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Comparison of Physico-chemical Properties of Soils under Different Forest Types in Dry Tropical Forest Ecosystem in Achanakmar-Amarkantak Biosphere Reserve, India

Harischandra Darro[1], S. L. Swamy[2], Rajesh Kumar[3] and Atul Kumar Bhardwaj[3]

[1]College of Agriculture, Katghora-Korba, Indira Gandhi Agricultural University (C.G.), India
[2]Department of Forestry, Indira Gandhi Krishi Vishwavidyalaya, Raipur, C.G., India
[3]Department of Forestry, Wildlife & Environmental Science, Guru Ghasidas (A Central University) Vishwavidyalaya, Bilaspur, C.G., India

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ABSTRACT

The present study was conducted to assess the variations in physico-chemical properties of soils under four forest types *viz.* Mixed Forest, Mixed Sal Forest, Mixed Teak Forest, and Teak Mixed Forests in a typical dry tropical ecosystem of Achanakmar-Amarkantak Biosphere Reserve (AABR), Central India. Soil samples were collected from four types of forest and analyzed for the soil samples were taken at three soil depths, i.e. at 0-20 cm, 20-40cm and 40-60 cm and analysed for pH, EC, Organic C, soil moisture, bulk density, nitrogen (N), phosphorous (P) and potassium (K). The pH of soil was lower (5.43) under Mixed Forest and higher (6.13) in Teak Mixed Forest, while EC in soil was lower (0.04 dS m^{-1}) in Mixed Sal Forest and higher (0.32 dS m^{-1}) under Teak Mixed Forest. Organic C varied from 11.5 Mg ha^{-1} to 17.8 Mg ha^{-1} at 0-20 cm soil depth which was highest in soil under Mixed Sal Forest and lowest in Teak Mixed Forest. The Organic C and EC values were decreased with an increase in soil depth, while the bulk density showed reverse trend. Soil nutrients in different depths varied between 160.2 -196.9 kg ha^{-1}, 10.4-17.7 kg ha^{-1} and 266.4-439.1 kg ha^{-1} for N, P and K, respectively. The nutrient quantities in soil were higher in Mixed Sal Forest and lower under Teak Mixed Forest, which decreased with soil depth. The paper discusses the possible variations in soil properties in relation to structure and composition of forest type and suggests appropriate management practices for the sustainable development of forest soils in dry tropical ecosystem.

Key words: *Biosphere Reserve, Litter, Nutrients, Soil health, Structure, Tropical Forest*

Introduction

Soils provide nutrients, water and space for vegetation, thus play an important role in bio-geochemical cycling of forest ecosystem (Goebes *et al.*, 2019). The morphological, physical, chemical and biological properties of soils are generally influenced by structure and composition of forest vegetation. Tropical forests are more dynamic as population of one species get replaced by another species in succession will significantly alter the properties of surface and subsurface soils such as pH, organic matter and exchangeable bases and nutrients at varying spatial and temporal scales (Poudel *et al.*, 2003). Bio-geochemical cycling is regulated by vegetation through litter production and decomposition. The bio elements affect composition and processes at all levels of biological organization. The accessibility of bio elements not only influences plant growth but also biodiversity but also ecosystem processes, which are intricately linked to C assimilation and its storage in soil and vegetation. Therefore, understanding physio-chemical properties of soils become imperative for improving the productivity and C stocking in tropical forests.

As tropical forests play an important role in global carbon cycle and levels of soil organic carbon (SOC) might determine ecosystem functions and influence soil characteristics. Hence, the management of SOC levels is crucial in mitigation of atmospheric levels of greenhouse gases and also the supporting diversity of life forms (IPCC, 2018). The soil properties in tropical forests and other vegetation need to be understood for maintaining long term health of soil and vegetation development. Only few studies have been conducted by earlier workers and a relatively very little attention given on tropical forests of Chhattisgarh (Thakur *et al.,* 2007; Jhariya *et al.,* 2012). Therefore, the present study was conducted to assess the variations in physic-chemical properties of soils under different vegetation types of tropical forest of AABR.

