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Physicochemical Analysis for Reclamation of Soils of Tingroi Hills in Lunghar, Ukhrul District, Manipur, India

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Abstract:
The study focussed on the assessment of physicochemical parameters of soil samples from Tingroi hills in Lunghar village of Ukhrul District in Manipur, to find out the possible reason for its infertile nature. The samples from the study sites along with control soils were collected and subjected to physicochemical parameter, macro and micro nutrient analyses. All the results were analyzed for its influence over the fertility factors of the soil and further compared with control soils to identify the factors responsible for its infertility. This was the first of its kind and a maiden attempt to study about the quality of the soil in order to enhance its fertility. The results showed that the acidic nature of the soil, shallow soil horizon; presence of high amount of Iron oxides; less Electrical Conductivity, fluctuating Cation Exchange Capacity and higher concentration of micro nutrients were the considerable factors. Based on the results, reclamation measures such as liming of soil, cropping pattern, sequence of cropping relevant to soil and environmental conditions, have been recommended. Hence the study have shown insights of the status of soil quality of Ukhrul District for its possible reclamation measures and also warrants for the need of continued monitoring to assess the complete soil profile in terms of all its physicochemical, biological and environmental factors and to devise management strategies, towards restoring the fertility of the soil.

Keywords: Manipur, Physicochemical properties, Reclamation, Soil.

1.0 Introduction:
The deterioration of soil quality/health is the combined result of soil fertility, biological degradation (decline of organic matter, biomass C, decrease in activity and diversity of soil fauna), increase in erodability, acidity, and salinity, and exposure of compact subsoil of poor physicochemical properties. Northeast India is characterized by high soil acidity, toxicity, heavy soil, and carbon loss, severe water scarcity during most parts of year though it is known as high rainfall area. The problem soils are those, which owing to land or soil characteristics cannot be used for the cultivation of crops without adopting proper reclamation measures. Highly eroded soils, ravine lands, soils on steeply sloping lands etc. constitute one set of problem soils. Acid, saline and alkaline soils constitute another set of problem soil (Saha *et al.,* 2012).

Soil health is the capacity of soil to function as a vital living system, within ecosystem and land-use boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and promote plant and animal health. Anthropogenic reductions in soil health, and of individual components of soil quality, are a pressing ecological concern (Doran and Zeiss 2000). Several studies in the past have shown that deforestation and cultivation of virgin tropical soils often lead to depletion of nutrients (N, P, and S) present as part of complex organic polymers. Bernoux *et al.(* 1998) indicated that long practices of deforestation and/or replacement of natural forests by agro ecosystem and uncontrolled overgrazing have been the major causes for soil erosion and climatic change.

With all these facts in concern, the present work attempted to analyse the physicochemical parameters of the soil of barren peak of Tingroi hills, Manipur. The main reason to study this area is that, sharp difference in vegetation is observed within the study area. In other words, to study what is the reason behind the difference in vegetation between these two areas that are lying together with sharp contact. And the most important aspect of choosing this area is to bring about afforestation and to implement possible reclamation measures on the basis of the results obtained through the study. The benefits of afforestation of this area are of paramount importance to the surrounding area and also to the villages nestling on the following range of the hill.

Hence the present study aims to analyse and find out why the soil does not support vegetation like the other region with thick vegetation which is lying just very close to it. The region is poorly understood even for its basic properties of the soil. This is the first of its kind and a maiden attempt to find out the reasons and to recommend any suitable programmes or methods to restore the soil fertility.

2.0 Materials and Methods:

2.1 Study Area – Tingroi Hills, Lunghar Village - Ukhrul District, Manipur

Ukhrul District is best introduced by its beautiful Shirui Lily, grown only on the peak of Shirui Kashung, some 18 Km. east of the district headquarters. The climate of the Ukhrul district is subtropical monsoon type. The district has alluvial, lateritic black regur and red ferruginous type of soil.

2.2 Sampling Locations:

The study area is situated along the mountain ranges of Tingroi Hills in Lunghar village. The hill is situated at an altitude of 3130 MSL. The exact location is assimilated with the help of GPS. The sampling site lies between 25010’34.7”N Longitudes and 094’27’10.5”E Latitudes. The area was divided into two groups - thickly vegetated area (treated as control) and barren land. Two sites were selected in the vegetated area and four sites were selected in the barren land (Figure 1, 2 & 3).

2.3 Sample Collection:

The samples were collected, as per the manual method for Soil testing in India, from six sites with the depth of 0-10 cm, 10-20 cm and 20-30 cm respectively. Two sites were taken from the thick vegetation area and four from the problem sites. The samples were collected in zip lock polythene covers and labeled against it with necessary data, then packed and sent to the laboratory for further analysis.

2.4 Laboratory Analysis.

The soil samples on collection were examined for various physical parameters such as the colour appearance, particle size distribution etc. The colour has been compared with universally accepted Munsell colour chart. Further the samples were subjected to physicochemical parameter analyses such as pH, Electrical Conductivity (EC), Cation Exchangable Capacity (CEC); Exchangeable cations (Ca, Mg, Na and K); Macro and Micro Nutrients. All the parameters were anlysed as per the Methods Manual for Soil testing in India, published by the Department of Agriculture & Cooperation Ministry of Agriculture Government of India New Delhi January, 2011.

