A comparative study of soil physicochemical properties between eucalyptus, teak, acacia and mixed plantation of Jhilmil Jheel wetland, Haridwar-Uttrakhand

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Abstract- The present study was conducted in Jhilmil Jheel wetland which is situated on the left bank of river Ganga between Latitude N29°32' to 29° 50' and Longitude E 78o10' to 78°15'covering an area of 3783.50 hectares. The altitude of the area varies from 200 to 250 meters above msl. This wetland is known for conservation of *Cervus duvauceli duvauceli* (Barasingha). It is situated between Haridwar - Najibabad highway in the natural course of the Ganges. A two-year study was conducted between the year 2012-2014 to analyse the soil physicochemical properties between different plantation sites of this magnificent wetland i.e., eucalyptus plantation, teak plantation, acacia plantation and mixed plantation. After the analysis, it was observed that the soil texture under eucalyptus plantation, teak plantation and acacia plantation was sandy loam in nature while it was observed clay loam under mixed plantation site. Maximum bulk density was observed under eucalyptus plantation site (1.50 g cm^{-3}) while it was minimum (1.29 g cm^{-3}) under mixed plantation site. Moisture content was observed maximum (14.57 %) under mixed plantation site whereas it was observed minimum (8.38 %) under acacia plantation site. Soil pH was observed near neutral (i.e., 6.82 and 6.78) under teak plantation and acacia plantation site while it was slightly acidic (i.e., 6.55 and 6.49) under eucalyptus plantation and mixed plantation site. The result revealed that the maximum soil organic carbon (1.99 %), total nitrogen (0.23%), available phosphorus (14.66 ppm) and exchangeable potassium (230 ppm) was observed under mixed plantation site whereas the result revealed that the minimum soil organic carbon (1.60 %), available phosphorus (9.26 ppm) and exchangeable potassium (111.5 ppm) was observed under acacia plantation site except for the total nitrogen which was observed minimum (0.17 %) under eucalyptus plantation site. One-way ANOVA and post-hoc tukey test was also applied to analyse and to compare the mean significant difference between each parameter under different sites.

Index Terms- Wetland, soil organic carbon, plantation, physicochemical characteristics, ANOVA.

I. Introduction

Rapid growth of population and industrialization has putted huge negative impact on the rich biodiversity of India which also include wetlands. Wetland soils are highly productive and fragile in nature. It supports rich biodiversity and extensive food chain and sometimes referred to as "Biological Supermarkets". Protection and improvement of such fragile ecosystem is highly required to ensure the productivity and health of this wetland ecosystem. Soil is the major source of nutrients for the growth of plants and while determining the degree of soil physicochemical characteristics is very necessary to evaluate the soil fertility. The nutrient transformation and its availability in soils depend on pH, clay minerals, cation and anion exchange capacity (Reddy and Reddy, 2010). One of the important factors to determine quality of soil and serves as sources of nutrients for improving physical and biological properties of soils in addition to productivity is organic matter. So, a study was conducted to analyse the fertility of soil under four plantation sites (i.e., eucalyptus, teak, acacia and mixed plantation) of Jhilmil Jheel wetland as the present investigation was an attempt to document the physicochemical properties under different land use and it is hope that the study will provide a baseline data and useful knowledge in the future as no such work was carried out.

II. STUDY AREA

Jhilmil Jheel wetland is a saucer shaped wetland situated on the left bank of River Ganges between N 29^0 32' to 29^0 50' and E 78^0 to 78^0 15' covering an area of 3783.50 ha of Reserve Forest. Of the total area covered by Jhilmil Jheel wetland, the plantation area covered 3116.6 ha which was further divided into different strata with eucalyptus plantation covering an area (1726.30 ha) followed by teak plantation (81 ha), acacia plantation (830.60 ha) and mixed plantation (478.7 ha). The altitude of the area varies from 200 to 250 meters above mean sea level. It is located on the Haridwar – Highway and besides the natural course of the Ganges to the south of it in Chidiyapur Forest Range of Haridwar Forest Division, Uttarakhand.

