International Journal of Plant & Soil Science

23(1): 1-13, 2018; Article no.IJPSS.40908
ISSN: 2320-7035

Role of Soil Parameters in Various Forest Types of Mukundpur, Satna Forest Division of Madhya Pradesh, India

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Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

Article Information

DOI: 10.9734/IJPSS/2018/40908
Editor(s):
(1) Kofi Agyarko, Associate Professor, College of Agricultural Education, University of Education, Winneba, Ghana.
Reviewers:
(1) Nebi Bilir, Suleyman Demirel University, Turkey.
(2) José Expedito Cavalcante da Silva, Federal University of Tocantins, Brazil.
Complete Peer review History: http://www.sciencedomain.org/review-history/24848

Original Research Article

Received 10th March 2018
Accepted 18th May 2018
Published 28th May 2018

ABSTRACT

The study area was the forest area of 111.55 km^2 of Mukundpur range of Satna Forest division, Madhya Pradesh, India which was susceptible to illicit felling, encroachment and illicit mining. To re-vegetate the blanks of the forest, the associations of soil parameters like pH, electrical conductivity, availability of major nutrients and micro nutrients of various forest types were analyzed under the present study.

The stratified systematic random sampling design was used for sampling. The 151 sample points at 30"x 30" were selected and laid on ground with the help of GPS. The layout of sample plot of 0.16 hectare with 9 quadrate of 2 mX2 m on ground was done with the help of prismatic compass. Half kg of soil sample was collected from central quadrat at a depth of 30 cm from the sample point and air-dried under shade. The soil parameters pH, electrical conductivity (mili mhos/cm), organic carbon (%), available nitrogen (kg/ha), available P_2O_5 (kg/ha), available K_2O (kg/ha) and micronutrient analysis for the availability of zinc (ppm), iron (ppm), manganese (ppm) and copper (ppm) were assessed at soil testing laboratory Rewa. The Microsoft access program was developed to evaluate the above soil parameters in various forest types.

Individually, in mixed type of forests electrical conductivity and available manganese had significant contribution but in teak forest type's, electrical conductivity, available phosphorus, iron and copper had significant association. Available iron and copper were the major responsible factors in teak

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forest type while available manganese was the major responsible factor in mixed forest types individually. The joint impact of available nitrogen, phosphorous and potassium did not have any association in the formation of forest types. In teak forest types individually Fe and Cu did have significant association while available Mn did contribute a significant association in mixed forest types.

Keywords: Forest types; pH; electrical conductivity; organic carbon content; macro nutrients and micro nutrients.

1. INTRODUCTION

Forests are large tracts of uncultivated lands occupied by trees, shrubs, herbs and other vegetations along with insects and animals, large and small, and microorganisms interacting together and remaining in a dynamic equilibrium with their a biotic environments. Forests cover almost 30% of the world's ice-free land and forests perform important ecological functions such as regulation of climate, sequestration of carbon and, biogeochemical cycling. Carbon is captured in tree biomass and in forest soils. Forests account for approximately 30% of terrestrial land cover and store about 45% of the carbon in terrestrial ecosystems [1,2,3,4] and are the major source of biodiversity.

As a source of biodiversity India ranks amongst one of the 12 mega biodiversity countries of the world and harbours 17,000 flowering plant species. It accounts for 8% of the global biodiversity with only 2.4% of the total land area of the world [5,6,7].

The study area was northern tropical dry deciduous mixed forest types with some patches of southern tropical dry deciduous teak forests situated in Mukundpur range of Satna district, Madhya Pradesh, India. The head quarter of Mukundpur range is in Mukundpur village. This range has a geographical area of 589.71 km^2 with forest area of 111.55 km^2 as discussed by Singh [8].

This forest area was susceptible to illicit felling, encroachment and illicit mining. The forests of the Mukundpur range have been changing from stocked - under stocked - blank forests. The majority of the area are blank and under stocked category. Some of the area was also encroached for agricultural purposes. Due to topography, some of the area was also erosion prone. This area of Mukundpur range also was surrounded by mining areas of bauxite and limestone. The nearby located cement factories were always in search of new areas, besides exploiting existing known areas. Thus the area was encountering impact of temperature rise, industrialization, desertification, shifting in the growing seasons of plants, loss of pollinators and seed dispersers, causing extinction of precious plants. Similarly the forests were more prone to developmental activities specially widening of roads. Thus the area of Mukundpur forest was under high ecological stress and forests disturbances.

To understand the ecology of disturbed forests some of the literatures were surveyed to know the effect of degradation of forests on the various forest soil parameters. The reviews of literatures in the study area did not show any significant work. Though, on global level contribution of some of the reviews of the literature were discussed. Zhu and Liu [9] had made the research on forest disturbance ecology, especially on the main ecological processes or the consequential results of disturbed forests, including the change of biodiversity, soil nutrient and water cycle and carbon cycle, regeneration mechanism of disturbed forests and so on. Forests have several carbon pools vegetation, dead wood and litter, soil organic matter, and humus. At the global level, 19% of the carbon in the earth's biosphere is stored in plants and 81% in the soil. In all forests, tropical, temperate, and boreal together, approximately 31% of the carbon is stored in the biomass and 69% in the soil. In tropical forests, approximately 50% of the carbon is stored in the biomass and 50% in the soil [10].