Materials and Methods

The study was conducted in Achanakmar Amarkantak Biosphere Reserve situated in parts of Bilaspur, Annupur and Dindori districts of Chhattisgarh and Madhya Pradesh, Central India (Fig. 1). It lies between 21^{0} 48′35" to 22^{0} 40′30" North latitudes and 81^{0} 29′45" to 82^{0} 02′ 10" East longitudes. The area adjoining Achanakmar forest village has a number of hillocks scattered all over the area. Dry deciduous forest, grasslands, agriculture lands and human habitations surrounds the study area. The climate of study area is dry humid tropical. The mean annual rainfall varies from 1200 to 1400 mm. It gradually decreases from southeast direction to northwest direction. About more than 90% of annual rainfall received in monsoon season from

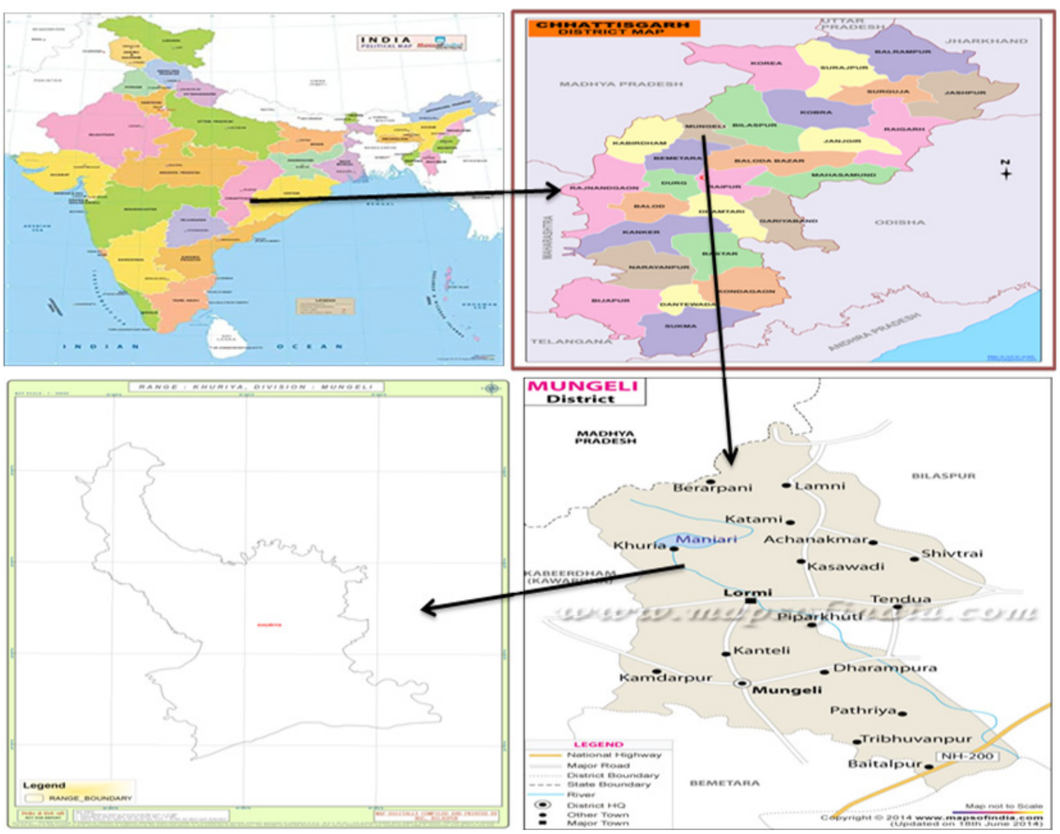

Fig. 1. Study area of Khuriya Forest Range, Mungeli Forest Division Chhattisgarh, India

June to October. The peak rainfall occurs in July-August months. Number of rainy days varies from 71-118 days. It gradually decreases from south east direction to North West direction. May and June are the hottest months, whereas December and January are the coldest months of the year with minimum temperature reaches to 3-50 °C. The mean temperature in January is about 21 °C and in May temperature rises between 31 °C and 41 °C. Soils of Achanakmar area are grouped in to three classes viz., Inceptisols, Alfisols and Vertisols. Different types of forest vegetation occur in the study area. The natural vegetation in the Achanakmar-Amarkantak Biosphere Reserve varies across the reserve. The forest area of the reserve has tropical deciduous vegetation harboring 1500 plant species represented by 151 plant families.

