Economic Valuation of NPK and Soil Vegetation Interrelationship in Three Forest Types of Dehradun.

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Abstract: Three forest types i.e, sal (*Shorea robusta*), teak (*Tectona grandis*) and shisham (*Dalbergia sissoo*) were analysed for physio-chemical properties and economic analysis. Soil samples from these forests were analyzed for texture, water holding capacity, pH, available potassium, available phosphorus, total nitrogen and organic carbon. Average available potassium was maximum (147ppm) in *Shorea robusta* forest followed by teak and shisham with 102ppm and 32ppm respectively. Similarly, available phosphorus was highest in teak (19.33ppm) followed by sal and shisham 18.17ppm and 2.75ppm, respectively. Organic carbon and total nitrogen were maximum under teak plantation. The soil pH under teak was neutral, whereas it was almost neutral in sal and it was slightly acidic in shisham. By applying a market price method, the values of all nutrients of the studied sites was estimated. The values were derived by multiplying the amount of available nutrients (kgha^{-1}) by the market price of the nutrients (Rskg^{-1}). The average value of NPK nutrients in one hectare of teak was calculated Rs 297,733 ha^{-1}(N), Rs 1,353ha^{-1} (P) and Rs 7,140 ha^{-1}(K) and in case of sal it was Rs 125,767 ha^{-1}(N), Rs 1,272 ha^{-1}(P), and Rs 10,290 ha^{-1} (K). Similarly in case of shisham the economic value of NPK was estimated Rs 74,800 ha^{-1}, Rs 193 ha^{-1} and Rs 2,241 ha^{-1}, respectively. The maximum basal area of 14,741 m^{2}ha^{-1} was recorded in teak plantation whereas it was 13,225 m^2/ha^{-1} and 10, 532 m^{2}ha^{-1} in sal and shisham vegetation, respectively. The highest tree density was 733 trees ha^{-1} in shisham plantation, declining to 433 trees ha^{-1} and 183 trees ha^{-1} in teak and sal vegetation, respectively.

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Introduction

Soil is one of the basic natural resources on which all forms of terrestrial life co-exist. The vegetation of forests has a pronounced bearing on the structure and functions of the underlying soils. Each year, trees add large quantities of organic matter in the form of litter, most of which gradually forms part of the soil and also supplies its constituents to the layers lying below. The littered soil of forest provides a unique microenvironment as it has a wide range of microbes to decompose litter and recycle it back to vegetation. The downward movement i.e. leaching of nutrients and humus depends upon the types of vegetation and soils, and to some extent the topography (Allison 1973). Besides moderating the water cycle the soil provides services such as sheltering of seeds, retaining nutrients, decomposition of organic wastes, returning the inorganic nutrients to plants and regulating elementary cycles (Sreeja 2009). Soil and vegetation, therefore, have a complex relationship because they develop together over a long period of time. The selective absorption of nutrient elements by different tree species and their capacity to return them to soil brings about changes in soil properties (Singh *et al*., 1986).

The yearly contribution of surface vegetation to soil, in the form of needles, leaves, cones, pollen, branches and twigs, gradually decomposes and becomes a part of the soil (Singh and Bhatnagar 1997). The nutrients thus returned to the soil exert strong influences on ecosystem processes (Pastor *et al*. 1984). Plant tissues (above and below ground litter) are the main source of soil organic matter, and influence the physico-chemical characteristics of soils, such as, texture, water holding capacity, pH and nutrient availability (Johnston 1986). Nutrient supply varies widely among ecosystems (Binkly and Vitousek 1989), resulting in differences in plant community structure and productivity (Ruess and Innis 1977). The present study was carried out to understand the impact of *Tectona grandis* (teak), *Shorea robusta* (sal) and *Dalberga sissoo* (shisham) forests on the physicochemical properties of soils and to estimate the economic value of N, P, K in soils under these forests.