Tewari et al. [11] had analyzed the physico-chemical properties of soils from different land use systems viz. agriculture, olericulture and two dominant forest types (*oak; Quercus leucotrichophora and pine; Pinus roxburgii*) in Uttarakhand, India.

Some physico-chemical parameters were selected as indicator of soil quality and were investigated by Baisya and Sharma [12]. Zaman et al. [13] had studied under the selected different land use system in Dimoria

Development Block under Kamrup District of Assam India. Chandra et al. [14] had discussed about the temperate and dry deciduous forest covers of terrestrial ecosystem in India. Grigal and Vance [15] reported about the influence of soil organic matter on forest productivity. Mohd et al. [16] studied about relationship between soil pH with selected soil biological and chemical properties.

Looking towards the blank and under stocking status of the forest of the study area it was necessary to re-vegetate the forest area, so that blank and under stocked area should be converted into stocked forests. The selection of species to re-vegetate the study area and the forest types should also be considered. The soil parameters in the study area needed to be studied in detail in relation to various forest types to associate forest ecology with soil ecology. Thus in the present study the associations of soil parameters like pH, electrical conductivity, availability of major nutrients (Nitrogen, Phosphorous and Potassium) and micro nutrients like (Copper, Manganese, Iron and Zinc) with various forest types were analyzed.

2. MATERIALS AND METHODS

2.1 Study Area

The area lies between north latitude of 24°11'35'' to 24°26'25'' and east longitude of 81°6'35'' to 81°22'20''. The map of the study area is shown in Fig. 1. The forest area of this range exists in 7 forest blocks namely Mand, Govindgarh extension, Papra, Jhinna, Sarhai, Kokahansar and Mankesar. The forest blocks of Govindgarh extension and papra extend in Satna and Rewa forest districts. The part of Mankesar forest block lies in submerged area of Bansagar dam. Northern boundary lies with Beehar River demarcating Satna and Rewa district. Eastern boundary lies mainly with the district boundaries bifurcating Rewa and Satna districts. The famous Charaki ghati forms one of its boundaries. Southern boundary lies mainly with submerged area of Son River and it extends to district boundaries of Shahadol and Satna districts. The major study area has northern tropical dry deciduous mixed forest types with some patches of southern tropical dry deciduous teak forests especially in Mand reserve. The soil in study area has the origin of Vindhyan formation and it consists of materials from sand stone, limestone and shale. The average annual rainfall in study area was noticed from 354.1 mm to 1748.4 mm with mean annual rainfall of 1074.26 mm. The area receives nearly 51 rainy days in year. South western mansoon plays the active role of precipitation in the study area starting from middle of June month. The average highest daily temperature ranges within 24.06°C to 41.73°C with mean temperature of 32.24°C. The highest daily temperature recorded was 47.7°C. Similarly the average lowest daily temperature was 8.85°C to 27.72°C with minimum daily temperature of 17°C [17].

From the results of stock mapping done by Jain [17], the study area has sal forest (125.356 ha.), teak forest (560.328 ha.), mixed forest (4405.371 ha.), blank (5490.047 ha.), encroachment (559.108) and others including nala, river, ponds and mining area etc. (14.948 ha.).

2.2 Assessment of Forest Resource

For the assessment of Forest resource survey of Mukundpur range, the vegetation sampling was done for the trees, shrubs, herbs, climbers, grasses and tubers. Stratified systematic random sampling method was used for sampling the vegetation [18]. For determining minimum number of sample points, the formula used was $n = z^2 \frac{pq}{E^2}$ where E= difference between population proportion mean and sample proportion average, p = population proportion, q= 1- p, z=1.96 for a level of significance of 95% [19].

Based on the secondary data from Mukundpur range and Satna forest division, the sample size for various tree parameters i.e. number of trees per hectare, volume per hectare and established regeneration per hectare was calculated at 10% error (E) between population and sample proportion at 95% level of significance keeping in view time and other resources [19].

A minimum of 95 sample points were calculated from the above formula to assess the vegetation. The forest maps of Mukundpur range on survey of India topo sheet is of the scale of 1:15000.

Each sample point was located on ground with the help of GPS.

The grids at 35”x 35” and 30”x30” intervals were drawn by trial and error, for systematic random sampling. For drawing the grids, GIS software was used. With this software 35”x 35” and 30”x30” grids were drawn on the map of Mukundpur forests range, so that criteria for minimum number of 95 grids were achieved.