The survey has been conducted in biosphere and identified four types of forests viz., Mixed Forest, Mixed Sal Forest, Mixed Teak Forest and Teak Mixed Forest. Soil samples were randomly collected from ten different sampling quadrates in these forest types. The soil samples were taken at three soil depths, i.e. at 0-20 cm, 20-40 cm and 40-60 cm from different sampling quadrates with the help of auger. In all 120 soil samples (4 types x 10 quadrates x three depths) was collected during growing season and subjected to physico-chemical analysis. Bulk density was calculated by soil core method. The soil core was drawn from each sampling plot at different soil depths. The following expressions were used for the estimation of soil moisture and bulk density.

$$\text{Soil moisture (\%)} = \frac{\text{Dry weight of soil (g)}}{\text{Wet weight of soil (g)}} \times 100$$

$$\text{Bulk density (g cm}^{-3}\text{)} = \frac{\text{Weight of oven dried soil (g)}}{\text{Volume of soil core (cm}^{-3}\text{)}}$$

The collected soil samples were analyzed in triplicate for pH, EC, organic C, available N, P and K. Soil pH and EC values were measured using pH and EC meters, respectively. Nitrogen was estimated by Micro- Kjeldahl method (Jackson, 1958) the total phosphorus following spectrophotometer and vando–molybdate yellow reagent procedure. Potassium was determined by flame-photometeric method (Jackson, 1958). The organic carbon in soil was determined by Walkley and Black (1934) method. The amount of nutrients and carbon in soil was determined by multiplying soil volume, bulk density and respective concentration of carbon and nutrient values for given soil depth corresponding to each vegetation type and extrapolated on Mg ha^{-1}.

Results and Discussion

Results on physical properties of soil in different forest types are summarized in Table 1 and depicted in Figs. 2-5. The pH values of soils are found to be slightly acidic in nature, which varied from 5.43 to 6.13. It increased with soil depth. Soil pH was highest under Teak Mixed Forest and lowest under Mixed Forest in comparison to other vegetation types. It increased with an increase in soil depth (Fig. 2). Electrical Conductivity (EC) of soil varied significantly, which was highest (0.32) under Teak Mixed Forest and lowest (0.06) in Mixed Sal Forest. It also gradually decreased with an increase in soil depth (Fig. 3).

Bulk density is an important soil physical property, which varied from 1.38 to 1.51 Mg m^{-3} at 0-20 cm soil depth under different vegetation types (Table 1). It was highest under Teak Mixed Forest and lowest under Mixed Sal Forest. The bulk density increased with an increase in soil depth (Fig. 4). Soil moisture (%) content varied from 78.24% to 89.09% at 0-20 cm soil depth under different vegetation types (Table 1). It was highest under Mixed Sal Forest and lowest under Teak Forest. The soil moisture (%) was almost 12% higher in Mixed Sal Forest

Table 1. Variation in physical properties of soil at different depths (cm) under vegetation types in Khudiya Forest Range of Mungeli Forest Division Chhattisgarh, India

Vegetation Types	pH			EC (dS m^{-1})			Bulk Density (Mg m^{-3})			Moisture (%)		
	00-20	20-40	40-60	00-20	20-40	40-60	00-20	20-40	40-60	00-20	20-40	40-60
Mixed Forest	5.43	5.72	5.95	0.15	0.11	0.09	1.44	1.47	1.49	88.3	88.6	90.0
Mixed Sal Forest	5.87	5.86	5.85	0.06	0.05	0.04	1.38	1.41	1.46	89.1	92.7	93.9
Mixed Teak Forest	5.8	5.8	5.79	0.18	0.08	0.07	1.47	1.5	1.51	88.1	91.8	94.2
Teak Mixed Forest	6.13	6.01	5.99	0.32	0.32	0.29	1.51	1.52	1.54	78.2	85.9	88.6
CD at 5%	0.22	0.26	0.29	0.12	0.11	0.11						