Each stratum has been further divided into different blocks:

1. Eucalyptus plantation (Ganga block 1a, 1b, 4, 6, 7a, 8a, 9a, 9b, 10a)
2. Teak plantation (block 9a and 8b)

3. Acacia plantation (Amsot 1a and 1b)
4. Mixed plantation (block 5 and 7b)

STUDY SITE

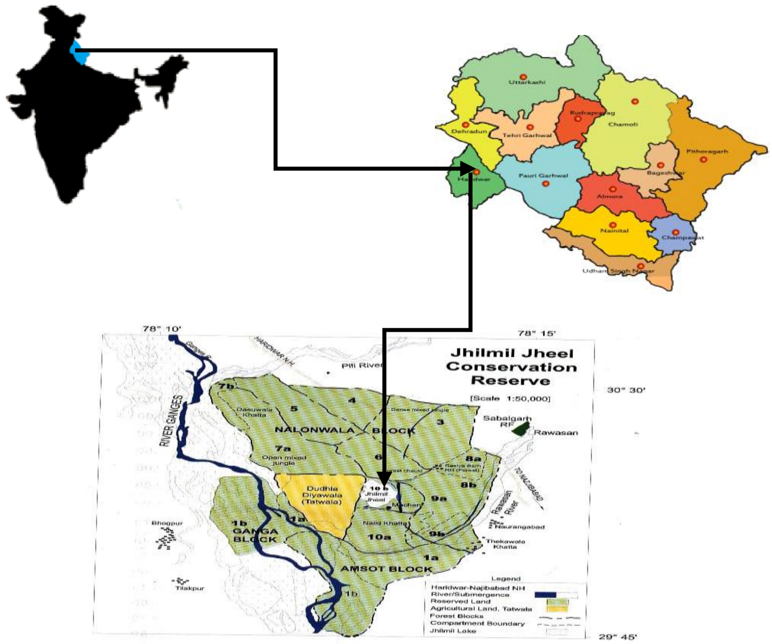

Figure 1. Extensive study area of Jhilmil Jheel wetland *(Source: Haridwar forest department)*

III. MATERIAL AND METHODS

Soil samples were collected from each site for estimation of different physico-chemical parameters. At each site, 30 soil cores were obtained randomly at a depth of 0-30 cm with the help of soil corer. The collected soil samples were brought into the laboratory. After air drying and removing twigs and pebbles, the soil samples were ground in a pestle mortar and then sieved through 2mm mesh sieve to determine the soil moisture, pH and bulk density, the sieved samples were stored in the thick quality polythene bags for the determination of different soil parameters like texture, organic carbon, total nitrogen, available phosphorus and exchangeable potassium. The analysis was done following the standard procedures:

1. Texture: Hydrometer method (Lemenih *et al.*, 2005)
2. Bulk density: Core sampler method (Blake, 1965)
3. Moisture: Sartorious moisture meter
4. pH: Digital Lutron pH-201 pH meter
5. Organic carbon: wet oxidation method (Walkley and Black, 1934)
6. Total nitrogen: Kjeldahl method (Bremner, 1960).
7. Available phosphorus: Olsen's method (1954)
8. Exchangeable potassium: Flame photometer

IV. RESULTS AND DISCUSSION

The negative impacts of monoculture tree plantations in forest areas have been thoroughly studied and documented in nearly all the countries where they are located. The plantation site was divided into four subsites i.e., eucalyptus plantation, teak plantation, acacia plantation and mixed plantation. Physicochemical parameters were set for all the four subsites and data was analysed. One-way ANOVA and post-hoc tukey test was applied to analyse the mean significant difference between each parameter under different sites which was shown in table 1.

Table 1. Soil physicochemical properties under eucalyptus, teak, acacia and mixed plantation site of Jhilmil jheel wetland

Parameter / Site	Texture				Bulk Density (g cm^{-3})	Moisture (%)	pH (1:2.5)	Organic Carbon (%)	Total Nitrogen (%)	Av. Phosphorus (ppm)	Ex. Potassium (ppm)
	Sand (%)	Silt (%)	Clay (%)	Texture class							
Eucalyptus plantation	56[a]	25[a]	19[a]	Sandy loam	1.50[a]	12.32[a]	6.55[a]	1.62[a]	0.17[a]	10.92[a]	175.5[a]
Teak plantation	64[c]	23[a]	13[c]	Sandy loam	1.37[b]	11.90[a]	6.82[b]	1.94[b]	0.21[b]	13.30[b]	220[b]
Acacia plantation	67[c]	20[b]	13[c]	Sandy loam	1.42[c]	8.38[b]	6.78[b]	1.60[a]	0.19[b]	9.26[c]	111.5[c]
Mixed plantation	33[b]	37[c]	30[b]	Clay loam	1.29[d]	14.57[c]	6.49[a]	1.99[c]	0.23[c]	14.66[d]	230[d]
F	22.53	11.11	5.40	-	95.77	47.09	59.36	6.86	18.83	74.72	50.63
P	0.000	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	***	***	***	-	***	***	***	***	***	***	***

Same alphabets represent statistically at par group

Soil texture under eucalyptus, teak, acacia and mixed plantation site: When the soil samples were analysed to see the texture of the soil under different land uses, it was observed that the soil under eucalyptus plantation, teak plantation and acacia plantation site was sandy loam while under mixed plantation site, the texture of the soil was depicted clay loam in nature as shown in table 1.