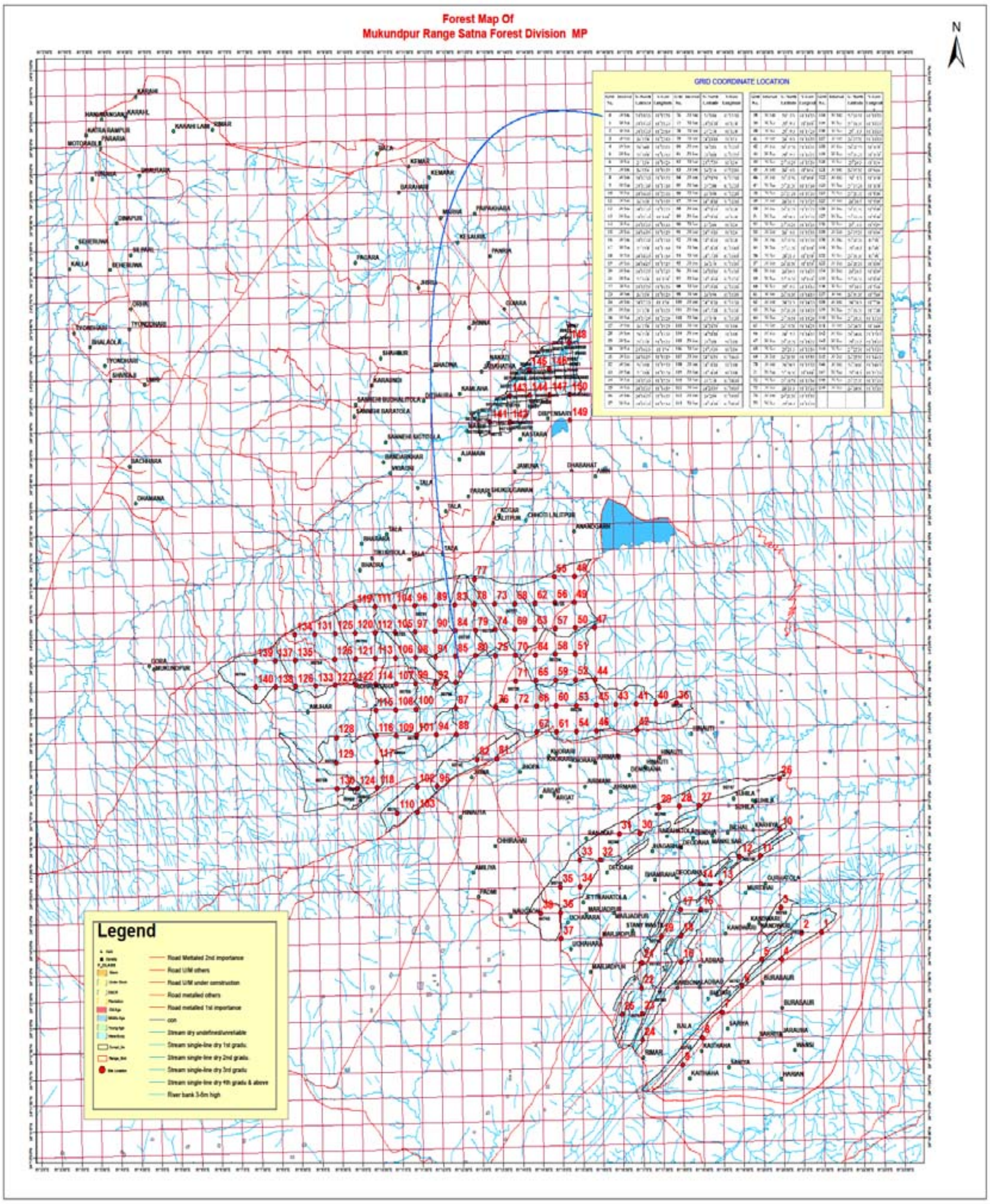
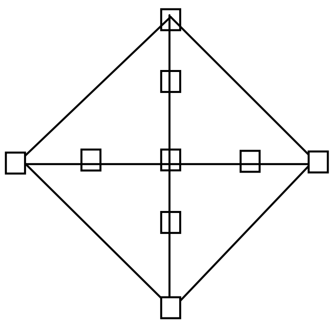


Fig. 1. Map of the study area



Sample plot area 0.16 or 0.1 ha
Quadrat of size 2 m x 2m, 9 in number

Fig. 2. Sample plot with their Quadrat

The 111 and 151 random points were recorded on above grid. The 151 sample points at 30"x 30" were selected on safer side, so that points may fall in river bed, submergence and encroachments to maintain minimum criteria of 95 numbers. The longitudes and latitudes of 151 points were noted and listed from topo sheets. Out of 151 points, 12 points were on encroachment, 67 points were on blanks, 51 points were on mixed forest types, 13 points were on teak forest types and remaining 8 points were on submerged areas of son river reservoir.

At each sample points, the layout of sample plot of 0.16 hectare with 9 quadrats of 2 m x 2 m on ground as shown in Fig. 2 was done with the help of prismatic compass [18]. At these points recording of data of the girth and species of the trees, alongside species of shrubs, climbers and tubers (numbers) were taken on whole sample plot of 0.16 hectare and data for species of herbs, grasses and established regeneration was recorded at each 9 quadrate of 2 m x 2 m. Department of Agriculture, Bhopal Madhya Pradesh, India had suggested the guide lines for collection of soil samples [20]. From the guide lines suggested by the Department, 0.5 kg of soil sample was collected from the central quadrat from the depth of 30 cm from the sample point and air-dried under shade. These air dried samples were transferred into clean cloth bag bearing a slip grid number, latitude and longitude. These sample were sent to the soil testing laboratory-Rewa to assess the soil parameter -pH, electrical conductivity (mmhos/cm), organic carbon (%), available nitrogen (kg/ha), available P_2O_5 (kg/ha), available K_2O (kg/ha), zinc (ppm), iron (ppm), manganese (ppm) and copper (ppm).

