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Research Article

FOREST TYPES AND SOIL CHARACTERISTICS – A REVIEW

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ABSTRACT

The differences in vegetation types imparted differences in soil properties. Forests and forest soils play a broad, complex and important interactive role within the environment. 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 favorable for plant growth. Evaluation of soil properties under different forest covers revealed profound impact on soil health. The pressure on limited forest resources is inevitable with fast growing human &livestock population, the area under forests is dwindling and also they are getting denuded/ degraded. 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. This paper undertakes a selective review of published work on the influences of different forest types on soil properties and therefore is neither comprehensive nor exhaustive in its cover age.

Keywords: Soil, forests, growth, Fertility, SOC.

INTRODUCTION

Soil and vegetation have a complex relationship, in which one influences the other. Forests, forest soils and their interactions carry out key functions that contribute to food security and a healthy environment. Forests soils play an important role in carbon storage which ultimately influences climate change. Climate emissions are major contributor to climate change. Forest soils store a quantity of carbon equaling that of the global forest biomass. The effect of tree on soil formation and nutrient cycling has been recognized for a long time (e.g. Shear and Stewart, 1934; Zinke, 1962; Alban 1982; Hobbie, 1992; Binkley *et al.,* 1991). Several authors have demonstrated the existence of a close interaction between plant and soil. Van Breemen (1993) reviewed studies on the influence of plants, soil animals and microorganisms on their physical substrate. He concluded that in many cases these microorganisms appear to affect soil fertility, soil moisture content and other soil properties in such way that with time the substrate becomes more favorable for the plant growth of plants and micro-organisms. According to Forest Survey of India 2019 report the forest cover of India constitutes 21.67% of the total geographical area. Due to increasing human population along with livestock and other developmental activities across the world the forest area is dwindling year after year. The existing forests are also affecting due to all these activities and are at the verge of degradation. Due to increasing demand of food, fodder, fuel, timber, wood products and other arising issues the forest production and the quality of forest soils is decreasing. The fast-growing species are also being grown to fulfill the need of industries along with to achieve the objective of 1952 forest policy. This warranted the need to review the investigations carried out on the effect of forest covers on physico-chemical properties and site characteristics. 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.

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It has also been recognized that vegetation exerts a decisive influence on the morphological, physical, chemical and biological properties of soil. Forest species have been found rejuvenating the degraded and barren lands. Tree plantations improves soil fertility, permeability, soil friability through the action of root system and by littering leaves on forest floor and forming organic matter (Szabolcs, 1989; Garg and Jain, 1991; Garg, 1992). Soil physical and chemical properties are influenced by vegetation, however the effect on soil properties vary with the kind of vegetation on the areas (Yadav, 1968). Litter fall brings about most important changes in biophysical environment (physical, chemical and biological characteristics of soil). Significant changes can be seen in surface sub surface soils such as pH, organic matter, Bulk density and other physical properties in different forest types and by replacing of one plant community by other. Therefore, an attempt has been made to review the effect of different forest types on soil quality properties.

Effect on soil physical properties

Soil is a complex matter and comprises minerals, soil organic matter, water, and air. These fractions greatly influence soil texture, structure, and porosity. These properties subsequently affect air and water movement in the soil layers, and thus the soil's ability to function. Therefore, soil physicochemical properties have a great influence on the soil quality.

Soil Texture: Soil texture especially can have a profound effect on many other properties. Texture indicates the relative content of particles of various sizes, such as sand, silt and clay in the soil. Texture influences the ease with which soil can be worked, the amount of water and air it holds, and the rate at which water can enter and move through soil. A study was conducted 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 throughout the depth. Mechanical eluviation of clay from top soil and its deposition in the subsoil were well marked in profiles and accounted for, however, well differentiation in A and B horizons (Yadav, 1963). Jose and Koshy (1972) studied the profiles under various teak plantations showed a slightly higher amount of clay in 30-90 cm layer. In Kangra District of Himachal Pradesh forest soils were mostly clay loam, silt loam and loam in texture and were having brown and varying shades of grey or yellow in color (Gupta *et al.* (1974). Kolay *et al.* (1975) studied the effect of different land uses on water stable aggregates, and found that the bigger sized aggregates (>2.0mm) were higher in grassland soils, whereas, smaller sized aggregates (0.25mm to 0.5mm) were dominant in cultivated and uncultivated soils. A study 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 average infiltration was in the order of good terraced croplands > poorly terraced crop plants > grasslands > forest lands. The infiltration rate in forest soils were lower due to the compact soil and scanty litter deposited on forest floor (Mohan and Gupta,1983). Pal *et al.* (1985) reported that soils developed underconiferand broad-leaved species had a finer texture than loamyfine sand.

