Vegetation dynamics and chemical properties of soils in relationship with the edaphic environment of tropical deciduous forests, Eastern India.

ABSTRACT

Aims: This study is significant as it elucidates the relationship between floristic composition and soil nutrient availability of India's Saranda Sal (*Shorea robusta* Gaertn.) forest.

Study design:

Place and Duration of Study: The study was conducted in Saranda Forest of West Singhbhum district, Jharkhand, Eastern India, during 2021-2022

Methodology: Sampling has been designed as grid methods (5 km X 5 km) following a forest survey of India, and vegetation sampling was done by quadrat method. The soil samples were collected from three depths (i.e., surface: 0–30 cm, sub-surface: 30–60 cm and inner: 60-90 cm from each selected site. ANOVAs were used to compare the chemical properties of soil samples from various forests. Pearson correlation analyses to examine the effects of climatic variables on chemical properties of the soil of selected Sal forest as well as their relation with plant diversity.

Results: A comprehensive analysis of 5432 vascular plants from 65 species and 34 families were conducted across the 17 sites. Fabaceae is the most dominant family with 07 species. The study also examined soil chemical parameters and micronutrients in different sites and established their relations with vegetation dynamics. Notably, tree density showed a significant positive correlation with soil pH ($r=0.59$, $p<0.05$), but a significant negative correlation with Shannon diversity (H') ($r=-0.53$, $p<0.05$). Similarly, there was a significant positive correlation of Organic carbon with copper ($r=0.59$, $p<0.05$) and iron ($r=0.61$, $p<0.00$); however, there was a significant negative correlation with Available Phosphorus ($r=-0.52$, $p<0.05$).

Conclusion: Research findings underscore the importance of soil nutrients in promoting forest health and growth. Importantly, they can guide the formulation of practical and effective soil-forest management strategies for S. robusta and its associated forests, directly benefiting the forestry and environmental science community.

Keywords: Saranda, Sal forests, soil chemical properties, tree diversity,

1. INTRODUCTION

Forest soil affects vegetation, tree growth, and natural reproduction (Bhatnagar, 1965). Forest health and vitality depend on biodiversity, which supports ecosystems by capturing limited resources, creating biomass, recycling, and retaining critical nutrients (Cardinale et al., 2012).

Soil has a dynamic function in sustaining life on Earth (Schoonover and Crim, 2015) and maintaining a balance between pedogenetic characteristics and natural vegetation in nature (Parr and Papendick, 1997). The soil structure affects the growth and activity of soil organisms (Angers and Caron, 1998). More than half of the world's tropical soil is extremely worn, leached, and poor; soil nutrient conservation is vital (Jordan, 1985). The global soils are deficient in zinc (Zn), copper (Cu), manganese (Mn), and iron (Fe) (Behera et al., 2014). Nutrient delivery varies greatly among ecosystems (Binkley and Vitousek, 1989), affecting plant community structure and production (Ruess and Innis, 1977).

Shorea robusta (Sal) tree in Jharkhand serves a variety of functions, including providing wood, medicine, food, fuel, leaf litter for cooking and heating, leaf plates, edible seeds, and religious uses (Kumar and Saikia, 2020b). The distribution of Sal forests is governed by climate and edaphic variables, and it ranges from just a few meters to over 1500 meters above mean sea level (Gautam and Devoe, 2006). Saranda of Chhotanagpur plateau forests are well known as Asia's largest Sal Forest. Sal thrives in a range of soil types, from alluvial to lateritic (Tiwari, 1995). Still, it does best in slightly acidic to neutral sandy loam (pH: 5.1-6.8) with an organic carbon concentration of 0.11 to 1.8 percent (Rana et al., 1988; Gangopadhyay et al., 1990).

Since no studies have been documented so far to compare the floristic diversity of Saranda Sal Forest in relation to soil nutrients, an attempt has been made to 1) study the floristic structure and composition of the Sal Forest of Saranda, Jharkhand, and 2) determine the influence of soil on vegetation composition and vice versa and their correlation with soil chemical variables and floristic variables.

