

# Evaluation of Soil Health and Heavy Metal Status in Forest, Grassland, and Cultivated Soils of Chandrapur District, Maharashtra

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**Abstract:** *Agricultural productivity and environmental stability depend heavily on the health of the soil. The evaluation of soil health and heavy metal status in the farmed, forest, and grassland soils in Chandrapur District, Maharashtra, is the main objective of this study. In order to identify the content of certain heavy metals like manganese (Mn), iron (Fe), zinc (Zn), and copper (Cu), as well as important physical and chemical characteristics such as conductivity of electricity, organic carbon content, pH value, soil samples were gathered from various land-use systems. The findings showed significant differences in heavy metal contents between cultivated, grassland, and forest soils, suggesting the impact of human activity and land-use patterns. Forest soils had improved soil health because of their natural vegetation cover and organic matter content, whereas cultivated soils had comparatively greater levels of several heavy metals, presumably as a result of resources for farming such Pest control and fertiliser products. The properties of grassland soils were in the middle. Their function in regulating metal mobility and accumulation is highlighted by the relationship between soil characteristics and heavy metal availability. In addition to serving as a baseline for environmental monitoring and sustainable land management techniques in the Chandrapur District, this study offers insightful information about soil quality assessment.*

**Keywords:** Soil health, Heavy metals, Pesticides, Land-use systems, Anthropogenic influence.

## I. INTRODUCTION

An essential natural resource, soil promotes plant growth, controls the cycles of nutrients and water, stores carbon, and maintains biodiversity. Thus, the production of food, the health of the environment, and human welfare all depend on healthy soil [1-3]. The degradation or contamination of the soil reduces its potential to supply these services, resulting in decreased agricultural yields, the reduction of ecosystem functions, and increasing health risks [4].

Soil contamination by heavy metals has grown to be an essential global environmental concern in recent years. Although soils naturally contain heavy metals like Iron (Fe), Zinc (Zn), Copper (Cu), Manganese (Mn), Cadmium (Cd), Lead (Pb), Arsenic (As), Chromium (Cr), and Mercury (Hg), the actions of humans can significantly increase their concentrations [5,6,7,8]. While some metals (Cd, Pb, As, Hg, and Cr) are mostly harmful, others (Fe, Zn, Cu, and Mn) are essential micronutrients for plants in trace quantities. These substances can damage plants and soil organisms when they are present in excess of safe limits. They can also contaminate the food chain and put human and animal health at risk. [5,7, 9,10].

### Soil Health and Heavy Metals

The soil's capacity to function as a biological system that sustains plants, animals, and people while preserving environmental quality is called soil health [1,2,11]. Physical, chemical, and biological markers such as organic carbon, pH, and electrical conductivity, texture, nutrient content, and biological activity are typically used to estimate the overall wellness of the soil [1,3,4]. These characteristics not only show soil quality, but also control the absorption and absorption and migration of heavy metals in soil.



Among the most essential components are the pH of the soil; neutral to slightly alkaline. Situations can decrease the movement of the many metals, while acidic soils frequently improve their solubility and plant uptake [6,4]. Metals may be linked by organic carbon and clay minerals, which decreases their availability to plants and groundwater circulation [6,12,10]. This indicates that the risk posed by heavy metals rely not just on their overall quantity as well as on the characteristics of the soil that affect how readily they can be absorbed by plants or leached from the soil [4, 6,12].

Heavy elements inhibit plant both physical and biological functions, such as photosynthesis, respiration, enzyme activity, and nutrient uptake, when they build up to hazardous levels in agricultural soils. This eventually lowers crop growth and production [5,6]. However, metals Crop-absorbed substances can enter human diet and cause a number various medical conditions, such as kidney damage, neurological conditions, cancer, and cardiovascular disease [5,7, 9,10].

### **Sources of Heavy Metals in Different Land Uses**

Natural as well as man-made sources can introduce heavy metals into soils. Volcanic activity and the weathering of parent rock material are examples of natural sources that discharge metals into the soil over extended time intervals [10,7]. However, human activity is primarily responsible for the rapid increase in soil metal contamination in recent decades, including the application of chemical insecticides, agricultural fertilisers, and manures based on sewage sludge in agriculture; smelting, mining, and emissions from industrial processes; fossil fuel combustion-related vehicle exhaust and atmospheric deposition; and waste disposal and wastewater irrigation [5,6,12,9,10,13].

The quantities and transportation of hazardous metals in soil have significantly impacted by land use and management methods as a result of these activities. Due to recurrent inputs from fertilisers, insecticides, manures, and irrigation water, agricultural (cultivated) soils frequently exhibit increased concentrations of various metals [5,6,12]. On the other hand, natural vegetation and leaf litter cover forest soils, which assist retain higher organic content and better structure, and they frequently get less direct inputs of agricultural products [14,1,2]. Depending on grazing intensity and management, grassland soils usually lie in the middle of these two extremes [15-16].

