

Impact of Biotic Stress on Physiochemical Properties of Soil at Doodhpathri Kashmir

ABSTRACT:

Anthropogenically disturbed soils have unique properties. In most of the ecosystems, especially under disturbed soil conditions, the soil properties are controlled by the accumulated materials. However, the equilibrium between the already present soil mass and the accumulated soil mass is very fragile and is affected by many factors. This study was carried out in the forest soil of Doodhpathri which is a famous tourist place in Kashmir in the spring and summer seasons at three sites (forest, meadow, and deforested sites) in 2019. Soil samples were collected at 15-30 cm depth. We determined soil texture, pH, electrical conductivity (EC), moisture, organic carbon (OC), available macronutrients (Nitrogen, Potassium, Phosphorus, Calcium, and Magnesium), and heavy metals (Copper; Cu, Nickel; Ni, Cadmium; Cd, Manganese; Mn, Lead; Pb, and Zinc; Zn). Soil texture analysis revealed the soils at all the study sites with a major proportion being comprised by the silt fraction and having a silty clay loam character. pH and electrical conductivity were found to be high at the deforested site in the summer. Organic carbon and moisture content were found higher at the forest site in summer and spring respectively. Nitrogen, potassium, and total bacterial count follow the same trend as higher concentration was found at the forest site in the summer while Phosphorus, magnesium, and calcium follow the same trend as their high concentration was found at the meadow site in the summer. Significantly higher values of heavy metals (Cu, Ni, Cd, Mn, Pb, and Zn) were found at the meadow site in the summer. The results could help to formulate conservation strategies for the soil at Doodhpathri that is affected by anthropogenic activities.

Keywords: Forest, Soil, Anthropogenic, Biotic.

I. INTRODUCTION:

Forest soils are critical in influencing the long-term productivity of forest ecosystems. Forest lands with good physical and chemical properties are critical for supporting terrestrial ecosystem production and driving processes that maintain environmental quality (Moussa *et al.*, 2008). Without an understanding of soil, it is impossible to comprehend the growth and reproduction of forests. Because they grow together over a long length of time, the soil and vegetation have a complex relationship. Soil characteristics are composed of two properties: physical and chemical, and a soil's behavior is usually determined by the proportion and organization. Minerals, air, water, and organic matter are the four basic components of soil. Minerals make up 45% of the total volume in most soils, water, and air 25% each, and organic matter 2 to 5%. (Retallack 2008).

Terrestrial ecosystems' soil characteristics depend on some abiotic (Total ion content, acidity, carbon, nitrogen, and total phosphorous) and biotic (Climate, landform, topography, soil texture, soil moisture, and the makeup of the plant community) elements that change both

seasonally and geographically (Peverill 1999), (Maria *et al.*, 2004), (Takata *et al.*, 2008). Forest lands with good physical and chemical properties are critical for supporting terrestrial ecosystem production and driving processes that maintain environmental quality (Moussa *et al.* 2008). Because soil and vegetation develop together throughout time, they have a complex interrelationship (Retallack 2008). Soil microorganisms are also significant components of terrestrial ecosystems because they play an important part in intrinsic phenomena such as the nutrient cycle and ecosystem functioning, which directly involve in soil fertility and structure maintenance. Soil microbial biomass creation is the living element of soil organic matter that is responsible for the decomposition and mineralization of the organic matter fraction that works as both a sink and a source of nutrients that become available during microbial biomass turnover (Chandra *et al.* 2016). Increase in tourist flows and the rapid development of tourism infrastructure further increases the quantum of waste generates that accelerates the magnitude of problem in tourist destinations with adverse impact on the environment such as soil and water and problem of sustainable waste management is becoming increasingly relevant in many tourist destinations Murava and Korobeinykova (2016). Keeping this in view, present study was carried to study the impact of biotic stress on the soils of forest at Doodhpathri (Budgam).