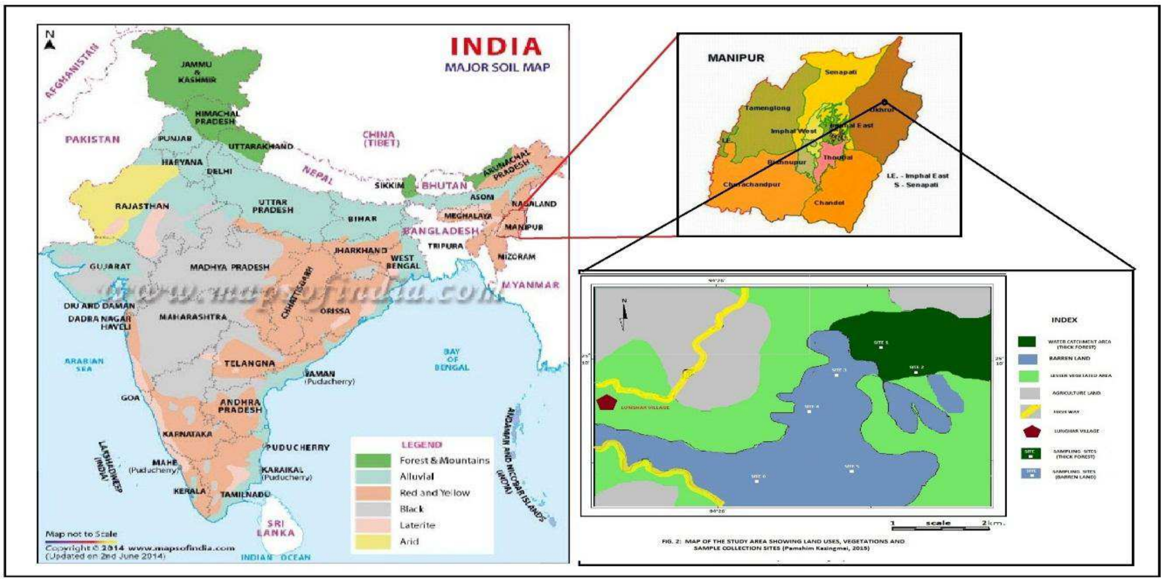

FIG. 1: LOCATION MAP OF THE STUDY AREA

Figure 1: Map showing Locations of the study areas

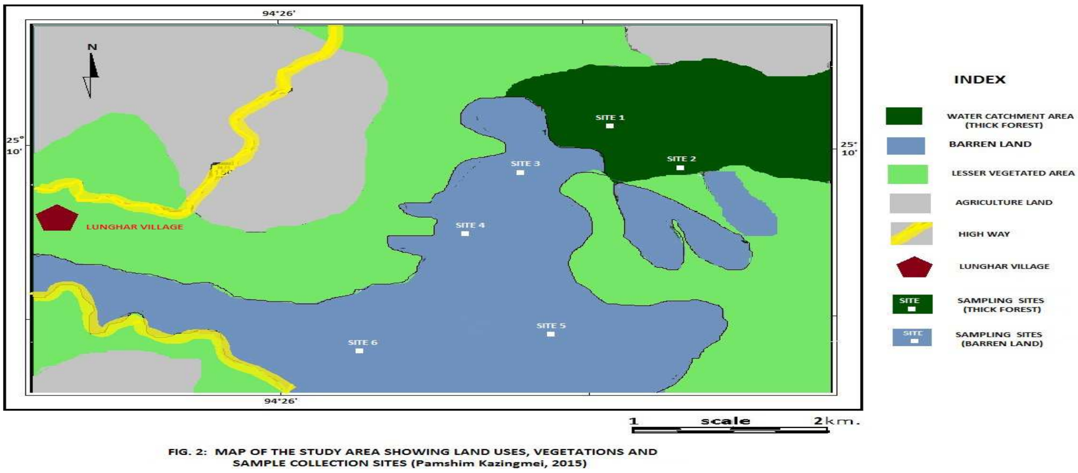

Figure 2: Base Map of the study area

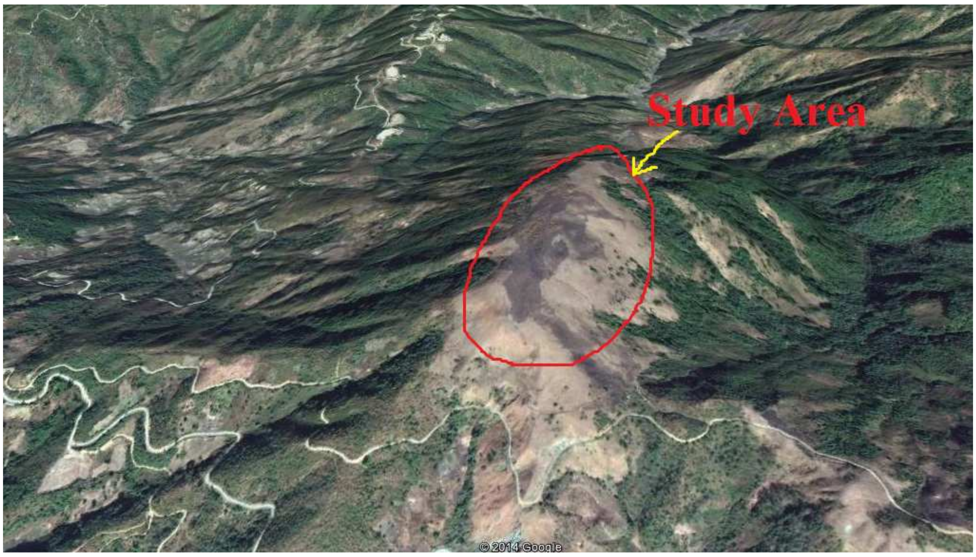

Figure 3. The study area is marked with the red line*.
(*Source: Google Maps - Marked based on GPS location of the site)

3.0 Results and Discussion:

3.1 Physical Characteristics and Particle Size Distribution:

The physical parameters of the soil such as the colour appearance, particle size distribution, colour etc. as per the observations were listed below (Table 1). The first thing noticed, when observing a soil is its colour. The soil colour is often determined by the presence of Iron oxides and Organic matter. When the presence of iron oxides dominates the organic matter, it appears from brown to reddish brown colour (Wopereis et al., 2009).

