International Research Journal of Earth Sciences ISSN 2321–2527
Vol. **5(4),** 1-7, May **(2017)** *Int. Res. J. Earth Sci.*

Consistent status of soil along disturbance gradient in the sub-tropical forest of Aizawl, Mizoram, India

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Available online at: www.isca.in, www.isca.me
Received 23rd November 2016, revised 28th Februry 2017, accepted 20th May 2017

Abstract

Disturbance plays a vital role in terms of change in fertility and dynamics of soil, as overexploitation of forest resources leads to thinning of vegetation and loss of plant diversity to a great extent. This may lead to change in physico-chemical properties of soil, and subsequently loss of productivity making the soil vulnerable to erosion. For present investigation, a total of three forest patches representing undisturbed (UD), moderately disturbed (MD) and highly disturbed (HD) sites were selected within the Pachhunga University College campus, Aizawl, Mizoram. The soil samples were analyzed seasonally (post-monsoon, pre-monsoon and monsoon seasons), for soil temperature, soil moisture content, water holding capacity, bulk density, pH, organic carbon, NPK. The soil temperature was increased with increase in degree of disturbance, showing direct influence of ambient temperature on seasonality. The soil moisture content and water holding capacity decreased from undisturbed to highly disturbed site. On the contrary, bulk density was reported to be high at disturbed site. The soil was acidic in nature irrespective of sites and seasons. There was a sharp decline in soil organic carbon, and NPK from undisturbed to highly disturbed stand, and highest values were recorded during post-monsoon season and lowest during monsoon season. The higher values during post-monsoon season may be attributed due to accelerated rate of decomposition of litter.

Keywords: Decomposition, Disturbance, Plant diversity, Soil fertility.

Introduction

Forest plays a significant role in protecting the soil and water resources, and mitigating the environment[1]. Forest soil is one of the most important ecological factors, on which all plants depend for nutrients, water and mineral supply[2], and soil plays a significant role in determining the productivity of the forest ecosystems[3]. The soil fertility (essential nutrients available in the soil) is the significant factor for the growth of the plants[4]. Therefore, changes in soil fertility and the nutrient balance are taken as key indicators to determine the quality of forest ecosystem[5]. The status of soil and water is largely linked with anthropogenic activities[6,7]. The urban and agricultural developments, logging, road construction and major developmental projects which have resulted in forest fragmentation, severe soil nutrient decline and decline in productivity of the soil[8,9]. The various human activities serve as a major factor for determining the plant communities and status of soil nutrients[10]. Chemical composition of soil is largely governed by nature of vegetation, as change in species composition serves as one of the major causes which determines the status and release of nutrients in soil[11,12]. The physical and chemical characteristics of forest soil are fundamental aspects for maintaining the quality of the environment[13] and sustainability[14,15]. A massive loss of carbon, nitrogen, phosphorus and sulphur from the terrestrial ecosystem occurs due to human-driven deforestation[16]. Therefore, it is an alarming task for soil biologists to look for sensitive, but clear evident indicators for various human impacts on soil[17-19]. So far no systematic study has been carried out to assess the soil characteristics in the sub-tropical forest in Pacchunga University College (PUC) campus, in Aizawl district of Mizoram, the only institution in Mizoram awarded the Indira Priyadarshini Vriksha Mitra (IPVM) in 1995, the national award for pioneering and innovative contribution in the field of afforestation/wasteland management, from the Ministry of Environment and Forests.

Therefore, in view of the above, the present study has been carried out with an aim to assess physico-chemical characteristics of soil collected from the sub-tropical forest in Pacchunga University College (PUC) campus from selected sites along disturbance gradient, using standard methods. The cause-effect analysis was computed by taking a comparative account of information procured on the subject.

Materials and methods

Description of study site: Mizoram (21^o 56'- 24^o 31' N and 92^o 16'- 93^o 26' E) is one of the 8 states under northeast India, and covers an area of 21,081 km^2. The state is bordered by Myanmar to the east and south; Bangladesh to the west; states of Assam, Manipur and Tripura to the north. Mizoram raises just more than 2000 metre asl near the Myanmar border. Aizawl (21^o 58'- 21^o 85' N and 90^o 30'- 90^o 60' E), the state capital which is 1132 metre asl. The altitude in Aizawl district varies from 800 to 1200 metre asl. The study site is situated in College Veng, a locality in eastern side of Aizawl city. The major anthropogenic activities are collection of fuel-wood and developmental activities.

