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A Review on the role of soil physico-chemical properties for soil quality improvement and sustainable agriculture

Vaibhav More, Pradip Dalavi and Kunal Rane

Abstract
The soil is the component that contributes most to meeting all of a person's basic needs. We use soil extensively in our farming. Indian agriculture holds a prominent role in the development of wheat, rice, jawar, legumes, sugarcane, vegetables, and fruits, among other crops, and this is because the physical and chemical state of the land is essential for the correct use of other management strategies. Because both physical and chemical qualities affect soil production, the Physico-chemical research of the area is crucial. A variety of factors, including pH, electrical conductivity, texture, moisture, temperature, soil organic matter, and readily available nitrogen, phosphorus, and potassium, are taken into consideration in this Physico-chemical analysis of soil. People who are interested will benefit from knowing this information.

Keywords: Soil composition, physico-chemical parameters, soil pollution, precautionary measures

1. Introduction

One of the most vital natural resources is soil. Plants are necessary for all life, and they grow in soil to meet our daily needs. Crops are grown on soils to produce food and textiles. In addition to being crucial for agriculture, soil is also more beneficial for living things. As a part of the terrestrial ecosystem, soil serves a variety of purposes, including those required to support plant growth. Since the inception of forest management as a science, people have understood the significance of soil as a storehouse of nutrients and moisture for the growth of forage and plant species. Any areas of the earth's surface that are covered in vegetation also sustain soil. The soil's state has a significant impact on how vegetation grows and is distributed.

The lithosphere (rock), atmosphere (air), hydrosphere (water), and biosphere are all dynamically interconnected through soil (living things). It is the region where creatures, rocks, and the air and water that circulate around, though, and in them interact. In addition to the physical components that make up soil, its many physical, biological, and chemical components interact actively with one another. The features of a soil determine how it performs as the base of the ecosystem. The state of the soil in a specific area and on a specific scale in relation to a set of standards that encompass healthy functioning is known as the soil's health. In order to reclaim and keep our soil's capacity to function at its peak, we must carefully manage it as an ecosystem teeming with life. The term "soil health" describes the ecological balance, functionality, and ability of a soil to sustain a productive, well-balanced ecosystem with high biodiversity above and below the surface.

"The continuous capacity of soil to function as a vital living system, within ecological and land-use constraints, to support biological productivity, enhance the quality of the air and water environments, and maintain plant, animal, and human health" is the definition of a healthy soil (Doran and Safley, 1997). The words "soil health" and "soil quality" are gaining popularity across the globe. The capacity of a soil to function, within ecological and land use limitations, to sustain productivity, preserve environmental quality, and promote plant and animal health is the definition of soil quality given by Doran and Parkin in 1994. Farmers typically use the term "soil health," although scientists typically prefer "soil quality."

Maintaining a healthy home for the numerous species that make up the soil food web is managing for soil health (better soil function). To achieve this, the soil should be disturbed as little as possible, as many diverse plant species as is practical should be grown, the soil should be kept alive as much as possible, and the soil should always be covered. The degree of compaction, water-holding capacity, and drainage ease of the soil are all important factors in the health of the soil and the plants. A healthy soil tilth encourages rainwater infiltration, which reduces runoff and enables the storage of moisture for use by plants later. It also promotes healthy root growth. Plant health and growth are enhanced when aeration and water availability are optimal. For instance, compared to crops growing in compacted soils, those in friable soils with proper aeration are less negatively impacted by both wet and dry circumstances. In contrast to compacted soils, which become physical impediments to root growth when circumstances get extremely dry, soils with strong physical structure maintain enough aeration during wet seasons.

pH, salt content, and nutrient availability are a few of the crucial chemical indicators of a soil's health. The growth of your crops can be negatively impacted by low nutrient levels, high concentrations of hazardous substances like aluminium, and high salt concentrations. Nutrient levels in healthy soil are adequate but not excessive. Overabundant nitrogen and phosphorus can contaminate surface and groundwater, increase the attractiveness of plants, or make them more insect-friendly. Healthy soils are better able to retain calcium, magnesium, and potassium by using organic matter that has through a thorough decomposition process.

