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RESEARCH ARTICLE

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Study of association of soil parameters with various site quality classes of forests of Mukundpur, Satna, Forest Division, Madhya Pradesh, India

PRACHI SINGH

ABSTRACT : Mukundpur forest range is situated in Amarpatan Tahsil of Satna district of Madhya Pradesh India. The range has geographical area of 589.71 km^2 with forest area 111.55 km^2. This area is under high disturbances and ecological stress due to manmade activities, the associations of soil parameters like pH, electrical conductivity, availability of major nutrients (Nitrogen, phosphorus and potassium) and micro nutrients like (Copper, manganese, iron and zinc) with site quality are analyzed. Individual effects of pH, EC and Organic Carbon play the significant role in site quality classes of study area *i.e.* these soil parameters affect the productivity of the forest individually. The combined impact of pH, EC and organic carbon does have significant association within various site quality classes of study area. Except encroachment category class, individually nitrogen and P_2O_5 does not make significant impact on various site quality classes, though individually K_2O does have significant impact on site quality class of IVA and VA. The combined impact of Nitrogen, P_2O_5 and K_2O (macro nutrients) do have significant association within various site quality classes of study area. Thus combined effects of macro nutrient of soil have significant bearing on forest productivity of study area. Except encroachment, individual Zn do not have significant impact on various site quality classes, though results of Fe shows significant role in site quality IVA individually. Individually the manganese does not play the significant role in site quality IVB and VA but this has strong influence on other site quality classes. Individually Cu does have significant in encroachment and site quality IVA but it does not have significant role in other site quality classes. The overall impact of Zn, Fe, Mn and Cu do not have significant association within various site quality classes of study area. Thus overall impact of micro nutrient does not have significant association in productivity of forests.

KEY WORDS : Site quality, pH, Electrical conductivity, Organic carbon content, Macro nutrients, Micro nutrients

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INTRODUCTION

India, a land of physical, cultural, social and linguistic diversity is endowed by nature with enormous biological diversity. As a result India ranks amongst one of the 12 mega biodiversity countries of the world and harbors 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 (Hajra and Mudgal, 1997 and Reddy, 2008).

In Satna district of the Madhya Pradesh, observation of medicinal importance of Sacred Plants of Chitrakoot Region Satna (M.P.) Bala and Singh (2015). This study discussed the 13 sacred plants species which are medicinally used by the tribes of Chirtakoot region district Satna, Madhya Pradesh.

The head quarter of Mukundpur range is in Mukundpur village, situated in Amarpatan Tahsil of Satna district in the state of Madhya Pradesh, India. This range has geographical area of 589.71 km^2 with forest area of 111.55 km^2. The first white tiger safari is established at this village.

The forest area of Mukundpur range is surrounded by mining areas of bauxite, limestone. The nearby located cement factories are always in search of new areas, besides exploiting existing known areas. These houses may obtain non forest land as compensatory forest land in other district of Madhya Pradesh for diversion. The emission of CO_2 in cement manufacturing across the world accounts for 5% of global CO_2 emission due to intensive and extensive mining activities. Thus area is 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. The forest area is also susceptible to illicit felling, encroachment and illicit mining. The forests of the Mukundpur range have been changing from stocked - under stocked - blank forests. Similarly the forests are more prone to developmental activities specially widening of roads. Thus area of Mukundpur forest is under high ecological stress and forests disturbances.

Various authors have contributed towards the ecology of the disturbed forests Zhu and Liu (2004) 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 vegetations, dead wood and litter, soil organic matter, and the 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 IPCC (2000).

Forests have a role in climate change through the sequestration of emission of carbon dioxide and other important GHGs. Biological growth can increase forest stocks and deforestation can increase carbon emissions. Carbon is captured in tree biomass and in forest soils (Sedjo and Sohngen, 2012). Forests account for approximately 30% of terrestrial land cover (FAO, 2006) and store about 45% of the of the carbon in terrestrial ecosystems (Anderegg *et al.,* 2012).

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 were analyzed by Tewari *et al.* (2016).