Foth, 1990 [3] Gupta, 2004 [5] described that soil texture determines the physical and chemical properties of soils. It affects water infiltration and retention, absorption of nutrients, aeration, and tillage and microbial activities irrigation practices. White 1997 [5] opined that the soil texture is one of the natural soil physical properties less affected by management. Six *et al.,* 2002 [11] indicated that the clay minerals with a higher cation exchange capacity (CEC) and large surface area have a greater potential to bind with SOM than clays with lower CEC and smaller surface area. Von Lutzow *et al.,* 2006 concluded that the adsorption of OM on the mineral surface of clay and silt creates atableorgano mineral complexes, which helps in stabilizing the OM from decomposition.

Bulk Density: Bulk density is an indicator of soil compaction. It is calculated as the dry weight of soil divided by its volume. This volume includes the volume of soil particles and the volume of pores among soil particles. Bulk density reflects the soil's ability to function for structural support, water and solute movement, and soil aeration. 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 sorlie 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. A study was conducted including 14 species of hardwoods and a total of 325 trees. Ten species were oak, which were divided inintoo a red oak group and white oak group. The red oak group had an average bulk density of 80.7 lb/ft^3, and the white group oak had an average bulk density of 79.2 lb/ft^3. A significant difference was found between the groups, as were significant differences between species between each group. Southern red oak had the highest value (83.03 lb/ft^3), and white oak had the lowest (77.0 lb/ft^3) (David *et al.,* 2011). Influence of tree plantations (*Tectona grandis*, *Dalbergiasisoo* 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. *sissoo* 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. *sissoo*. Similarly, the BD was lowest and the pore space were highest in surface soil (0-30 cm) under brushwood followed by eucalyptus and then under sal forest due to higher organic matter contents (Narain PetaI, 1985). Brady and Weil, 2002; Gupta, 2004 described that bulk densities of soils are inversely related to the quantity of pore space and soil OM. For instance, intensive cultivation enhances bulk density resulting in reduction of soil porosity. The study results of Woldeamlak and Stroosnijder (2003) and Mulugeta (2004) revealed that bulk density of cultivated soils is higher than the bulk density of forest soils. Mulugeta, 2004 stated that soil bulk density increased in the 0-10 and 10-20 cm layers related to the length of time the soils were subjected to cultivation.

Soil Water: Soil water content was higher in soils under forest plantation as compared to agricultural soils (control site) unplanted site. An article by Fricke (1904) throws considerable light on soil moisture as a frequent determining factor in germination and survival of reproduction under full canopies. Aaltonen (1926) is of particular interest for the significances of soil moisture in the forest. From a detailed study conducted in Finland under both natural and second growth conditions, the conclusion comes to that there exist between the members of each species a very definite space arrangement which is directly dependent upon the quality of the soil. According to Thornthwaite's (1955) concept of "potentialevapo-transpiration ", a calculable amount of water will be moved into the atmosphere from a land surface for any given set of conditions - and with a continuously ample supply of water in the soil.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 percent, respectively and attributed this to increase in finer fractions and organic matter content under vegetated areas. Rawls *et al.* 2003 [49] initially reviewed that the studies on the effects of soil OM on soil water retention properties and relationships between water holding capacity and soil organic matter.

Soil Porosity: Foth, 1990 described that total porosity of soils generally lies between 30% and 70%. In soils with the same particle density, the lower the bulk density, the higher .is the percentage of total porosity and different forests shows varying values of soil porosity and bulk densities. Generally, exhaustive cultivation causes soil compaction and degradation of soil properties including porosity. Macro pores can occur as the spaces between individual sand grains in coarse textural soils. Although a sandy soil has relatively low porosity, the soil aeration and water through such soil is surprisingly rapid because of the dominance of macro pores. According to Mulugeta, 2004, increase in soil bulk density, soil total porosity shows marked declines in both soil layers (0-10 and 10-20 cm) with increasing period under cultivation. The lowest total porosity is the reflections of the low OM content.

Effect on soil chemical properties:

