65) and eucalyptus (5.75).

Organic carbon: Forest ecosystem contributes a lot of organic matter to the soil in the form of leaves, twigs, stems, flowers and fruits, which after decomposition result in the formation of organic carbon and release of different nutrients. There is an increase in soil organic matter by root growth especially in the instance of a permanent cover, or the incorporation of vegetation such as green manure, which improves the physical and chemical properties of soil. The nature and amount of organic carbon produced after decomposition of litter depends on the dominating tree species present and the site characteristics of the area, which regulate the physical and chemical properties of soil. Tree plantations with fast growing species have been established at many places in India on unproductive wastelands either for increasing forest cover or fuel production in India. Tree plantations also exert an ameliorative effect on such lands by improving soil fertility and permeability by adding OM through litter fall (Szabolcs, 1989; Garg and Jain, 1992; Garg, 1992).

Banerjee *et al.* (1985) observed 1.48 and 3.06 per cent organic carbon in soils under teak and sal plantation. Singh *et al.* (1985) also observed changes in OC in the surface soils of Darjeeling forest division under plantations of *Cryptomeria japonica* (dhupi) *Tectona grandis* (teak), *Shorea robusta* (sal), *Pinus patula* (pine) and mixed species. Highest OM was noticed in *C. japonica* plantation (11.6 %) followed by pine (7 %) and lowest under sal (2.09%). This was due to crop canopy, basal area and maximum litter returns in the sites under *C. japonica* followed by mixed species and *P. patula* indicating that differences in vegetation type will impart differences in soil properties. Prasad *et al.* (1985) carried out investigations on soil properties under three-vegetation type viz. natural forest, pure teak forest and mixed plantation. The maximum amount of organic carbon was observed in natural forest (1.7%) followed by mixed plantation (1.5%) and the lowest under teak plantation (0.8%). They attributed the differences in OC under these species to composition and the age of the forests.

Organic carbon in general was significantly more in surface layer under tree plantation as compared to control (Pratap Narain *et al.,* 1990; Ravender Singh *et al.,* 1990; Chavan *et al.,* 1995; Hosur and Dasog, 1995; Contractor and Badanur, 1996). Among the different plantations, the maximum OC was under brushwood (1.57%) followed by eucalyptus (1.33%) and lowest under sal (1.07%). Lower OC status under sal forests could be attributed to biotic interference and physical removal of sal leaves by villagers for animal litter and burning purposes, low decomposability and loss of sal leaves with runoff water. The low decomposability of sal leaves has also been reported by earlier workers (Pratap Narain and Singh, 1985; Tomar *et al.,* 1987). They also reported that low OC status in agricultural land, might be because of crops cultivation which accelerated the oxidation of OM and thus resulting in release of available N which either lost due to leaching or taken up by agricultural crops. Other workers (Totey *et al.*, 1986; Nitant *et al.*, 1992) have also observed improvement in organic carbon content of soils by forest tree plantations.

Balamurgan *et al.* (2000) observed higher OC status under *E. citriodora* plantation than in open space. The important inputs for OC in soil are litter fall and root biomass, which are greater under tree canopy (Nath and Benerjee, 1992; Mordelet *et al.*, 1993). Mongia and Bandopadhyaya (1992) also recorded higher OC content under natural forests than under padauk, rubber, teak and red oil palm due to the higher litter falls. The OC content was greatest near the surface soil and declined with depth under *Eucalyptus hybrid, Terminalia arjuna* and *Prosopis juliflora* (Jain and Garg, 1996).

Hosur and Dasog (1995) studied the OC status under 15 year old plantations of *Tectona grandis, Dalbergia sisioo* and *Acacia catechu* and observed that in general OC was more under plantation as compared to control site. Among the species, it was highest under *D. sisoo* due to highest litter fall. Chakraborty and Chakraborty (1989) compared the changes in OC of soil under *Acacia auriculiformis* plantations of different ages and found it to increase from 0.96 per cent in two-year-old plantations to 2.70 per cent in four-year-old plantation. The attributed this to the fast growing nature this species where even three year old plantation can provide a good soil coverage and accumulation of leaf litter.