One-way ANOVA was applied to compare the mean difference of sand, silt and clay content between each site. The analysis showed the mean of sand, silt and clay under the four subsites showed significant difference at ($P < 0.05$ level). Post-hoc analysis revealed that mean sand percentage under eucalyptus plantation site and mixed plantation site showed significant difference with each other and between other two subsites, while no mean significant was observed between teak plantation site and acacia plantation site in terms of mean sand percentage. Similarly, silt content under acacia plantation site and mixed plantation site showed significant mean difference between each other and with eucalyptus plantation and teak plantation site while no significant mean difference was observed between eucalyptus plantation and teak plantation site. Finally, clay content under eucalyptus plantation site and mixed plantation site showed significant difference between each other and with teak plantation site and acacia plantation site but no significant difference was observed between teak plantation and acacia plantation site.

Soil moisture under eucalyptus, teak, acacia and mixed plantation site: The result revealed that the soil moisture content was observed maximum (14.57 %) under mixed plantation site followed by eucalyptus plantation site (12.32 %), teak plantation site (11.90 %) and the minimum (8.38 %) soil moisture was observed under acacia plantation site (Table 1). The high soil moisture content under the mixed plantation site was may be due to high litter layer on the surface as compare to other sites which helps protect the moisture from evaporation. Another reason for having high moisture content under mixed plantation site and low moisture content under acacia plantation site was because of the texture of the soil. It was depicted from the study that the texture of the mixed plantation site was clay loamy while it was sandy loamy under eucalyptus plantation site, teak plantation site and acacia plantation site. Clay particles can hold soil moisture for longer period of time as compare to the sandy soil.

In contradiction to the above findings, Srivastava (1993) had estimated that the eucalyptus sp. had high water holding capacity in the soil. There was more soil moisture under eucalyptus than a nearby open area even after three consecutive drought years. Abbasi and Vinithan (1997) had established that eucalyptus hybrid plantations didn't depleted soil moisture and their performance in their report always compared favourably with plantation of another tree species. Regarding complaints against eucalyptus that it draws water from water table, several researchers had investigated its root behaviour also in different soil conditions. George (1977) noticed that tap root of eucalyptus hybrid had descended to a depth of 3 m and the lateral roots had spread up to 3.5 m. These findings were also supported by Rao (1984) and Davidson (1985) in a study made in 10-year-old plantations of eucalyptus globules and *Pinus radiata* near Rome reporting that the tap root of the former reached a depth of 4.20 m and of the latter a depth of 2.20 m and the lateral roots a radius of 11 m and 5 m respectively.

One-way ANOVA suggested significant mean difference in the soil moisture content between different subsites at ($P < 0.05$ level). Post-hoc test revealed that eucalyptus plantation site, acacia plantation site and mixed plantation site showed strong significant mean difference while no significant mean difference was observed between eucalyptus plantation site and teak plantation site with respect to the mean values of soil moisture for homogenous subsets (table 1).

Soil bulk density under eucalyptus, teak, acacia and mixed plantation site: In table 1, the analysis showed that the bulk density was estimated highest (1.50 g cm^{-3}) under eucalyptus plantation site followed by acacia plantation site (1.42 g cm^{-3}), teak plantation site (1.37 g cm^{-3}) and the lowest bulk density was observed under mixed plantation site (1.29 g cm^{-3}). Low bulk density under mixed plantation site was may be because of high organic matter content in the soil as high organic matter improves the overall quality of the soil. From the field study, less quantity of litterfall was observed under monoculture plantation sites which adds to less amount of organic matter into the soil. Okoro *et al.,* (1999) on comparing the soil physical properties of some monoculture plantations (*T. grandis. Nauclea diderrichii* and *G. arboreai*) in the lowland rain forest belt of South-western Nigeria with that of natural forest found that the texture of the soils was not affected by the respective plantation species. Amponsah and Meyer (2000) studied soils of natural forests converted to teak plantations (21.3 to 5.1 years) in the Offinso and Juaso forest districts in the Ashanti region, Ghana and found that in the 0-20cm and 20-40cm depth, bulk density significantly increased.