II. Materials and methods:

Study area: The present study was carried out in the Doodhpathri area of Kashmir. Doodhpathri lies within the geo-coordinates of 33° 54' 23" N latitude and 74° 36' 15" E at an elevation of 2544m above sea level, in the Budgam district of Kashmir. Two seasons (Spring and Summer) and three study sites were selected; site I (Forest), site II (Meadow), and site III (Deforested) to study the physicochemical properties of soil. The study sites were selected based on anthropogenic activities for comparison. Soil sampling was performed during the spring and summer seasons (June to November). At each site, six soil samples were obtained randomly at 15-30 cm depth with the help of a soil auger and then mixed to form the composite sample. Three replicates from the composite were sealed and labeled in the thick polythene bags and used for further analysis. The samples were examined for soil texture (Piper, 1966); Ph, EC, available potassium (Jackson, 1973); organic carbon (Walkley and Black, 1947); moisture (Prihar and Sandhu, 1968); available nitrogen (Subbiah and Asija, 1956); available phosphorus (Olsen *et al.*, 1954); calcium and magnesium (EDTA method), and heavy metals (Lindsay and Norwell, 1978).

Explained methodology:

1. Soil texture: The particle size distribution of the soil samples was carried out by International Pipette method. Sodium meta-phosphate was used for purpose of dispersion and prior to that H₂O₂ was used for decomposition of organic matter. Then standard procedure was followed to determine individual contents of sand, silt and clay as proposed by Piper (1966).
2. pH and EC: Soil pH and electrical conductivity was determined by potentiometric method with the help of pH meter and electrical conductivity meter (Jackson, 1973). In this method, 10 g sieved soil sample was taken in a 100 ml beaker and 25 ml of distilled

water was added to it. The mixture was stirred for at least four times over half an hour so as to allow the soil and water to reach at equilibrium. In the meantime pH meter was calibrated by putting the electrodes into buffer solution of known pH and finally electrodes were washed with distilled water and dried with tissue paper. Before taking the reading, soil suspension was stirred and electrodes were dipped into it. The reading displayed on pH meter was recorded and electrode was rinsed after every sample reading. Soil suspension was kept control over night so that all the soil content will settle down. Then electrodes of electrical conductivity meter were dipped in the supernatant liquid and reading was noted which gave the electrical conductivity of the soil sample.

3. Available potassium: The available potassium was determined as per the method given by Jackson (1973). The processed soil sample (5 g) each were taken in 100 ml plastic bottles to which 25 ml ammonium acetate solution was added and were shaken on electric shaker for 5 minutes. The suspension was filtered through Whatman's No. 1 filter paper. The readings of the filtrate were taken on flame photometer.
4. Organic carbon: Organic carbon was determined by Walkley and Black's rapid titration method (Walkley and Black, 1947). In this method 0.5 g of processed samples was taken in a 250 ml conical flask, 10 ml of 1N $K_2Cr_2O_7$ solution was added and shaken gently to mix the content. After that 20 ml of concentrated H_2SO_4 was added while swirling the flask slowly. Flask was kept on dry tile for 30 minutes to acquire the room temperature as the reaction was exothermic and lot of heat was produced. After that 5 ml of ortho-phosphoric acid, 100 ml distilled water and 10 drops of di-phenyl amine as indicator was added and shaken again. Titration was done with 0.5N ferrous ammonium sulphate till the colour changes from violet to bright green through blue. Then volume of ferrous ammonium sulphate solution used for titration was measured. Similarly in blank (without sample) titration was also carried out.

Calculations:

$$\text{Organic carbon in soil (\%)} = \frac{(S-B) \times N \times 0.003 \times 100}{\text{Weight of the sample}}$$

S = ml of 0.5N ferrous ammonium sulphate used for soil sample

B = ml of 0.5N ferrous ammonium sulphate used for blank

5. Moisture: Soil moisture was determined by gravimetric method (Prihar and Sandhu, 1968). In this method fresh soil samples were taken and sealed at the site of collection in moisture boxes. The soil was weighed in moisture boxes (of known weight) and then kept in oven at $105^\circ C$. After two days, samples with zero per cent of moisture were weighed again. Moisture percentage was then determined by the following formula:

$$\text{Moisture percentage (per cent)} = (\text{loss in weight/oven dry weight}) \times 100$$