Soil pH: Soil pH is one of the most indicative measurements of soil because it plays an important factor for the survival of the organisms (Evans *et al.,* 1984). Murthy *et al.,* (1985) reported pH values in the range of 5.4 to 6.1 for the soil of Garhwal Himalayas under Pine forest and was noticed to increase with soil depth. The pH is a most commonly used method for expressing soil acidity or alkalinity. Most often forest soils have a pH range varying from 3.5 to 6.5 (Prithcett, 1979). Sharma (1991) and Malik (1992) found soil pH values ranging from 5.0 to 8.4 and 5.1 to 7.9 respectively under chir-pine forest of Solan division and noticed progressive increase in pH down the profile. Garg and Jain (1992) observed, after eight years of establishment of *Acacia auriculiformis* plantation, enrichment of soils through leaf litter and noticed increase in soil pH from 4.98 to 5.37. Phogat et al. (1999) studied soil properties under Acacia tortilis in arid region of Haryana. Acacia plantation was found to considerably increase the organic matter but decreased soil pH in 10 to 15 cm soil depth. Gairola *et al.,* (2012) for Conifer mixed broadleaf forest and *Abies pindrow* forest in Mnadal-Chopta, Chamoli Garhwal region and Khera *et al.* (2001) for *Quercus leucotrichophora* and Q.*floribunda* forest in Uttarkashi Garhwal region have also reported acidic pH values i.e. 5.47 and 5.20. This may be due to higher organic matter content and protected nature of forest. Tiwari *et al.,* (2013) studied the physico-chemical properties of soils in cool-temperate forests of the 'Nanda Devi Biosphere Reserve' in Uttrakhand (India). The soil was found acidic in nature, which ranged from 5.09±0.06 to 6.46±0.05 for 0 to 45cm depth. Vishnu *et al.,* (2017) studied physico chemical properties of Forest Soils in kerala and found the soil reaction was found to be acidic in different forest types and it ranged from 5.1 to 6.5. Soil pH decreased with soil depth nearly in all the plots but significantly different in 0- 15 cm depth (6.9312[a]) and highest in plot 37 (7.635[a]). This higher value is expected as most soil in the tropics has their ranging from acidic to slightly neutral (Alloway and Aryes, 1997). Similar trend has been observed in the study by Oyedele *et al.* (2008).

Soil fertility: Soil fertility is the ability of soil to sustain plant growth and optimize crop yield. This can be enhanced through organic and inorganic fertilizers to the soil. There is always seen an improvement in fertility status of the soils through the addition of root and shoot biomass which gives contribution in soil organic matter as well as SOC. Alexender (1989) explored the potential of Acacia albida in ameliorating the soil. The study revealed that soil mounds, organic carbon, total N, pH, percentage base saturation and exchangeable Ca, Mg and Na were all significantly higher in soils from beneath the canopy than those from outside. Bhola (1995) investigated the soil enrichment potential of seven nitrogen fixing trees (NFTs) including *Acacia auriculiformis* and found considerable improvement in soil chemical properties under all species. The overall enrichment was 15.52 to 39.52 per cent in organic-C, 8.8-17.98 per cent in available nitrogen, 15.36 to 98.91 per cent in available P, 4.88 to 17.92 per cent in available K, 2.09 to 14 per cent in exchangeable Ca and 1.93 to 9.54 per cent in exchangeable Mg. He further reported significantly lower pH under NFT's.

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 anp 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.

Soil Organic Matter: Doran and Safley, 1997 explained that the suitability of soil for sustaining plant growth is a function of physical properties (porosity, water holding capacity) and chemical properties (nutrient supply capability, pH) many of which are functions of SOM content. Krull et al (2004) identified the importance of soil organic matter to carry out certain functions in the soil varies with soil type. For example, the need for soil organic matter to provide cation exchange capacity is the most important in sandy soils. On the other hand, the need for soil organic matter to provide food and energy sources for the microbial population is needed in all soils, regardless of clay content or texture. Quilty and Cattle 2011 stated that additions of large amount of organic materials as composts or as biochar can enhance the levels of soil organic matter in soils.