Fertility status: There is an improvement in fertility status of the soils through the addition of root and shoot biomass. Granulation of the soil is key to soil fertility and vegetation is the best granulating agent. The available evidences (Banerjee *et al.*, 1985; Miles, 1985) suggested that vegetation had a pronounced effect on many soil properties. But when plants of different species replace a population of one species, significant changes are in the offing. Singh *et al.*, (1985) investigated the soil properties under *Tectona grandis, Shorea robusta* and other trees and observed maximum content of Ca in soils under the former. A study by Shanmughavel (1993) on the nutrient return through litter fall in bambusa recorded highest concentration on N, P, Ca, and Mg in leaf litter. On the annual basis, the total return on N was 141 kg/ha followed by 121 kg/ha P, 79 kg/ha Mg, 72 kg/ha of Ca and 131 kg/ha K. Maximum amount of all the nutrients was returned through leaf.

Roots take up chemical constituents and concentrate them in biomass. Litter falls than transfer much of this biomass to the soil and its decomposition releases these bio-phyllic chemical constituents to the soil material. A study by Hosur and Dasog (1995) on the influence of tree plantation (*Tectona grandis, Dalbergia sisoo* and *Acacia catechu*) revealed decrease in available N in soils under *T. grandis* and *A. catechu* over the agricultural soils (control) due to more depletion of N by these two species. However, available N was increased under *D. sisoo* over control due to greater return of N through litter fall in *D. sisoo* compared to *A. catechu* and *T. grandis.* Available P and K contents decreased in all the three plantations compared to control site. There was marginal decrease in nutrient status after 14-16 years suggesting the sustainability of the system. Exchangeable Ca was higher and exchangeable Mg slightly lower in the soils, especially under plantation as compared to control site in surface soils. Among the three plantations, Ca content was the highest in soils under teak, which might be due to higher content of Ca in teak leaves (Singh *et al.*, 1985). Among the various nutrients, return of N, Ca, K was higher under all the three species. But the P and Mg returns were considerably lower (Sugar, 1989; Hosur and Dasog, 1995). *D. sisoo* returned highest N, P, K and Ca among the three plantations. The nutrient return followed the order: Ca > K > N in *D. sisoo* and *A. catechu*, Ca > N > K in teak. In all the three plantations, fewer nutrients were returned under teak plantation, which could be attributed to low litter falls owing to younger growth stage. Differences in soil and leaf nutrient status under chirpine (*Pinus roxburghii*), deodar (*Cedrus deodara*) and oak (*Quercus incana*) revealed superiority of oak litter over pine and deodara in terms of making more nutrients available to the soil. The amount of nutrients (N, P and K) made available to soil by pine, deodar and oak amounted 53.46, 62.85 and 88.32 kg/ha respectively and was in the order: oak > deodar > pine (Singh and Bhatnagar, 1997).

Contractor and Badanur (1996) studied the soils (shallow Vertisols) collected from beneath the canopy of 14 years old plantations of eight forest species in contiguous area and cultivated fields (control) and revealed that available N and P content and CEC increased significantly under forest plantation as compared with control. Availability of N and P was highest under teak due to higher litter fall in comparison to other species. However, the available K content decreased significantly under different plantations except under teak over the control. Among the exchangeable cations, Ca was the dominant and its status was significantly higher under teak as compared with other plantations due to higher accumulation of litter, which further resulted in higher OC. The highest CEC was observed in soils under eucalyptus. They further suggested that teak, Bengali jali, tamarind and neem were the most suitable for dry tact of northern Karnataka.