6. Available nitrogen: Available soil nitrogen was determined by potassium permagnate method (Subbiah and Asija, 1956). In this method 2 g of sieved soil sample was taken in the Kjeldahl's cylindrical tube and 25 ml of 0.32 per cent potassium permagnate and 20 ml of 2 per cent boric acid in a conical flask were added and both the cylindrical tube and the conical flask were placed in the Kjeldahl's assembly. After that 30 ml of 2.5 per cent sodium hydroxide was added into the cylindrical tube and the heat distills out ammonium

gas which was collected in the conical flask. The contents were titrated in conical flask against 0.02 N sulphuric acid till colour changed from green to pink. Similarly blank titration was carried out.

Calculations:

$$\text{Available Nitrogen (mg kg}^{-1}\text{)} = \frac{(\text{S}-\text{B}) \times \text{N} \times 0.04 \times 10^6}{\text{W}}$$

N = Normality of acid

S = ml of 0.02N H₂SO₄ used for soil sample

B = ml of 0.02N H₂SO₄ used for blank

W= Weight of soil sample.

7. Available phosphorus: The processed soil samples (2.5 g) were taken in a 125 ml Erlenmeyer flask. 50 ml (0.5 N) sodium bicarbonate (NaHCO₃) solution and a pinch of activated charcoal were added to the flask. The content was shaken for 30 minutes on a reciprocating shaker at 120 strokes per minute. The suspension was filtered on Whatman's No. 40 filter paper. Five ml aliquot of the extract was pipetted in a 25 ml volumetric flask. Then 5 ml of ammonium molybdate and 1 ml of working stannous chloride were added and final volume was made with distilled water. The colour intensity was then recorded at 660 nm on spectrophotometer. Blank was also run for final calculation (Olsen *et al.*, 1954).

Calculations:

Weight of soil =1 g

Volume of 0.5 M NaHCO₃ used = 20 ml

1st dilution =20/1

Volume of extractant taken = 10 ml

Final volume made = 50

Second dilution =50/10

Total dilution 20 × 5 =100

Available P (mg kg⁻¹) = A × 100 (A= reading on flame photometer)

8. Calcium and magnesium: a) Calcium: In 250 ml Erlenmeyer flask 10 ml of soil extract was added and diluted to 30 ml with double distilled water. 2 ml of NaOH (2N) and 50 mg of ammonium purpurate indicator was then added. The solution was then titrated with 0.01 N EDTA. The colour was changing from red to lavender-purple. Separately blank was also run containing all reagents but no soil.

Calcium plus Magnesium:10 ml of soil extract was transferred into a 250-mL flask and diluted to 30 ml with double distilled water. 3 ml buffer solution and 0.5 ml Erichrome black

indicator then added. The solution was then titrated with 0.01 N EDTA until the colour changed from red to blue.

Calculations:

$$\text{Ca (meq/100g)} = \frac{A \times 400.8 \times V}{V \times 20.04 \times 5 \times 10}$$

$$\text{Mg (meq/100g)} = \frac{B \times 400.8 \times V}{V \times 10 \times 1.645 \times 12.16}$$

Where,

A = Volume of EDTA (ml) used for calcium determination

B = Volume of EDTA (ml) used for calcium + magnesium determination

V = Total volume of sediment extract prepared (500 ml)

9. Heavy metals: The presence of heavy metals was determined by Lindsay and Norwell's method (Lindsay and Norwell, 1978) using DTPA extraction method with the help of atomic absorption spectrophotometer (AAS). In this method 10 g of sieved soil sample and 20 ml DTPA solution were taken in flasks and was shaken for two hours. After shaking, the contents were filtered through Whatman's filter paper no. 42 and crystal clear filtrates were collected in glass tubes and these were analyzed for detection of heavy metals viz., Pb, Cu, Ni, Cd, and Zn using AAS.

