



Characterization of Soil Quality in Highway-Influenced Areas of Uttarakhand

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Abstract

Soil is a composite of biological and physical structures that give vital support to plants. The rocks' weathering process forms it. Soil plays a major role in providing facilities to our society, most importantly, food production. Soil comprises minerals, organic matter, water, and air that provide micronutrients for the finest growth and reproduction of animals and plants. Soil quality and health are defined as the volume of soil that functions as a vigorous living system within land-use borders. Highways navigate many agricultural areas, and they often have destructive effects on agricultural soils, including the modified stability of SOM. Here, we analyse the physicochemical properties of the soil of Udham Singh Nagar district of Uttarakhand, India. Few samples were collected along the road in the Udham Singh Nagar district, based on distance from the highway, and analysed for their physicochemical properties. The current study will assist the farmers in understanding soil quality and what fertilisers or manures need to be added to their soil for worthwhile productivity.

Keywords: Agricultural land; Highway construction; Organic carbon; Soil chemistry, Soil pollution.

1. Introduction

The word soil came from the Latin word 'solum', which means earthly material in which a plant grows (Hu J. et al., 2013). There are five main groups based on the bonding characteristics of elements that soil contains. Lithophile elements for example Li to Zn, rare earth and halogens, Chalcophile elements, for example, Fe to Te, and As, etc, Siderophile elements, for example, Fe to Os, and Au (accomplished of establishing metabolic bonds), Atmosphere elements, for example, O to Ar incline to persist in atmospheric gases, Biophile elements which are accompanying by living organisms such as C, H, O, N, and V, etc (Kaur H., 2018). Our agricultural land is affected by major urbanisation. Construction sites have already replaced huge agricultural areas and converted them into roads, living buildings, offices, company sites, or marketplaces. Continuous use of chemical fertilisers slowly changes soil properties; eventually, production in the long run is reduced. It has resulted in the leakage of chemicals into the surface and groundwater (Kupka D. et al 2021) (Singh P. et al., 2022). Due to the increasing demand for cash

harvests, monoculture cropping patterns have further helped to deteriorate water and soil quality (Raut R. et al. 2020). The richness of the plant nutrient exchangeable bases Mg⁺⁺, Na⁺, K⁺, and Ca²⁺ rises with closeness to roads. Soil colour can be symptomatic of the chemistry of soil and, consequently, the impact of closeness to roads. Humus and clay minerals usually deepen soil and can increase CEC through an increase in colloidal surfaces. Iron oxides generally impart red hues on soil (Kamal R. et al., 2023). In recent years, highways have crossed many agricultural areas, often having harmful effects on agricultural soil, including the modification of soil organic matter (SOM) stability. Naturally, soil properties can be described as follows:

1.1. Soil Components

Soil is a mixture of weather-beaten rocks, existing organisms, organic material, nutrients, water, and air. It consists of four major components:

1.2. Soil Texture

The international system used to name soil texture, which is generally followed in India, is as follows:

Table 1 Major Components of Soil

Components	Percentage
Mineral matter	45%
Organic matter	05%
Soil water	25%
Soil air	25%

(Sahai V.N., 2012)

Table 2 International System of Naming Soil Separates

Particle size	Soil type
Below 0.002mm	Clay
0.002-0.05mm	Silt
0.05-0.20mm	Fine sand
0.20-2.00mm	Coarse sand

(Sahai V.N., 2012)

The texture of the soil is delineated by the relative amounts of sand (0.05 to 2mm Particle size), clay (less than 0.002mm), and silt (0.002 to 0.05mm). In texture class, particles bigger than 2mm and coarse fragments like stones, pebbles, and boulders are not included (Thien S.J., 2011).

1.3. Soil Tint and Colour

We can see soil around us in various colours with several tints and shades. These shades of soil are due to the presence of various elements in it. Some of them are harmful, while most of them are beneficial for plant growth and reproduction. These elements are iron, lime, manganese, and organic matter, etc. (Kupka D. et al., 2021). Based on colour, soil is of the following types:

- White colour- due to the excess of calcium carbonate.
- Bluish and greenish colour- due to the presence of a ferrous compound in the soil.
- Black and dark grey colour- due to organic matter present in the soil.
- Red-yellow colour- due to the richness of iron oxide, soil occurs in red colour while hydrated compounds turn it into a yellow shade (Sahai V.N., 2012).