Red and brown soil colors are attribute- able to the Fe compounds resulting from the formation of secondary Fe oxides. This finding is supported by a similar finding by Hausenbuiller (1978) who reported that pronounced red and yellow colors are due to mineral substances that have undergone extensive weathering. Apart from this several studies report that the colour is mainly due to the parent rock material Hence the soil samples collected for the present study indicates the presence of higher quantum of Iron oxides rather than organic matter and its bright colour also indicates that it has originated from ferruginous urolithic rocks.

Soil structure is defined as the arrangement of the soil particles. With regard to structure, soil particles refer not only to sand, silt and clay but also to the aggregate or structural elements, hich have been formed by the aggregation of smaller mechanical fractions. Hence the particle size distribution and its water holding capacity is analyzed and the results were tabulated in Table 2. The results indicate the loamy nature of the soil and since the water holding capacity appear to be very less; it is evident that the nature of the soil is hardly supporting the plant growth or the circulation of nutrients in the soil (Defoer *et al.*, 2000).

Further the soil is subjected to physicochemical parameter analyses such as pH, Electrical Conductivity (EC), Cation Exchangable Capacity (CEC) and Exchangeable cations (Ca, Mg, Na and K). The results are tabulated in Table 3.

Table 1: Soil Sample Details and Color Interpretation

S. No.	Sample ID	Latitude, Longitude& Elevation(MSL)	Depth of the soil (cm)	Hue Value/Chroma (Munsell colour system)	Color interpretation
1	1 A	N 25°10’ 34.7”	0-10	10R 4/3	Dark reddish brown
2	1 B	E 094°27’21.8”	10-20	10YR5/4	Moderate yellowish brown
3	1 C	2150M	20-30	10YR 5/4	Moderate yellowish brown
4	2 A	N 25°10’27.1”	0-10	10YR 4/2	Dark yellowish brown
5	2 B	E 094°27’28.8”	10-20	10YR5/4	Moderate yellowish brown
6	2 C	2017M	20-30	10YR5/4	Moderate yellowish brown
7	3 A	N 25°10’16.4”	0-10	10YR 4/2	Dark yellowish brown
8	3 B	E 094°27’16.0”	10-20	10R4/6	Moderate Reddish brown
9	3 C	2086M	20-30	10R4/6	Moderate Reddish brown
10	4 A	N 25°10’23.2”	0-10	10R 4/6	Moderate reddish brown
11	4 B	E 094°27’14.7”	10-20	10R 4/6	Moderate reddish brown
12	4 C	3130M	20-30	10R 4/6	Moderate reddish brown
13	5 A	N 25°10’16.8	0-10	10YR 4/2	Dark yellowish brown
14	5 B	E 094°27’ 10.5”	10-20	10R 4/6	Moderate Reddish brown
15	5 C	2151M	20-30	5YR 4/4	Moderate brown
16	6 A	N25°.10. 55.8”	0-10	5YR 3/4	Moderate brown
17	6 B	E094^{0}27’5.3”	10-20	5YR 4/4	Moderate brown
18	6 C	2850M	20-30	10R 4/6	Moderate reddish brown

3.2 pH:

The pH of the soil samples ranged from 4.9 to 5.5 and all the samples were found to be acidic in nature. The acidic nature of soils as observed presently could also be a property inherited directly from the parent material. At low pH, acidity can directly inhibit plant growth and make most of the elements including toxic metals in soil bio- available and induce production of toxic soluble aluminium in the soil-water solution. In general, all forms of acidity fall after fire. The acidity again starts increasing because of the regeneration of organic matter in the soil and increase in exchangeable Al^{3+} level. Exchangeable bases in soil decrease during cultivation because of removal of weeds/plants, leaching and erosion losses from the soil. As organic matter is a major contributor of pH dependent acidity in the soils, it may decrease after fire due to the burning of organic matter in the soil (Kumar *et al.,* 1995). The study of soil pH is important since it controls the base status and microbial activities (Miller and Donahue, 1997).