The different types of soil microorganisms include bacteria, actinomycetes, fungus, algae, protozoa, and viruses. Each of these groupings has unique traits that characterise the organisms and serve various purposes in the soil they inhabit. Importantly, these organisms interact with one another and have a greater or equal impact on soil fertility than do the individual activities of the organisms.

Soil fungal biodiversity to enhance soil quality and boost the productivity of agricultural environments (Bagyaraj and Ashwin, 2017). That could eventually be referred to as "the second green revolution." By implementing such methods, it might be possible to shift away from the current overuse of fertilisers and toward more complex manipulations of plant productivity. The breakdown of organic materials is aided by helpful microorganisms that also provide nutrients for plant growth. They play a critical role in protecting plants against biological pathogens that affect soil health, such as pathogenic bacteria (Frac *et al*., 2015).

Characteristics of a healthy soil

1. **Good soil Tilth:** In the context of a soil's suitability for crop production, soil tilth refers to the general physical characteristics of the soil. A healthy tilth is crumbly, well-structured, dark with organic matter, free of huge, hard clods, and crumbly.
2. **Sufficient depth:** The depth of the soil profile that allows roots to spread out and locate water and nutrients is referred to as sufficient depth. Due to historical erosion or compaction, shallow soils are more vulnerable to harm from major weather changes, putting crops at risk for stress from pathogens, floods, or drought.
3. **Good water storage and good drainage:** A healthy soil contains broad, stable pores that can absorb water during a strong downpour. The medium and tiny holes, which are located between these huge pores, transport the water to be stored for later use. A healthy soil's range of pore sizes enables plants to store more water during dry spells. Long rainy periods won't stop the big pores from emptying by gravity and letting in fresh air so that soil organisms and plants can grow.
4. **Sufficient supply of nutrients:** For optimum plant growth and to sustain a healthy cycle of nutrients within the system, there must be a sufficient and readily available supply of nutrients. In addition to toxicity for plants and microbial communities, an abundance of nutrients can cause leaching and probable ground water pollution, high nutrient runoff, and greenhouse gas losses.
5. **Small population of plant pathogens and insect pests:** Plant pathogens and pests can inflict diseases and crop damage in agricultural production systems. The population of these organisms is low or is less active in a healthy soil. This might be the result of direct competition for nutrients or habitat from other soil organisms, excessive parasitism, etc. Additionally, strong plants are better able to protect themselves from various pests.
6. **Large population of beneficial organisms:** The functioning of the soil depends on the creatures that live there. They aid in nutrient cycling, the breakdown of organic matter, the preservation of soil structure, the biological control of plant pests, and other processes. In order to perform these tasks and support the ongoing maintenance of a healthy soil condition, a healthy soil will have a vast and diversified population of beneficial organisms.
7. **Low weed pressure:** The pressure from weeds is a significant barrier to agricultural productivity. For water and nutrients that are crucial for plant growth, weeds compete with crops. Weeds can obstruct sunlight, hinder the establishment of harvest and cultivation operations, and host viruses and pests that can spread disease.
8. **Free of chemicals and toxins that may harm the crop:** Healthy soils can either detoxify or bind toxic pollutants or are free of excess levels of these substances. Due to these processes and the soil's abundance of stable organic matter and various microbial populations, these hazardous substances are rendered inaccessible to plants.
9. **Resistant to degradation:** More unfavourable events, such as wind and rain erosion, excessive rainfall, extreme drought, vehicle compaction, disease outbreak, and other potentially degrading impacts, can be resisted by a healthy, well-aggregated soil that is home to a wide population of living creatures.
10. **Resilience when unfavourable conditions occur:** An adverse event, such as harvesting under wet soil conditions or if land constraints prevent or alter scheduled rotations, will have a more negative impact on a healthy soil's ability to recover.