Materials and methods

This study was carried out in three different vegetation types at Dehradun city of Uttarakhand, which lies between 77 20'4"- 78 18'30" E longitude, 29 58'40"-30 20'4" N latitude at an elevation of 640 m (a.m.s.l). It is surrounded by the outer Himalayas in the north, Shiwalik ranges in the south, river Yamuna in the west and Ganges in the east. Longitudinally, it spread from north-west to south-east, between Mussoorie in the north and Mohan Shiwalik ranges in the south. The study was conducted at three different sites (Site 1-Lachhiwala, Site 2-Dhaulkot and Site 3-Sidduwala) of Dehradun Forest Division.

Soil samples were collected from three predetermined depths i.e. 0-10, 10-30 and 30-60cm by opening pits. The water holding capacity (WHC) and moisture content of the soil samples was determined as per Mishra (1968), whereas the bulk density was estimated by the method of Wilde *et al*. (1964). Porosity was expressed in percent by volume calculated from the bulk density (BD) and particle density (PD) of soil (Brady 1996). Munsell Colour Chart was used to determine the soil colour. Walkley and Black rapid titration method as modified by Walkley (1947) was adopted for organic carbon estimation and the organic matter was estimated by multiplying soil organic carbon by a factor of 1.724. The pH of soil was determined directly with using a Control Dynamics digital pH meter (model AP + 175E/C). Total nitrogen was determined by the colorimetric technique. Available potassium was extracted by neutral normal ammonium acetate (Morwin and Peach; 1951). Available phosphorus was determined in the soil by Olsen's method, (Olsen *et al*. 1954). The vegetation analysis was done by laying out quadrats. On each selected site 25 quadrats were laid (each 10 x 10 m) randomly to study tree components as described by Curtis and McIntosh (1950) and Mishra (1968).

For economic valuation of soil nutrients, the productivity method (derived value method) was adopted. The available form of NPK in the market is urea which was Rs 25/kg, diammonium phosphate (DAP) was Rs 35/kg and potash was Rs 35/kg. The economic value of nutrients (NPK) was estimated per kilogram on the basis of the current market price (Rs Kg^{-1}), which was assured from the local market in the form of nutrients sold in the market for the year 2010 (Sreeja et al. 2009).

Results

In the teak forest the texture of the soil was silty loam at 0-10 cm depth and silty clay loam at 10-30 cm and 30-60 cm depths. The percentage of clay was higher (40.0%) at 30-60cm depths, which indicated that there was movement of clay from the upper to lower horizons. The percent water holding capacity was higher (54.02%) at 0-10 cm depth. The soil colour varied from dark yellowish brown to yellowish brown. The bulk density was higher (0.95%) at 0-10 cm depth. The soil porosity was higher (68.84%) at 10-30 cm depth. Soil pH was neutral and ranged from 7.06 to 7.17. Total nitrogen was higher (0.30%) at 0-10 cm depth. The percent organic carbon was higher (2.02%) in the upper horizon and decreased with soil depth. Soil organic matter was maximum (3.48%) at 0-10 cm depth. Available phosphorus was maximum (22.5ppm) at 30-60 cm depth and minimum (18.0ppm) at 0-10 cm depth. Available potassium was maximum (153 ppm) at 0-10 cm depth (Table 1).

The soil texture in the Sal forest was silty clay loam at 0-10 cm and 30-60 cm depths and silty loam at 10-30 cm depth. Soil colour varied from pale brown to brownish yellow. Bulk density increased with increasing depth. Soil porosity decreased with depth. Soil moisture content (13.38%) and water holding capacity (52.77%) was higher at 30-60cm depth. Soil pH was slightly acidic and ranged from 6.97 to 6.30. Organic carbon content was higher in the surface horizon and decreased with increasing depth (i.e; 1.60% at 0-10cm depth, 0.34% at 10-30cm depth and 0.78% at 30-60cm depth respectively). Available phosphorus was maximum (25.0 ppm) at the upper horizon decreased with increasing depth. Soil potassium was maximum (168ppm) at the surface of the soil and it also decreased with increasing depth. Similarly, total nitrogen was higher (0.17) in the upper surface of the soil and decreased with increasing depth. Soil texture was loamy at 10-30cm depth and silty loam at 0-10cm and 30-60cm depths. Bulk density increased with depth whereas porosity decreased with depth. Water holding capacity (WHC) was higher (46.66%) at 0-10cm depth. WHC was higher when the percentage of clay was high (Table 2).