2. MATERIALS AND METHODS

2.1. Study area

The study was conducted in Saranda Sal Forest of West Singhbhum district, Jharkhand, Eastern India (**Fig. 1**). It is situated from 22°5'19.072"N to 22°16'0.812"N latitude and 85°25'7.659"E to 84°58'55.752"E longitude, and the altitude varies from 200 to 800 m above mean sea level (AMSL).

2.2. Soil and vegetation sampling

The soil samples were collected from three depths (i.e., surface: 0–30 cm, sub-surface: 30–60 cm, and inner: 60-90 cm from each selected forest. On the other hand, the vegetation of the selected forest was sampled using a quadrat method (31.1 m × 31.1 m (0.1 ha) size in each site. Every single mature tree (≥ 10 cm G.B.H.) was measured using a measuring tape at its girth at breast height (GBH), or 1.37 m above ground level.

2.3. Data analyses

Following Misra (1968), quantitative analyses of the vegetation were conducted, and Vegetation indices were calculated using the standard formula. The chemical properties of soil samples from different forests were compared using ANOVAs.

3. RESULTS AND DISCUSSION

3.1. Forest structure and composition

There were 65 species from 34 families recorded in Saranda Sal Forest. Apocynaceae (05 spp.), Anacardiaceae, and Asteraceae each have four species, followed by Fabaceae, which has seven species, and Acanthaceae, Combretaceae, Malvaceae, and Rubiaceae, which each have three species. There are two species in each of the Lamiaceae Leguminosae, Lythraceae, Meliaceae, and Poaceae. A total of 19 (55.88 %) families were monotypic, represented by only one species. Among others, 07 (20.58 %) families were represented by two species, 04 (11.76%) families with three species, 2 (5.88 %) families with four species, and only two families with one species (2.94 %), respectively.

The *S. robusta* contributed the maximum IVI (139.05) followed by *Terminalia alata* Heyne ex Roth (42.47) and *Buchanania cochinchinensis* (Lour.) M.R.Almeida (21.19). In terms of frequency, dominances, and density, *S. robusta* contributed the highest frequency (100%), density (42.76 %) and basal cover (74 %) of the respective totals, followed by *T. alta* (71.43, 16.44, and 10.15 %) *B. cochinchinensis* (50, 7.23 and 2.84 %) *T. anogeissiana* (35.71, 5.26 and 2.06 %) *Diospyros melanoxylon* (28.57, 4.60 and 0.57%) IVI values show the eminence of the species in the forest ecosystem. Tree species with IVI and other quantitative properties such as dominance (RDm), relative frequency (R.F.), relative density (R.D.), IVI, basal area (BA.), and tree density (TD.) are shown in **Table 1.**

The highest tree density was provided by *S. robusta* (465 ind. ha^{-1}), followed by T. alata (179), which together produced 59 percent of the overall density. Tree basal areas in the examined Sal forests ranged from 0.0078 to 91.43 (M=6 ± 4.31 SD) m^2 ha^{-1}, with a mean of 123.45 m2 ha^{-1}. *S. robusta* contributed the most basal area (91.43 m2 ha-1) to the examined Sal forests, while *Phyllanthus emblica* L. contributed the least (0.0078 m^2 ha^{-1}).

3.3 Plant species diversity of Saranda Sal Forest

The values for the Margalef Species Richness Index, evenness index, and Shannon diversity at the various sampling sites are 0–2.65 (M=1.4 ± 0.73SD), 0–0.99 (M=0.80± 0.30SD), and 0–1.97 (M=1.18 ±0.54SD) respectively. A high value of the evenness index in S17 illustrates the greatest possible number of individuals from the same species living in close proximity to one another. Site S6 only had one species, S. robusta; hence, the species richness and evenness were very low, almost zero. The diversity of tree species, including *T. alata*, *Lagerstroemia parviflora* Roxb., *D. melanoxylon*, and *D. latifolia*, is shown by the high species richness (2.65) at S8. *B. cochinchinensis*, *S. robusta*, *Syzygium cumini* (L.) Skeels, and *T. anogeissiana*. Shannon diversity (H') and the species evenness index (E) significantly positively correlated, and both variables rose across all sites under study **(Fig. 2).**