2. Physico-Chemical Properties in Soil Quality

2.1 pH

The pH level of the soil is the most important aspect because of how it affects all other soil parameters. As a result, pH is taken into account while analysing any type of soil. A soil is described as acidic if the pH is less than 6, normal if the pH is between 6 and 8, and alkaline if the pH is greater than 8.5.

2.2 Soil texture

In order to categorise agricultural soils according to their physical texture, soil texture is a qualitative classification tool that is used in both the field and the lab. Different regions' soil has a different texture, which is largely determined by the size of the particles. The impact of soil texture on root penetration and aeration is evident. It has an impact on the soil's nutrient level as well. Electrical conductivity is an important indicator of soil texture.

2.3 Soil moisture
The amount of water that a material, such as soil, contains is known as its water content or moisture content. One of the most crucial characteristics of soil is moisture. The soil's ability to absorb nutrients is mostly dependent on the moisture level of the soil, which also affects the soil's texture.

2.4 Soil temperature
The proportion of absorbed to lost energy determines the temperature of the soil. The temperature of soil varies from -20 to 60 °C. The most significant characteristic of the soil is its temperature since it demonstrates how it affects the chemical, physical, and biological processes involved in plant growth. Season, time of day, and regional climate all affect soil temperature.

2.5 Electrical conductivity
Another crucial characteristic of soil is electrical conductivity, which is used to assess the soil's quality. It measures the number of ions in a solution [13]. A soil solution's electrical conductivity rises as the concentration of ions does. Electrical conductivity is a rapid, easy, and affordable way to assess the health of soils. It measures the number of ions in a solution. A soil solution's electrical conductivity rises as the concentration of ions does.

2.6 Nitrogen
The most important element that plants may acquire from the soil is nitrogen, which also serves as a growth barrier for plants [14]. Nitrogen makes up about 80% of the atmosphere. Nitrogen gas diffuses into the water, where blue-green algae can "fix" (convert) it to ammonia for use by the algae. Inorganic nitrogen and ammonia are other forms of nitrogen that can infiltrate lakes and streams. Since nitrogen can enter aquatic systems in a variety of ways, there is a plentiful supply of nitrogen that is readily available in these systems.

2.7 Phosphorous
Every biological cell contains the essential ingredient phosphorus [13]. It is one of the most crucial micronutrients required for plant development. Most frequently, phosphorus limits the amount of nutrients that stay in plant nucleus and serves as an energy reserve.

2.8 Potassium
Potassium is a crucial element for the development of the plant and plays a significant function in a variety of physiological processes in plants [15]. It is engaged in a wide range of plant metabolism events, from the creation of plant sugars for diverse metabolic requirements in plants to the regulation of photosynthesis and the formation of lignin and cellulose, which are used to construct cellular structural components.

2.9 Soil organic matter
It is a crucial characteristic of soil. The rate of soil erosion is accelerated by a lack of organic matter in the soil [13]. If there is soil organic matter available, then agricultural activities can exploit this soil. Animal manures, compost, and other organic materials may be put to the soil to add organic matter. Another potential explanation for the pH's decline is the higher organic matter content of the soil, which has reduced from the surface to the subsurface as a result of levelling.

3. Review of past Work
A.Anita Joshi Raj, V Umayoru Bhagan, 51 samples of surface soil and 51 samples of underground water from 10 fluorotic sites in the Agastheeswaram Union, South India, were examined for fluoride content and other significant physicochemical parameters. Fluoride levels in surface soil samples from every fluorotic location were higher than those in subsurface water samples. Fluoride concentrations in the soil and water samples ranged from 1.3 to 2.7 ppm and 2 to 3.5 ppm, respectively. Both values were discovered to be over the permitted amount. In addition, measurements were made of the pH, alkalinity, total hardness, calcium, magnesium, chloride, salinity, and sodium. All of the soil and water samples from different seasons were found to have alkalinity and pH levels that were greater than the permitted limit.