A Microsoft access program was developed to evaluate the above soil parameters in various forest types.

Theses forest types are described by [18] as below.

Forest types: Depending upon the composition of species it may be defined as: Teak forest, Sal forest (more than 20% of teak & sal composition), Salai forest (more than 40% of miscellaneous), Khair forest (more than 20% of khair trees), mixed forest (species composition less than 20%), blank – canopy density less than 0.2, Others – encroachment, submerged areas, rocks and river beds as mentioned in Working plan code.

The average value of different soil parameters in different forest types and in whole study area is evaluated and standard error for whole study area is calculated. In order to assess the association of various soil parameters within various forest types, testing of hypothesis at 5% level of significance is done using Z statistics. The Z value is calculated from the formula given below:

Z_{cal} of particular soil parameter = | (Observed average value of the soil parameter in particular forest types - average value of the soil parameter in the study area) / Standard error of the soil parameter in the study area |

At 5% level of significance, the following hypothesis was formulated:

1. **Null hypothesis (H_0):** There is no significant difference in average value of the soil parameters and average value of the soil parameter of the study area.
2. **Alternate hypothesis (H_i):** There is a significant difference in average value of the soil parameters and average value of the soil parameter of the study area.

At 5% level of significance, the testing of hypothesis was done by the following decision rules:

1. If $Z_{calculated} < Z_{tabulated}$ Null hypothesis is not rejected. It means there is no significant difference in average value of the soil parameters and average value of the soil parameter of the study area.
2. If $Z_{calculated} > Z_{tabulated}$ Null hypothesis rejected. It means there is a significant difference in average value of the soil parameters and average value of the soil parameter of the study area.

After calculating Z value of various soil parameters the combined effects of the following parameters were studied using χ^2 analysis at 5% level of significance:

1. Combined effect of pH, electrical conductivity and organic carbon within the various forest types of the study area.
2. Combined effect of Macro nutrient (available N, P_2O_5 and K_2O) within the various forest types of the study area.
3. Combined effect of Micro nutrient (available Zn, Fe, Mn and Cu) within the various forest types of the study area.

At 5% level of significant the following hypothesis for χ^2 analysis was formulated:

1. **Null hypothesis (H_0):** There is no significant difference of the combined effect of the soil parameter within the various forest types of the study area.
2. **Alternate hypothesis (H_i):** There is a significant difference of the combined effect of the soil parameter within the various forest types of the study area.

At 5% level of significance, the testing of hypothesis for χ^2 analysis following decision rules are followed:

1. If $\chi^2_{\text{calculated}} < \chi^2_{\text{tabulated}}$ Null hypothesis is not rejected. It means There is no significant difference combined effect of above studies within the various forest types of the study area
2. If $\chi^2_{\text{calculated}} > \chi^2_{\text{tabulated}}$ Null hypothesis rejected. It means There is a significant difference combined effect of above studies within the various forest types of the study area

χ^2 is calculated with the formula as $\chi^2_{cal} = \sum \frac{(O-E)^2}{E}$, where O = Observed Values and E = Expected Values

3. RESULTS AND DISCUSSION

3.1 Association of Individual Soil Parameters in the Various Forest Types

The soil parameters studied were pH, Electrical conductivity (milli mhos/cm), organic carbon (%), available Nitrogen (kg/ha), available Phosphorous and available potassium (kg/ha), Zn, Fe, Mn and Cu (ppm). Calculated values of these parameters in various forest types were analyzed and presented in Table 1 of this section.

From Table 1 the Z $_{\text{calculated}}$ for various soil parameters within various forest types of study area is presented below in Table 2 and it is compared with the tabulated value of Z to test the hypothesis at 5% level of significance.

From Table 2 the soil parameters in the various forest types of the study area were discussed below:

pH: The soil pH influences the rate of nutrients released through its influence on decomposition, carbon exchange capacity and solubility of materials. Further, soil pH influences plant growth by way of improving the soil physical condition and nutrients availability, whereas, high or low pH of nutrient medium has adverse effect on plant growth [21]. The pH of the various forest types i.e. encroachments, blanks, mixed and teak varied from 7.06 to 7.12 with average pH of 7.09. Results indicated that the average value of pH in different forest types did not change significantly with average value of pH of the study area as $Z_{cal} < Z_{tab}$ **(1.645)** as it was also reported for different forest types by Yazici and Turan [22]. Thus the pH did not play significant role within the various forest types. It means that the forest types (mixed and teak) in the study area and pH of the study area were independent variables. The pH was the important parameter of soil ecology and it might have the role in individual plants or vegetation but it did not play any role in the formation of the different forest types.