3.4 Soil chemical properties of Saranda Sal Forest

The soil pH ranged from 5.18 to 8.71 (Mean=6.08 ± 0.74 Standard deviations). The pH level was lowest in S16 (5.18), and it was highest in the upper layer (0-30) of S1 (8.71). The pH of all sites was found to be in the acidic range, except for site S1. At two depths, 0–30 cm and 30–60 cm, the soil at site S1 was found to be alkaline. The maximum number of sampling sites (17 no.) were moderately acidic. However, the soil of only one site (S1) shows "Strongly Alkaline" in nature in all forest areas. ANOVA suggested that PH in the soil was not significantly different at three different depths (F_{crit}= 0.84P < 0.05). The classification of soils from the study area based on pH is summarised in **Table 2**.

In the research area, the E.C. values of soil at various levels (0-30, 30-60, and 60-90 cm) ranged from 22.59 to 509 (M=113.74 ±26.04 S.E.) μS cm^{-1}. The values of EC were changed at different depths (0-30, 30-60 and 60-90 cm). The soil in Ankua (S3) at a depth of 60–90 cm had the lowest value, and the soil in Hinua (S1) had the highest value, at 509.8 μS cm^{-1}. At Kiriburu, soil organic carbon (SOC) was highest (2.77 per cent) in the surface layer (0-30 cm) and lowest (0.12 per cent) in the 60-90 cm depth**.** The current study's measurements of soil organic matter (SOM) ranged from 0.21 to 4.77 per cent, with the exception of S2, S6, S10, and S13, where they were at their highest. AN, A.P., and A.K., which are macronutrients, were found in soil at concentrations respectively ranging from 66.54 to 209.24 (M= 127.34 43.52 SD), 0.04 to 3.94 ppm (M=1.53± 0.88 SD), and 13.9 to 119.4 ppm (M= 50.98 ±25.98 S.D.). Micro soil nutrients like Fe, Zn, Cu, and Mg ranged from 0.01 to 4.66 ppm (M=1.11 ± 1.10SD) for Cu, from 0 to 1.93 ppm (M=0.33 ± 0.41SD) for Zn, from 0 to 19.33 ppm (M=0.33± 0.41SD) for Mn, and from 0.33 to 22.97 ppm (M=6.06± 5.20SD) for Fe. The maximum concentration of Cu (4.66 ppm) was found at 0-30 cm depth at Ghatkuri (S3) of the Gua forest range, while the lowest concentration was found at 30-60 cm depth at Kiriburu (S15). The homogeneity of the sample was tested using a two-factor analysis of variance (ANOVA) and found a significant impact of soil parameter on sampling site's critical F value of O.C. (F_{crit} = 0.94, $p < 0.05$), O.M. (F_{crit} = 3.94, $p < 0.05$), and Available phosphorus (F_{crit} = 1.04, $p < 0.05$), however, most of the parameters showed no significant difference on sampling sites **(Table 3)**

3.5 Relationships among soil chemical variables

For the 10 soil variables pH, E.C., OC, OM, AN, AP, AK, Cu, Zn, Mn, and Fe, principal component analysis (PCA) was performed for the 17 forest study sites **(Fig. 3).** The first axis of PCA is the most significant to explain variance across the variables. **Fig. 3** displays the findings of the principal component analysis performed using the soil chemical parameters. The percentage variance for the axes was 37.63 and 15.34, respectively, and the eigenvalues for PCA axes 1 and 2 were 3.76 and 1.53, respectively. Based on eigenvalue, two principal components (PC) have been formed, and two components shared 53 % of the variance. High

eigenvalues for the first two axes indicated the occurrence of various chemical soil parameters. In order to interpret a PC, it is necessary to consider which variables are most closely correlated with each component *i.e.,* which of these numbers are large in magnitude, the farthest from zero in either direction. The first P.C. is moderately positively correlated with three variables, OC. (0.43), OM. (0.43) and Cu (0.41). In the first PC., increased OC, then the remaining two (OM and Cu) tend to increase as well. Thus, these two variables provide ecological stability to the forest. In the second PC, pH (-0.54) has a strong negative correlation with Fe; however, pH used to decrease with increasing Fe.