Soil organic carbon: Total organic matter accumulated in soils constitutes a major portion of the world's fixed carbon reserves. Bohn (1976) estimated that the soil contains approximately 30 x 1014 kg organic carbon. Distribution of this organic matter among soil types is highly variable and generally not easily predictable from above ground vegetation types. The quantity of organic material retained with in the soil matrix is the difference between total biomass production and decomposition. Trees improve soil productivity through ecological and physico-chemical changes that depend upon the quantity and quality of litter reaching soil surface and rate of litter decomposition and nutrient release (Meentemeyer and Berg, I986). Batjes and Dijkshoorn (1999) reported the mean carbon densities to a depth of lm range from 4 kg m-2 for coarse textured Arenosols to 72.4 kg m-2 for the poorly drained Histosols of the Latin America. Mean carbon density for the mineral soils excluding Arenosols and Andosols (30.5 kg cm- 2) was 9.8 kg m-2. In total the top 1m holds 66.9 Pg C and 6.9 Pg N. Approximately 52 per cent of the carbon pool was held in the top 30 cm of the soil layer which was most prone to changes upon land use conversion and deforestation. Bhatt *et al.,* (2000) worked on the soil organic carbon of five study sites (i.e., Ghimtoli, Dhanolti, Dewarkhal, Devidhar and Jhadidhar) of Garhwal Himalaya and found the moderate variation in soil organic carbon of all the sites with an average range of 1.18±0.22% to 2.07±0.9%. They observed highest organic carbon parentage in the soils of Devidhar (2.07±09%), it was due to occurrence of more herb species. Manhaset al. (2006) considered that the total C stored in Indian forests around 1085.16 Mt and 1083.81 Mt for the year 1984 and 1994 respectively. The order of C contribution stocked for the major forests types is Miscellaneous forests >Shorearobusta forests >*Tectonagrandis* forests > *Temperate* forest > Tropical forest > Bamboo forest, etc. The average C stock within the country is estimated at 24.94t C/ha and 24.54 t C/ha for the year 1984 and 1994 respectively. Sahaet al. (2014) studied on soil organic carbon stock and fraction in relation to land use and soil depth in degraded lower Himalaya the SOC stock in the 1m soil profile was highest (83.5 Mg ha^{-1}) in forest and lowest (55.6 Mg ha^{-1}) in eroded lands. The SOC stock at the surface (0-15cm) soil constituted 6.95, 27.6, 27 and 42.4 per cent of the total stock in the 1m profile of eroded, cultivated, forest and grassland soils, respectively. The soil organic carbon percentage varies from 1.98-2.83%, 1.72-2.11% and 1.56-1.74% at soil depth of 0-15cm, 16-30cm and 31-45cm respectively with mean values of 2.34%, 1.87% and 1.64%. The soil organic carbon showed a decreasing trend with increasing soil depth (Thakur and Verma, 2019). Similar trend of decreasing SOC values with increase in depth have also been seen by Dar and Somaiah (2013) and Jobbagy and Jackson (2000).

Singh *et al.* (2010) evaluated the effect of pure stands of tree species and poplar-based agroforestry system on soil organic carbon (SOC) and available N, P and K contents. They observed that soil organic carbon and available nutrients in the surface were significantly higher in the surface soil (0-15cm) than the lower depths, irrespective of tree species. Organic carbon and available nutrients were significantly more under all the tree species compared to control in the surface layer. Organic carbon increased by 90.3% under Siris followed by Kikar (84.5%), Sissoo (82.2%) and Subabul (80.8%) over control. In poplar-based agroforestry system, the average content of organic carbon was higher by 22.2% than pure pearl millet- wheat rotation. Further, the interaction effects of soil depths and cropping systems were significantly related to organic carbon.

Koppad and Pavanthikhile (2016) reported that the assessment of carbon sequestration in soils of different land use, dense forest, sparse forest, agriculture and open land were identified. The soil samples at 1m depth were drawn at grid point in flat land and along the profile in sloppy land in different land use system. Among the different land use classes, higher SOC was sequestered in dense forest (200.10 t ha^{-1}) followed by sparse forest (166.89 t ha^{-1}). The SOC in open land and agriculture land is 145.78 and 82.79 t ha^{-1}, respectively. The carbon mitigation potential of dense forest is 2.42 times higher compared agricultural land, followed by sparse forest (2.02 times) lands.

Krishan *et al.* (2017) investigated belowground carbon density in the forest ecosystem in the temperate region of the Garhwal Himalaya. Investigators have studied the component wise belowground carbon flux in trees, soil organic carbon (SOC) and litter carbon of six different forest types for measuring total belowground carbon allocation (TBCA). The maximum SOC was exhibited by Abies pindrow forest (110.83±5.04 Mg C ha^{-1}), followed by *Pinus roxburghii* forest (108.22±13.03 Mg C ha^{-1}), *Quercus floribunda* forest (97.37±7.64 Mg C ha^{-1}) whereas minimum SOC was recorded for Cedrus deodara forest (56.94±5.13 Mg C ha^{-1}). The study showed that belowground carbon stocks in *Abies pindrow* forests is maximum in carbon accumulation capacity, whereas Cedrus deodara forest has minimum Below ground carbon stocks.

Conclusion

Forest has the potential to contribute to climate change through their influence on the global carbon cycle. Forest is being recognized as playing important roles in global biochemical cycle. Major pools of carbon are the atmosphere, fossils fuels, oceans and terrestrial biota and soils. In general, the influence of forest vegetation on soil related to the producing of a new substratum of soil and the changing of soil structure. Forest vegetation assists in the formation of soil by the accumulation of plant remains by stimulating weathering through the action of acids formed by vegetation, and by the resistance which forest vegetation offers to moving air and water.Forests modify physical and chemical properties of soil through addition of organic matter, decomposition of leaves and other plant parts, root penetration and activity of other animals inhabiting the forest. The forest is more than a defense against erosion. All the studies reviewed in the present paper indicated that forests have the potential to improve and increase different soil properties under different types of forests.

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