Geology and soil: The rock system is generally weak, unstable, weathered and prone to seismic and weather influence. There are no useful minerals of economic significance. Soil varies from sandy loam to clay, generally mature but leached mostly due to heavy rainfall and is poor in water holding capacity. Soil is highly porous, sandy loam and humus.

Climate and rainfall: The study area is experiencing sub-tropical climate. In summer, temperature ranges from 20-30 degrees Celsius, and in winter 11-21 degrees Celsius. It is highly influenced by monsoon, and rainy season is extending from May to September with little rainfall in the dry season also. The average annual rainfall is about 208cm.

Vegetation: The campus has its unique feature-lush green vegetation, the result of 30 years of maturing the semi-isolation of the campus, wide-open space with luxuriant natural vegetation. The 136 acre campus is covered with a verdant reserve of forest making a serene environment and picturesque scenery. The common tree species are *Castanopsis tribuloides, Aporusa octandra, Albizia Chinensis, Schima wallichii*, *Callicarpa arborea*, *Castanopsis indica*, *Lithocarpus elegans*, *Syzygium grandis*. The common medicinally important plants are *Cuscuta speciosa*, *Embilica officinalis*, *Mimosa pudica*, *Mikania micrantha*.

Site selection and collection of samples: The study was conducted during 2012-2013. A reconnaissance survey of study area was made and following three study sites were selected along disturbance: i. Highly Disturbed stand (HD): Forest area for developmental activities. ii. Moderately Disturbed stand (MD): Buffer zone of the Reserve Forest. iii. Undisturbed stand (UD): Core zone of the Reserve Forest.

Soil samples were collected randomly from each site with 4 replicates Post-Monsoon season (October and November), Pre-Monsoon season (March and April) and Monsoon (May and June). The forest floor was first cleared of the fallen leaves and any unwanted material. The soil samples were collected for top-soil (depth up to 10cm).

The soil temperature was measured at the site. The samples were brought to the laboratory and soil moisture content and pH were determined immediately. Thereafter, samples were air dried and powered with the aid of mortar and pestle and sieved with 2mm sieve and stored for analysis of chemical characteristics such as water holding capacity, bulk density, soil organic carbon, total nitrogen, available phosphorus and exchangeable potassium, adopting standard methods[20,21]. The temperature of the soil was measured by using Digital Soil Thermometer. The soil moisture content was calculated as the difference between fresh and dried soil samples after drying in oven for 24 hours at 105°C. The water holding capacity was determined as an amount of maximum water held in saturated soil using keen box. The bulk density of soils (g cm-3) was calculated using mass and volume[22]. The soil pH was measured electrometrically by digital pH meter using 1:2.5 suspensions of soil and water[23]. Soil organic carbon- Soil organic carbon was determined by rapid titration method[24]. Total nitrogen was analyzed by using the standard Kjeldahl method[25]. Available phosphorus was determined by Olsen method[26]. Exchangeable potassium was extracted by neutral normal ammonium acetate method[27] and was determined by the flame photometer method[28].

Results and discussion

Soil temperature: The soil temperature ranged from 21.1˚C± 0.03 (post-monsoon season in UD stand) to 32.6˚C± 0.03 (pre-monsoon season in HD stand). The values were higher at highly disturbed site and lower values were observed at undisturbed site in all the seasons. There was direct influence of solar radiation reaching on land surface. The cumulative effect of light interception and canopy cover resulted in gradual increase in soil temperature from undisturbed to highly disturbed stand. There was gradual decrease in soil temperature during the post-monsoon and again an increase in the pre-monsoon with a slight decrease in the monsoon season (Figure-1). This may be due to seasonality[2,12].

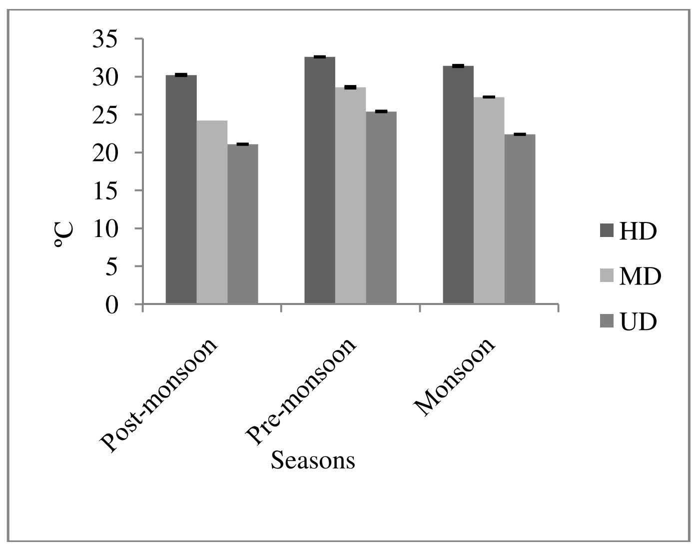

Figure-1: Seasonal variation in soil temperature along disturbance gradient.