The organic matter reflects towards the capacity of soils for exchanging the cations. The soils under *C. japonica* plantation had maximum CEC (62.5 me/100g) followed by that under mixed (43.3 me/100g) and pine (34.5 me/100g) plantations (Singh *et al* 1985) due to higher OM under *C. japonica* (11.6%) and lowest under *P. patula* (7.0 %). The CEC depends upon the nature and composition of humus present in the soil (Mukhopadhyay and Banerjee, 1985). The status of exchangeable K^+ was highest in soils under teak plantation. Yadav and Sharma (1968) showed that the soils under teak had higher exchangeable Ca^{++} than those under sal. They observed that predominance of teak or sal appeared to be governed to some extent by the amount of exchangeable Ca, as this was dominant among the cations. There was tremendous increase in CEC, exchangeable cations and base saturation under forest tree cover.

The changes in soil properties (N, P, OC, pH, WHC) in 2, 3 and 4 year old *Acacia auriculiformis* plantations in comparison to control site were remarkable due to fast growing nature of this species (Chakraborty and Chakraborty, 1989). The three-year-old plantation provided good soil coverage and accumulation of leaf litter. Chavan *et al.* (1995) found that under field conditions, the effect of forest tree species on the physical properties was not distinct during a 10-year period. However, the soil chemical properties especially that of surface layer were much influenced by the addition of OM and release of nutrient through litter decomposition. The highest CEC was observed in soils under *Eucalyptus* plantation and decreased in order: eucalyptus > shivan > teak > casurina > karanj > australian babul > control due to the variations in the rate of humification of organic matter added through the litter fall of these species. The exchangeable Ca^{2+} increased in the soils as a result of incorporation of litter from growing trees. It was dominant cation among all cations. The soils under eucalyptus, shivan and teak showed higher exchangeable Ca^{2+} followed by suru, karanj, ain and australian babul. Nath *et al.* (1988) reported the base saturation in teak soils varying from 37.7 to 88.3 per cent.

Singh *et al.* (1985) investigated the changes in nutrient status in soils under *Cryptomeria japonica* (dhupi) *Tectona grandis* (teak) *Shorea robusta* (sal), *Pinus patula* (pine) and mixed species and observed maximum content of Ca^{++} and K^{+} in site of teak plantation. Considering the total amount of exchangeable bases in the surface soils under five different vegetations, the soils under teak had maximum amount (16.0 me/100g) where major part was contributed from Ca^{++} alone (11.0 me/100g). The soils under other species were in the order: sal (10.6 me/100g) > mixed (10.3 me/100g) and pine (10.3 me/100g) > dhupi (5.4 me/100g). They suggested that to maintain natural balance and to avoid drastic changes in soil properties, mixed plantation may be preferred than to pure plantation because of differential bio-cycling potentialities of the individual plants which in turn help to maintain a balanced status of nutrients and productivity.

An investigation by Prasad *et al.* (1985) on the changes in soil properties owing to conversion of natural forest into mixed and teak plantation were carried out. The P, K and Mg status were highest in mixed plantation followed by teak forest plantation. In the case of Ca, the differences due to vegetation type were not appreciable. The highest amount of total exchangeable cations was recorded in teak (12.1 me/100g) and lowest (8.4 me/100g) in mixed plantation. The maximum loss of fertility in terms of OC, P_2O_5 and Mg was found in teak plantation than in the mixed plantation and might be due to the lower retention of nutrients as well as higher return of nutrients in the natural forests.

The effect of different vegetation to enrich nutrient status depended on the forest cover, nature and type of soil, organic matter accumulation, microbial activity and quantity, degree of weathering of nutrient bearing minerals etc. (Aweto, 1981; Bhoumik and Totey, 1990). Balamurugan *et al.* (2000) recorded appreciable increase in CEC, total and available nutrients in sites under vegetation than under open spaces. The available N, P and K in the open spaces ranged from 34-109, 9.3-10.9, 132-143 kg/ha, respectively. The corresponding values under vegetation varied from 38-192, 9.9-13.9 and 159-184 kg/ha. The higher CEC and nutrient status were due to increase in OM under plantation and also CEC of humus is much more than clay.

Biological Properties

The kinds of microorganisms found in forest soils may not differ significantly from those found in other soils. The variety, number and activity, however are generally much greater in forest soils than in agricultural soils. Forests soils contain four major groups of microflora: bacteria, *actinomycetes*, fungi and algae. The favourable environment of the forest floor encourages the proliferation of myriads of microorganisms that perform many biological processes and complex tasks relating to soil formation, organic matter decomposition, nutrient availability and recycling and tree metabolism and growth.