3.6 Correlation among soil chemical variables and floristic diversity

A correlation matrix of 14 variables (09 soil and 05 floristic variables) of different forest sites exhibited a correlation, shown in **Table 3**. Soil chemical variables (A.P., Zn, Mn and Fe) did not show much affinity or correlation with floristic parameters (S.R., H, E and T.D.), and Pearson correlation (r) values were very low**;** however, B.A. showed a positive significant correlation of O.C. ($r=0.63$, $p<0.01$) and AN ($r=0.52$, $p<0.05$), while showing a negative correlation with T.D. ($r= -0.80$, $p<0.05$). Similarly, T.D. showed a significant positive correlation with soil pH ($r=0.59$, $p<0.05$), but a significant negative correlation with H' ($r=-0.53$, $p<0.05$). Shannon H' showed a significant positive correlation with EC ($r= 0.53$, $p<0.05$) (**Table 3).** A significant positive correlation of OC with Cu (ppm) ($r=0.59$, $p<0.05$), and Fe (ppm) ($r=0.61$, $p<0.05$); however, a significant negative correlation with AP ($r=-0.52$, $p<0.05$) were observed. Few floristic variables e.g. SR with E ($r=0.76$ $p<0.01$), and with H ($r=0.94$ $p<0.01$), E with H ($r=0.75$ $p<0.01$) showed very high positive significant correlation.

The soil nutrient concentrations (such as O.C., AN, A.P., and A.K.) are good indicators of soil quality and ecosystem productivity via enhanced chemical and biological soil characteristics (Cao et al., 2011). The optimal pH range for adequate soil nutrient availability is 6.0 to 7.5. (Guide, 2005). Soil pH is important for plant growth because it aids in the movement of key nutrients such as AN, A.P., and A.K., which are required in certain amounts for seed germination, plant growth, and development (Osemwota, 2010). Highly acidic forest soil may be caused by basic cation leaching and the accumulation of aluminium ions (Artiola et al., 2019), which will more likely absorb hazardous metals and finally die from poisoning (Chibuike and Obiora, 2014).

There is no evidence in the current study that the strongly acidic and acidic condition of the soil is advantageous to forest soil health (**Table 2).** The soil at the majority of locations is highly acidic (82.35 per cent) (although not significant). The moderate acidic pH range may be owing to an increase in ionisation, which releases more H+ ions, and the ongoing breakdown of surface litter. The carbon dioxide that is produced during root respiration and the microbial decomposition of soil organic matter, which is probably another factor contributing to the soil's

mild acidity, was dissolved in the soil water to create the weak organic acid. In moderately acidic to neutral soils (pH 5-7), pH measurements could be used as a good indicator of the nutritional state of plant life (Hardtle et al., 2003). The base supply and the base saturation is generally well indicated in forest soils with pH values between 4 and 7, especially in the main root horizon (Hardtle et al., 2004). This can be explained by the fact that slightly acidic to neutral soils are marked mostly by high cation exchange and increased pH levels of soil (Qi et al., 2017).

The values of E.C. showed strong variations in different studied sites (22.59 to 509 (113.74± 26.29 SE) µS cm^{-1}) **(Table 3).** Fluctuation of the E.C. of soil was observed in different sites. It was maximum (509 µS cm^{-1}) at S1 at 60-90 cm depth. The higher values of EC in S1 depict low flushing rate, and sluggish groundwater movement, as well as transportation of salts with negligible surface runoff (Van der Kamp and Hayashi, 2009). There is no significant impact of sites (Fcrt=2.07, $p<0.05$) in soil EC.