Table 2: Particle Size Distribution and Water Holding Capacity

Sample ID	Particle size distribution				Water Holding Capacity (%)
	> 2mm (grams)	% Composition	< 2mm (grams)	% Composition	
1 A	112.08	34.1	216.72	65.9	66
1 B	112.50	38.4	180.57	61.6	46
1 C	148.08	37.0	252.17	63.0	74
2 A	138.94	40.2	207.02	59.8	52
2 B	189.61	45.7	225.34	54.3	58
2 C	220. 00	57.8	160.88	42.2	52
3 A	11.87	6.5	170.55	93.5	54
3 B	45.35	11.3	356.12	88.7	56
3 C	155.21	34.8	290.72	65.2	62
4 A	58.14	17.1	281.57	82.9	46
4 B	121.65	31.8	261.48	68.2	50
4 C	95.60	22.9	321.12	77.1	54
5 A	60.48	17.3	289.28	82.7	56
5 B	82.05	21.6	297.32	78.4	52
5 C	117.29	30.6	266.28	69.4	62
6 A	30.53	7.2	394.54	92.8	52
6 B	41.34	9.2	410.15	90.8	56
6 C	31.48	7.1	411.02	92.9	64

Table 3: Physicochemical Parameters

Sl No.	Sample ID	pH	Electrical Conductivity (EC) dSm^{-1}	Cation exchange capacity (CEC) $mol^{(+)}/kg$	Calcium (Ca)	Exchangeable cations $mol^{(+)}/kg$		
						Magnesium (Mg)	Sodium (Na)	Potassium (K)
1	1A	5.15	0.02	10.5	1.1	1.0	0.28	0.04
2	1B	5.21	0.01	11.1	1.4	1.2	0.28	0.06
3	1C	5.22	0.01	10.1	1.7	1.0	0.27	0.08
4	2A	6.02	0.02	10.1	1.1	1.4	0.27	0.05
5	2B	5.21	0.01	11.1	1.4	1.2	0.28	0.06
6	2C	5.22	0.02	10.1	1.7	1.0	0.27	0.08
7	3A	4.98	0.03	20.1	1.2	1.0	0.27	0.05
8	3B	5.10	0.01	21.0	0.9	1.2	0.25	0.03
9	3C	5.50	0.02	21.5	0.7	0.8	0.27	0.02
10	4A	5.08	0.03	21.5	1.2	0.8	0.28	0.06
11	4B	5.15	0.01	22.1	0.9	1.2	0.27	0.02
12	4C	5.37	0.01	23.7	0.7	0.6	0.27	0.02
13	5A	5.33	0.02	23.2	0.7	1.4	0.26	0.05
14	5B	5.35	0.01	23.7	0.9	1.0	0.27	0.01
15	5C	5.58	0.01	22.7	0.7	3.0	0.26	0.02
16	6A	5.15	0.02	22.9	1.2	1.3	0.25	0.09
17	6B	5.37	0.01	22.3	0.9	0.2	0.25	0.02
18	6C	5.41	0.01	23.3	0.9	0.3	0.25	0.02

1043.3 Electrical Conductivity (EC):

The Electrical Conductivity of the soil ranged from 0.01 to 0.03 dS/m. When pH is a good indicator of the balance of available nutrients in your soil, Electrical Conductivity can almost be viewed as the quantity of available nutrients in your soil. The wide variation of EC of the soils might be due to the different concentration of basic cations in the soils. In the soil, the Electrical Conductivity (EC) reading shows the level of ability, the soil water has to carry an electrical current. The EC levels of the soil water are a good indication of the amount of nutrients available for the crops to absorb. When ions (salts) are present, the EC of the solution increases. If no salts are present, then the EC is low indicating that the solution does not conduct electricity well (Hanlon, 2009). Hence the EC values of the samples indicate that it is not having appreciable quantity of ions meant for transportation of nutrients as mentioned in several manuals and reports published elsewhere.

3.4 Cation Exchange Capacity (CEC):

Cation exchange capacity, or CEC, refers to the quantity of negative charges in soil existing on the surfaces of clay and organic matter. The CEC of soil samples analyzed in the present study ranged from 10.1 to 23.7 mol/kg. Only a small percentage of the essential plant nutrient cations (K^+, Ca^{2+}, Mg^{2+}, and $NH4^+$) will be 'loose' in the soil water and thus available for plant uptake. Thus the CEC is important because it provides a reservoir of nutrients to replenish those removed from the soil water by plant uptake.Similarly, cations in the soil water that are leached below the root zone by excess rainfall or irrigation water are replaced by cations formerly bound to the CEC (James Cambereto, 2001). The wide variation in the CEC values of the control soils when compared to the test soils indicate the difference in clay particle composition of the soil (Bhattacharyya *et al*., 1994). Hence the CEC of the soil samples appears to be a detrimental factor influencing the fertility of the soil.

3.5 Exchangeable Cations:

The exchangeable cations in the soils analyzed in the present study showed higher concentration of Ca^+ followed by Mg^+, Na^+ and K^+ ions respectively with reference to both control and test soils. It is being stated that soil acidity is strongly influenced by the species differences in decomposing biomass deposited on the soil. The low value of exchangeable acidity in the surface soils can be due to removal of exchangeable ions through chelation with organic acids into lower horizons (Gangopadhyay *et al.,* 2011). Hence due to the lower concentration of exchangeable ions, nutrient uptake process by the plants is greatly hindered causing infertility to the soil (Figure 4).

3.6 Available Macro Nutrients and Organic Carbon:

The nutrients are largely interlinked and influenced by other physico-chemical characters of the soil, depending on seasonal changes (Hagedorn *et al.,* 2001). The present study showed higher concentration of available nitrogen (226 to 302 Kg/ha) when compared to available phosphorous (50 to 100 Kg/ha) and Potash (90 – 575Kg/ha). The significant variation could not be observed for nitrogen and phosphorous between control and test soils. Besides this, high fluctuation of Potash was observed between the samples analyzed. This could be attributable to the influence of CEC and soil acidity (Athokpam and Garkoti 2013) (Figure 5 &6). However, Soil nitrogen content is an important environmental factor that affects the rate of nutrient uptake by plants. For that matter, the higher concentration of nitrogen in the upper layer of soils may be due to the presence of immobilized nitrogen in the detritus on the soil surface (Barbosa and Fearnside, 1996; Kao *et al.,* 2003), which is prone to microbial decomposition in soils in the subsequent layers (Maharudrappa *et al.,* 2000; Prusty, 2007).