Soil moisture content: The soil moisture content ranged from 19%±0.03 (post-monsoon season in MD stand) to 24.7%± 0.03 (monsoon season in UD stand). The soil moisture content was found to be highest at undisturbed site during monsoon season, this may be because of the proper root system inside the forest area which can hold on more water whereas the findings of the present study depict low retention of moisture content under moderately disturbed condition, this could be linked with removal of vegetation and destruction of top-soil, resulting in highly weathered condition of the soil or its coarse texture which can quickly drain the water. The moisture content in highly disturbed stand was normally slightly greater than moderately disturbed stand, as soil became more porous in former case and litter was removed in later case. During pre-monsoon season, the soil moisture content was found to be the lowest this may be due to the prevailing dry weather condition (Figure-2). The findings are in conformity with the work of earlier workers[29].

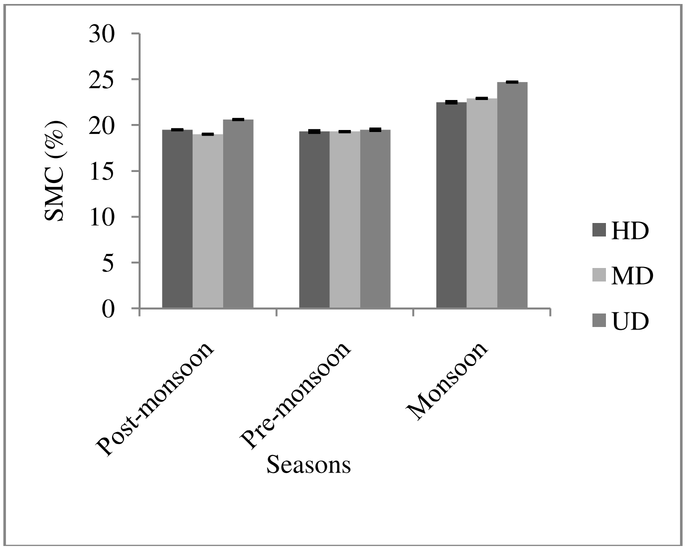

Figure-2: Seasonal variation in soil moisture content along disturbance gradient.

Water holding capacity: The water holding capacity ranged from 47.3%± 0.12 (monsoon season in HD stand) to 60.2%± 0.09 (pre-monsoon season in UD stand). The water holding capacity of soil in the undisturbed site was found to be the highest. This could be attributed due to presence of high organic matter. On the contrary, lower values at highly disturbed site may be due to the soil texture. There was no marked influence of seasonality and disturbance regime on water holding capacity of soil, as slight difference in values was reported. The water holding capacity was highest in the pre-monsoon season, as soil pores are devoid of any pre stored water content during dry months thereby soil can retain more water[12] (Figure-3).

Bulk density: The bulk density ranged from 0.53± 0.01(pre-monsoon season in UD stand) to 0.98± 0.01 (monsoon season in HD stand). The bulk density was sharply decreased from highly disturbed to undisturbed stand irrespective of seasons. The higher values at highly disturbed site may be due to soil texture and presence of less porous space between the soil particles. On the contrary, lower values at undisturbed site may be the result of high organic matter content on forest floor (Figure-4). The finding of the present investigation are in conformity with work of past workers[30,31] .

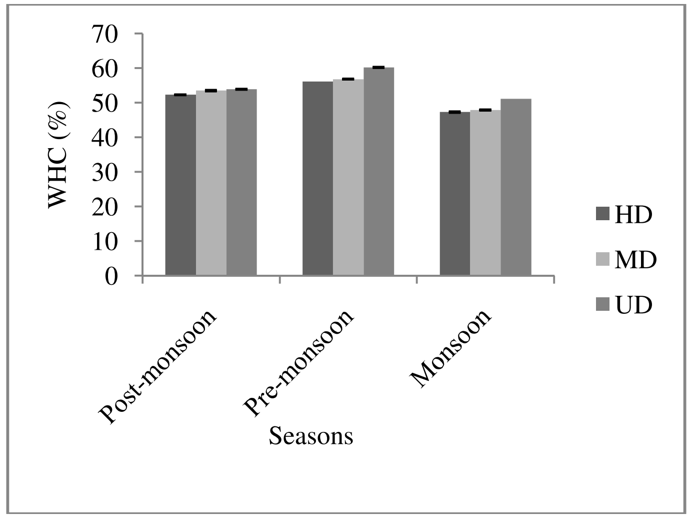

Figure-3: Seasonal variation in soil water holding capacity along disturbance gradient.