The recorded range of OC (0.12- 2.77 %) in the present study is high and in conformity with earlier reports (Rana et al., 1988; Bhattarai and Mandal, 2016, Kumar and Saikia, 2021) as *S. robusta* grows best in organic carbon content between 0.11 and 1.80 %. More than 3 % of organic matter of top 23 cm depth of soil seems to be harmful to natural regeneration because of the restricted moisture and nutrient availability (Seth and Bhatnagar, 1959; Yadav, 1966), however, the regeneration of *S. robusta* in the extent of 2 % is favourable (Griffith and Gupta, 1947). Significantly higher organic carbon content may be due to increased input of organic matter by plant residues (litter) of forest (Singh and Kashyap, 2007). High tree density (900 ind.ha-^{1}) was probably the source of high litterfall in S4, which is the highest OC (2.77 %) in S4. The leading source of carbon and nitrogen in the soil is organic matter, and both carbon and nitrogen pursue a related pattern as the rise in carbon content also contributes to an increase in the latter (Allen, 1964). Forest sites with high BA have high AN and OC, and vice-versa, which could clearly be observed at S6. Soil phosphorus (P) is a highly prevalent micronutrient that limits the growth of plants under natural circumstances (Liu et al., 2014). Global soil AP assessments reveal that the total quantity of soil AP is lowest in tropical and subtropical regions (Zhang et al., 2005). In the present study, both the highest (3.94 ppm) and lowest (0.04 ppm) soil available phosphorus values have been observed at the upper layer (0-30 cm) depth. Potassium (K^+) is the basic element and essential macronutrient in terrestrial ecosystems, and synergies between these dominant base cations and other nutrients are potentially important for the health and stability of ecosystems (Lucas et al., 2011). Soil parent materials (rocks) contain potassium and the K+ ions released, which are exchangeable ions and it is the third most important element for plant productivity (Foth and Ellis, 1997). Potassium (K) is not only essential for the increase of soil fertility status but also directly involved with plant development and It is essential for promoting early development,

increasing protein production, improving water quality, and enhancing disease and insect resistance (Hossain et al., 2015). Results show that (**Tables 2**) minimum AK content was found in S10 (13.9 ppm) and maximum (119.4 ppm) in S9 with a mean of 53.83 ± 26.14 SD. The adequate level of AK in site S9 that comes under MDF may be attributed to the prevalence of K-rich clay minerals like illite and kaolinite. In the soil-plant system, potassium behaves with extreme differences in solubility and mobility. In general, trends of AK increase with OC In S10 OC (0.37 %) and AK (13.9 ppm) both recorded low values at 0-30 cm compared to S9 (1.45 % and 119.4) at the same depth. OC and AK showed a positive correlation (r= 0.41). However, the availability of microelements (Cu, Fe, Zn, and Mn) in high amounts due to various causes create a serious problem. it acts as toxic, and these elements act as heavy metals generally; the concentration of heavy metals in soil differs among plant species (Rascio and Navariizzo, 2011).

Fabaceae as the most dominant family in the deciduous Saranda Sal Forest is consistent with the other deciduous forests of the planet, in which Fabaceae is also the most specious family (Pandey and Shukla, 2003; Deka et al., 2012; Kumar and Saikia, 2020a). The total tree density in the surveyed forest was 1085 ind. ha-1, significantly more than the previous data from the tropical dry deciduous Sal Forest of Bokaro, which was mainly composed by *S. robusta* (368 ind. ha-1) (Narayan and Anshumali, 2016), a forest of Chotanagpur plateau, Jharkhand (436 ind. ha^{-1}) (Narayan et al., 2017), Sal Forest of Ranchi (515 ind. ha^{-1}) (Kumar and Saikia, 2020a). The biodiversity of any ecosystem can be measured using distinctive tools, i.e., species richness and species diversity (Daly et al., 2018). Shannon-Weiner diversity (H') in forest depicts the numbers of various species present in a specific area; however, the evenness index depicts how close in numbers each species exists in an environment. H' for Indian forest has been reported to range from 0.83 to 4.10 (Jha and Singh 1990; Ayyappan and Parthasarathy, 1999; Pandey, 2000, Kumar and Saikia, 2020a). The value of H' for trees in the current study, 2.07, is lower than the recorded value of 3.59 for the tree in the Eastern Himalayan Sal Forest (Shankar, 2001), but it is still within the range reported for tropical forests, (3.10) West Bengal moist Sal forest of India (Kushwaha and Nandy, 2012), (3.68) tropical forest of Balasore district, Odisha (Mishra et al., 2018). The concentration of dominance in the present study was (0.06-0.25) lower than the reported range of 0.64-1.34 in another forest. CD has been documented to range from 0.03 to 0.9 for trees in Northeastern Bangladesh (Rahman et al., 2011), (1.0) for the tropical dry deciduous forest of Malyagiri hill ranges, Eastern Ghats (Sahu et al., 2012), and (0.97 to 0.98) for the tropical deciduous forests of Northcentral Eastern Ghats (Tarakeswara et al., 2018).