Available Phosphorous, and Potash irrespective of the sites, showed a decreasing trend when compared to available Nitrogen across the soil layers. It is important to note that soils high in organic matter generally exhibit relatively low levels of phosphorus and potash. Phosphates or Potassium ions do not normally stay for very long in soils and are readily absorbed by plants (Brady, 1996). Distribution and forms of phosphorous in soils help in evaluating the phosphorous status and degree of chemical weathering of the soils (Majumdar *et al.,* 2007). Phosphorous availability and soil acidity are closely related and different phosphorous fractions in soils depend on the magnitude and proportion of different forms of soil acidity. However the acidity and lower CEC properties of the soil interrupt the uptake of these nutrients by the plants, leaving the soil infertile.

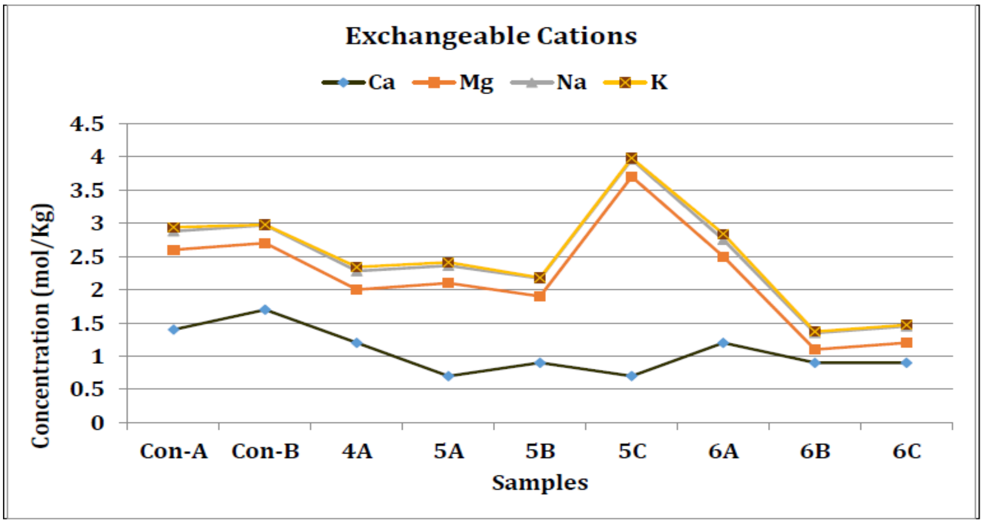

Figure 4: Exchangeable Cations in the Soil samples

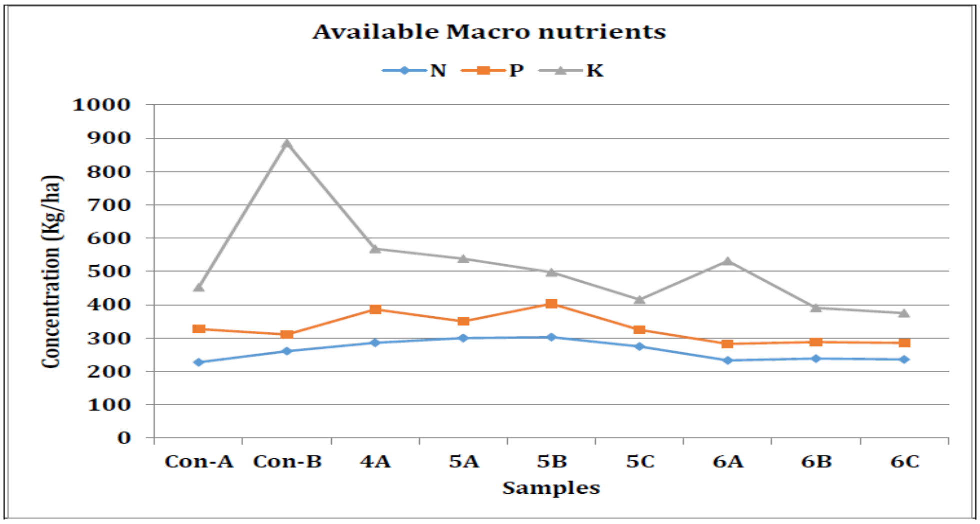

Figure 5: Available Macronutrients in the Soil samples

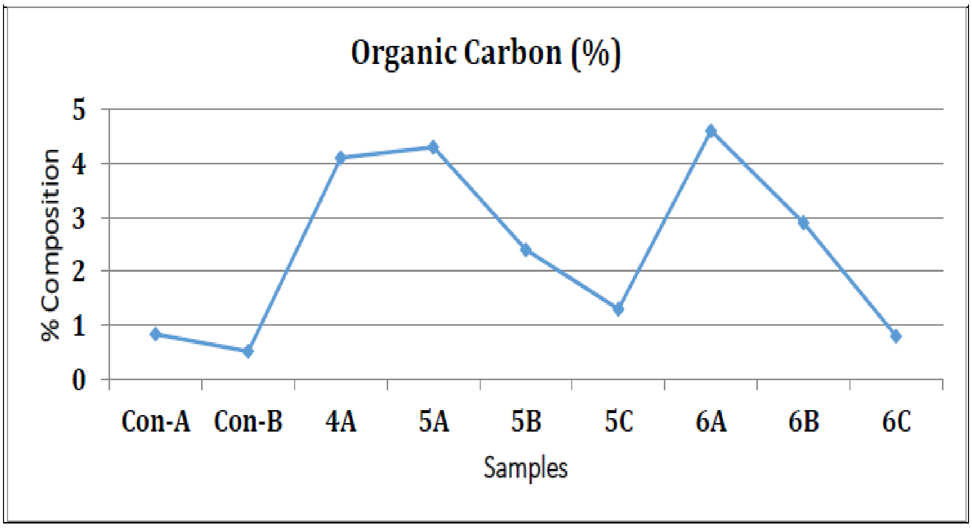

Figure 6: Organic Carbon (%) in the Soil samples

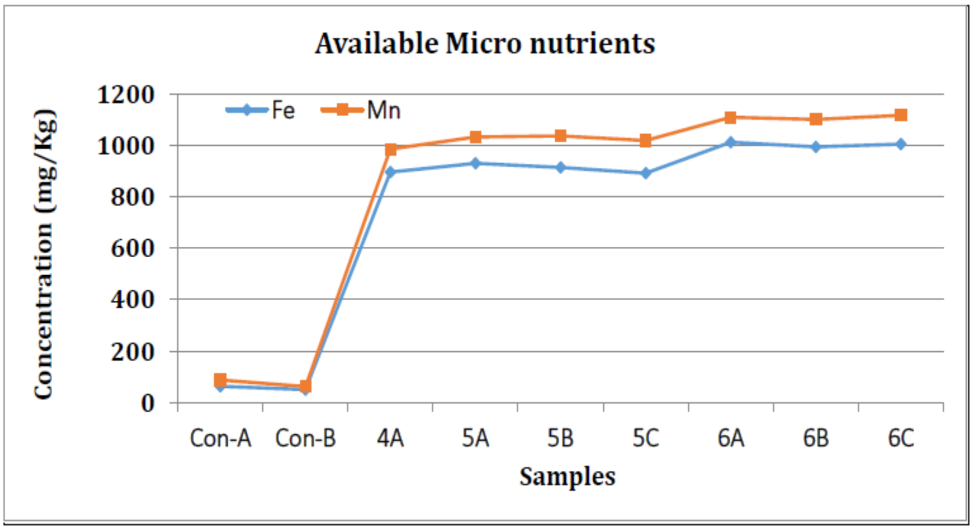