Similarly in *Dalbergia sissoo* plantation organic carbon was maximum (0.72%) at the surface horizon of the soil and decreased with depth. Soil pH was near neutral and ranged from 5.66 to 6.36. Soil phosphorus was mximum (3.75ppm) at 0-10cm depth. Potassium was also maximum (51 ppm) at the soil surface and decreased with increasing depth. Total nitrogen was maximum (0.098%) at the soil surface and decreased with increasing depth. (Table 3)

Average total nitrogen percent was higher (0.27%) under teak plantation (Table 1) and was lower (0.068%) in Shisham plantation (Table 3).

The average available potassium was higher (147ppm) in Sal forest (Table 2) and lower (32ppm) in Shisham plantation (Table 3). Average phosphorus was higher (19.33ppm) in teak plantation (Table 1) and lower (2.75ppm) in Shisham plantation (Table 3).

In Teak plantation, a highly significant positive correlation was observed between total nitrogen (TN) and organic carbon (OC) (0.94); TN and soil organic matter (SOM) (0.94); SOM and WHC (0.96); and between available potassium and OC (0.94). Non-significant correlation was observed between pH and TN (-0.90), pH and SOM (-0.70), and bulk density and pH (-0.88) (Table 4).

In Sal forest, a highly significant positive correlation was observed between available potassium (K) and OC (0.93); pH and available phosphorus (P) (0.94) and SOM and available K (0.93), whereas a non-significant correlation was observed between bulk density (BD) and available P (-0.95) and BD and pH (-1.00) (Table 5).

In Shisham plantation, a highly significant positive correlation was observed between total nitrogen and OC (0.99); available K and TN (0.97); WHC and OC (0.91), and SOM and WHC (0.91). Non-significant correlation was recorded between pH and TN (-0.84), pH and OC (0.75);,B.D and TN (-0.85), and BD and WHC (-0.97) (Table 6).

A linear relationship existed between OC and TN; porosity and BD (Figs. 1-6) whereas a non-linear relationship existed between WHC and clay content in all three vegetation types (Figs.7-9)

Maximum basal area (14,741.35m^2ha^{-1}) was recorded in teak plantation, as compared to 13225.85m^2ha^{-1} in sal and 10532.04m^2ha^{-1} in shisham plantations. Maximum tree density of 733 trees ha^{-1} was recorded in Shisham plantation, followed by 433 trees/ha in teak and 183 trees/ha in sal plantation (Table 7-9).

The total amount of N was maximum in teak plantation (5413$kgha^{-1}$), followed by 2287$kgha^{-1}$ in sal and 1360 $kgha^{-1}$ in shisham plantation. Average available phosphorus was maximum (39 $kgha^{-1}$) in teak plantation, followed by 36 $kgha^{-1}$ in sal and 5.5 $kgha^{-1}$ in shisham plantation. Average available potassium was maximum (294$kgha^{-1}$) in sal forest, followed by teak (204 $kgha^{-1}$) and shisham (64$kgha^{-1}$) plantations (Table 10).

By applying market prices we estimated the economic value of all nutrients of the study sites. Economic values were derived by multiplying the amount of available nutrients ($kgha^{-1}$) by the market price of the nutrients ($Rskg^{-1}$). The average values of nutrients in one hectare of teak were calculated as Rs 297,733ha^{-1}(N), Rs 1,353ha^{-1}(P), and Rs 7,140ha^{-1}(K). In sal plantations, values were Rs 125,767ha^{-1}(N), Rs 1,272ha^{-1}(P) Rs 10,290ha^{-1}(K). In Shisham plantations, the values were Rs 74,800ha^{-1}(N), Rs 193ha^{-1}(P), and Rs 2,241ha^{-1}(K) (Table 10). Figs. 10 to 12 show the nutrients in $kgha^{-1}$ and their market values for teak, sal, and shisham plantation types.