Significant variations in soil metal concentrations and contamination risk are commonly reported in comparative studies across land use types, reflecting variations in plant cover and human disturbance [4,17,15,16]. For instance, agricultural inputs and dust deposition may cause farmlands and rangelands to accumulate Cd, Pb, and As, while certain wetland or marshland soils exhibit higher levels of Fe, Zn, Cu, and Ni due to hydrological circumstances and upstream sources [15]. While comparatively unaffected natural regions display values closer to geochemical background levels, mining and industrial sites typically display the highest levels of pollution [12,18,17].

### **Importance of Evaluating Soil Quality and Heavy Metals**

Evaluating the current state of heavy metals and soil health is important under various land uses for a number of reasons. First, it aids in separating anthropogenic enrichment from natural background levels, enabling the identification of regions where pollution has been greatly increased by human activity [12,10,17]. Second, as per these elements regulate metal mobility and plant availability, connecting metal levels with soil characteristics (pH, organic carbon, etc.) enables a more accurate evaluation of actual issues related to health and the environment [6,12,4]. Third, land use-based comparisons give governments and land managers useful information about which systems are most susceptible to pollution and where management adjustments are most necessary [4,1,2,15].

Monitoring metals such as Fe, Zn, Cu, and Mn is crucial in agricultural areas due to their potential toxicity as well as the fact that they are necessary nutrients that can damage crops in both excess and deficit [5,6]. In addition to supporting sustainable fertiliser recommendations, establishing local baseline data for these components and other soil health indicators helps stop the long-term buildup of hazardous metals in the dietary chain [5,9,3]. Soil quality evaluations support the preservation of biodiversity, carbon storage, and water regulation in forest and grassland ecosystems, all of which are essential to climate and conservation objectives [1,2,11].



**Justification for the Present Study**

Because of agricultural development, forest resources, and other human activities, the Chandrapur District in Maharashtra is made up of a patchwork of grasslands, woods, and cultivated areas. Population increase, intensive farming, and potential industrial emissions may have an impact on soil quality and lead to Heavy metal buildup in various land use systems, such as the case in many regions of India [18,12,19]. However, there is frequently a lack of comprehensive, site-specific data on heavy metal status and soil health indicators across these land uses.

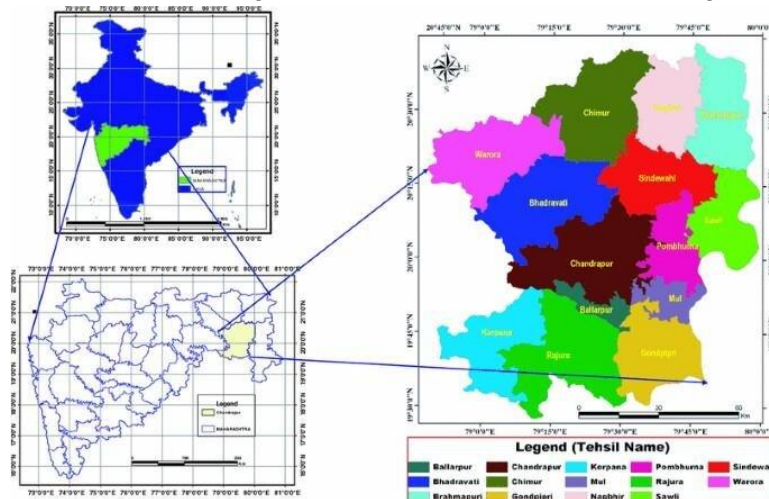
In forest, grassland, and farmed soils, a methodical assessment of pH, electrical conductivity, organic carbon, and specific heavy metals (Fe, Zn, Cu, and Mn) can help compare soil health among these major land use types, reveal how land use and management influence heavy metal accumulation, clarify relationships between soil properties and metal availability, and provide a baseline dataset for sustainability lands management strategy and continuous environmental surveillance in the district [12,4,1,15,16]. Such information is essential for designing measures to maintain soil fertility, protect ecosystem services, and minimize hazards to human health as well as the environment in Chandrapur and similar regions.

**II. STUDY AREA**

Located in the Coalfield and covering in the Wardha Valley approximately 11,364 km<sup>2</sup>, Chandrapur region in eastern Vidarbha (Maharashtra) is a significant hub for coal mining, thermal power, industry, and agriculture [20]. Between 1991 and 2011, industrialisation and urbanisation led to a decrease in thick and open forest and an increase in mining, farming, and built-up area. Land use mapping reveals huge areas under cultivated land, forest, settlements, and mining/overburden dumps [20]. The region has basalt-derived black soils and a monsoonal climate, with environmental pressure from mining, deforestation and changing rainfall patterns [20-21].