III. RESULTS AND DISCUSSION

3.1 Soil texture/particle distribution

Soil texture is a property of soil that does not change within a short period. The average clay, silt, and sand contents of soil were found as 24, 49, and 27% at the deforested site, 26, 50, and 24 % at the forest site, and 25, 50, and 25 % at the meadow site respectively. Using the USDA graph for the determination of soil textural classes, the soil under study from the experimental and control sites was found to fall in the silt clay loam class (Table 1).

Table 1: Soil texture of sampling sites

Site	Sand %	Silt %	Clay %	Class
Deforestrated	27	49	24	Silty clay loam

Forest	24	50	26	Silty clay loam
Meadow	25	50	25	Silty clay loam

3.2 Assessment of biotic stress on physicochemical parameters of soil

(i) Moisture (°C)

The soil from forest sites has higher moisture content followed by meadow and deforested sites. The moisture contents were in the spring and summer 24.178 ± 0.789 and 14.151 ± 0.468 at the forest site, 21.368 ± 0.497 and 11.808 ± 0.440 at the meadow, and 18.470 ± 0.573 and 9.011 ± 0.540 deforested sites respectively. Moreover, the moisture content was significantly higher ($P < 0.05$) in the spring as compared to summer at all three sites. This may be attributed to the high rate of precipitation during spring and more vegetation cover in the particular area (Joshi *et al.*, 2010; Faruqi *et al.*, 2013, Shah and Jeelani, 2015).

(ii) pH and Electrical Conductivity (dS/m)

The soils at the forest site have lower values of pH compared to the other sites. The mean pH values of soil at the forest, meadow, and deforested sites were 6.440, 6.546, and 6.970 respectively. Furthermore, the mean value of pH was significantly higher in the summer at the deforested site, while at meadow and forest sites the pH values were significantly higher in the spring. The increase in pH in the deforested area is attributed to the decrease in organic matter accumulation which directly depends upon the forest cover. The increase in pH can also be attributed to decrease in accumulation and subsequent slow decomposition of organic matter, which releases acids (de Hann, 1977). The electrical conductivity (EC) of soils was found significantly higher ($P < 0.05$) at the deforested site as compared to the meadow and forest sites (Table 2). The observed values of EC in the spring and summer were 0.217 ± 0.001 and 0.322 ± 0.002 at the deforested site, 0.165 ± 0.003 and 0.284 ± 0.001 at the meadow site, and 0.147 ± 0.001 and 0.222 ± 0.001 at the forest site respectively. Highest pH and electrical conductivity near to the deforested and meadow sites could be due to decline of forest flora (Grigalaviciene *et al.*, 2005; Joshi *et al.*, 2010; Das and Dkhar, 2011 and Shah and Jeelani, 2015).

(iii) Organic Carbon (%)

The % organic carbon in forest soils was significantly higher ($P < 0.05$) as compared to the other two sites. The mean value of 2.226 % organic carbon was observed at the forest site, 1.996% at the meadow, and 1.496% at the deforested site. The observed % organic carbon values were significantly higher ($P < 0.05$) in the summer at all the three sites. This may be due to the

presence of dense vegetation and high temperature during the summer, which leads to the more accumulation and decomposition of litter fall. Lesser contents of organic carbon in deforestrated area and higher in forest area may be the result of differential accumulation and decomposition of litter (Joshi *et al.*, 1993 and Joshi *et al.*, 2010).

(iv) Assessment of biotic stress on nutrient status of soil

The maximum means value of available nitrogen and potassium was found at the forest site (327.66 and 202.560 mg.kg⁻¹) respectively, while phosphorus, calcium, and magnesium contents showed a marked increase at the meadow site (22.416, 515.67, and 71.632 mg.kg⁻¹). Moreover, the concentration of all the available nutrients was significantly higher ($P < 0.05$) in the summer. Furthermore, the deforested site had a minimum concentration of all the available nutrients. The higher concentration of available nitrogen in the forest area may be due to the high concentration of organic matter in the form of leaf foliage. The decrease in available nitrogen in the deforested area may be due to deforestation, grazing, and tourism which is proportional to the decrease in organic matter and the latter being the bank of soil nitrogen. Verma *et al.* (2005) and Zargar *et al.* (2005) also reported a significant decrease in available nitrogen in degraded forests, Singh (2004) reported medium to high available nitrogen content in forest soils of Kashmir Valley (Bogomolov *et al.*, 1996; Joshi *et al.*, 2010; Das and Dkhar, 2011 and Shah and Jeelani 2015).