Some physico-chemical parameters were selected as indicator of soil quality and were investigated by Baishya and Sharma (2017). Zaman *et al.* (2010) had studied under the selected different land use system in Dimoria Development Block under Kamrup District of Assam India. Chandra *et al.* (2016) had discussed about the temperate and dry deciduous forest covers major portion of terrestrial ecosystem in India. Grigal and Vance (2000) reported about influence of soil organic matter on forest productivity. Mohd-Aizat *et al.* (2014) studied about relationship between soil pH with selected soil biological and chemical properties. The reviews of literatures in the study area do not show any significant work. In the present study the associations of soil parameters like pH, electrical conductivity, availability of major nutrients (Nitirogen, phosphorus and potassium) and micro nutrients like (Copper, manganisum, iron and zinc) with various site quality of forest are analyzed. This will help for the restoration of productivity of present forests.

Study area :

Mukundpur region mainly comprises the present area of Mukundpusr range of Satna forest division. The range has geographical area of 589.71 km^2 with forest area 111.55 km^2. The area lies between north latitude of $24^0$11'35" to $24^0$26'25" and east longitude of $81^0$6'35" to $81^0$22'20". The map of the study area is shown in Fig. A.

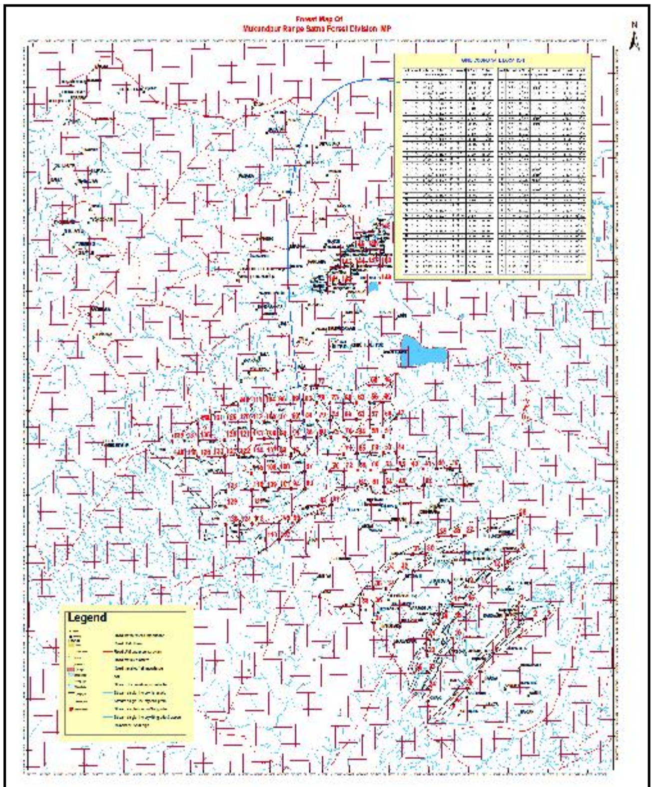

Fig. A : Map of the study area

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 Soil in study area has the origin of Vindhyan formation and it consists of materials from sand stone, limestone and shale. The record of 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 study area starting form middle of June month. The average highest daily temperature ranges within 24.06^0C to 41.73^0 C with mean temperature of 32.24^0C. The highest daily temperature recorded was 47.7^0 C. Similarly the average lowest daily temperature was 8.85^0 C to 27.72^0 C with minimum daily temperature of 1.7^0 C the minimum temperature varies in the months from November to February.

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 compositions of main vegetation are:

Trees :

Anogeissus latifolia, Diospyros melanoxylon, Terminalia tomentosa, Lannea coromandelica, Sterculia urens, Boswellia serrata, Madhua indica, Tectona grandis, Terminalia belerica, Pterocarpus marsupium, Buchanania lanzan, Salmalia malabarica, Emblica officinalis, Mitragyna parviflora, Schleichera oleosa, Miliusa tomentosa, Terminalia arjuna etc.

Shrubs:

Nyctanthus arbortristis, Lantana camara, Carissa spinarum, Zizyphus marritianna, Woodfordia fruiticosa, Vitex negundo, Grewia hirsuta, Adhatoda vasica etc.