Discussion

Soil texture influences productivity through its impacts on moisture availability, soil temperature, nutrient pools and the accessibility of soil organic matter to microbial decomposition (Schimel *et al*., 1996). Although soil texture is one basic property that cannot be changed easily, the downward movement of soil particles along with water results in preferential migration of finer soil particles to the lower layers due to the changes brought about by organic matter and root activities of plants under a plantation (Gupta, 1987; Gupta and Sharma, 2008). Clay layers therefore, move to lower horizons in the soil. In the present study also the downward movement of clay from upper to lower horizons was noticed in all profiles. Geis *et al*. (1970) reported accelerated movement of clay from A to B horizon under different types of forest vegetation. Raina *et al*. (2001) found that soils with greater illuvation and thicker B horizon were the developed soils.

In all forest plantations of the present study the bulk density increased with increasing soil depths, because the lower layers were more compact under the weight of upper portion of soil and also due to the lower amount of organic matter in deeper layers (as also reported by Haans, 1977, Patil and Prasad, 2004). But in case of teak plantation there was variation in the trend i.e., the bulk density was found higher in the upper horizon, which might have been due to the forest fires that were noticed at the time of sampling. During burning, the plant cover and litter layers are consumed and mineral soil is heated. This causes changes in soil bulk density, porosity, texture, colour, moisture content, and permeability (Wells *et al*., 1979).

The water holding capacity increased with increasing clay content at all sites and was low on the sites where percentage of sand was higher. In the present study the water holding capacity was higher in the upper horizons of all the forest types, it was also higher in some lower horizons, where the percentage of clay was higher.

The average soil pH (7.12) was higher under teak forest. The pH was negatively correlated with organic carbon, organic matter, whereas it was positively correlated with phosphorus Paudel and Sah (2003) reported similar results for soils in tropical sal (*Shorea robusta* Gaertn.) forests in eastern Nepal.

Average nitrogen (0.27%) and average SOC (1.60%) were higher in the teak plantation. Total nitrogen increased with increasing organic matter. According to Jha *et al*. (1984), if the soil is rich in organic matter, it is definitely rich in total nitrogen also. Haans (1977) also analysed that the availability of nitrogen depends upon the amount and properties of organic matter.

Potassium performs vital processes like regulation of transpiration and respiration and also influence enzyme action, synthesis of carbohydrates and proteins etc. (Brady, 1966). Potassium is not much influenced by soil organic matter because it is not the direct supplier of potassium (Gupta and Sharma, 2008). Maximum potassium was recorded under Sal forest, whereas phosphorus was higher in the lower horizons of the teak forest, possibly due to the leaching properties of the soils.

In the present study a positive correlation was found between organic carbon, total nitrogen, organic matter and available phosphorus in all plantation types. Gupta and Sharma (2008) have also observed that nitrogen, organic carbon and phosphorus were positively correlated chiefly because all these attributes were intimately linked with soil humus.

The contribution of surface vegetation to soil is significant in the form of branch, twigs, leaves which gradually decompose and become part of the soil. The nutrients thus returned to the soil provide strong feedback to ecosystem processes (Pastor *et al.,* 1984). The availability of NPK is directly related to soil organic matter content, which was supported by the positive correlation between SOM and NPK. Thus, the higher availability of nitrogen and phosphorus (5413kgha^{-1} and 39kgha^{-1}, respectively) resulted in the occurrence of higher basal area in the *Tectona grandis* forest.

Sheikh and Kumar (2010), while evaluating the economic analysis have reported that the maximum contribution among the nutrients was of potassium, followed by phosphorus and nitrogen under oak and pine forests. In the present study the maximum contribution among the nutrients was of nitrogen, followed by potassium and phosphorus in all three forest plantations. The average economic value of nitrogen was found higher in teak followed by sal and shisham. This might have been due to the higher basal area in teak followed by sal and shisham.