Mongia and Bandyopadhyay (1994) reported that the replacement of virgin forest with highly valued plantation species viz., *Pterocarpus dalbergiodes, S. robusta, T. grandis* and *Elaeis guinensis* plantation in Andaman led to a rapid deterioration in soil physical properties and found that bulk density of the surface soil increased to (1.30 gm/cc), (1.49 gm/cc), (1.35 gm/cc) and (1.28 gm/cc) in plantations respectively, compared to bulk density of 1.05 gm/cc in the virgin forest.

When we compared the mean values under each subsite (table 3), one-way ANOVA depicted significant mean difference at ($P < 0.05$ level). After applying post-hoc tukey test, the analysis revealed all the four subsites were strongly and significantly different from each other with respect to the mean values of soil moisture.

Soil pH (1:2.5) under eucalyptus, teak, acacia and mixed plantation site: In our study, the soil pH under the four subsites of plantations were estimated which was shown in table 1. The soil pH was observed near neutral under teak plantation and acacia plantation site while soil pH under mixed plantation and eucalyptus plantation site was observed to be slightly acidic in nature as shown in table 1. Decomposition of soil organic matter releases organic acids leading to decrease in pH in forest (Killham, 1994). This may be one of the reason for having low soil pH under mixed plantation site as it produces large components of litter as compare to the other three sites. Eucalyptus trees are invasive species that survive by inserting an acid into the soil killing the plant roots that surround it. Therefore, the eucalyptus side was slightly acidic. This would make sense that why the eucalyptus plantation site has high pH concentration as compare to teak plantation site and acacia plantation site. Relatively low values for pH, organic carbon, exchangeable bases and exchange acidity were observed in monoculture teak and eucalyptus (uncoppiced and coppiced) compared to those in mixed plantations by Balagopalan *et al.,* (1992) in the state of Kerela. Similar observations were also being made by (Hann, 1997) where they mentioned that the reduction in soil pH can be attributed to accumulation and subsequent slow decomposition of organic matter, which releases acids in the forest soil.

Despite having high organic matter present in the teak plantation site, Nazir and Netajini (2014) in their study showed that the average soil pH (7.12) was higher under teak forest and pH showed negative correlation with organic carbon, organic matter, whereas it was observed positively correlated with phosphorus under three forest types in Dehradun. Paudel and Sah (2003) reported similar results for soils in tropical sal (*Shorea robusta Gaertn.)* forests in eastern Nepal.

when the data for the selected parameter was subjected to one-way ANOVA to see whether significant differences exist with respect to different land use at ($P < 0.05$ level), it was depicted from the analysis that there was significant difference between different subsites. The post-hoc analysis also showed that that between eucalyptus plantation site and mixed plantation site showed strong significant mean difference between each other and with the other subsites with respect to the mean values of soil pH while no mean significant difference were observed between teak plantation site and acacia plantation site (table 1).

Soil organic carbon under eucalyptus, teak, acacia and mixed plantation site: The result showed that the mixed plantation site has got the maximum percentage of soil organic carbon followed by teak plantation site, eucalyptus plantation site and the least amount of percentage soil organic carbon was observed under acacia plantation site. Large quantity of litterfalls adds to large quantity of organic matter into the soil which ultimately leads to increase in the organic carbon content in the soil. Similar observations were made out in our study where mixed plantation site and teak plantation site having high litter contents had high organic matter in the soil whereas less litterfall under the eucalyptus plantation site and acacia plantation site showed low soil organic carbon content in the soil as shown in table 1.

Wang *et al.,* (2008) conducted a study on litterfall and its decomposition rates in a monoculture and mixed stand in southern China. Their study depicted that the annual litterfall at the pure and mixed stands varied from 244 to 788 and 455 to 1041 g m^{-2} yr^{-1}, respectively. They estimated that the mean annual litterfall at the mixed stand (699 g m^{-2} yr^{-1}) was higher 24% than that at the pure stand (565 g m^{-2} yr^{-1}). Xu and Nie (2002) stated that that the productivity of well-managed plantations can be sustained whereas poor management practices result in dramatic yield declines across rotations and continued soil degradation. The mixed stand of forest species seemed to be the best plantation system, as it increased soil organic matter and fertility level and improved soil structure. Chaubey *et al.*, (1988) found that litter production was 1.5-2.0 times greater in the teak plantations (20-23 year) than in adjoining forests in Madhya Pradesh. Annual leaf litterfall was higher in teak than in eucalyptus (Singh *et a1.,* 1993). It was also observed that decay rate of the litter varied significantly both in the field and in the laboratory. Teak litter decomposed rapidly when compared to that of *E. tereticornis* (Singh *et al.,* 1993; Pande and Sharma, l993a).