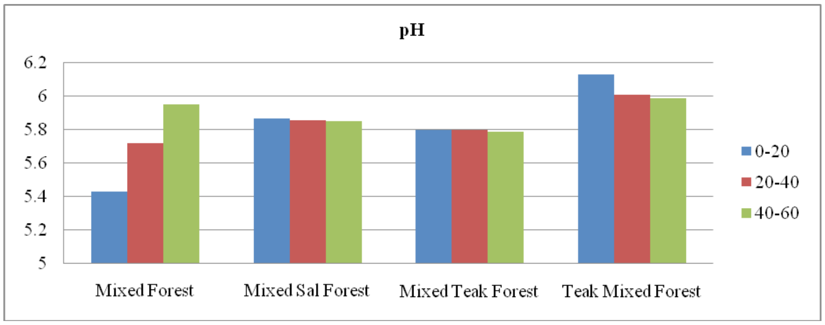

Fig. 2. Contribution of pH value in different vegetation types

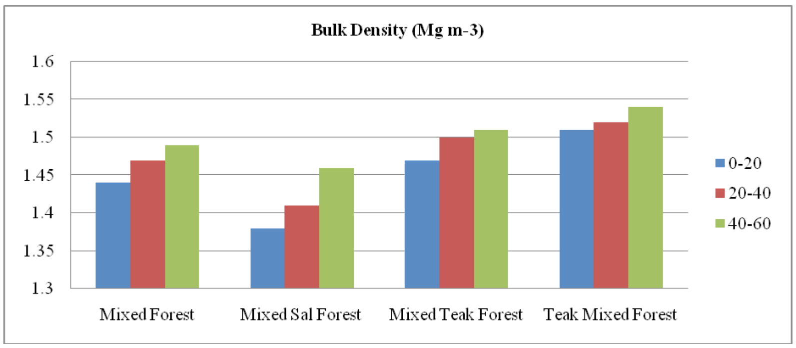

Fig. 3. Contribution of EC value in different vegetation types

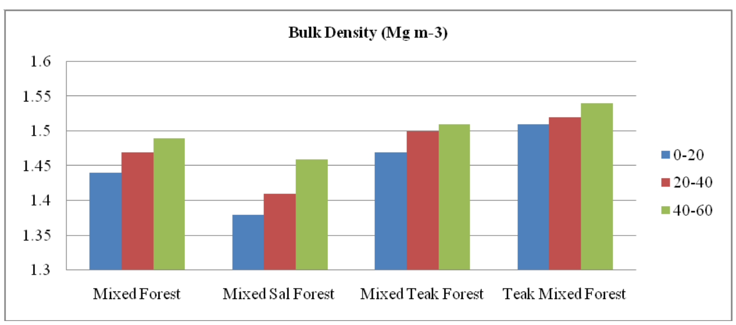

Fig. 4. Contribution of bulk density value in different vegetation types

compared to Teak Mixed Forest. The soil moisture (%) increased with soil depth (Fig. 5).

Results on chemical properties of soil in different forest types are summarized in Table 2 and depicted in Figs. 6- 9. Soil C varied across vegetation types and also at varying soil depths (Table 2). It ranged from 7.5 to 17.8 Mg ha^{-1}. Soil organic C was highest under Mixed Sal Forest followed by Mixed Forest and Mixed Teak Forest. It was lowest in Teak Mixed Forest. The organic C levels decreased with an increase in soil depth (Fig. 6). Available N in soil ranged from 160.7 kg ha^{-1} to 196.9 kg ha^{-1} under different vegetation types. It decreased with an increase in soil depth (Table 2). It was highest in Mixed Sal Forest and lowest in Teak Mixed Forest. The available N levels were statistically at par in Mixed Sal, Mixed Teak and Mixed Forest at different depths (Fig. 7). The available P values in soil under different vegetation types ranged from 12.1 to 17.7 kg ha^{-1}, 11.6 kg ha^{-1} to 16.6 kg ha^{-1} and 10.4 kg ha^{-1} to 13.3 kg ha^{-1} at 0-20 cm, 20-40 cm and 40-60 cm depths, It was highest in Mixed Sal Forests followed by Mixed Teak Forest and Mixed Forest and lowest under Teak Mixed Forest (Table 2). The P values were statistically at par in Mixed Sal Forest and Mixed Forests. Similarly, it was also statistically at par in Mixed Teak Forest and Teak Mixed Forests (Fig. 8). K in the soil under different forest types

Table 2. Variation in available organic C, N, P and K (Kg ha^{-1}) of soil at different depths (cm) under vegetation types in Khudiya Forest Range of Mungeli Forest Division Chhattisgarh, India