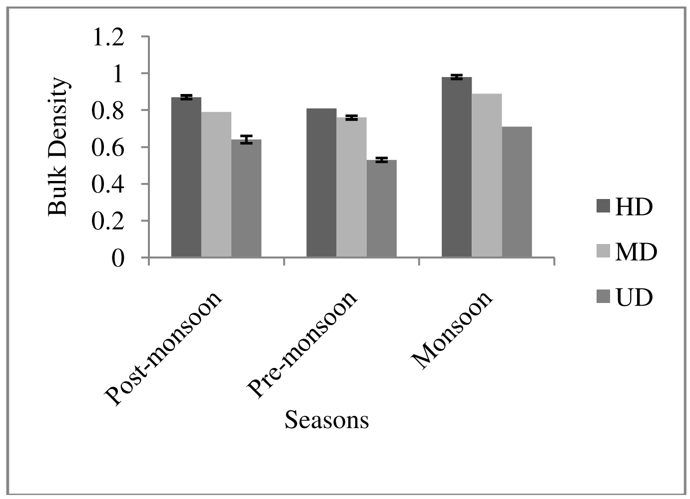

Figure-4: Seasonal variation in soil bulk density along disturbance gradient.

pH: The pH of soil ranged from 4.3± 0.06 (monsoon season in HD stand) to 6.1± 0.03 (post-monsoon season in UD stand). The lower values at highly disturbed site during monsoon season may be because of either excessive rainfall which leaches base cations from the soil surface or due to rain water reaction with CO_2 in the atmosphere that forms carbonic acid (Figure-5). A similar trend of results was also reported by other workers[31].

Soil organic carbon: The soil organic carbon ranged from 0.21% ± 0.00 (monsoon season in HD stand) to 0.58% ± 0.01 (post-monsoon season in UD stand). The values were higher in the undisturbed site irrespective of season. This may be due to the soil type and the soil conditions which favour growth of soil microbes for more decomposition which signifies high microbial biomass which may be due to increased moisture content thereby increasing in the C-content of the soil[11,32-34]. The carbon content was found to be lower in the monsoon season at disturbed stand. There was marked decrease in soil organic carbon at highly disturbed site. This could be attributed due to removal of top-soil and loss of nutrients with surface run-off. The decline in the C-content maybe attributed to the removal of vegetation cover from the soil surface (Figure-6).

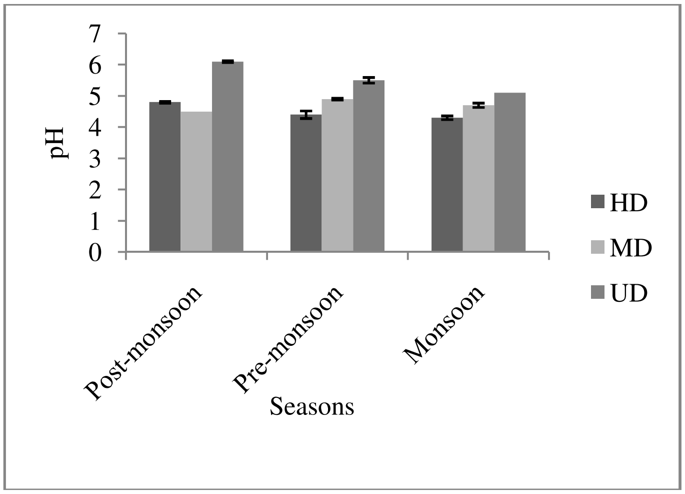

Figure-5: Seasonal variation in soil pH along disturbance gradient.