Chaubey *et. al.,* (1988) found that litter production was 1.5-2.0 times greater in the teak plantations (20-23 year) than in adjoining forest. Annual leaf litterfall was higher in teak than in eucalyptus (Singh *et. a1.,* 1993). It was also observed that decay rate of the litter varied significantly both in the field and in the laboratory. Teak litter decomposed rapidly when compared to that of *E. tereticornis* (Singh *et. al.,* 1993; Pande and Sharma, l993a; Sankaran, 1993; Maharudrappa *et. al.,* 2000; Panda and Swain, 2002).

One-way ANOVA was subjected to analyse the mean difference among each site under plantation at ($P < 0.05$ level) which was shown in table 1. The analysis showed that sites with respect to soil organic carbon showed significant mean difference. The post-hoc test also showed that teak plantation site and mixed plantation site were significantly different with each other and also with eucalyptus plantation and acacia plantation site and while no significant difference were observed between eucalyptus plantation site and acacia plantation site with respect to the mean values of soil organic carbon content for homogenous subsets.

Soil total nitrogen under eucalyptus, teak, acacia and mixed plantation site: Our result showed that total nitrogen was maximum (0.23 %) under mixed plantation site followed by teak plantation site (0.21 %), acacia plantation site (0.19 %) and the least was depicted under eucalyptus plantation site (0.17 %). The study also showed that total nitrogen was strongly and positively correlated with SOC and that with high soil organic carbon observed under mixed plantation site leads to high concentration of total nitrogen in the soil. Another possible explanation for having high nitrogen content in the soil was due to higher plant litter production in the mixed plantation site. Total nitrogen increased with increasing organic matter which was also observed by Nazir and Netajini, (2014) in their study. According to Jha *et al.,* (1984), if the soil is rich in organic matter, it is definitely rich in total nitrogen also. Haan (1977) also analysed that the availability of nitrogen depends upon the amount and properties of organic matter.

Our study depicted high nutrient values under mixed plantation site and teak plantation site but in contrast to our findings, Blanford (1933) reported that teak cropping lead to serious soil erosion especially due to the removal of undergrowth and soil erosion was the main form of soil deterioration in Burma. After a, thorough study in pure teak plantations of Burma, Castens (1933) notes that soil deterioration due to teak cropping may be slow. Increased nitrogen content in soil under mixed plantation site as compare to other sites depicted high rate of litter decomposition, the decomposition rate was more rapid on nitrogen rich site (Gosz, 1981; Vitousek *et al.,* 1994 and Prescott, 1995) and nutrient supply to the soil due to decomposition of litter was reduced with increased in degree of disturbance (Conn and Dighton, 2000 and Zimmer, 2002) which was visible in the eucalyptus plantation site and acacia plantation site. When the selected parameter was subjected to one-way ANOVA to observe the significant mean difference between all the four subsites, the analysis showed that mean values of total nitrogen with respect to its subsites showed significant difference at ($P < 0.05$ level). Further, post-hoc test also revealed that there exists a strong mean difference between eucalyptus plantation site and mixed plantation site while no mean significant difference was observed between teak plantation site and acacia plantation site with respect to the mean values of soil total nitrogen for homogenous subsets (table 1).

Soil available phosphorus under eucalyptus, teak, acacia and mixed plantation site: Our result showed that the maximum (14.66 ppm) available phosphorus was observed under mixed plantation site followed by teak plantation site (13.30 ppm), eucalyptus plantation site (10.92 %) and the least (9.26 ppm) was observed under acacia plantation site. Marquez *et al.,* (1993) studied the effect of teak chronosequence (in 2-7- and 12-year old plantations) on soil properties in the Ticoporo Forest Reserve, Venezuela. Their findings showed that the available soil phosphorus concentration showed a significant decline with plantation age. They suggested the possibility that older teak trees could take nutrients more efficiently from deeper soil horizons and return them to the soil surface as leaf litter. The increase in soil nutrients observed under teak plantation could be a consequence of leaf litter decomposition and further nutrient cycling which proves the higher concentration of available phosphorus under teak plantation site and mixed plantation site as well.