1.4. Cation Exchange in Soil

It is a measure of soil fertility and indicates

the health of the soil to retain nutrients for plants. Cations are positively charged ions, such as magnesium (Mg^{2+}), calcium (Ca^{2+}), potassium (K^+), hydrogen (H^+), ammonium (NH_4^+), and sodium (Na^+). (Kaur H., 2018)

In most of the available studies, soil characteristics in surface soil have been measured, not the whole profile. To evaluate the sustainability/unsustainability of diverse management practices simultaneous analysis of the physical, biological, and chemical characteristics of soil is required. Most studies in emerging countries have looked at chemical and physical characteristics only. (Laishram J. et al., 2012)

Soil can be tested on two parameters – Physical parameters and Chemical parameters. Both parameters are very significant in distinguishing between fertile and non-fertile soil.

- Physical Parameters: Soil moisture, water holding capacity, Porosity, Texture
- Chemical parameters: Electrical conductivity (EC), pH, Organic carbon (OC), Macronutrients (Chloride, Phosphorus, Nitrogen, Magnesium, Calcium) and Micronutrients (Copper, Zinc, Manganese, Iron) (Bao W. et al., 2024)

Some studies recognised the harmful effects of vehicle transportation on the environment and human health (WHO, 2005). An extensive range of contaminants, among which heavy metals (HM), polycyclic aromatic hydrocarbons (PAH), de-icing salts (DS), and total petroleum hydrocarbons (TPH) are included, are generated by Motor vehicles. (Nikolaeva O. et al., 2021) The adverse effects of HM on human health include the ability to promote blood, neurological, and respiratory diseases, as well as cancer (report, 2004).

2. Method

We analysed soil samples collected at a depth of 15-25 cm from different plots in the region of Udham Singh Nagar (Uttarakhand) to determine the effect of highways on the above two parameters of soil.

2.1. Soil Sampling

Soil samples were collected with the help of a hand-skew auger. Firstly, we collect 10-15 sub-samples in

a zig-zag pattern. Mix every sub-sample taken for a specific site with each other in a plastic container, then take the soil profile by using quartering and compartmentalisation methods for monitoring. After shade drying and complete aeration of samples, we brought them to Kshetriya Bhumi Parikshan Prayogshala, Rudrapur, for testing. Soil Samples and Their Location Six different soil samples, filled in the sample bags with their area name and their distance from NH 74, are as follows:

Table 3 Soil Sample Codes and Location

Area name	Sample code	Distance from the highway in metres
Uttam nagar	S1	50
Pulbhatta	S2	90
Kichcha	S3	10
Lalpur	S4	20
Rudrapur	S5	120
Daanpur	S6	150

2.2.Procedure

2.2.1. Testing of Organic Carbon:

Take 1 g of the soil sample in a flask and put 10 mL of 1N potassium dichromate in it while constantly stirring. Now add 10 ml conc. Sulfuric acid with 1 min smooth stirring, and put it on rest for 30 min. Add 200 ml of DDW to dilute it, and then pour 10 ml of Orthophosphoric acid (85%) into it. Add 1 ml diphenylamine indicator and titrate it with 0.5N ferrous ammonium sulphate till the colour changes into bright green.

$$\text{Total Organic Carbon(OC\%)} = (\text{Blank reading-burette reading}) \times 0.14$$

2.2.2. Testing of Potassium:

Take a 5 g soil sample and put 25 ml ammonium acetate solution (77 g/1000ml with SDD) with a pipette. Keep it in an electronic shaker for 10-15 minutes, then filter it with Whatman filter paper no. 1. Take the filtrate with a flame photometer and note the reading.