. In the present study, a significant decrease ($P < 0.05$) in available potassium was recorded in the deforested area. The data revealed that the forest area was having higher potassium contents as compared to the meadow and deforested areas. Furthermore, the soil potassium concentration was highest (187.770 mg/kg) in summer and lowest in spring (150.892 mg/kg), this may be due to the high-temperature conditions during the summer, which enhances the more availability of potassium in soil due to various chemical processes. The decrease in potassium content in the disturbed areas could be probably due to the decrease in the forest litter under degraded conditions. Basumatary and Bordoloi (1992) and Boruah and Nath (1992) found that a layer of organic matter significantly improves the retention of potassium in the soils. Moreover, disturbed area (deforested conditions) enhances the rate of leaching of minerals (i.e. K⁺) and possibly decreases the concentration of available potassium in the soil. This may be the reason for less content of potassium in the deforested area and high in the forest area. These findings are following Singh (2004), Zargar *et al.* (2005), Chaudhari (2013), and Shah and Jeelani (2015). Ghiri *et al.* (2011) reported that the distribution of the different potassium forms in the soils varied considerably. This variation may be attributed to the differences in the chemical properties of the soils and possibly the extent to which potassium salts in the different soil series have leached.

Phosphorus is an essential macronutrient because of the relatively large amount of phosphorus required by plants. Much of the phosphorus in the soil is not available to plants as it is influenced by soil reaction (pH) and a normal pH (6-7) promotes the most availability of phosphorus to plants (Kimura *et al.*, 2009). Phosphorus availability was strongly influenced by

soil pH. Furthermore, the soil phosphorus concentration was highest (24.638 mg/kg) in summer and lowest in spring (12.116 mg/kg), this may be due to the high-temperature conditions during the summer, which enhances the availability of phosphorus in soil due to various chemical processes. The lower pH in the forest area may be the reason for the low availability of phosphorus in the forest area. It has been reported that a large proportion of phosphorus is stored in the unavailable forms (Murphy and Riley 1958), for example, H_2PO_4 , which becomes available at low pH values and suffers from fixation by hydrous oxides and silicate minerals (Soromessa *et al.*, 2004). The soil pH is an important factor for phosphorus availability and maximum availability was reported in the range of pH 6 to 7 (Tisdale *et al.*, 1997). Singh (2004), Chaudhari (2013), and Rasool *et al.* (2014) also observed that the available phosphorus in the forest soil increases with an increase in pH i.e. towards neutral (6-7).

In the present study significant ($P < 0.05$) increase in calcium and magnesium was recorded at the meadow site. The data revealed that the meadow site as having higher calcium and magnesium contents as compared to the forest and deforested areas. Calcium and magnesium contents showed a marked increase at the meadow site (515.67 and 71.632 mg/kg respectively) followed by forest and deforested sites. Furthermore, the soil calcium and magnesium concentrations were highest (472.39 mg/kg and 66.244 mg/kg) in the summer and lowest in the spring (362.16 mg/kg and 42.072 mg/kg), this may be due to the high-temperature conditions during summer, which enhances the availability of calcium and magnesium in soil due to various chemical processes and nutrient uptake by plants. The increase in calcium and magnesium at the meadow site might be due to the decomposition of litter while the subsequent decrease at the forest and deforested sites may be due to leaching and uptake by plants (Richter and Markewitz, 2001).