In the Wardha Valley coalfield, Chandrapur (11,364 km<sup>2</sup>) is a coal and agricultural district where, in recent decades, mining, cultivation, and settlements have grown as the forest has decreased [20].

The 1,028.9 km<sup>2</sup> Warora Taluka is primarily rain-fed agricultural terrain with black soils, a sizable rice field, and a significant chance of soil erosion, necessitating conservation and better soil-fertilizer management [21-23].



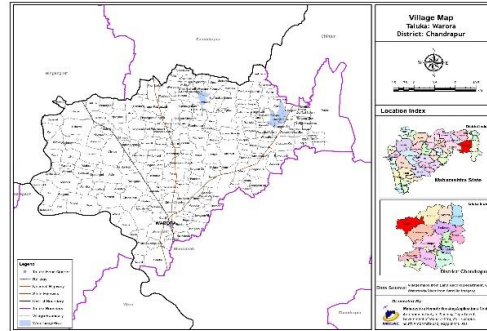
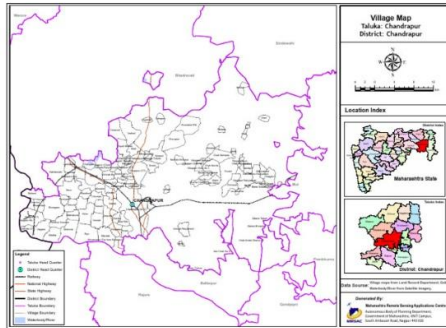
**Fig. 1 Chandrapur district of Maharashtra, India Map. (www.google.com)**

**III. MATERIALS AND METHODS**

Twelve soil samples from six distinct areas—forest, grass, and cultivated land—in the Chandrapur and Warora tehsil in the Chandrapur District of Maharashtra are analysed in this study. The soil samples had been collected separately in polythene bags in accordance with the laboratory manual and standard methods that were advised [24,25,26]. A spade or khurpi was used to collect soil samples, and V-shaped holes were drilled at depths between 0 to 15 cm and 15 to 50 cm



to obtain a consistent 2 cm thick slice of soil. A plastic bucket was used to gather the soil. On a fresh piece of cloth, the samples were rolled and turned to completely mix them. After allowing them to air dry in the shade, dirt clods were broken up using a pestle and mortar. A 2 mm stainless steel mesh was used to filter the entire amount. After sieving, the coarse material that remained was crushed and sieved once again. Organic wastes and stones were thrown away. In the end, twelve samples of soil were gathered, put in sterile plastic bags, and brought to the lab for additional examination.



**Fig. 2 Chandrapur district of Chandrapur Taluka Map Fig. 3 Chandrapur district of Warora Taluka Map**

A pH meter measures the pH of the soil, while a conductivity meter measures electrical conductivity (EC) in a soil: water suspension (usually 1:2.5 or 1:5) [29,30,31,32]. By oxidising organic matter with potassium dichromate in an acidic environment to produce a green chromium (III) complex whose absorbance is then measured, soil organic carbon (OC) can be detected spectrophotometrically [33]. Available nitrogen in Nitrogen analysers based on the Dumas combustion method, which combines dry combustion and thermal conductivity detection, can measure soil quickly and precisely, providing a quicker analysis than conventional Kjeldahl methods [34,35]. Modern nitrogen analysers automate sample processing, enabling high-throughput and precise nitrogen determination with minimal labour and environmental hazards [35,36]. In neutral to alkaline soils, accessible phosphorus (P) is extracted using Olsen's sodium bicarbonate method; in acidic soils, Bray's method is used, colorimetric measurement follows next [37,30,38,39]. Available potassium (K) is removed using neutral 1 M ammonium acetate and measured using flame photometer [37,30,38,40]. Atomic absorption spectroscopy (AAS) is a popular technique for finding heavy metals that involves atomising the sample and calculating the light's intensity that the metal atoms absorb at particular spectrums [41-42].

**Table 1: Soil Nutrient Index for organic carbon (OC) under Different Land Use Systems**

Land Use System	OC Nutrient Index	Status
Forest Soil 🌳	2.3 – 2.8	High
Grassland Soil 🌾	1.8 – 2.3	Medium
Cultivated Soil 🌱	1.3 – 1.8	Low to Medium

**IV. RESULTS AND DISCUSSION**

The physicochemical characteristics and nutritional status of soil samples taken from the Warora and Chandrapur regions under various land-use systems varied significantly throughout depths, according to the analysis.