Electrical conductivity: The measure of electrical conductivity shows the total amount of soluble salts present in the soil. It is the most common measure of soil salinity. The electrical conductivity is a major of ions present in solution [23]. The Average value of electrical conductivity for soil of the study area is 0.28 mmhos /cm. This varied from 0.27 to 0.35 mmhos /cm for various forest types. Results indicated that the electrical conductivity within the encroachment, blank, mixed and teak forest types significantly changed with average electrical conductivity of the study area as $Z_{cal} > Z_{tab}$ **(1.645)**. Thus electrical conductivity did play significant role in formation of different forest types, especially in teak forests. In mixed forest types the average value of electrical conductivity was nearly equal to the average value of electrical conductivity of the study area though this parameter had significant role in mixed forest types. In the encroachment process all the trees species are removed and forest land is cultivated for agriculture purposes and in these lands encroachers had added the in organic fertilizer which had increased the ion concentration in soil solution and contributed the increased the electrical conductivity and was the highest value.

Organic Carbon Content: The level of soil organic matter determines the multiplication of microorganisms and makes the system more dynamic. The observed values of organic matter content in percentage for the various forest types i.e. encroachment, blank, mixed and teak forest

Table 1. Values of soil parameters within the various forest types

Forest Type	PH	EC(mmhos/cm)	OC(in%)	N kg/ha	P_2O_5 (kg/ha.)	K_2O (kg/ha.)	Zn (ppm)	Fe(ppm)	Mn(ppm)	Cu(ppm)
Blank	7.060	0.270	0.660	247.820	38.210	213.030	0.180	4.460	1.660	0.270
Encroachment	7.110	0.350	0.380	178.000	45.130	202.000	0.040	1.910	1.000	0.420
Mixed	7.090	0.270	0.610	235.250	38.520	206.750	0.210	5.420	1.170	0.290
Teak	7.120	0.300	0.640	244.230	35.790	215.680	0.190	4.280	1.380	0.370
Average	7.090	0.280	0.630	240.060	37.980	210.190	0.190	4.900	1.350	0.300
stderr	0.022	0.006	0.013	3.383	1.196	5.540	0.027	0.320	0.109	0.021

Table 2. Z Calculated for the various soil parameters within the various forest types

Soil Parameters	Forest types								Z_{table} at 5% level of significance (one tailed test)
	Blank		Encroachment		Mixed		Teak		
	Average	Z_{cal}	Average	Z_{cal}	Average	Z_{cal}	Average	Z_{cal}	
pH	7.060	1.360	7.110	0.909	7.090	0.000	7.120	1.364	1.645
EC	0.270	1.667	0.350	11.667	0.270	1.667	0.300	3.333	1.645
O/C	0.660	2.300	0.380	19.200	0.610	1.538	0.640	0.769	1.645
N	247.820	2.293	178.000	16.345	235.250	1.422	244.230	1.233	1.645
P_2O_5	38.210	0.192	45.130	5.978	38.520	0.452	35.790	1.831	1.645
K_2O	213.030	0.513	202.000	1.478	206.750	0.621	215.680	0.991	1.645
Zn	0.180	0.370	0.040	5.560	0.210	0.741	0.190	0.000	1.645
Fe	4.460	1.375	1.910	9.343	5.420	1.625	4.280	1.938	1.645
Mn	1.660	2.840	1.000	3.211	1.170	1.651	1.380	0.275	1.645
Cu	0.270	1.429	0.420	5.714	0.290	0.476	0.370	3.333	1.645

types were 0.38, 0.66, 0.61, and 0.64% respectively with an average value of 0.63%. The result indicated that the organic carbon contents in the encroachment and blank forest, were significantly higher than the average value of organic carbon content of the study area as $Z_{cal} > Z_{tab}$ **(1.645).** But in mixed and teak forest types the organic carbon content did not differ significantly from the average organic carbon value of the study area as $Z_{cal} < Z_{tab}$ **(1.645).** In the mixed and teak forest types the forest soil maintained the average value of soil carbon. The breaking of land due to agriculture reduced the soil organic carbon significantly as it assumes a value of 0.380 less than average value of 0.630.

Available Nitrogen: Nitrogen is an important factor affecting decomposition. The availability of nitrogen is due to the regular addition of plant residues on the soil and decomposition. The organic compounds are converted into inorganic nitrogen by certain bacteria, which can be absorbed by the plants. Results for the average value of available nitrogen for the whole forest of study area was 240.06 kg/ha. Results indicated that the average values of available nitrogen were 178.00, 247.820, 235.25 and 244.23 kg/ha in encroachment, blank, mixed and teak forest types respectively. The average value of available nitrogen in the encroachment and blank forest types significantly changed from the average value of the available nitrogen of the study area as $Z_{cal} > Z_{tab}$ **(1.645).** The average value of available nitrogen in the mixed and teak forest types did not change significantly with the average value of available nitrogen of the study area as $Z_{cal} < Z_{tab}$ **(1.645).** The mixed and teak forest types were able to sustain the available nitrogen in the soil of the study area. As soon as it was converted into blank and encroachment due to degradation, the available nitrogen changed significantly. The available nitrogen decreased very significantly when it comes to the encroachment category.