Table 1: Physico-chemical properties of soil under Tectona *grandis* plantation Site 1

Depths	WHC %	Soil porosity %	Bulk Density %	Moisture Content %	Soil Texture %	Soil Colour			Total Nitrogen %	Organic Carbon %	C/N Ratio	Available Phosphorus (ppm)	Available Potassium (ppm)	pH
						Hue	Value Chroma	Colour						
0-10	54.02	63.46	0.95	4.4	Silty Loam	10/YR	4/4	Dark Yellowish Brown	0.308	2.021	6.56	18.0	153	7.06
10-30	52.47	68.84	0.81	10.1	Silty Clayey Loam	10/YR	5/4	Yellowish Brown	0.266	1.603	6.02	17.5	84	7.17
30-60	51.98	65	0.91	9.57	Silty Clayey Loam	10/YR	5/4	Dark Yellowish Brown	0.238	1.186	4.98	22.5	69	7.14
Mean	52.82	65.76	0.89	8.02					0.27	1.60	5.85	19.33	102	7.12

Table 2: Physico-chemical properties of soil under *Shorea robusta* forest Site 2

Depths	WHC %	Soil porosity %	Bulk Density %	Moisture Content %	Soil Texture %	Soil Colour			Total Nitrogen %	Organic Carbon %	C/N Ratio	Available Phosphorus (ppm)	Available Potassium (ppm)	pH
						Hue	Value Chroma	Colour						
0-10	50.49	63.84	0.94	6.6	Silty Clayey Loam	10/YR	6/3	Pale Brown	0.179	1.602	8.94	25.01	168	6.97
10-30	48.36	61.53	1.00	9.78	Silty Loam	10/YR	7/3	Very Pale Brown	0.055	0.349	6.34	17.0	120	6.75
30-60	52.77	57.30	1.11	13.38	Silty Calyey Laom	10/YR	6/6	Brownish Yellow	0.109	0.788	7.22	12.5	153	6.30
Mean	50.54	60.89	1.01	9.92					0.11	0.91	7.5	18.17	147	6.67

Table 3: Physico-chemical properties of soil under *Dalbergia sissoo* plantation Site 3

Depths	WHC %	Soil porosity %	Bulk Density %	Moisture Content %	Soil Texture %	Soil Colour			Total Nitrogen %	Organic Carbon %	C/N Ratio	Available Phosphorus (ppm)	Available Potassium (ppm)	pH
						Hue	Value Chroma	Colour						
0-10	46.66	63.70	0.85	1.42	Silty Loam	10/YR	7/4	Very Pale Brown	0.098	0.722	7.36	3.75	51	5.66
10-30	38.45	66.15	0.88	1.72	Loam	10/YR	7/4	Very Pale Brown	0.064	0.290	4.53	2.50	25	5.71
30-60	23.38	56.15	1.14	1.52	Silty Loam	10/YR	6/4	Light Yellowish Brown	0.042	0.132	3.14	2.00	20	6.36
Mean	36.16	62	0.95	1.56					0.068	0.38	5.01	2.75	32	5.91

Table 4: Statistical correlation between various parameters in *Tectona grandis* plantation

	T.N%	OC%	C/N R	AV.P	AV.K	pH	WHC%	Soil.P%	SOM	B.D	M. C %
T.N%	1										
OC%	0.94**	1.00									
C/N R	0.87	0.98**	1.00								
AV.P	-0.58	-0.82	-0.91	1.00							
AV.K	1.00	0.94	0.86*	-0.57	1.00						
pH	-0.90	-0.70	-0.56	0.16	-0.91	1.00					
WHC%	1.00	0.96**	0.89*	-0.62	1.00	-0.88	1.00				
Soil.P%	-0.58	-0.28	-0.10	-0.33	-0.59	0.88*	-0.54	1.00			
SOM	0.94**	1.00	0.98**	-0.82	0.94	-0.70	0.96	-0.28	1.00		
B.D	0.58	0.28	0.10	0.33	0.59	-0.88	0.54	-1.00	0.28	1.00	
M. C %	-0.96	-0.82	-0.70	0.34	-0.97	0.98	-0.95	0.78	-0.82	-0.78	1.00