Microbial biomass: Soil microbial mass constitutes a transformation matrix for organic matter in soil and act as an active reservoir for plant available nutrients (Jenkinson and Ladd, 1981). Microbial biomass responds much more rapidly than does the total organic matter to any change in ecosystem conditions and thus its measurement is a valuable tool for understanding and predicting the long term effects of changes (Powlson *et al.*, 1987).

Cultivation leads to a considerable loss of soil organic matter and microbial nutrients (Adams and Laughlin, 1981; Srivastava and Singh, 1999). Micrcbial biomass and population is often used as a guide for evaluation of fertility status of soil.

Studies by Maithani *et al.* (1996) and Arunachalam and Arunachalam (2002) on dynamics of soil microbial biomass under different land use conditions indicated greater microbial C, N and P in tropical forest ecosystem soils followed by paddy field and riverbed. They attributed this to various reasons *viz.*, soil types and its nutrient status, soil microbial population, substrate quality and its availability, climate and moisture condition and type of species growing. However, the microbial biomass N values were much lower when compared to reports of coniferous forest soils (Martikainen and Palojarve, 1990). Srivastava (1999) studied the dynamics of microbial biomass and available nutrients under a dry tropical forest in Vindhyan Hills in Sonbhadra district of Uttar Pradesh and found that microbial C, N and P were greatest under forest soils and lowest under 15 year crop field. Microbial biomass contributed 1.8-3.5 per cent to total organic carbon, 1.9-4.6 per cent to total N and 4.8-12.3 per cent to the total P. There was a strong positive correlation among microbial biomass and available nutrients.

Biological N_2 fixation: Fixation of atmospheric N_2 by different tree species through symbiotic and non-symbiotic relationships is probably the most important pathway for this element to enter the forest ecosystems. Many forest tree species has ability to add nitrogen to the soil through the process of biological fixation of atmospheric nitrogen. But it is very difficult to estimate the exact amount of N_2 fixed by the trees and shrubs, which is actually used or potentially available to the associated crop during the various periods of time.

Symbiotic fixation occurs through the association of plant roots with nitrogen fixing microorganisms and many legumes form an association with bacteria *Rhizobium*. Nonsymbiotic fixation is effected by free living bacteria (*Clostridium*, *Azotobacter* and *Beijerinkia* species) and blue green algae, and can be a significant factor in natural ecosystems, which have relatively lesser nitrogen requirements from outside systems. It is not believed to be much and account only for few kilogram of N/ha/yr in most forest soils (Brady, 2000). However, nonsymbiotic N_2 fixation is of minor importance in agricultural systems that have far greater demands of nitrogen. Symbiotic N_2 fixation in non-legumes is carried out by *Rhizobium* in association with members of the family *Leguminosae* and *Frankia*, a genus of *Actinomycetes*. A large number of leguminous species were believed to occur naturally in forests. Some legumes have been successfully introduced into problem areas as a source of N in preparation of site for afforestation (Gadgil, 1971). Symbiotic N-fixation by *actinorhizal* plants made significant contributions of N in many forest ecosystems. Presumably, this type of biological nitrogen fixation varies according to the species, organic matter content, climate, soil type, microbial activity, management practices etc. Various workers have estimated biological N_2 fixation by many tree species in different areas. Sanginga *et al.* (1995) in their review, cited N_2 fixation levels of 100-300 kg N/ha/yr and some times up to 500 kg N/ha/yr. Such estimates are subject to a number of variables such as soil, climate and plant management conditions. Among the 650 woody species belonging to nine families that are capable of fixing atmospheric N_2 515 belong to the family *Leguminosae* (320 in *Mimosoideae*, 170 in *Paplionoideae* and 25 in *Caesalpinoideae*) (Nair *et al.*, 1998).