Bamboo :

Dendrocalamus strictus on slopes.

Herbs :

Cassia tora, *Xanthium strumarium, Sida cardifolia* etc.

Grasses :

Heteropogon contortus, Themeda quadrivalvis, Apluda aristala, Ischacmum rugosum, Sehima nervosum, Cynodon dactylon etc.

Lianas (woody climbers) :

Zizyphus oenoplia, Butea superb, Ventilago calyculata, Ichnocarpus frutscens, Celastrus paniculata, Gymnema sylvestris, Smilaz macrophylla, Heruidesnus indicus etc.

EXPERIMENTAL METHODS

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 Anonymous (1996). For determining minimum number of sample points, the formula used is $n = z^2 \frac{pq}{E^2}$ 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% Elhance (1994).

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 Jain (2008).

Minimum 95 numbers of 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 points were located on ground with the help of GPS.

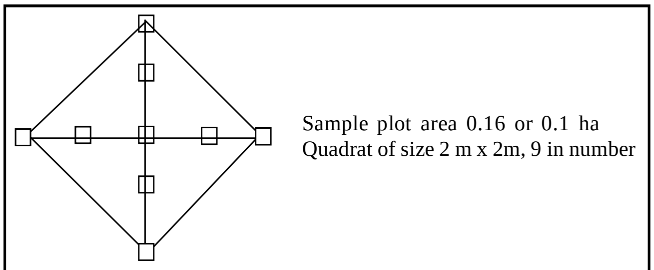

Fig. B : Sample plot with their quadrat

The grids at 35"x 35" and 30"x30" intervals are drawn by trial and error, for systematic random sampling. For drawing the grids, GIS software is used. With this software 35"x 35" and 30"x30" grids are drawn on the map of Mukundpur forests range, so that criteria for minimum number of 95 grids are achieved. 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 are on encroachment, 67 points are on blanks, 1 points are on site quality class of IVA, 9 points are on site quality class of IVB, 7 points are on site quality class of VA, 47 points are on site quality class of VB and remaining 8 points are on submerged areas of son river reservoir.

At each sample points, the layout of sample plot of 0.16 hectare with 9 quadrate of 2mx2m on ground as shown in Fig. B was done with the help of prismatic compass Anonymous (1996). At these points recording of data of the girth and species of the trees, along with 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 2mx2m. Half kg of soil sample was collected from central quadrat from the depth of 30 cm from the sample point and sent to office of Assistant Soil Testing officer at soil testing lab Rewa to assess the soil parameter pH, electrical conductivity (in mili mhos/cm),organic carbon (in %), available nitrogen (in kg/ha), available P_2O_5 (in kg/ha), available K_2O (in kg/ha) and micronutrient analysis for availability of zinc (in ppm), iron (in ppm), manganese (in ppm) and copper (in ppm). Anonymous (2004), The Microsoft access programme was developed to evaluate the above soil parameters in various site quality classes of forests.

Theses site quality classes are described by Anonymous (1996) as below. Site quality: It is represented by average height of top 50 trees of a particular stand. These are VthB (average height less than 9 m), VthA- height (9m – 12m), IVthB- height (12m – 15m), IVthA- height (15m – 20m), III- height (20 - 25m), II- height (25-30 cm), I- height (above 35m).

The average value of different soil parameter in different site quality classes 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 site quality classes, 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 site quality class - average value of the soil parameter in study area) / Standard error of the soil parameter in study area |

At 5% level of significant following hypothesis is

formulated:

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

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

– 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 study area.

– 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 study area.

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

– Combined effect of pH, electrical conductivity and organic carbon within various site quality classes of study area.

– Combined effect of Macro nutrient (available N, P_2O_5 and K_2O) within various site quality classes of study area.

– Combined effect of Micro nutrient (available Zn, Fe, Mn and Cu) within various site quality classes of study area.

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

- **Null hypothesis (H_0):** There is no significant difference combined effect of above studies within various site quality classes of study area.
- **Alternate hypothesis (H_i):** There is a significant difference combined effect of above studies within various site quality classes of study area.