Available Phosphorous: Phosphorous is an essential constituent of protoplasm. It does not move readily through the soil and is not easily leached by rain. Phosphorous is absorbed by the plants as H_2PO_4, HPO_4, or PO_4 depending upon soil pH. Most of the total phosphorous is tied up chemically in compound of limited solubility. The results of available phosphorous in kg/ha for the study area was 37.98 kg/ha. The average value of available phosphorous in blank and mixed forest types did not change significantly with the average value of available phosphorous of the study area as $Z_{cal} < Z_{tab}$ **(1.645).** The average values of available phosphorus in the encroachment and teak forest type were significantly higher than the average value of available phosphorous of the whole study area as $Z_{cal} > Z_{tab}$ **(1.645).** The breaking of forest land due to agriculture significantly increased the available phosphorous. This means that the breaking of land exposes the rocks, soil and geology devoid of vegetation, which then increase the available phosphorous to significant levels. In the teak forest type, the vegetation utilizes more phosphorous as the return of phosphorous nutrient were considerably lower [24,25] as compared to the vegetation of the mixed forest types and the vegetation of blank category (grasses and herbs), hence the available phosphorus in the soil of the teak forest was less than the available phosphorus in the soil of the mixed and blank forests of the study area.

Available Potassium: Potassium is an activator of dozens of enzymes responsible for energy metabolism, starch synthesis, nitrate reduction and also plays a major role in protection against diseases by thickening the cell walls of plants tissue. Results of available K_2O in kg/ha for the study area was 210.190 kg/ha. The average value of K_2O in the encroachment, blank, mixed and teak forest types were 202.000, 213.030, 206.75 and 215.68 kg/ha respectively. The average value of available K_2O in the encroachment, blank, mixed and teak forest types did not change significantly with the average K_2O value of the study area as $Z_{cal} < Z_{tab}$ **(1.645).** The available K_2O did not reveal any significant change in the various forest types. The undisturbed forests (mixed, teak and blank forest) were converted to encroachment category by removal of trees and other vegetation and forest land was cultivated, available potassium in soil was reduced to lowest level as it was leached from surface in disturbed soil. Prictchet [26] reported that trees are capable of absorbing potassium from the weathered parent material and potassium is rapidly and efficiently cycled in established forest stands and very little potassium appears to be leached from surface root mat in undisturbed soil.

Available Zinc: Zinc, as Zn^{2+}, which occurs as an exchangeable cation, is strongly absorbed onto several soil constituents, and is complexed by organic matter. Zinc is required for the photosynthesis. Zinc solubility is low in soils and it forms chelates with organic matter to increase the phytoavailability in mineral soils, but can lead to deficiency in organic soils [27]. The result of the average value of zinc in the study area was 0.19 ppm. The average value of zinc in encroachment, blank, mixed and teak forest types were 0.040, 0.18, 0.21 and 0.19 ppm respectively. The average zinc values in the blank, mixed and teak forest types did not change significantly from the average value of the study area as $Z_{cal} < Z_{tab}$ **(1.645).** The average zinc value in the encroachment category significantly changed from the average value of the study area as $Z_{cal} > Z_{tab}$ **(1.645).** Results indicated that the breaking of forest land resulted in major loss in Zn availability. Zinc plays an important role in photosynthesis of vegetation in individual plants but it did not play significant role in the formation of forest types at community level, even for the grasses and herbs of the blank category.

Available iron: Iron is weathered from minerals and appears as divalent cations in solutions as such, they are available to plants. Iron is required as a trace element and required by photosynthesis and for nitrogen metabolism. The result of available Fe for the study area was 4.9 ppm. The average value of Fe in the encroachment, blank, mixed and teak forest types were 1.910, 4.460, 5.42 and 4.28 ppm respectively. The average values of Fe in the blank and mixed forest types did not change significantly with the average value as $Z_{cal} < Z_{tab}$ **(1.645).** But the average value of Fe in the encroachment and teak forest types varied significantly with the average value of the study area as $Z_{cal} > Z_{tab}$ **(1.645).** The breaking of land due to agriculture significantly lowered the Fe content in the encroached soil. Again in the formation of teak forest types the available iron had significant role but it did not have a significant role in mixed forest types.

Available Manganese: Manganese is weathered from minerals and appears as divalent cations in solution as such they are available to plants. This element is required in trace amount and required for photosynthesis and other metabolism functions. The average observed value of available Mn for the study area was 1.35 ppm. The average Mn values for the encroachment, blank, mixed and teak forest types were 1.000, 1.660, 1.17 and 1.38 ppm respectively. The average values of Mn in the encroachment, Blank and mixed forest types varied significantly with the average values of the study area as $Z_{cal} > Z_{tab}$ **(1.645).** But the average value of Mn in teak forest types did not change significantly with the average value of the study area as $Z_{cal} < Z_{tab}$ **(1.645).** Thus when the forest area was devoid of vegetation, there was a significant reduction in available manganese. The available manganese in blank and mixed forest type revealed significant role while in teak forest types it did not show significant role.