**Table 2: Chemical properties of different Soil**

Area	Sample Type	Depth	pH	EC (ds/m)	OC (%)	N (kg/ha)	P (kg/ha)	K (kg/ha)	Zn (mg/kg)	Mn (mg/kg)	Cu (mg/kg)
Warora	Forest Land	0–15 cm	6.33	0.31	0.6	280.1	18.9	355.2	0.8	382.1	1.6
		15–50 cm	6.71	0.25	0.5	190.69	12.2	306.36	0.6	253	1.2
	Grass Land	0–15 cm	7.31	0.37	0.3	220.9	15.1	320.6	0.7	289	1.8
		15–50 cm	7.48	0.29	0.4	189.1	10.6	285.7	0.5	245.4	1
	Cultivated Land	0–15 cm	6.74	0.42	0.2	215.36	23.3	307	0.6	261.23	1.5
		15–50 cm	7.14	0.36	0.3	150.28	15.4	268.23	0.4	225	0.8
Chandrapur	Forest Land	0–15 cm	5.8	0.26	0.7	300.14	16.8	380.96	0.9	351.37	1.8
		15–50 cm	6.03	0.18	0.6	235.29	13.2	336.82	0.6	319	1.4
	Grass Land	0–15 cm	6.63	0.31	0.2	255.05	14	342.4	0.7	296.5	1.3
		15–50 cm	7.11	0.22	0.2	170.89	10.2	315.61	0.5	270.12	1
	Cultivated Land	0–15 cm	6.72	0.48	0.1	246.04	22.3	310.52	0.6	310.1	1.3
		15–50 cm	7.14	0.36	0.3	176.27	16	281.2	0.4	230.26	0.9

**pH:** The soil's pH ranged from 5.8 to 7.48, suggesting a moderate acidity. to neutral conditions. Because of the decomposition of organic materials and base leaching, the pH of Chandrapur's forest soils was lower than that of grassland and cultivated soils, particularly in deeper layers. The pH was found to gradually rise increasing depth.

**Electrical conductivity (EC):** Electrical conductivity (EC) ranged from 0.18 to 0.48 dS/m, indicating that the soils were appropriate for agriculture and were not salty. Forest soils had lower EC because of little disturbance, while cultivated soils had somewhat greater EC because of fertiliser and irrigation inputs.

**Organic carbon (OC):** The amount of organic carbon (OC) varied from 0.1% to 0.7%, with the highest values found in forest soils as a result of litter buildup and the lowest in cultivated soils as a result of oxidation and biomass removal. In all land-use schemes, OC declined with depth.

**Available Nitrogen (N):** The range of available nitrogen (N) was 150.28 to 300.14 kg/ha; forest soils had higher values because of more organic matter and mineralisation, whereas cultivated soils had lower levels, particularly at depth, suggesting depletion from ongoing cropping. Nitrogen was typically in the low to medium range and declined with depth.

**Available Phosphorus (P):** The amount of available phosphorus (P) varied from 10.2 to 23.3 kg/ha; farmed surface soils had higher levels because of fertiliser application, whereas forest soils had lower levels; phosphorus's low mobility and fixation caused it to decrease with depth.

**Available Potassium (K):** The range of available potassium (K) was 268.23 to 380.96 kg/ha; forest soils had greater values because of mineral weathering and residue recycling, whereas cultivated soils had comparatively lower levels due to crop removal; potassium marginally declined with depth.

**Micronutrient Analysis:** According to micronutrient analysis, the ranges for zinc, manganese, and copper were 0.4 to 0.9 mg/kg, 225 to 382.1 mg/kg, and 0.8 to 1.8 mg/kg, correspondingly. Due to increased organic matter and reduced losses, forest soils had higher levels of micronutrients, but cultivated soils had relatively lower levels, particularly zinc, which indicated depletion from intensive farming. Because micronutrients are associated with organic materials on the surface, their content decreases with depth.

While cultivated soils displayed nutrient depletion as a result of ongoing agricultural practices, forest soils generally demonstrated improved soil health with increased concentrations of micronutrients, nitrogen, potassium, and organic matter. The fertility levels of grassland soils were modest.

## V. CONCLUSION

According to the study, soil characteristics and nutrient availability in Warora and Chandrapur are heavily impacted by soil depth and land use. Because of constant cropping, farmed soils had lower fertility than forest soils, which had increased concentrations of micronutrients, potassium, nitrogen, and organic matter. The fertility of grassland soils was



moderate.

The majority of soils were non-saline, slightly acidic to neutral in pH, and favourable for plant growth; nutrient levels declined with depth. Low to medium nitrogen levels, however, point to the need for improved Nutrition control techniques, like balanced fertilisation and naturally additions, to preserve soil health.

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