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

– If $\chi^2_{calculated} < \chi^2_{tabulated}$ Null hypothesis is not rejected. It means There is no significant difference combined effect of above studies within various site quality classes of study area

– If $\chi^2_{calculated} > \chi^2_{tabulated}$ Null hypothesis rejected. It means There is a significant difference combined effect of above studies within various site quality classes of study area

χ^2 is calculated with the formula as $\chi^2_{cal} = \Sigma \frac{(O-E)^2}{E}$

where O = Observed values and E = Expected values

EXPERIMENTAL RESULTS AND ANALYSIS

The results obtained from the present investigation as well as relevant discussion have been summarized under the following heads :

Association of individual soil parameters in various site quality classes:

The soil parameters studied are pH, Electrical conductivity (milli mhos/cm), organic carbon in %, available nitrogen (in kg/ha), available phosphorus and available potassium (in kg/ha), Zn, Fe, Mg, Cu (in ppm). Calculated value of these parameters in various site quality classes are analyzed and presented in Table 1 of this section.

From the Table 1 the $Z_{calculated}$ for various soil parameters within various site quality classes 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 the Table 2 for results of the study of soil parameters in various site quality classes of study area are discussed below:

pH:

pH of various site quality classes *i.e.* Encroachments, Blanks, VB, VA, IVB and IVA varies from 7.06 to 7.21 with average pH is 7.09. Results indicate that in site quality classes of Encroachment, Blank and VB $Z_{cal} < Z_{tab}$ (1.645). Thus in site quality classes of Encroachment, Blank and VB soil pH does not change significantly but as soon as site quality improves from VA, IVB and IVA, $Z_{cal} > Z_{tab}$ (1.645). Thus the pH plays significant role in improving the site quality classes *i.e.* the productivity of the forest significantly affected by soil pH of the study area.

Electrical conductivity:

Average Electrical conductivity for soil of study area is 0.28. This varies from 0.27 to 0.35 for various site quality classes of IVA to encroachments. Results indicate that when site quality classes decrease from IVA to encroachment category the electrical conductivity does vary significantly as $Z_{cal} > Z_{tab}$ (1.645) except site quality VA. As Z_{cal} is 1.667, 1.667, 1.667, 1.667 and 11.667 in IVA, IVB, VB, Blank and Encroachment site quality classes. In the VA site quality class $Z_{cal} = 0$ as average value of electrical conductivity in this site quality is equal to average value of the electrical conductivity of the study area. This abnormal result due to equality of EC in site quality VA with the average value of EC of study area can be ignored as EC value in calculation becomes 0.28 to 0.27 or 0.29 the Z_{cal} will be significant. Thus electrical conductivity plays an important role in various site quality classes. But as encroachment happens *i.e.* breaking of forest soil for agriculture its electrical conductivity parameter becomes highly significant.

Organic carbon content:

The observed values of organic matter content in percentage for various site quality class *i.e.* encroachment, blank, VB, VA, IVB and IVA categories are 0.38, 0.66, 0.61, 0.63, 0.60 and 0.63, respectively with average value of 0.63. The result indicates that in encroachment, blank and VB site quality classes organic carbon content is significantly higher than the average value of organic carbon content of the study area as $Z_{cal} > Z_{tab}$ (1.645). But in VB, VA and IVA category of site quality class organic carbon content is equal to average organic carbon value of the study area as $Z_{cal} < Z_{tab}$ (1.645). The result of organic carbon in site quality IVB is 0.6 and if it changed to 0.61 then $Z_{cal} < Z_{tab}$ (1.645) and it will be insignificant in this site quality class. This result can be ignored as organic carbon of this site quality in higher altitude and may accumulate in the other site quality classes due to precipitation. The breaking of land due to agriculture reduces the soil organic carbon significantly as it assumes the value of 0.380 less than average value of 0.630.