(V) Assessment of biotic stress on heavy metal analysis of soil

The result depicts the impact of biotic stress on the heavy metal status of soil at three sites viz., deforested, forest, and meadow sites. The average value for copper contents showed a remarkable increase at the meadow site (7.67 mg.kg^{-1}), the forest (7.17 mg.kg^{-1}), and the deforested site (4.57 mg.kg^{-1}). The average nickel, cadmium, manganese, and lead contents were higher at the meadow site (1.53, 0.74, 6.47, and 0.86 mg.kg^{-1} respectively), deforested site (1.17, 0.58, 5.00, and 0.69 mg.kg^{-1} respectively), and forest site (0.79, 0.43, 5.00, and 0.43 mg.kg^{-1} respectively). The available zinc contents were found significantly ($P < 0.05$) higher at the meadow site (4.45 mg.kg^{-1}), the forest site (4.02 mg.kg^{-1}), and the deforested site (2.38 mg.kg^{-1}). The heavy metal accumulation was significantly ($P < 0.05$) higher in the summer. The increased heavy metal contents may be due to an increase in tourism and transport in the meadow area. Furthermore, the high rate of exhausts, wear, and tear of motor vehicle tires, and tourism pressure could have added a high degree of heavy metal contamination to the soil (Paggotto *et al.*, 2001). Weckwerth (2001) has reported that roadside soil contains a high percentage of heavy metal contamination. Kord *et al.* (2010) also reported that the highest and the lowest metal content were found in the heavy traffic zone and low traffic zone respectively. High levels of

heavy metals were found at the nearest point to the highway (Garcia and Millan, 1994). Heavy metals (Zn, Fe, Cu, and Ni) showed an increasing trend in their contents with increased urbanization and transportation (Aksoy and Ozturk, 1996). The present results were in agreement with those of Asksoy and Ozturk (1996), Paggotto *et al.* (2001), Wreckwerth (2001), Petrova *et al.* (2014), and Panda and Dhal (2015).

(VI) Total bacterial count in soil

The most important role of soil microorganisms in the ecosystem is to cause the decomposition of organic matter, synthesize it, and release them into inorganic forms that plants can use (Setiadi, 1989). Most microbes in the terrestrial ecosystem are present in the soil. Bacteria are the most dominant group of soil microbes. It was observed that the total viable bacteria in the soil was significantly higher at the forest site followed by the meadow and deforested sites. The observed values for total viable bacteria in the summer and spring seasons were $217 \pm 1.46 \times 10^6$ and $197 \pm 1.78 \times 10^6$ CFU.g⁻¹ at the forest site, 169 ± 0.94 and $152 \pm 0.79 \times 10^6$ CFU.g⁻¹ at the meadow site, and $109 \pm 0.74 \times 10^6$ and $98 \pm 0.67 \times 10^6$ CFU.g⁻¹ in the deforested site. The total mean microbial count was significantly ($P < 0.05$) higher in summer as compared to the spring (149×10^6 and 165×10^6 CFU.g⁻¹) because of the higher amount of organic carbon present at the forest site followed by the meadow site and also higher temperature favors decomposition of forest litter (Ogunmwonyi *et al.*, 2008). Also, low level of microbial population and activity due to the deforestation and degradation of natural tropical forests was reported by several authors (Sahani and Behera, 2001; Hossain *et al.*, 2010;)

CONCLUSION:

The impact of biotic stress results from the degradation of physicochemical parameters of the soil among deforested and meadow (soil) due to deforestation and enhanced anthropogenic activities as compared to forest sites. Poor soil health and the reduction in vegetation cover due to various factors make the soils prone to erosion but also lead to the loss of major plant nutrients by leaching. High nutrient levels at the forest site are due to nutrient regeneration from fallen leaves, twigs, buds, flowers, animal excretal, decaying roots, etc. Therefore, the conservation of forest vegetation is crucial for maintaining soil health in tourist destinations as it mitigates the damage caused by deforestation and anthropogenic activities.