Available copper: Copper is released from mineral weathering to the soil solution as Cu^{2+}. This micronutrient cations can be adsorbed onto cation exchange sites. This element is required for other metabolism. It forms chelates with organic matter to increase phytoavailability in mineral soils. The results for the study area indicated that average observed value of Cu was 0.30 ppm. The average Cu value for the encroachment, blank, mixed and teak forest types were 0.420, 0.270, 0.29 and 0.37 ppm respectively. The average values of Cu in the Blank and mixed forest types did not change significantly with the average value of the study area as $Z_{cal} < Z_{tab}$ **(1.645).** But average values of Cu in the encroachment and teak forest types significantly changed from the average value of the study area as $Z_{cal} > Z_{tab}$ **(1.645).** Thus when the forest area was devoid of vegetation, there was a significant increase in available copper. The available copper did not show any significant role in the blank and mixed forest but it did play a significant role in the teak forest types.

3.2 Association of Combined Soil Parameters (ph, EC, Organic Carbon) in the Various Forest Types

From Table 2 the Z value of pH, EC and organic carbon of the various forest types of the study area are given in Table 3.

Table 3. Z values of pH, EC and Organic Carbon within various forest types

Forest types	pH	EC	O/C	Total
Blank	1.360 (0.423)	1.667 (2.134)	2.300 (2.771)	5.327
Encroachment	0.909 (2.522)	11.667 (12.727)	19.200 (16.527)	31.776
Mixed	0.000 (0.254)	1.667 (1.284)	1.538 (1.667)	3.205
Teak	1.364 (0.434)	3.333 (2.189)	0.769 (2.843)	5.466
total	3.633	18.334	23.807	45.774

To understand the association about the combined effects of the pH, EC and organic carbon within the various forest types of the study area, these values are converted into Z scores to maintain the same dimensional unit and hypothesis is done using χ^2 analysis. In Table 3, figures presented in brackets and bold represent the expected Z value.

$\chi^2_{calculated}$ = 8.295

Degree of freedom = (4-1) * (3-1) = 6

At 5% level of significance at 6 degree of freedom, $\chi^2_{tabulated}$ = 12.592

Since $\chi^2_{cal} < \chi^2_{tabulated,}$ null hypothesis is accepted. Hence combined impact of pH, EC and organic carbon did not have significant association within the various forest types of the study area. Individual effects of pH and organic carbon also did not have significant role but EC had significant role in the formation of forest types. As there are two ecosystems operating simultaneously i.e. one below the earth (soil ecosystem) and other one on the surface of earth (forest ecosystem). These parameters are making a connection between both ecosystems. These parameters were functioning in land ecosystem as a resultant action of climate and soil microorganism on the parent material of the surface of earth to produce soil. In soil ecology these parameters did have role but jointly these parameter did not associate the soil ecology with the forest ecology on forest ecosystem but the electrical conductivity parameter of soil ecology connect individually to the different forest types.

3.3 Association of Combined Macro Nutrient of Soil Parameters (Nitrogen, P_2O_5 and K_2O) in the Various Forest Types

From Table 2 the Z value of Nitrogen, P_2O_5 and K_2O within the various forest types of study area are given in Table 4.

To understand the association of the combined effects of the Nitrogen, P_2O_5 and K_2O within the various forest types of the study area, these values are converted into Z scores to maintain the same dimensional unit and hypothesis is done using χ^2 analysis. In Table 4 figures presented in brackets and bold represent the expected Z value.

$\chi^2_{calculated}$ = 3.726

Degree of freedom = (4-1) * (3-1) = 6

At 5% level of significance at 6 degree of freedom, $\chi^2_{tabulated}$ = 12.592

Since $\chi^2_{cal} < \chi^2_{tabulated,}$ null hypothesis is accepted. Hence combined impact of Nitrogen, P_2O_5 and K_2O **(**macro nutrients**)** did not have significant association within the various forest types of the study area. Except the encroachment forest, individually the available nitrogen and K_2O did not play significant role in the formation of forest types, but P_2O_5 individually did make significant impact on teak forest types. Thus available phosphorous is an important parameter which is responsible in development of teak forest types.

3.4 Association of Combined Micro Nutrient of Soil Parameters (Zn, Fe, Mn and Cu) in the Various Forest Types

From Table 2 the Z value of Zn, Fe, Mn and Cu within the various forest types of the study area are given in Table 5:

To understand the association of the combined effects of Zn, Fe, Mn and Cu within the various forest types of the study area, these values are converted into Z scores to maintain the same dimensional unit and hypothesis is done using χ^2 analysis. In Table 5 figures presented in brackets and bold represent the expected Z value.