$$\text{Potash (kg/hect)} = \text{Flame photometer reading} \times 11.2$$

2.2.3. Testing of Sulphur

To find the tangent, draw a graph between sulfur working solutions and the absorbance reading of the

spectrophotometer. Now take a 10 g soil sample in a flask and put 20 ml of CaCl₂ in it, and put it in an electrical shaker for 30 min. After that, filter it with Whatman filter paper. Now, take 10 ml of filtrate in a flask and add 5 ml of barium chloride to it. After 5 minutes, pour 1 ml of gum acacia solution into it and prepare up to 25 ml with DDW. Now use a spectrophotometer to take readings.

$$\text{Sulphur (ppm)} = \text{Reading} \times \frac{12.5}{\text{tangent}}$$

2.2.4. pH Testing

Take 10gm soil sample in a beaker and add 20 mL of DDW to it, stir it properly, and put it on rest for 30 min. Switch on the pH meter 10 min before taking the reading. After standardising it with buffer solutions, take the reading with the soil solutions.

2.2.5. Electrical Conductivity Testing

With the help of a 0.01N potassium chloride solution, standardise the EC meter. Take a 10 g soil sample in a beaker with 20 ml of DDW and stir it properly. By using the EC meter, note the reading.

2.2.6. Testing of Boron

Prepare a buffer solution by adding 250 g Ammonium acetate, 15 g E.D.T.A., and 125 ml acetic acid(glacial) in a beaker and bring it up to 1000 ml by adding DDW. Maintain pH up to 5.5. Now take 0.50 g Azomethyl-H and 1 g Ascorbic acid and prepare a solution up to 100 ml by adding DDW. Take a 20 g filtered soil sample with 40 ml calcium chloride in a beaker and put this mixture on a hot plate for 10-15 minutes till the mixture boils. Now filter it and take 2ml extract, 2ml buffer solution, and 1 mL Azomethyl-H in a beaker. To make a graph between the colourimeter's concentration and absorbance reading, take the reading of standard solutions with colourimeter 115 and find the tangent. After this, take readings of soil extracts.

$$\text{Boron (ppm)} = \text{Reading} \times \frac{\text{Tangent}}{5}$$

2.2.7. Testing of Phosphorus

Take 2.5 g of soil, 1 g of charcoal, and 50 ml of sodium bicarbonate in a flask and shake it for 30 min in a rotatory shaker. Filter it with a 1-number filter paper. Now take 5 ml filtrate in a volumetric flask and add 5 ml ammonium molybdate, 0.5 ml stannous chloride, and prepare a 25 ml solution by using DDW. Now test the prepared solution in a

colourimeter.

2.2.8. Testing of Micronutrients (Zn, Mn, Cu, Fe)

Prepare a working solution by adding 1.47 g of calcium chloride, 1.967 g of DTPA, and 13.3 mL of T.E.A. to 1 L of DDW. Take 10 g of soil and 20 ml of the working solution in a conical flask, and put it in a rotatory shaker for 2 hours. Then filter it and take the extract in a beaker. Test it with an atomic absorption spectrophotometer to note the concentration reading in ppm.

3. Results and Discussion

3.1. Results

After completion of the test in Kshetriya Bhumi Parikshan Prayogshala, Rudrapur, six soil sample results are mentioned below in six separate tables:

Table 4 Soil Test Results for S1

S.no	Parameter	Result	Analysis
1	Colour	Brownish-Black	
2	pH	7.2	Neutral
3	EC	1.83	
4	C	0.70%	M
5	P	21.36 Kg/h	M
6	K	105.39 Kg/h	L
7	S	19.65 Ppm	N
8	Zn	1.462 Ppm	M
9	B	0.23 Ppm	L
10	Fe	26.00 Ppm	M
11	Mn	11.23 Ppm	M
12	Cu	2.354 ppm	M

Table 5 Soil Test Results for S2

S.no	Parameter	Result	Analysis
1	Colour	Brownish-Black	
2	pH	7.19	
3	EC	1.75	
4	OC	0.63%	M
5	P	31.84 Kg/h	H
6	K	155.23 Kg/h	M
7	S	56.85 Ppm	H
8	Zn	2.076 Ppm	M
9	B	0.27 Ppm	L
10	Fe	13.13 Ppm	M
11	Mn	12.55 Ppm	M
12	Cu	1.864 Ppm	M