***significant at 1% level & **significant at 5% level**

Table 5: Statistical Correlation between various parameters in *Shorea robustra* forest

	T.N%	OC%	C/N R	AV.P	AV.K	pH	WHC%	Soil.P%	SOM	B.D	M. C %
T.N%	1.00										
OC%	1.00	1.00									
C/N R	0.99**	1.00	1.00								
AV.P	0.69	0.75*	0.76	1.00							
AV.K	0.96**	0.93	0.92	0.45	1.00						
pH	0.39	0.48	0.49	0.94**	0.11	1.00					
WHC%	0.42	0.33	0.31	-0.37	0.66	-0.67	1.00				
Soil.P%	0.42	0.50	0.51	0.95	0.14	1.00	-0.65	1.00			
SOM	0.99**	1.00	1.00	0.76*	0.93	0.48	0.32	0.51	1.00		
B.D	-0.42	-0.50	-0.51	-0.95	-0.14	-1.00	0.65	-1.00	-0.51	1.00	
M. C %	-0.53	-0.61	-0.62	-0.98	-0.27	-0.99	0.55	-0.99	-0.62	0.99	1.00

***significant at 1% level & **significant at 5% level**

Table 6: Correlation between various parameters in *Dalbergia sissoo* plantation

	T.N%	OC%	C/N R	AV.P	AV.K	pH	WHC%	Soil.P%	SOM	B.D	M. C %
T.N%	1.00										
OC%	0.99**	1.00									
C/N R	1.00	1.00	1.00								
AV.P	0.99**	1.00	1.00	1.00							
AV.K	0.97**	0.99**	0.98	0.99	1.00						
pH	-0.84	-0.75	-0.79	-0.76	-0.67	1.00					
WHC%	0.96	0.91	0.93*	0.92	0.86*	-0.96	1.00				
Soil.P%	0.85	0.77	0.81	0.78*	0.69	-1.00	0.97	1.00			
SOM	0.99	1.00	1.00	1.00	0.99**	-0.75	0.91	0.77	1.00		
B.D	-0.85	-0.77	-0.81	-0.78	-0.70	1.00	-0.97	-1.00	-0.77	1.00	
M. C %	-0.51	-0.62	-0.57	-0.61	-0.70	-0.05	-0.24	0.02	-0.62	-0.02	1.00

***significant at 1% level & **significant at 5% level**

T.N. = Total Nitrogen, OC = Organic carbon, C/N R = Carbon Nitrogen ratio, AV.P = Available phosp, AV.K = Available potassium, WHC = Water Holding Capacity, Soil. P = Soil Porosity, SOM = Soil organic matter, B.D. = Bulk density, M.C. = Moisture content.

Table7: Phyto-sociological attributes of site -1 (*Tectona grandis* forest)

S. No	Name of Tree spp.	Frequency %	Density plants/ha	Abundance	Basal area m^2/ha	Dominance	Relative dominance %	Relative density %	Relative frequency %	IVI
1.	Teak	83.33	433	5.2	14741.35	2454.98	100	100	100	300

Table 8: Phyto-sociological attributes of site -2 (*Shorea robusta* forest)

S. No	Name of Tree spp.	Frequency	Density	Abundance	Basal area m^2/ha	Dominance	Relative dominance %	Relative density %	Relative frequency %	IVI
1.	Sal	66.66	183	2.2	13225.85	2205.27	90.58	85.1	67.34	243.02
2.	*Mallotus philppenensis*	16.66	0.16	0.2	1146.49	183.43	7.53	7.44	16.32	31.29
3.	Jamun	16.66	0.16	0.2	286.62	45.85	1.88	7.44	16.32	25.64
	Total						**99.99**	**99.98**	**99.98**	**299.95**

Table 9: Phyto-sociological attributes of site -3 (*Dalbergia sissoo* plantation)