Figure 7: Available Micronutrients in the Soil samples

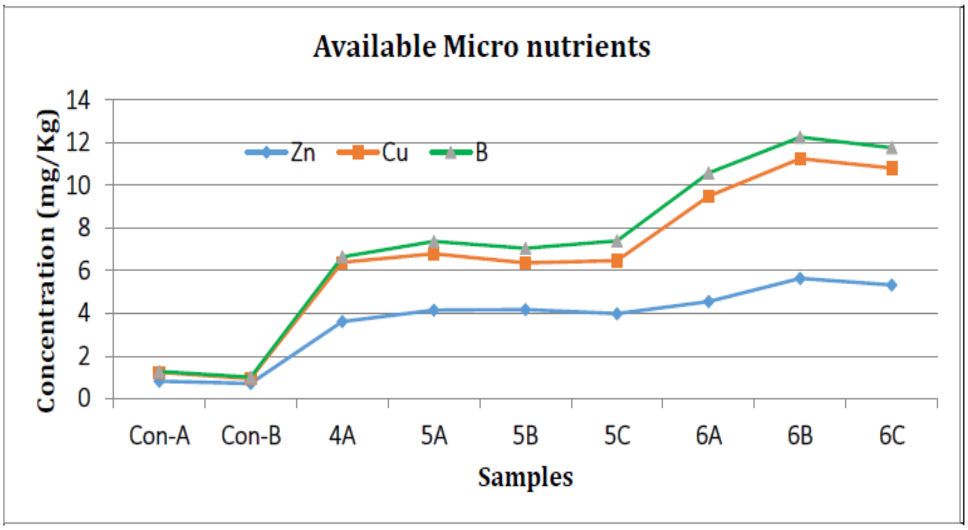

Figure 8: Available Micronutrients in the Soil samples

Organic matter is a primary source of organic carbon in the soil and gets accumulated in the top soil (Brady, 1996). The present study had recorded higher OC content in top layer soil than the bottom horizons. It is also stated that OC content is supposed to be higher on slopes with lower steepness (Rachna *et al.,* 2012). The accumulation of relatively high soil OM in the soil in general could be due to the presence of high precipitation which promotes plant growth, cooler temperature and high soil acidity of the area which could decrease the rate of decomposition and mineralization of soil OM. Reports have also revealed that soil OM accumulation increases with increasing precipitation and de- creases with increasing temperature (Cole *et al*., 1993). Thus the macro nutrients and organic content of the soils need higher order studies to understand the interrelations between them. However it is also attributable to various environmental factors such as erosion, rainfall, temperature influencing its variations.