4. CONCLUSIONS

The present study showed soil chemical properties vary with vegetation structure in Saranda Sal forests. At most sampling sites (14), moderately lower pH values favour S. robusta. Sal forest of Saranda is home to 32.03% IUCN. Red listed species, including vulnerable (*D. latifolia*), least concern (*S. cumini*, *B. ceiba*, *B. variegata* etc.), and data deficient plant species (*C. longa* and *M. indica*). Effective conservation and management activities are needed to save a variety of species in this unique forest environment and restore the beauty of the Saranda sal forests. The present study may provide baseline information on soil nutrient status that can be used to assess forests' floristic diversity and vegetation structure. The findings of the study would be of immense value in formulating appropriate forest management strategies for the Sal forests of Saranda to protect *S. robusta*, the high-economic timber tree, and its associates.

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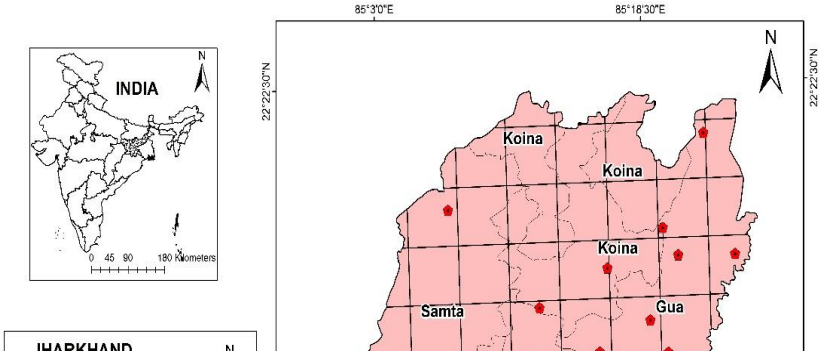

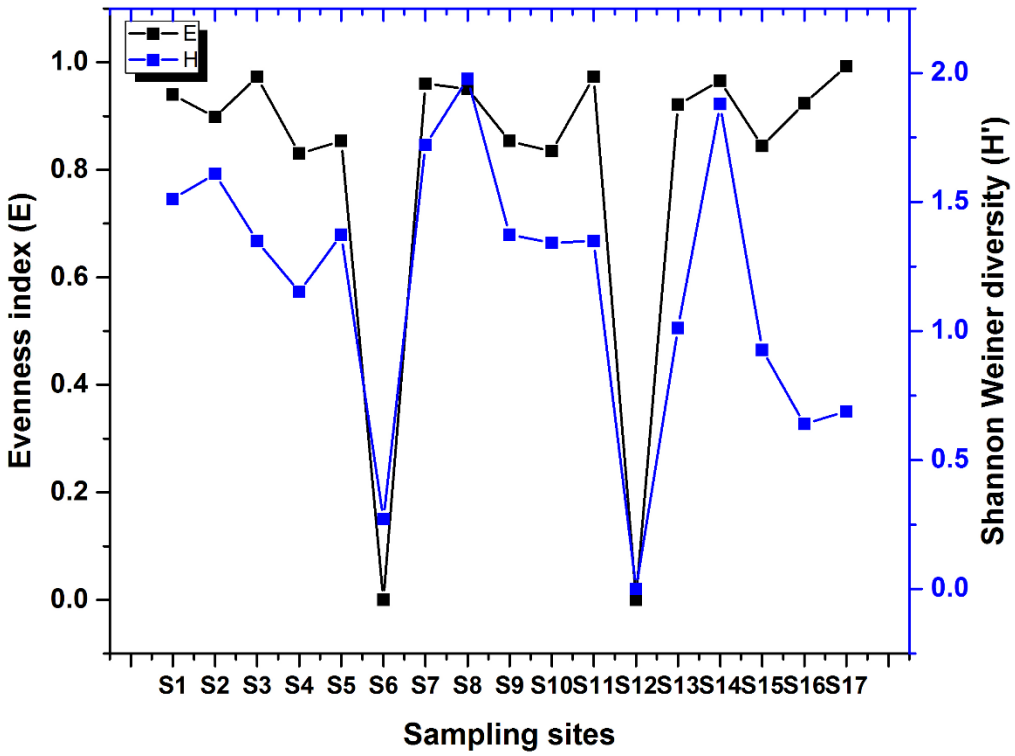

Fig. 2: Relationship between evenness index and Shannon Wiener diversity in different studies sites