S. No	Name of Tree spp.	Frequency %	Density plants/ha	Abundance	Basal area m^2/ha	Dominance	Relative dominance %	Relative density %	Relative frequency %	IVI
1.	Shisham	100	733	733	10532.94	1754.54	100	100	100	300

Table 10: Comparison of NPK per hectare under Teak, Sal and Shisham vegetation and their market cost

S. No.	Species	N/ha (kg/ha)	Market Cost (Rs/ha)	P/ha (kg/ha)	Market Cost (Rs/ha)	K/ha (kg/ha)	Market Cost (Rs/ha)
1	Teak	5413.33	297733.33	38.66	1353.33	204	7140
2	Sal	2286.66	125766.66	36.34	1271.9	294	10290
3.	Shisham	1360	74800	5.5	192.5	64	2240

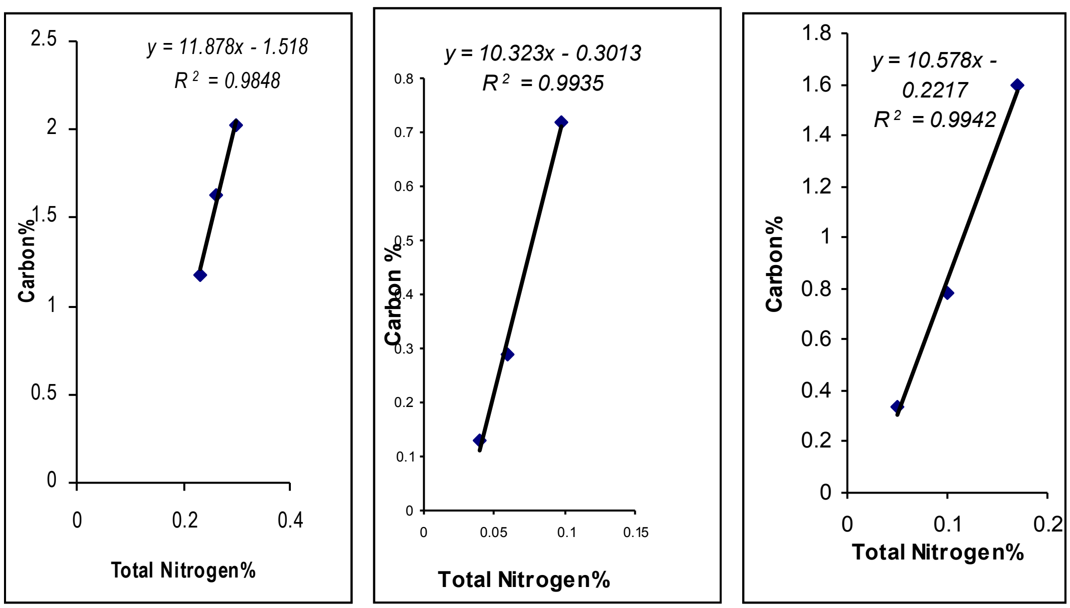
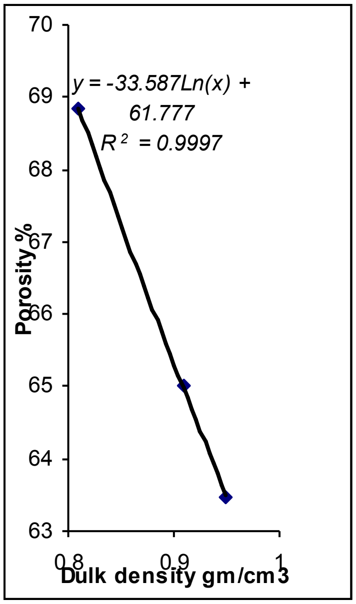
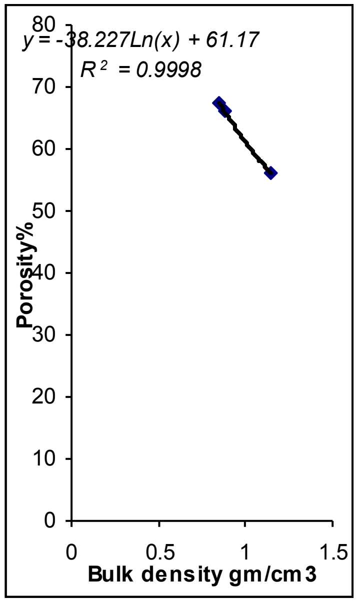


Fig.(1) Fig. (2) Fig. (3)

Line of regression showing the linear relationship between the carbon% and Total nitrogen in Teak, sal and shisham plantations.