Vegetation Types	Organic C (Mg ha^{-1})			N (kg ha^{-1})			P (kg ha^{-1})			K (kg ha^{-1})		
	0-20	0-40	0-60	0-20	0-40	0-60	0-20	0-40	0-60	0--20	0-40	40-60
Mixed Forest	7.1	6.9	4.5	83.6	78.1	60.2	7.2	5.5	4.7	09.7	83.5	296.4
Mixed Sal Forest	7.8	7.3	5.2	96.9	84.4	70.6	7.7	6.6	3.3	39.1	23.8	411.2
Mixed Teak Forest	6.6	5.3	1.1	84.7	79.4	61.2	6.9	4.4	1.5	95.8	72.1	284.4
Teak Mixed Forest	1.5	.2	.5	74.2	64.2	60.7	2.1	1.6	0.4	14.4	80.7	266.4
CD at 5%	.2	.6	.2	1.7	1.5	.7	.7	.6	.6	8.2	4.2	16..8

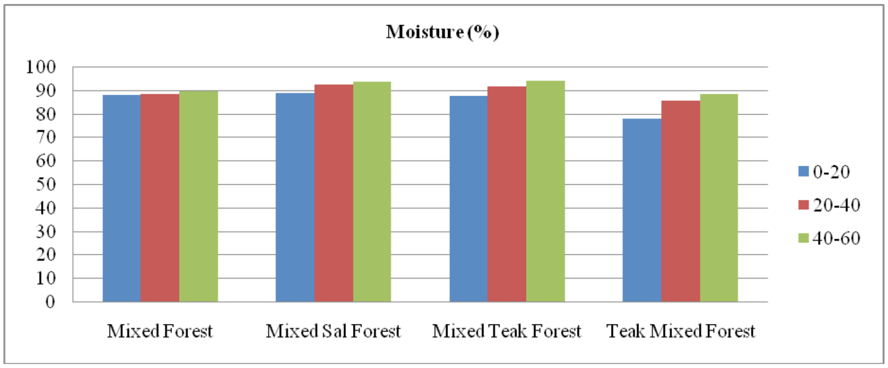

Fig. 5. Contribution of moisture (%) value in different vegetation types

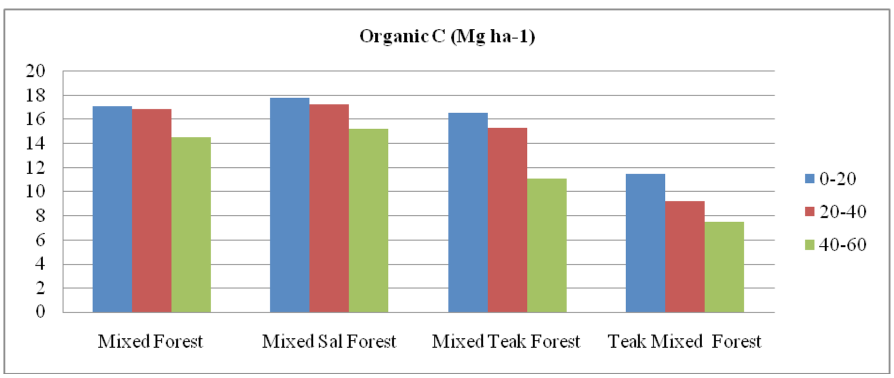

Fig. 6. Contribution of organic C value in different vegetation types

ranged from 314.4 kg ha^{-1} to 439.1 kg ha^{-1}, 280.7 kg ha^{-1} to 423.8 kg ha^{-1} and 266.4 kg ha^{-1} to 411.2 kg ha^{-1} at 0-20 cm, 20-40 cm and 40-60 cm depths, respectively (Table 2). It was highest in Mixed Sal Forests and lowest in Teak forest. The available K content decreased with an increase in soil depth (Fig. 9)

The structure and composition of forest vegetation strongly influence the soil pH, organic matter and exchangeable bases and nutrients (Poudel *et al.*, 2003). The results on physical properties of soil revealed that pH, EC, moisture % and bulk densities varied significantly across vegetation types and also along soil depth. The soil properties of this study were comparable to soil characteristics of tropical forest reported by Huston, (1980), Singh and Singh, (1991), Thakur *et al.* (2007). The soil bulk density and pH levels were higher under Mixed Sal forest and lower under Teak forest. This might be due to higher organic matter as a consequence of more litter deposition which decreased bulk density and increased the humid acid content at the time of decomposition of litter into humus result in a stronger acidic reaction. The supply of nutrients for vegetation also significantly influences the soil pH as it in-