Pande and Sharma (1993b) noted teak and sal conserved more nutrients than pine and eucalyptus, and conservation of nitrogen and phosphorus was found greater than that of other nutrients which supported our findings and explained the reason for having low concentration of available phosphorus under eucalyptus plantation and acacia plantation site.

We applied one-way ANOVA to depict whether there exists any significant difference among different land uses. After the analysis, the result showed that each site with respect to the mean value of available phosphorus showed significant difference at ($p < 0.05$ level). Post-hoc test also revealed that the mean values of each subsite were observed strongly and significantly different from each other for homogenous subsets with respect to the mean values of soil available phosphorus.

Soil exchangeable potassium (ppm) under eucalyptus, teak, acacia and mixed plantation site: Our study showed that soil exchangeable potassium was maximum (230 ppm) under mixed plantation site followed by teak plantation site (220 ppm), eucalyptus plantation site (175.5 ppm) and the least (111.5 ppm) was observed under acacia plantation site (Table 1). As it was mentioned in previous studies that clay soil particles can hold more soil nutrients then the sandy soil particles and our findings also showed similar trend with high exchangeable potassium content under mixed plantation site which has clay loamy texture in comparison to the remaining three subsites which were having sandy loamy texture. This may be one of the reason for having high potassium content under mixed plantation site. This study was supported by Kaila (1965) who observed in his study that potassium fixation by samples of many soils of Finland increased with clay content which indicated that soils with higher clay contents were likely to contain more non-exchangeable potassium. Sands were often made up of almost entirely of quartz and therefore contain very small amounts of potassium minerals.

Levy (1964) reported greater exchangeable potassium availability to plants in soils of coarse texture than on fine texture. Thus, replacement of a given amount of exchangeable bases will cause release of more potassium ions from sandy soils than from clayey soils with equal exchangeable potassium content. Some researches tried to find out relation between soil pH and potassium. Our study showed that there was low potassium content where high soil pH was observed except for the teak plantation site where potassium content was depicted quite high even when the soil pH was near neutral. York *et al.*, (1953) noted that the fixation of fertilizer potassium takes place more readily in neutral than in acid soils and liming an acid soil increases its ability to fix potassium. Geodert *et al*., (1975) stated that though liming decreases potassium susceptibility to leaching, it might also reduce solution potassium to levels where plants suffer deficiencies.

When one-way ANOVA was applied, the statistical data suggested that there was significant difference at (P 0.05 level). Post hoc test revealed that all the subsites were strongly and significantly different from each other for homogenous subsets with respect to the mean values of soil exchangeable potassium.

V. CONCLUSION

It was observed from the above study that mixed plantation site has got the maximum nutrient values followed by teak plantation site and the least was observed under both acacia plantation site and eucalyptus plantation site. It was also observed that mixed plantation site had very dense vegetation as compare to the rest of the three subsites. The amount of litter fall was again observed maximum under mixed plantation site as it was obvious with having high vegetation density. We also observed high ground litter production under teak plantation site due to presence of its large leaves which adds extra litter to the surface of the ground. The physical properties of soils in monocultures of teak (*Tectona grandis*) and eucalyptus (*E. terericornis*, uncoppiced and coppiccd) and mixed stands of teak and bombax (*Bombax ceibu* /*B. malabaricumil*) in Thrissur forest division, Kerala was studied by Balagopalan *et al.*, (1992). They found that the differences in physical properties were negligible. Chavan *et al.*, (1995) studied the effect of forest tree species viz. *T. grandis, Terminalia tomentosa*. *Pongamia pinnata, G. arborea, eucalyptus, Acacia auriculiformis,* and (*Casuarina equisetifolia* on properties of lateritic soil (Maharashtra) and concluded that there was no change in soil physical properties. They also found that chemical properties of soils under monocultures of teak (*T. grandis*), eucalyptus (*E. tereticornis*, uncoppiced and coppiced), and mixed stands of teak and bombax (*B. ceiba [B. ma1abaricum])* in Kerala differed between plantations. Finally, it was concluded that the mixed plantation site of plantation forest was depicted to be the most fertile site followed by teak plantation site, eucalyptus plantation site and the least fertile site was depicted to be the acacia plantation site which had got the least mean values with respect to soil physicochemical properties.

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