3.7 Available Micronutrients:

Micronutrients are elements that are required by plants in very small amounts. Their availability often correlates with soil pH and organic matter levels. The micronutrients analysed in the present study includes Iron, Manganese, Copper, Zinc and Boron. These elements were found to be at high concentration in test soils when compared to the control soils (Figure 7 & 8). Available Fe contents in the soils ranged from 50.04 to 1004.80 mg kg-1. All the soils had extremely high amount of Fe considering 4.5 mg kg-1 as critical limit as suggested by Lindsay and Norvell (1978). Similar results were also reported by Verma *et al*., (2005), Jiang *et al*., (2009) and Bassirani *et al*., (2011).

Available Mn in the soils varied from 12.10 to 112.40 mg kg-1. Considering 1.0 mg kg-1 as critical limit for Mn deficiency (Lindsay and Norvell, 1978), all the test soils had higher amounts of available Mn than the control soils. Soil micro- nutrient cations like Fe, Cu and Zn have significant correlation with available Mn, suggesting variation in their distribution dependent upon common soil factors (Follect and Lindsay, 1970; Bassirani *et al*., 2011).

Available copper content in the soils ranged from 0.23 to 5.60 mg kg-1. . Considering 0.2 mg kg-1 as critical limit for Cu deficiency (Lindsay and Norvell, 1978), all the soils were found to be in higher concentration leading to Cu toxicity to plants. This finding was in conformity with that of Singh *et al.,* (2006), Verma *et al.,* (2007), Jiang *et al.,* (2009) and Bassirani *et al.,* (2011). Available Zn in the studied surface soils varied from 0.72 to 5.64 mg kg-1 Similar finding was also reported by Raina *et al.,* (2003) in apple growing soils of Himachal Pradesh, India. Considering 0.6 mg kg-1 as critical limit of available Zn as suggested by Takkar and Mann (1975), the entire representative soils were under highly concentrated categories. This result is also supported by the finding of Bassirani *et al.,* (2011). Hot water soluble B content in the soils ranged from 0.039 to 1.09 mg kg-1 with a The range of available B in soils of different states of India varied from traces to 12.2 mg kg-1 (Das, 2000). The chemical properties of the soils did not influence the B content in the soils. The above results clearly indicate the presence of higher concentration of all the micronutrients which can be considered as the significant factor responsible for soil infertility.

4.0 Conclusion:

The management of acid soils should aim at improving the production potential by addition of amendment to correct the acidity and manipulate the agricultural practices so as to obtain optimum crop yields under acidic conditions. One of the practices is to grow acid tolerant crops/ varieties and to supplement nutrients through suitable carriers. Liming is a desirable practice when the soil is highly acidic and where multicropping involving acid sensitive crops is adopted. Liming improves base saturation and availability of Ca and Mg. Fixation of P and Mo is reduced by inactivating the reactive constituents. Toxicity arising from excess soluble Al, Fe and Mn is corrected and thereby root growth is promoted and uptake of nutrients improved. Liming also stimulates microbial activity and encourages N_2 fixation and nitrogen mineralization, and hence, legumes are highly benefited from liming.

Liming of acid soils has been advocated by soil scientists. However the lime requirement based on laboratory tests is usually too high for most of the farmers to afford. Besides, high transport cost of large quantity of lime and inadequate storage facilities at consumption sites have discouraged large scale use of the ameliorant. Now, it has been established that band placement/incorporation of lime at 1/10 of lime requirement along with recommended level of fertilizers every year is economical, practicable and effective.

Traditionally, farmers of Acid Soil Regions (ASR) have been growing rice irrespective of the type of land (upland, medium land & low land). The acid sensitive crops like cotton, soybean, groundnut, beans, pigeon pea etc. are better adaptable to acid soils with proper liming. Crops are classified according to their relative response to liming. This information can be utilized in fixing suitable cropping sequence. Soil erosion and shifting cultivation are major problems in hilly-tracts of ASR. Agri-horticultural and agro forestry systems need to be introduced in such tracts. In general, regions receiving more than 900 mm rainfall and with a moisture storage capacity of 200 mm in the root zone, double cropping can be taken up. These reclamation measures can be put in trial to assess its potential to reclamate the potential fertility of the soil. Hence it is expected some possible measures can be taken on the basis of the nature of the soil as represented by this study.

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References:

1) Athokpam FD and Garkoti SC (2013) Variation in evergreen and deciduous species leaf phenology in Assam, India. Trees 27:985–997.
2) Barbosa R. L and Fearnside P. M (1996). Carbon and Nutrient Flows in the Amazonian Forest: Fine Litter Production and Composition at Apiau, Roraima, Brazil. *Tropical Ecology*, Vol. 37, No. 1, pp. 115-125.
3) Bassirani N, Abolhassani M, Galavi M (2011). Distribution of available Micronutrients as related to the soil characteristics of Hissar; Haryana (India). Afr. J. Agric. Res. 6:42394242.
4) Bernoux, M., Cerri, C.C, Neill C., and De Moraes J.F.L.. (1998). The use of stable carbon isotopes for estimating soil organic matter turnover rates. Geoderma 82:43–58.
5) Bhattacharyya T, Sen T.K, Singh R.S Nayak D.C and Sehgal J.L (1994). Morphological characteristics and classification of Ultisols with Kandic horizon in North Eastern Region. Journal of the Indian Society of Soil Science 42, 301-306.
6) Brady N.C (1996) .The Nature and Properties of Soils. Prentice Hall, Upper Saddle River.
7) Cole V. C, Paustian K, Elliott E. T, Metherell A. K, Ojima D. S. and Parton W. J (1993) Analysis of Agroecosystem Carbon Pools *Water Air and Soil Pollution*, Vol. 70, No. 1-4, pp. 357-371.
8) Das D.K (2000). Boron. In: Micronutrients: Their Behaviour in Soils and Plants. Kalyani Publishers, Ludhiana.
9) Defoer T.A, Budelman Toulmen D and Carter Se. (2000). Building Common Knowledge: In; Managing Soil Fertility. A resource guide for participatory learning knowledge and research in the Tropics: Royal Tropical Institute, Netherlands.
10) Department of Agriculture & Cooperation, Ministry of Agriculture, Government of India, New Delhi, January, (2011). Manual Method for Soil testing in India.
11) Doran JW and Michael R. Zeiss (2000). Soil health and sustainability: managing the biotic component of soil quality. Applied Soil Ecology 15, 3–11.
12) Follect R.H, Lindsay W.L (1970). Profile distribution of Zn, Fe, Mn and Cu in Colorado soil. Tech. Bullet. Colorado 110:79.
13) Gangopadhyaya S. K. Utpal Baruah and Dipak Sarkar (2011). Forest soils of Upper Brahmaputra valley of Assam - their characteristics and classification. Agropedology, 21 (2), 1-9.
14) Hagedorn F, Maurer S, Egli P, Blaser P, Bucher J. B, and Siegwolf R (2001). Carbon Sequestration in forest soils: Effect of soil type, atmospheric CO**2** enrichment and N Deposition. *European Journal of Soil Science*, Vol. 52, No. 4, pp. 619-628.
15) Hanlon E.A (2009). Soil pH and Electrical Conductivity: A County Extension Soil Laboratory Manual Soil and Water Science Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Original publication date April 1993. Revised February 2009.
16) Hausenbuiller R.L (1978). Soil Science Principles and Practices. WMC Brown Company Publishers, IOWA, Washington.
17) James J. Camberato (2001). An article on Cation Exchange Capacity – Everything You Want to Know and Much More in *South Carolina Turf grasss Foundation News, October-December.*
18) Jiang Y, Zhang YG, Zhou D, Qin Y, Liang WJ (2009). Profile distribution of Micronutrients in an aquic brown soil as affected by land use. Plant Soil Environ. 55:468-476.
19) Kao J.T, Titus J.E and Zhu W.X (2003). Differential Nitrogen and Phosphorus Retention by Five Wetland Plant Species. *Wetlands*, Vol. 23, No. 4, pp. 979-987.
20) Kumar K, Rao K.V.P, and Singh L.J (1995). Forms of Acidity in Some Inceptisols under Different Land Use in Manipur , *Journal of the Indian Society of Soil Science*, Vol. 43, No. 3, pp. 338-34
21) Lindsay W.L, Norvell W.A (1978). Development of DTPA soil test for Zn, Fe, Mn and Cu. Soil Sci. Soc. Am. J. 42:421-428.
22) Maharudrappa A, Srinivasamurthy C. A, Nagaraja M. S, Siddaramappa R, and Anand H. S (2000) Decomposition Rates of Litter and Nutrient Release Pattern in a Tropical Soil. *Journal of the Indian Society of Soil Science*, Vol. 48, No. 1, pp. 92-97.
23) Majumdar B. Venkatesh M.S. and Kumar K (2007) Forms of Phosphorous and Soil Acidity in Different Land Management Systems of Meghalaya. *Indian Journal of Forestry*, Vol. 30, No. 2, pp. 127-134.
24) Miller W.R and Donahue R.L (1997). Soils in Our Environment, Prentice-Hall of India Private Limited, New Delhi.
25) Prusty B. A. K (2007). Distribution of Select Nutrients and Metals in the Soils of a Wetland-Terrestrial Ecosystem Complex: A Case Study of Keoladeo National Park, Bharatpur, India. Ph.D. Dissertation, Bharathiar University, Coimbatore.

26) Rachna C, Narayanan G, Prusty BAK, Azeez PA(2012). Soil Properties of a Tropical Savannah in the Eastern Ghats of India, *Open Journal of Soil Science*, 2012, 2, 353-363
27) Raina, V.K., Srivastava, S.K., Syamasunder, K.V., 2003. Essential oil composition of Acorus calamus L. from the lower region of the Himalayas. Flavour Frag. J. 18, 18– 20.
28) Saha R, Chaudhary R S and Somasundaram J (2012). *Review Article:* Soil Health Management under Hill Agroecosystem of North East India. Hindawi Publishing Corporation Applied and Environmental Soil Science Volume 2012, Article ID 696174, 9 pages
29) Singh R.D, Kumar S, Panse H (2006). Micronutrient status of soils under different vegetations in Uttaranchal Hills. J. Indian Soc. Soil Sci. 54:115-116.
30) Takkar PN, Mann MS (1975). Evaluation of analytical methods of estimation of available zinc and response of applied zinc in major soil series of Ludhiana, Punjab. Agrochemica 19:420 430.
31) Verma V.K, Setia R.K, Sharma P.K, Khurana M.P.S, Kang S (2007). Pedospheric distribution of micronutrient cations in soil developed on various landforms in northeast Punjab. J. Indian Soc. Soil Sci.55:515-520.
32) Wopereis, M.C.S., T. Defoer, P. Idinoba, S. Diack and M.J. Dugué, (2009). Participatory Learning and Action Research (PLAR) for Integrated Rice Management (IRM) in Inland Valleys of Sub-Saharan Africa: Technical Manual. WARDA Training Series. Cotonou, Benin: Africa Rice Center. 128.