Table 1 : Various soil parameters with various site quality classess

Site quality	PH	EC (milli mhos/cm)	O/C (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
IVA	7.210	0.270	0.630	244.310	36.600	241.310	0.170	5.550	1.130	0.340
IVB	7.020	0.270	0.600	234.730	37.040	211.000	0.200	5.120	1.280	0.310
VA	7.160	0.280	0.640	240.650	38.950	198.590	0.160	5.400	1.510	0.320
VB	7.060	0.290	0.610	235.130	37.990	202.080	0.230	4.840	1.110	0.290
Average	7.090	0.280	0.630	240.060	37.980	210.190	0.190	4.900	1.350	0.300
Std Error	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 various soil parameters within various site quality classes

Soil parameters	Site quality classes												Z_{table} at 5% level of significance (one tailed test)
	Blank		Encroachment		IVA		IVB		VA		VB		
	Average	Z_{cal}	Average	Z_{cal}	Average	Z_{cal}	Average	Z_{cal}	Average	Z_{cal}	Average	Z_{cal}	
pH	7.060	1.360	7.110	0.909	7.21	5.455	7.020	3.182	7.160	3.182	7.060	1.364	1.645
EC	0.270	1.667	0.350	11.667	0.27	1.667	0.270	1.667	0.280	0.000	0.290	1.667	1.645
O/C	0.660	2.300	0.380	19.200	0.63	0.000	0.600	2.308	0.640	0.769	0.610	1.538	1.645
N	247.820	2.293	178.000	16.345	244.31	1.256	234.73	1.576	240.65	0.174	235.13	1.457	1.645
P_2O_5	38.210	0.192	45.130	5.978	36.60	1.154	37.040	0.786	38.950	0.811	37.990	0.008	1.645
K_2O	213.030	0.513	202.000	1.478	241.31	5.617	211.00	0.146	198.59	2.094	202.08	1.464	1.645
Zn	0.180	0.370	0.040	5.560	0.17	0.741	0.200	0.370	0.160	1.111	0.230	1.481	1.645
Fe	4.460	1.375	1.910	9.343	5.55	2.031	5.120	0.687	5.400	1.563	4.840	0.188	1.645
Mn	1.660	2.840	1.000	3.211	1.13	2.018	1.280	0.642	1.510	1.468	1.110	2.202	1.645
Cu	0.270	1.429	0.420	5.714	0.34	1.905	0.310	0.476	0.320	0.952	0.290	0.476	1.645

Available nitrogen:

Results for average value of nitrogen availability for whole forest of study area is 240.06 kg/ha. Results indicate that the average value of available nitrogen is 178.00, 247.820, 235.13, 240.65, 234.73 and 244.31 kg/ha in encroachment, blank, VB, VA, IVB and IVA site quality classes, respectively. The average value of available nitrogen in encroachment and blank category significantly changes from average value of the available nitrogen of the study area as $Z_{cal} > Z_{tab}$ (1.645). The average value of available nitrogen in VB, VA, IVA and IVB category do not change significantly with average value of available nitrogen of the study area as $Z_{cal} < Z_{tab}$ (1.645). Thus as long as forest of the study area maintains the site quality classes and remains in un degraded state the average value of available nitrogen maintains the average value of study area. As soon as it is converted into blank and encroachment due to degradation, average value of available nitrogen changes significantly. It decreases very significantly when it comes to encroachment category.

Available phosphorus:

The results of available phosphorus in kg/ha for study area is 37.98 kg/ha. The average value of available phosphorus in blank, VB, VA, IVB and IVA site quality classes do not change significantly with average value of available phosphorus of the study area as $Z_{cal} < Z_{tab}$ (1.645). The average value of available phosphorus in encroachment category is significantly is higher than the average value of available phosphorus of the whole study area as $Z_{cal} > Z_{tab}$ (1.645). The observed value of available phosphorus in kg/ha maintains its average value of available phosphorus in all site quality classes till the degradation in site quality does not take place. When there is a breaking of forest land due to agriculture there is a significant increasing available phosphorus. This means breaking of land exposes the rocks, soil and geology devoid the vegetation, which increases the available phosphorus.