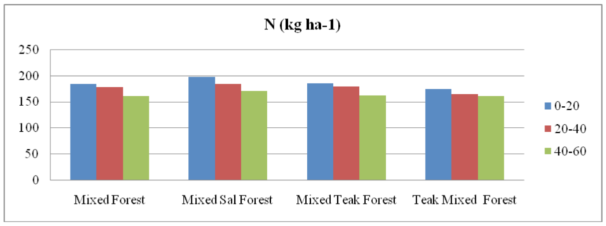

Fig. 7. Contribution of N value in different vegetation types

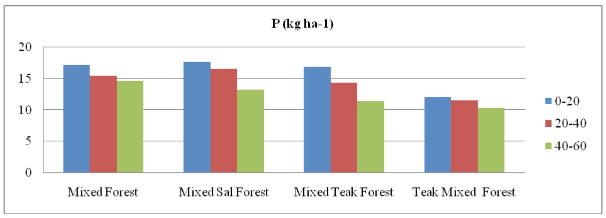

Fig. 8. Contribution of P value in different vegetation types

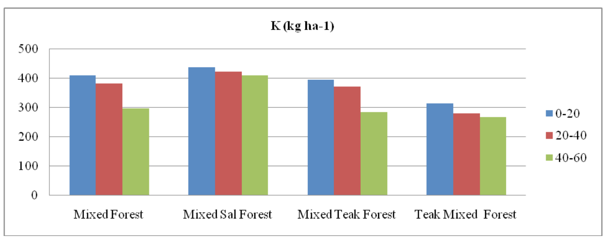

Fig. 9. Contribution of K value in different vegetation types

dicates the soil fertility (Zhao *et al.* 2012). This could be due to slow transformation of organic acids to humid substances in Mixed Sal Forests compared to other forest types. The moisture (%) is also higher in Mixed Sal Forest, which might attributed to better soil texture and structure, which corroborated with findings of earlier workers (Bhuyan and Sharma, 2015; Salve *et al.*, 2018). They opined that higher amount of litter crop might act as mulch which could increase infiltration rate and preventing the moisture loss by reducing the levels of evaporation from soil surface. The study also showed soil moisture levels increased with an increase in soil depth, which was not an extraordinary phenomenon as the evaporation losses decrease with soil depth. The moisture losses are usually higher in soil surface and lower in sub surface layers and our values were comparable with other studies (Paudel and Sah, 2003).

The results revealed that organic C content, available N, P and K were higher under Mixed Sal Forest, which might be attributed higher amount of nutrient return to soil by vegetation via litter crop. Such affects were also reported by previous workers (Bijalwan *et al.*, 2010; Thakur, 2014; Behera *et al*. 2017). Both standing litter and litter crop were higher under Mixed Sal Forest, which were lower under Teak forest resulted in low nutrient status in soil (Darro and Swamy, 2020). Different vegetation components contain different amounts of nutrients and accordingly build up the soil organic matter. The amount of nutrients added through litter crop varies with structure and composition of vegetation and environmental conditions. The decrease in nutrients and organic C in soil with increase in depth is not uncommon as several workers also observed similar trend (Poudel and Sah, 2003; Gariola *et al.*, 2012; Abdalmoula *et al.*, 2019). The management of litter crop is very essential as most of the dry tropical forests are subjected to forest fires in summer. Besides, the illegal grazing and harvesting of firewood and small timber from Teak Mixed Forest and Mixed Teak Forests should be regulated. The involvement of local people and community based management approach needs to be invigorated for the addressing the problems of societies, improving status of vegetation and also soil health for sustainable development of tropical forests of AABR.

Conclusion

The study clearly demonstrated that quite useful for characterization of physio-chemical properties of soils under different forest types in dry tropical ecosystem. The classification accuracy was found significantly higher for soils use and vegetation classes, which facilitated the qualitative and quantitative analysis of soils. The nutrient quantities in soil were higher in Mixed Sal Forest and lower under Teak Mixed Forest, which decreased with soil depth. The spatial data analysis helped in discriminating four vegetation types. Each vegetation type was unique, showed marked soils depth in different layers. The anthropogenic pressure was high in Teak Forests. The encroachment in Teak Mixed and Mixed Teak forests are also reduced the soils quality and diversity levels. Therefore, there is need of closure and protection of these vulnerable types for conservation biodiversity. Will not only affect the well being of large population of indigenous whose livelihoods and economy is intricately linked with the forest wealth. There is need to implement suitable policies and involve local people for community based approach and sharing the benefits to sustainable management of forests to secure the interests of both local and global communities.

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