Mycorrhizal fungal flora in forest species: Mycorrhizal infections are known to increase the absorption phosphate and other poorly mobile ions in soil such as Zn^{2+}, Cu^{2+}, Mo^{2-} and K^{+}. Mycorrhizal fungi are most often associated with the roots of nitrogen-fixing trees. Endomycorrhizae, which penetrate the host roots, are more common than ectomycorrhizae, which remain external to the roots. Most of the species of the *Pinaceae, Silicaceae, Betulaceae, Fagaceae, Juglandaceae, Tiliaceae, Myrtaceae* etc. normally form ectomycorrhizae belonging to class *Basidiomycetes* primarily in the Amanitaceae, Boletaceae, Cortinariaceae, *Rubbulaceae, Trichotomataceae, Rhizopogonaceae* and *Sclerodermataceae* and in several orders of *Actinomycetes*, primarily *Eurotiales* (Marx, 1972).

Twenty species of ectomycorrhizae from *Boletaceae* were identified (Sharma and Lakhanpal, 1982) in forest trees of northwest Himalayas during extensive survey conducted during 1974-80. The ectomycorrhizae of *Pinus Wallichiana* and species of *Quercus, Rhododendron* and *Betula* appeared simple, unforked roots, bifurcated roots, multiforked knots and coralloid or even nodular roots. Whitish and yellowish white ectomycorrhizae were found in *Pinus roxburghii* forming well-developed harting net (Sharma *et al.,* 1985). In high altitude forest and culturable soils, species of *Endogone* were noticed frequently (Jalali, 1986) belonging to genra *Glomus, Gigaspora* and *Sclerocystis.* Forest soils of Dehradun, dominated with *Glomus macrocarpus* in hoop pine (*Araucaria cunninghammi*) and teak (*Tectona grandis*) plantation (Thapar and Khan, 1973). The *Glomus* was also present in sub-humid and humid tropical forests of northwest Himalayas (Sharma *et al.,* 1984). Other mycorrhizae found in new Dehradun forest soils under *Tectona grandi* were *Pedocarpus gracilior, Gigaspora gilmori, Gigaspora aurigloba, Gigaspora margarita, Gigaspora heterogama, Glomus fasciculatus, Glomus monosporous.*

Pal *et al.* (1985) studied the forest soils of Darjeeling Himalayan region having *Pinus patula* vegetation and observed that fungi and *actinomycetes* have greater proliferation than bacteria irrespective of profile depth. All the microorganisms thrived best in the surface, with the population decreasing more or less down the profile. They attributed this to the abundant supply of organic matter at the surface horizons rendering conditions most favourable for fungi and *actinomycetes.* These are known to depend on the plant contribution while others on fertility status of soil. Greater proliferation of all types of microorganisms in the surface soils, the environment where maximum influence of plants on microorganisms and *vice versa* are observed and gradual decrease in lower horizons is associated with fertility status, moisture retention, aeration, reaction and other environmental conditions of the profile (Alexander, 1977).

CONCLUSION

Forest litter is rich in many nutrient elements and it has profound influence on ameliorating the land productivity. Many research works indicated that forests improved the soil health and environment. The influence of forest plantation on soil properties was more profound in surface soil than in the subsurface soil. Some of the forest species are efficient enough in absorbing nutrients from deeper soil layers and accumulate them in surface layer through litter fall which eventually improve the physical, chemical and biological properties of the soils. Forests also amended the problem soils such as sodic/alkali/acidic soils. However, the magnitude of impact varied from species to species and also depends upon the nature and type of soil, climate, organic matter accumulation, microbial activity and quantity, degree of weathering nutrient bearing minerals etc. Development of forests on lands unsuitable for the agricultural purpose could be an effective and eco-friendly way of managing and ameliorating these, which is the need of the day. Also under the conditions where there is severe competition for lands to be utilized for food, fodder and fuel production, establishment of fast growing short rotation forest species is indispensable for improving/reclaiming marginal/degraded/wastelands. These lands can be exploited later as good fertile soils for arable farming at certain rotational interval. All the studies indicated the potential of forests for improving the soil health.

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