Available potassium:

Results of available K_2O in kg/ha for study area is 210.190 kg/ha. The average value of K_2O in encroachment, blank, VB, VA, IVB and IVA site quality classes are 202.000, 213.030, 202.080, 198.59, 211.00 and 241.31 kg/ha, respectively. The average value of available K_2O in encroachment, blank, VB and IVB do not change significantly with average K_2O value of study area as $Z_{cal} < Z_{tab}$ (1.645). In IVA and VA site quality class category the average value of K_2O shows significant change with average value of K_2O of the study area.

Available zinc:

The result of the average value of zinc in study area

Table 3 : Z value of pH, EC and organic carbon within various site quality classes

Site quality	pH	EC	O/C	Total
Blank	1.360 (1.374)	1.667 (1.631)	2.300 (2.322)	5.327
Encroachment	0.909 (8.197)	11.667 (9.726)	19.200 (13.853)	31.776
IVA	5.455 (1.837)	1.667 (2.180)	0 (3.105)	7.122
IVB	3.182 (1.846)	1.667 (2.191)	2.308 (3.120)	7.157
VA	3.182 (1.019)	0 (1.209)	0.769 (1.722)	3.951
VB	1.364 (1.179)	1.667 (1.398)	1.538 (1.992)	4.569
Total	15.452	18.335	26.115	59.902

Table 4 : Z value of N, P_2O_5 and K_2O within various site quality classes

Site quality	N	P_2O_5	K_2O	Total
Blank	2.293 (1.598)	0.192 (0.618)	0.513 (0.782)	2.998
Encroachment	16.345 (12.688)	5.987 (4.909)	1.478 (6.213)	23.810
IVA	1.256 (4.277)	1.154 (1.655)	5.617 (2.095)	8.027
IVB	1.576 (1.336)	0.786 (0.517)	0.146 (0.654)	2.508
VA	0.174 (1.641)	0.811 (0.635)	2.094 (0.803)	3.079
VB	1.457 (1.561)	0.008 (0.604)	1.464 (0.764)	2.929
Total	23.101	8.938	11.312	43.351

is 0.19 ppm. The average value of zinc in encroachment, blank, VB, VA, IVB and IVA is 0.040, 0.18, 0.23, 0.160, 0.20 and 0.17 ppm, respectively. The average zinc value in blank, VB, VA, IVB and IVA site quality classes do not change significantly with average value of the study area as $Z_{cal} < Z_{tab}$ (1.645). But average value of zinc in encroachment category class changes significantly with average value of the study area. Results indicate that breaking of forest land results in major loss in Zn availability.

Available iron:

The result of available Fe for study area is 4.9 ppm. The average value of Fe in encroachment, blank, VB, VA, IVB and IVA site quality classes is 1.910, 4.460, 4.840, 5.4, 5.12 and 5.55 ppm, respectively. The average value of Fe in blank, VB, VA and IVB category do not change significantly with the average value of as $Z_{cal} < Z_{tab}$ (1.645). But average value of Fe in encroachment and VA site quality class category varies significantly with average value of the study area as $Z_{cal} > Z_{tab}$ (1.645). Thus breaking of land due to agriculture significantly lowers the Fe content in encroached soil. Similarly average value of available Fe significantly increases as site quality improves.

Available manganese:

The results of average observed value of available Mn for study area is 1.35 ppm. The average Mn value for encroachment, blank, VB, VA, IVB and IVA site quality class is 1.000, 1.660, 1.11, 1.51, 1.28 and 1.13 ppm, respectively. The average value of Mn in encroachment, Blank, VB and IVA site quality classes varies significantly with the average value of the study area as $Z_{cal} > Z_{tab}$ (1.645). But average value of Mn in VA and IVB category does not change significantly with average value of study area as $Z_{cal} < Z_{tab}$ (1.645).

Available copper:

The results for study area indicate that average observed value of Cu is 0.30 ppm. The average Cu value for encroachment, blank, VB, VA, IVB and IVA site quality classes is 0.420, 0.270, 0.29, 0.32, 0.31 and 0.340 ppm, respectively. The average values of Cu with in Blank, VB, VA and IVB site quality classes do not change significantly with average value of the study area as $Z_{cal} < Z_{tab}$ (1.645). But average value of Cu in encroachment and IVA category significantly changes with average value of study area as $Z_{cal} > Z_{tab}$ (1.645).