Table 6 Soil Test Results for S3

S.no	Parameter	Result	Analysis
1	Colour	Yellowish-brown	
2	pH	7.18	
3	EC	2.46	
4	OC	0.21%	VL
5	P	30.08 Kg/h	H
6	K	76.60 Kg/h	L
7	S	82.77 Ppm	H
8	Zn	1.612 Ppm	M
9	B	0.27 Ppm	L
10	Fe	18.87 Ppm	M
11	Mn	11.13 Ppm	M
12	Cu	2.354 Ppm	M

Table 7 Soil Test Results for S4

S.no	Parameter	Result	Analysis
1	Colour	Brown	
2	pH	7.2	
3	EC	1.69	
4	OC	0.42%	L
5	P	34.2 Kg/h	H
6	K	105.72 Kg/h	L
7	S	30.52 Ppm	H
8	Zn	1.566 Ppm	M
9	B	0.23 Ppm	L
10	Fe	15.14 Ppm	M
11	Mn	9.750 Ppm	M
12	Cu	2.326 Ppm	M

Table 8 Soil Test Results for S5

S.no	Parameter	Result	Analysis
1	Colour	Blackish-brown	
2	pH	7.2	
3	EC	2.00	
4	OC	0.56%	M
5	P	26.8 Kg/h	H
6	K	106.73 Kg/h	L
7	S	82.35 Ppm	H
8	Zn	2.202 Ppm	M
9	B	0.04 Ppm	VL
10	Fe	19.43 Ppm	M
11	Mn	9.5222 Ppm	M
12	Cu	2.12 Ppm	M

Table 9 Soil Test Results for S6

S.no	Parameter	Result	Analysis
1	Colour	Brown	
2	pH	7.2	
3	EC	2.15	
4	OC	0.70%	M
5	P	28.4 Kg/h	H
6	K	99.79Kg/h	L
7	S	16.72 Ppm	N
8	Zn	2.26 Ppm	M
9	B	0.32 Ppm	L
10	Fe	24.22 Ppm	M
11	Mn	10.57 Ppm	M
12	Cu	2.518 Ppm	M

3.2.Discussion

- Sample 1 contains a lower amount of potassium and boron levels with mild salinity.
- Sample 2 has moderate Potassium and organic matter with boron deficiency.
- Sample 3 shows high sulfur and phosphorus but very low organic carbon, low potassium and boron deficiency.
- Sample 4 has good phosphorus and sulphur content but low organic carbon, low potassium and boron deficiency.
- Sample 5 has good phosphorus and sulfur content, moderate organic carbon, but boron deficiency, low potassium, and moderate salinity.
- Sample 6 shows a balanced pH, moderate salinity, high phosphorus levels, but low potassium and boron availability.

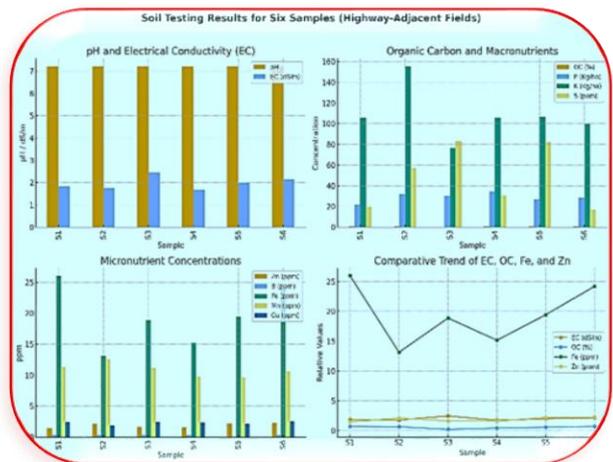


Figure 1 Graphical Presentation of Results

Conclusions

After the cohesive analysis of soil samples adjacent to the highway, we can recapitulate that most of the samples have boron deficiency, nutrient imbalance and organic matter depletion. To maintain crop production and environmental quality, nutrient management in such regions is very important. External contamination should be controlled, and maintenance of soil health is required in such regions to sustain long-term productivity. Biofertilisers and GM crops could be useful for better crop yield in



these areas.

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