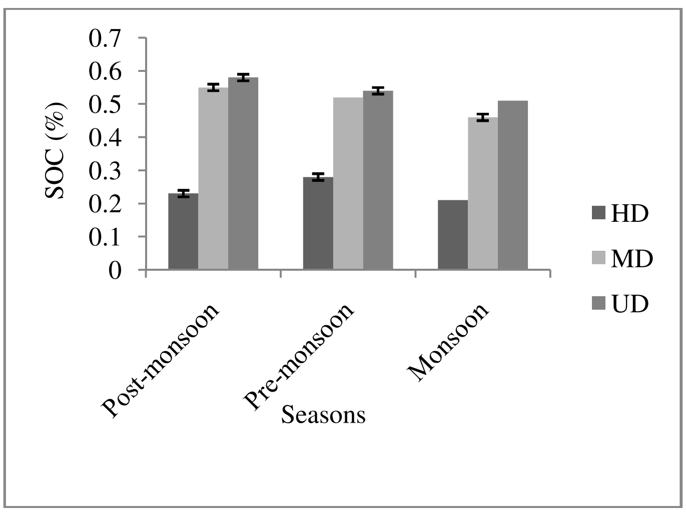

Figure-6: Seasonal variation in soil organic carbon along disturbance gradient.

Total Nitrogen: The total nitrogen ranged from 0.13% ± 0.01 (monsoon season in HD stand) to 0.35 % ± 0.02 (post-monsoon season in UD stand). The anthropogenic disturbances adversely affected soil fertility, and as a result, a sharp decrease in total nitrogen content from undisturbed to highly disturbed site was established. The values were higher in the undisturbed soil during post-monsoon season as compared to the highly disturbed and moderately disturbed soils. The presence of high amount of nitrogen content in the soil at undisturbed site may be due to the presence of more N-fixing bacteria or the presence of leguminous plants which support growth of microbes. There was a gradual decline in the nitrogen content in the disturbed site during the monsoon season maybe due to the leaching of the nitrogen from the soil of the disturbed site (Figure-7). The finding of the present study was in conformity with the earlier work on effects of various anthropogenic activities that altered the nitrogen cycle in many ecological systems including the savannas[35].

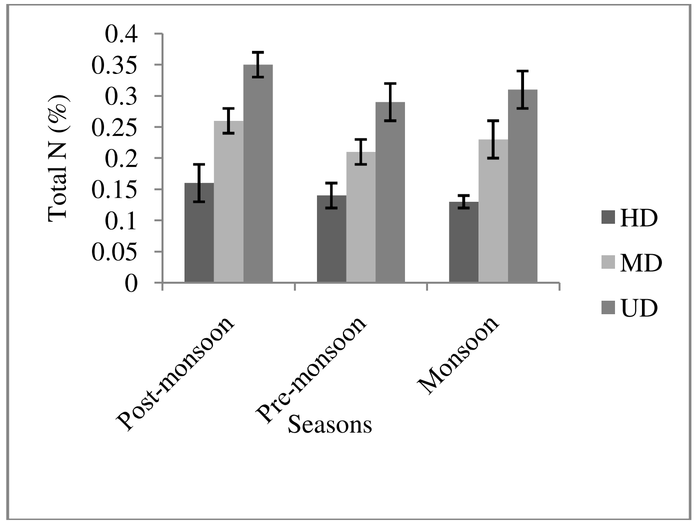

Figure-7: Seasonal variation in soil total nitrogen along disturbance gradient.

Available phosphorus: The available phosphorus ranged from 18.19 Kgha-1 ±0.32 (pre-monsoon season in HD stand) to 75.76 Kgha-1±0.23 (post-monsoon season in UD stand). The values were higher in the undisturbed and moderately disturbed stands irrespective of season. This may be due to the presence of rocks containing phosphates and orthophosphate. Beside this, the leaf litter may also add to the increase in the phosphorus content. The relatively higher concentration during post-monsoon season may be due to drier months favoring greater retention of phosphorus in soil[36].

The disturbed stand had very low concentration of phosphorus, as the peak of phosphorus availability is at pH 6.5[37], therefore, phosphorus starts forming insoluble compounds with iron and aluminum through chemisorptions at low pH[38] (Figure-8). A similar decreasing trend in the value of available phosphorus from undisturbed to the disturbed stand was also reported by past workers[31].

Exchangeable potassium: The exchangeable potassium ranged from 95.01Kgha-1±0.22 (monsoon season in HD stand) to 287.53Kgha-1±0.34 (post-monsoon season in UD stand). The findings reveal that the rate of potassium available in the soil showed a marked reduction in values with increase in degree of disturbance. The values were higher in the post-monsoon and lower in the monsoon season (Figure-9). The decline in the potassium content may be due to the high mobility especially during the rainy season as leaching and drainage are very common[4,39].