Association of combined soil parameters (pH, EC, organic carbon) in various site quality classes of study area:

From Table 2 the Z value of pH, EC and organic carbon various site quality classes of study area is given in Table 3.

To understand the association about the combined effects of the pH, EC and organic carbon within various site quality classes of 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 figure represented in bracket and bold represent the expected Z value.

$\chi^2_{\text{calculated}} = 27.096$

Degree of freedom = (6-1) * (3-1) = 10

At 5% level of significance at 10 degree of freedom, $\chi^2_{\text{tabulated}} = 18.307$

Since $\chi^2_{\text{cal}} > \chi^2_{\text{tabulated}}$, Null hypothesis is not accepted. Hence combined impact of pH, EC and organic carbon does have significant association within various site quality classes of study area. Individual effects of pH, EC and Organic Carbon also play the significant role in site quality classes of study area *i.e.* these soil parameters affect the productivity of the forest individually and jointly.

Association of combined macro nutrient of soil parameters (Nitrogen, P_2O_5 and K_2O) in various site quality classes of study area:

From Table 2 the Z value of Nitrogen, P_2O_5 and K_2O within various site quality classes of study area is given in Table 4.

To understand the association about the combined effects of the Nitrogen, P_2O_5 and K_2O within various site quality classes of 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 figure represented in bracket and bold represent the expected Z value.

$\chi^2_{\text{calculated}} = 19.045$

Degree of freedom = (6-1) * (3-1) = 10

At 5% level of significance at 10 degree of freedom, $\chi^2_{\text{tabulated}} = 18.307$

Since $\chi^2_{\text{cal}} > \chi^2_{\text{tabulated}}$, Null hypothesis is not accepted. Hence, combined impact of Nitrogen, P_2O_5 and K_2O (macro nutrients) do have significant association within various site quality classes of study area. Except encroachment category class, individually nitrogen and P_2O_5 does not make significant impact on various site quality classes, though individually K_2O does have significant impact on site quality class of IVA and VA. Thus combined effects of macro nutrient of soil have significant bearing on forest productivity of study area.

Association of combined micro nutrient of soil parameters (Zn, Fe, Mn and Cu) in various site quality classes of study area:

From Table 2 the Z value of Zn, Fe, Mn and Cu within various site quality classes of study area is given in Table 5.

To understand the association about the combined effects of the Zn, Fe, Mn and Cu within various site quality classes of 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 figure represented in bracket and bold represent the expected Z value.

$\chi^2_{\text{calculated}} = 7.060$

Degree of freedom = (6-1) * (4-1) = 15

At 5% level of significance at 10 degree of freedom, $\chi^2_{\text{tabulated}} = 24.996$

Since $\chi^2_{\text{cal}} < \chi^2_{\text{tabulated,}}$ Null hypothesis is accepted. Hence overall impact of Zn, Fe, Mn and Cu do not have significant association within various site quality classes of study area. Except encroachment, individual Zn do not have significant impact on various site quality classes, though results of Fe shows significant role in site quality IVA individually. Individually the manganese does not play the significant role in site quality IVB and VA but this has strong influence on other site quality classes. Individually Cu does have significant in encroachment and site quality IVA but it does not have significant role in other site quality classes. But overall impact of micro nutrient does not have significant association in productivity of forests.

Conclusion :

The effects of individual soil parameters on various site quality classes of forests are summarized below:

The pH plays significant role in improving the site quality classes *i.e.* the productivity of the forest significantly affected by soil pH of the study area.

Thus electrical conductivity plays an important role in various site quality classes. But as encroachment happens *i.e.* breaking of forest soil for agriculture its electrical conductivity parameter becomes highly significant.

In encroachment, blank and VB site quality classes, the organic carbon content is significantly higher than the average value of organic carbon content of the study area but in VB, VA and IVA category of site quality class organic carbon content is equal to average organic carbon value of the study area. The breaking of land due to agriculture reduces the soil organic carbon significantly.