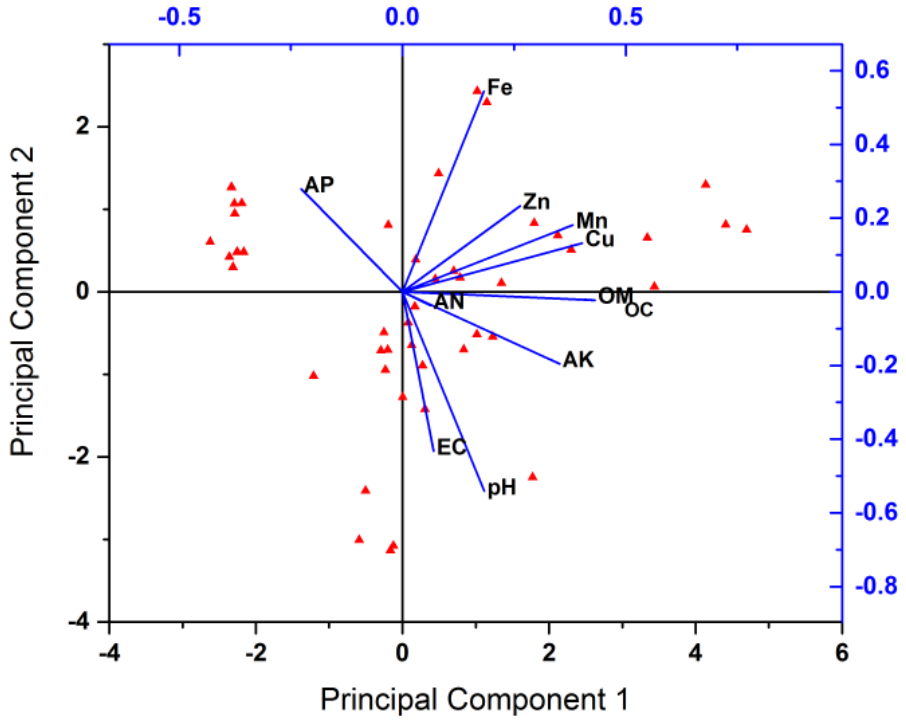

Fig 3 : Results of Principal component analysis

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Table 1: List of tree species present in study sites in terms of relative dominance (RDm), relative frequency (RF), relative density (RD), IVI, basal area (BA) and tree density (TD).

Sl.No	Species Name	Family	RDm (%)	RF (%)	RD (%)	IVI	BA ($m^2h a^{-1}$)	TD (ind.h a^{-1})
1	*Toona ciliata* M. Roem.	Meliaceae	0.09	1.59	0.66	2.33	0.11	7.14
2	*Terminalia alata* Heyne ex Roth	Combretaceae	10.15	15.87	16.45	42.47	12.53	178.57
3	*Tectona grandis* L.f.	Lamiaceae	0.27	1.59	1.32	3.17	0.33	14.29
4	*Syzygium cumini* (L.) Skeels	Myrtaceae	0.60	4.76	3.29	8.66	0.75	35.71
5	*Shorea robusta* Gaertn.	Dipterocarpaceae	74.06	22.22	42.76	139.05	91.43	464.29
6	*Semecarpus anacardium* L. fil.	Anacardiaceae	0.13	1.59	0.66	2.37	0.16	7.14
7	*Phyllanthus emblica* L.	Phyllanthaceae	0.01	1.59	0.66	2.25	0.01	7.14
8	*Mangifera indica* L.	Anacardiaceae	2.27	3.17	1.32	6.76	2.80	14.29
9	*Lannea coromandelica* (Houtt.) Merr.	Anacardiaceae	0.11	1.59	0.66	2.36	0.14	7.14