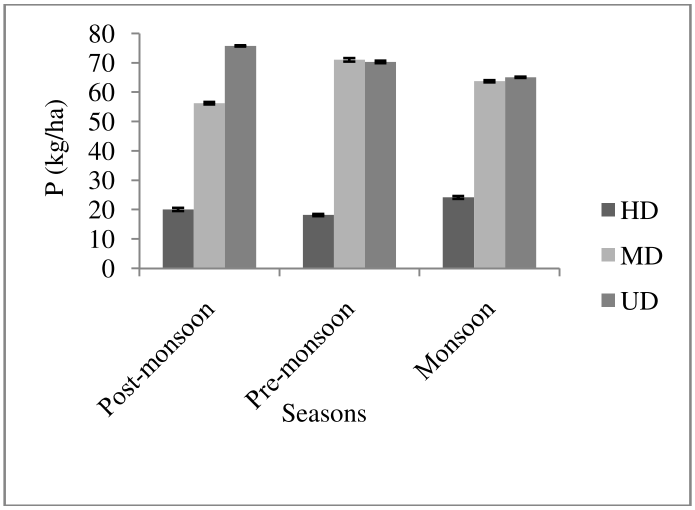

Figure-8: Seasonal variation in soil available phosphorus along disturbance gradient.

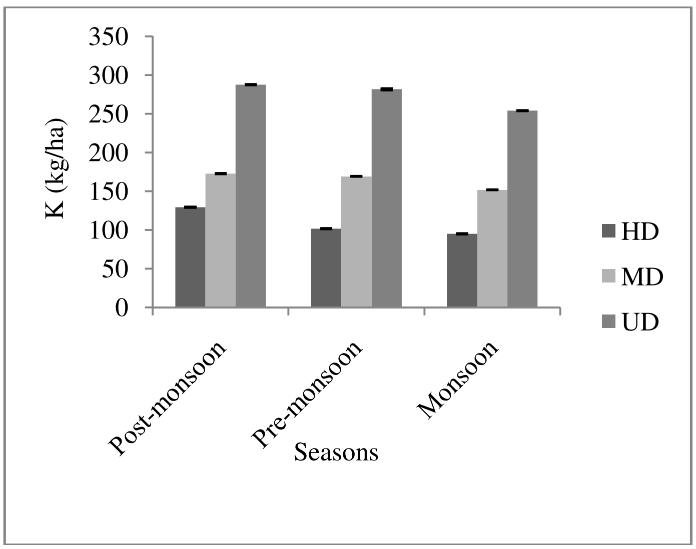

Figure-9: Seasonal variation in exchangeable potassium along disturbance gradient.

Conclusion

The findings of the present investigation reveal that anthropogenic disturbances lead to thinning of vegetation and subsequently degradation of soil to a great pace. Disturbance causes drastic change in micro-environment and resulting into direct influence of prevailing climatic conditions. It was observed that rainfall favoured microbial growth and bacterial decomposition. Moreover, percolating water leads to leaching of nutrients, and top-soil becomes nutrient deficient in disturbed stand. The slope of the area also determines the nutrient availability because in hilly areas with steep slope the soil is susceptible to erosion due to heavy rain and wind.

The developmental activity particularly construction of buildings around study area leads to deterioration of soil, loss of vegetation and loss of soil fertility. The physico-chemical analyses of soil along disturbance gradient depict that there is a direct impact of human activities on soil fertility of study area. From the analysis done for three seasons i.e., Post-monsoon, Pre-monsoon and Monsoon it was observed that the soil of the disturbed site is highly degraded and poor in nutrient status. There was a sharp decline in OC, total nitrogen, available phosphorus and potassium content of soil from undisturbed to highly disturbed stand moreover, values were higher during post-monsoon indicating high rate of litter decomposition. On the contrary, temperature, and bulk density showed a reverse trend in results. Soil moisture content and bulk density were relatively higher during monsoon. The main on-site impact is the reduction in soil quality which results from loss of the nutrient-rich upper layers of the soil, and the reduced water-holding capacity of the eroded soil. A similar decreasing trend in values was established for soil moisture content, organic carbon, total nitrogen, available phosphorus and exchangeable potassium, from undisturbed to highly disturbed stand. On the contrary, values for soil temperature and bulk density increased from undisturbed to highly disturbed stand.

Acknowledgements

The authors are thankful to the Principal of Pachhunga University College, Aizawl for allowing us to conduct this basic research in Pachhunga University Campus, Aizawl successfully and effectively.

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