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Table 2: Assessment of biotic stress on physicochemical parameters of soil at

Parameters	Site	Season		Mean	C.D (P≤0.05)
		Spring	Summer		
Moisture content (%)	Deforestrated	18.470±0.573	9.011±0.540	13.740	Sites (S): 0.446
	Forest	24.178±0.789	14.151±0.468	19.165	Season (S): 0.364
	Meadow	21.368±0.497	11.808±0.440	16.588	Sites × Season (S × S): 0.81
	Mean	21.338	11.657		
pH	Deforestrated	6.913±0.024	7.026±0.022	6.970	Sites (S): 0.014
	Forest	6.700±0.014	6.181±0.017	6.440	Season (S): 0.011
	Meadow	6.813±0.013	6.280±0.014	6.546	Sites × Season (S × S): 0.025
	Mean	6.808	6.496		
Electrical conductivity (dS/m)	Deforestrated	0.217±0.001	0.322±0.002	0.269	Sites (S): 0.001
	Forest	0.147±0.001	0.222±0.001	0.185	Season (S): 0.001
	Meadow	0.165±0.003	0.284±0.001	0.224	Sites × Season (S × S): 0.002
	Mean	0.176	0.276		
Organic carbon (%)	Deforestrated	1.426±0.060	1.566±0.055	1.496	Sites (S): 0.054
	Forest	1.855±0.041	2.598±0.099	2.226	Season (S): 0.044
	Meadow	1.706±0.033	2.286±0.058	1.996	Sites × Season (S × S): 0.098
	Mean	1.662	2.150		

The data are given in Mean±Standard Error of 6 replicates.

Table 3: Assessment of biotic stress on available nutrients (mg/kg) in the soil at different sites

Parameters	Site	Season		Mean	C.D (P≤0.05)
		Spring	Summer		
Nitrogen (N)	Deforestrated	160.19±4.13	194.76±1.12	177.47	Sites (S): 8.861
	Forest	295.18±1.82	360.15±25.63	327.66	Season (S): 7.235
	Meadow	280.38±0.39	300.86±1.24	290.62	Sites × Season (S × S): 16.096
	Mean	245.25	285.25		
Phosphorus (P)	Deforestrated	8.700±0.303	16.983±0.813	12.841	Sites (S): 0.664
	Forest	21.766±0.674	26.983±0.990	19.875	Season (S): 0.542
	Meadow	14.883±0.617	29.950±1.122	22.416	Sites × Season (S × S): 1.206
	Mean	12.116	24.638		
Potassium (K)	Deforestrated	94.865±1.802	132.125±0.928	113.495	Sites (S): 1.582
	Forest	183.783±2.411	221.033±0.997	202.560	Season (S): 1.292
	Meadow	124.030±3.183	209.866±1.027	191.948	Sites × Season (S × S): 2.874
	Mean	150.892	187.770		
Calcium (Ca)	Deforestrated	284.623±5.731	360.413±5.726	322.51	Sites (S): 14.366
	Forest	336.126±15.787	491.126±23.661	413.65	Season (S): 11.73
	Meadow	465.700±24.389	565.646±11.951	515.67	Sites × Season (S × S): 26.096
	Mean	362.15	472.39		
Magnesium (Mg)	Deforestrated	23.928±2.569	43.420±1.983	33.674	Sites (S): 2.080
	Forest	44.813±3.289	63.526±2.053	54.170	Season (S): 1.698
	Meadow	57.476±1.903	85.786±2.070	71.632	Sites × Season (S × S): 3.778
	Mean	42.072	66.244		

The data are given in Mean±Standard Error of 6 replicates

Table 4: Assessment of biotic stress on heavy metal status (mg/kg) in the soil at different sites