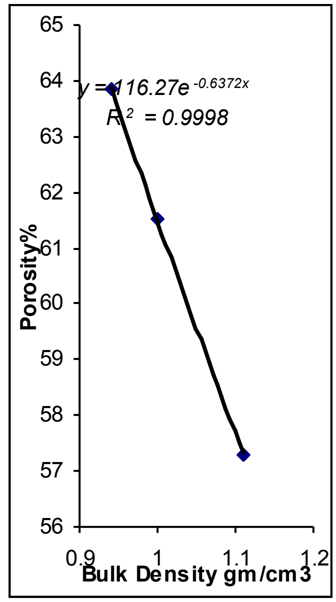
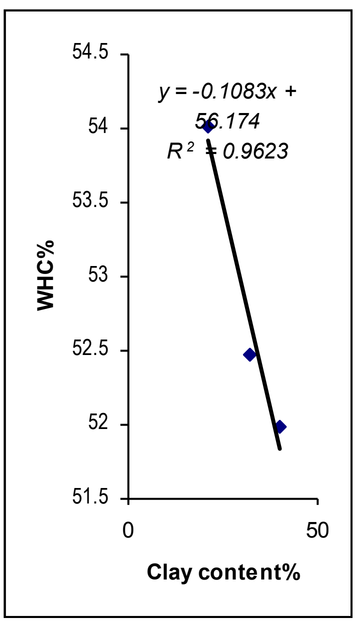
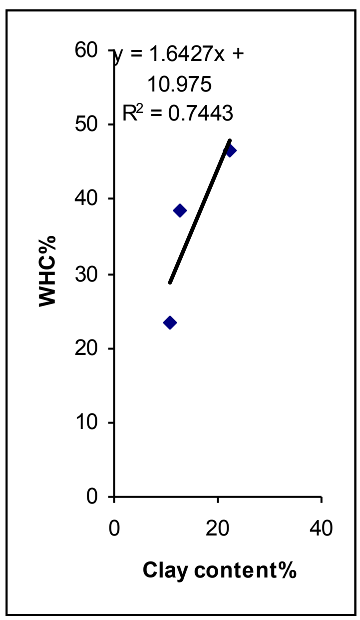


Fig.(4) Fig.(5) Fig. (6)

Line of regression showing the linear relationship between the porosity% and Bulk density gm/cm^3 in Teak, sal and shisham plantations.





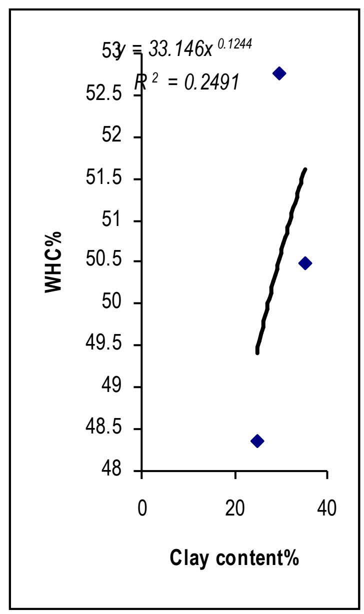


Fig. (7) Fig.(8) Fig.(9)

Line of regression showing the linear relationship between the WHC% and Clay content under Teak, Sal and Shisham vegetation.

Fig. (10) Fig. (11) Fig.(12)

The market value Rsha^{-1} and the nutrient status under Teak, Sal and Shisham plantation.

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