$\chi^2_{calculated}$ = 9.056

Table 4. Z values of N, P_2O_5 and K_2O within the various forest types

Forest types	N	P_2O_5	K_2O	Total
Blank	2.293 (1.914)	0.192 (0.760)	0.513 (0.324)	2.998
Encroachment	16.345 (15.197)	5.978 (6.033)	1.478 (2.571)	23.801
Mixed	1.422 (1.593)	0.452 (0.632)	0.621 (0.270)	2.495
Teak	1.233 (2.589)	1.831 (1.028)	0.991 (0.438)	4.055
Total	21.293	8.453	3.603	33.349

Table 5. Z values of Zn, Fe, Mn and Cu within the various forest types

Forest Types	Zn	Fe	Mn	Cu	Total
Blank	0.370 (1.006)	1.375 (2.154)	2.840 (1.203)	1.429 (1.652)	6.014
Encroachment	5.560 (3.986)	9.343 (8.533)	3.211 (4.766)	5.714 (6.544)	23.828
Mixed	0.741 (0.752)	1.625 (1.609)	1.651 (0.899)	0.476 (1.234)	4.493
Teak	0 (0.928)	1.938 (1.986)	0.275 (1.109)	3.333 (1.523)	5.546
total	6.671	14.281	7.977	10.952	39.881

Degree of freedom = (4-1) * (4-1) = 9

At 5% level of significance at 6 degree of freedom, $\chi^2_{tabulated}$ = 16.919.

Since $\chi^2_{cal} < \chi^2_{tabulated,}$ null hypothesis is accepted. Hence overall the impact of Zn, Fe, Mn and Cu did not have significant association within the various forest types of study area. Individually the Zn did not play significant role in the formation of forest type but Fe and Cu did play significant impact on formation of teak forest types and Mn also was significant in mixed forest types. Thus in teak forest types individually micronutrient of Fe and Cu did have significant association while available Mn did contribute a significant association in mixed forest types.

4. CONCLUSION

In the encroachment forest the pH and K_2O did not play any role but the other parameter of soil like electrical conductivity, organic carbon, nitrogen, phosphorous, zinc, iron, manganese and copper played significant role. The breaking of forest land was the highest degradation activity by man and had increased the electrical conductivity and available phosphorous significantly and had reduced the organic carbon available nitrogen, zinc, iron, manganese and copper significantly.

In the blank forest, the pH, phosphorous, potassium, zinc, iron and copper did not contribute any role while electrical conductivity, organic carbon, available nitrogen and manganese did have significant association. Even though there was a degradation of forest to a blank status, the nutrient status of organic carbon, available nitrogen and manganese changed significantly while the other parameters phosphorus, potassium, zinc, iron and copper maintained their respective average values. On further degradation of the forest land due to the cultivation on encroachment status, the nutrient status of electrical conductivity, organic carbon, nitrogen, phosphorus, zinc, iron, manganese and copper suffered significantly. The vegetation of herbs, shrubs and grasses on the blank forest were able to maintain some of the nutrient status (pH, phosphorous, potassium, zinc, iron and copper) even though trees were reduced due to manmade activities.

In the mixed type of forests the pH, organic carbon, available nitrogen, phosphorus, potassium, zinc, iron and copper did not have significant association but the electrical conductivity and available manganese had significant contribution. The electrical conductivity and the available manganese were the responsible parameters individually in maintaining the other nutrient status like organic carbon, available nitrogen, phosphorus, potassium, zinc, iron and copper. The diversity of different vegetation in mixed forest may be the responsible factor for maintaining and managing the nutrient status.

In the teak forest types the pH, organic carbon, available nitrogen, potassium, zinc and manganese did not have significant role but electrical conductivity, available phosphorus, iron and copper had significant association. The micronutrients, available iron and copper were the major responsible factors in teak forest type while available manganese was the major responsible factor in mixed forest types. The significant status of electrical conductivity may be the responsible factor for maintaining organic water level, cation exchange capacity and other soil properties in both mixed and teak forest types.

The combined impact of pH, EC and organic carbon did not have significant association within the various forest types of the study area. Individual effects of pH and organic carbon also did not have significant role but EC had significant role in the formation of forest types. In soil ecology these parameters did have roles but jointly these parameters did not associate the soil ecology with the forest ecology but the electrical conductivity parameter of soil ecology connected individually to the different forest types.

The combined impact of Nitrogen, P_2O_5 and K_2O (macro nutrients) did not have significant association within the various forest types of the study area. Except the encroachment forest, individually the available nitrogen and K_2O did not play significant role in the formation of forest types, but P_2O_5 individually did make significant impact on teak forest types. Thus available phosphorous is an important parameter which is responsible in the development of teak forest types.

Overall, Zn, Fe, Mn and Cu did not have significant association within the various forest types of the study area. Individually the Zn did not play any significant role in the formation of forest type but Fe and Cu did play significant impact on formation of teak forest types and, Mn was significant in mixed forest types. Thus in teak forest type, individually the micronutrient, Fe and Cu did have significant association while the available Mn did contribute a significant association in the mixed forest types.

ACKNOWLEDGEMENT

Authors are thankful to the staff member of the forest department of Satna, Rewa and Shivpuri for providing help during the study. Authors are also grateful to the Nepal Singh Govindgarh, Ravishankar Yadav, Rajesh Kumar Kol and L.S. Kushwaha for providing valuable knowledge for identifying the species.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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Peer-review history:
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http://www.sciencedomain.org/review-history/24848