Parameters	Site	Season		Mean	C.D (P≤0.05)
		Spring	Summer		
Copper (Cu)	Deforestrated	3.25±0.49	5.88±0.52	4.57	Sites (S): 0.634
	Forest	6.49±0.34	7.85±1.21	7.17	Season (S): 0.518
	Meadow	4.76±0.47	10.67±1.15	7.67	Sites × Season (S × S): 1.152
	Mean	4.84	8.19		
Nickel (Ni)	Deforestrated	1.06±0.58	1.28±0.54	1.17	Sites (S): 0.515
	Forest	0.77±0.47	0.82±0.95	0.79	Season (S): 0.420
	Meadow	1.43±0.32	1.64±0.87	1.53	Sites × Season (S × S): 0.935
	Mean	1.08	1.25		
Cadmium (Cd)	Deforestrated	0.55±0.03	0.62±0.13	0.58	Sites (S): 0.085
	Forest	0.37±0.04	0.50±0.10	0.43	Season (S): 0.070
	Meadow	0.71±0.06	0.77±0.16	0.74	Sites × Season (S × S): 0.155
	Mean	0.54	0.63		
Manganese (Mn)	Deforestrated	4.76±04	5.25±10	5.00	Sites (S): 1.034
	Forest	5.61±05	6.30±09	5.95	Season (S): 1.018
	Meadow	6.03±02	6.92±06	6.47	Sites × Season (S × S): 2.052
	Mean	5.45	6.16		
Lead (Pb)	Deforestrated	0.55±0.03	0.83±0.13	0.69	Sites (S): 0.085
	Forest	0.37±0.04	0.50±0.10	0.43	Season (S): 0.070
	Meadow	0.77±0.06	0.95±0.16	0.86	Sites × Season (S × S): 0.155
	Mean	0.56	0.76		
Zinc (Zn)	Deforestrated	1.85±0.33	2.94±0.98	2.38	Sites (S): 0.952
	Forest	3.07±0.60	4.98±1.74	4.02	Season (S): 0.777
	Meadow	3.60±0.26	5.30±1.63	4.45	Sites × Season (S × S): 1.729
	Mean	2.84	4.40		

The data are given in Mean±Standard Error of 6 replicates

Table 5: Total viable bacteria CFU $\times 10^6$ g⁻¹ in soil

Sites	Season		Mean
	Spring	Summer	
Deforestrated	98 \pm 0.67	109 \pm 0.74	103.5
Forest	197 \pm 1.78	217 \pm 1.46	207
Meadow	152 \pm 0.79	169 \pm 0.94	160.5
Mean	149	165	

The data are given in Mean \pm Standard Error of 6 replicates

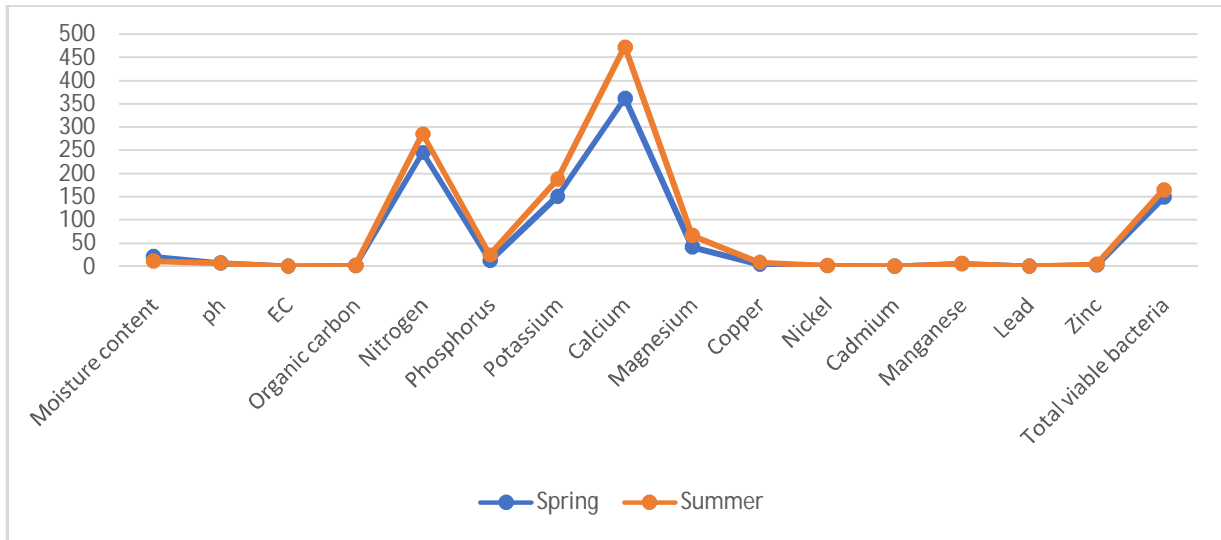


Fig. 1. Graphical representation of mean values of soil quality parameters at different seasons.

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