10	*Lagerstroemia parviflora* Roxb.	Lythraceae	0.85	4.76	1.97	7.58	1.05	21.43
11	*Soymida febrifuga*	Meliaceae	1.48	3.17	2.63	7.28	1.83	28.57
12	*Holarrhena pubescens* Wall ex G. Don	Apocynaceae	0.15	1.59	3.95	5.68	0.19	42.86
13	*Gardenia latifolia* Aiton	Rubiaceae	0.39	1.59	1.32	3.29	0.48	14.29
14	*Diospyros melanoxylon* Roxb.	Ebenaceaea	0.58	6.35	4.61	11.53	0.71	50.00
15	*Dalbergia latifolia* Roxb.	Fabaceae	0.10	1.59	0.66	2.35	0.13	7.14
16	*Cassia fistula* L.	Fabaceae	0.05	1.59	0.66	2.30	0.06	7.14
17	*Casearia graveolens* Dalzell	Salicaceae	0.18	1.59	1.32	3.08	0.22	14.29
18	*Buchanania cochinchinensis* (Lour.) M.R.Almeida	Anacardiaceae	2.84	11.11	7.24	21.19	3.51	78.57
19	*Boswellia serrata* Roxb. ex Colebr.	Burseraceae	0.46	1.59	0.66	2.70	0.57	7.14
20	*Bombax ceiba* L.	Malvaceae	1.34	1.59	0.66	3.58	1.65	7.14
21	*Bauhinia variegata* L.	Fabaceae	1.83	1.59	1.32	4.73	2.26	14.29
22	*Terminalia anogeissiana* Gere & Boatwr.	Combretaceae	2.07	7.94	5.26	15.27	2.55	57.14
	Total		**100**	**100**	**100**	**300**	**123.45**	**1085.71**

Table 2. ANOVA showing different chemical properties of soil, with soil depth at significance value (P < 0.05) in studied sites.

Soil chemical parameters	Mean (M) +SD	F crit.	Significance value (P < 0.05)
PH	6.11 ± 0.77	0.84	0.5131
EC	89.48 ± 85.71	2.07	0.1123
OC	0.79 ±0.65	0.94	**0.0411**
OM	1.37 ± 1.13	3.94	**0.0001**
AN	169.55± 301.70	3.94	**0.0002**
AP	1.5 ± 0.88	1.04	**0.0411**
AK	48.58 ± 26.28	1.23	0.3412
Cu	1.03 ± 1.10	1.07	0.3912
Zn	0.27 ± 0.27	1.67	0.2012
Mn	7.16 ±6.03	1.23	0.3022
Fe	6.29 ±5.05	0.66	0.8011

Table 3. Pearson correlations among Saranda Sal forest soil chemical variables (09) and floristic variables (05).

pH	**EC**	**OC**	**AN**	**AP**	**AK**	**Cu**	**Zn**	**Mn**	**Fe**	**SR**	**E**	**H'**	**TD**	**BA**

pH	1														
ECOCAN	.33	1													
APAK	.13	.08	1												
Cu	-0.02	0.09	.742**	1											
Zn	-.25	-.27	-.52*	-0.36	1										
Mn	-.19	.37	.41*	.63**	-.03	1									
Fe	.04	.34	.59*	0.41	-.35	.55*	1								
SR	-.09	.31	.10	-0.16	-.23	.17	.67**	1							
EC	-.15	.27	.24	0.45	-.21	.29	.50*	.17	1						
HE	-.30	-.02	.61*	.70**	-.04	.22	.43	-.07	.39	1					
TD	.59*	.31	.13	0.10	-.22	.33	.07	-.00	.07	-.37	.31	.05	-.53*	1	
BA	0.06	0.77	0.63**	.52*	0.28	-0.39	0.34	-0.09	0.33	0.41	-0.40	-0.49*	-0.24	-0.81*	1

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Abbreviation: EC= Electric conductivity, OC= Organic Carbon, AN= Available Nitrogen, AP= Available Phosphorus, AK= Available Potassium, Cu= Cupper, Zn= Zinc, Mn= Manganese, Fe= Iron, E= Evenness index, H= Shannon diversity, TD= Tree density, BA= Basal area