The average value of available nitrogen in VB, VA, IVA and IVB category do not change significantly with average value of available nitrogen of the study area. The average value of available nitrogen in encroachment and blank category significantly changes from average value of the available nitrogen of the study area. Thus as long as forest of the study area remains in un degraded state the average value of available nitrogen maintains the average value of study area. As soon as it is converted into blank and encroachment due to degradation, average value of available nitrogen changes significantly. It decreases very significantly when it comes to encroachment category.

Except in encroachment category, the average value of available phosphorus in blank, VB, VA, IVB and IVA site quality classes do not change significantly with average value of available phosphorus of the study area. The observed value of available phosphorus in kg/ha maintains its average value of available phosphorus in all site quality classes till the degradation in site quality does not take place. When there is a breaking of forest land due to agriculture, there is a significant increasing available phosphorus. This means breaking of land exposes the rocks, soil and geology devoid the vegetation, which increases the available phosphorus.

The average value of available K_2O in encroachment, blank, VB and IVB do not change significantly with average K_2O value of study area. In IVA and VA site quality class category the average value of K_2O shows significant change with average value of K_2O of the study area.

Except in encroachment category, the average zinc value in blank, VB, VA, IVB and IVA site quality classes do not change significantly with average value of the

Table 5 : Z value of Zn, Fe, Mn and Cu within various site quality classes

Site quality	Zn	Fe	Mn	Cu	Total
Blank	0.370 (1.203)	1.375 (1.897)	2.840 (1.546)	1.429 (1.368)	6.014
Encroachment	5.560 (4.767)	9.343 (7.515)	3.211 (6.127)	5.714 (5.419)	23.828
IVA	0.741 (1.339)	2.031 (2.112)	2.018 (1.721)	1.905 (1.523)	6.695
IVB	0.370 (0.435)	0.687 (0.686)	0.642 (0.559)	0.476 (0.495)	2.175
VA	1.111 (1.019)	1.563 (1.607)	1.468 (1.310)	0.952 (1.159)	5.094
VB	1.481 (0.870)	0.188 (1.371)	2.202 (1.118)	0.476 (0.989)	4.347
Total	9.633	15.187	12.381	10.952	48.153

study area. The breaking of forest land results in major loss in Zn availability.

The average value of Fe in blank, VB, VA and IVB category do not change significantly with the average value. But average value of Fe in encroachment and VA site quality class category varies significantly with average value of the study area. Thus breaking of land due to agriculture significantly lowers the Fe content in encroached soil. Similarly average value of available Fe significantly increases as site quality improves.

The average value of Mn in encroachment, Blank, VB and IVA site quality classes varies significantly with the average value of the study area. But average value of Mn in VA and IVB category does not change significantly with average value of study area.

The average values of Cu with in Blank, VB, VA and IVB site quality classes do not change significantly with average value of the study area. But average value of Cu in encroachment and IVA category significantly changes with average value of study area.

The combined impact of pH, EC and organic carbon does have significant association within various site quality classes of study area. Individual effects of pH, EC and Organic Carbon play the significant role in site quality classes of study area *i.e.* these soil parameters affect the productivity of the forest individually and jointly.

The combined impact of Nitrogen, P_2O_5 and K_2O (macro nutrients) do have significant association within various site quality classes of study area. Except encroachment category class, individually nitrogen and P_2O_5 does not make significant impact on various site quality classes, though individually K_2O does have significant impact on site quality class of IVA and VA. Thus combined effects of macro nutrient of soil have significant bearing on forest productivity of study area.

The overall impact of Zn, Fe, Mn and Cu do not have significant association within various site quality classes of study area. Except encroachment, individual Zn do not have significant impact on various site quality classes, though results of Fe shows significant role in site quality IVA individually. Individually the manganese does not play the significant role in site quality IVB and VA but this has strong influence on other site quality classes. Individually Cu does have significant in encroachment and site quality IVA but it does not have significant role in other site quality classes. But overall impact of micro nutrient does not have significant association in productivity of forests.

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