Saroj Mahajan and Dilip Billore, Between July 2008 and June 2009, work was done on the analysis of physicochemical parameters including pH, specific conductivity, chloride, total alkalinity, calcium, magnesium nitrate, sulphate, phosphate sodium, and potassium. Numerous indicators fluctuated over the course of the research year. The findings of the investigation indicated that the soli were alkaline throughout the research year. The soil's quality affects an ecosystem's productivity. The quality and productivity of pond soil are impacted by several factors being above and below acceptable limits.

Anu, Upadhyaya S.K, Bajpai Avinash [3], there is evidence that rubbish dumping pollutes soil. Solid waste is defined as trash, sludge, refuse, and other materials that have been abandoned (including solids, liquids, and enclosed gases) as a result of operations in the industrial, commercial, mining, and agricultural sectors as well as community activities. To evaluate the soil quality, samples were gathered from Shahpura Lake in Bhopal. Physical and chemical characteristics of the soil, including pH, moisture content, bulk density, and chloride, were evaluated during the study period using the accepted techniques. High chloride values suggest soil sediment pollution as a result of urbanisation, industrialization, and agricultural system modernisation, which leads to excessive use of chemical fertilisers and pesticides.

Osakwe, SA [4]. In a study, the physicochemical characteristics of soils from parts of the Isoko Region of Delta State, Nigeria, damaged by a natural flood disaster were examined. The findings showed a general decrease in soil pH (5.425 0.313), phosphorus (7.476.34mgkg-1), and nitrate (0.340.07mgkg-1), as well as exchangeable calcium (1.970.31mgkg-1 potassium (0.090.01mgkg-1), and effective cation exchange capacity (5.0761.532 (cmolkg-1) and related parameters with 3.870.21, 77.575.83 and 7. The values of exchangeable magnesium (1.500.25mgkg-1), exchangeable sodium (0.280.004mgkg-1) and exchangeable acidity, with values of 0.43+0.08 and 0.421.02mgkg-1 for Hydrogen and Aluminium, respectively, rose. Total Organic Carbon (0.400.096%), Total Nitrogen (0.250.035%), and Sulphate (0.100.02mgkg-1) levels did not change significantly. The overall findings show that the flood lowered soil metal adsorption capacity and increased soil acidity, but had little to no impact on biodegradable and compostable components. The government must take the initiative and come up with plans to stop more flood tragedy in the nation.

Kiran G. Chaudhari [5] Various metrics, including total organic carbon, nitrogen (N), phosphorus (P2O5), potassium (K2O), pH, and conductivity, are used in the physicochemical analysis of soil, according to research. We draw a conclusion on the amount of nutrients available in the soil of Bhusawal, District Jalgaon, based on this study (Maharashtra). According to the findings, all eight of the Bhusawal locations that were chosen contain medium to high mineral contents. in order to research how applying nitrogen and phosphorus fertiliser might boost crop production by percentage. This knowledge will assist farmers in resolving issues with soil nutrients, including how much fertiliser should be applied to maximise crop yield.

Rajesh P. Ganorkar and P.G. Chinchmalatpure [6] Work has been done on soils' physical characteristics, chemical characteristics, and micronutrients. Six different areas around Rajura Bazar in Warud Tahsil of Amravati District (Maharashtra), India, were used to collect soil samples. In the month of February 2013, the soil's moisture content, pH, EC, carbon, calcium carbonate, TDS, magnesium, calcium, nitrogen, copper, potassium, and phosphorus contents were examined. The soil sample pH values showed that all samples were alkaline and contained a moderate amount of readily available micronutrients.

Joel O.F, Amajuoyi C.A [7] examined heavy metals and a few chosen physicochemical characteristics at a drilling cutting dump site. According to test results, the majority of the plots in the research region had a high degree of contamination for various heavy metals as copper, iron, and calcium. Copper was at 84 mg/kg, calcium was at 12560 mg/kg, and iron was at 880 mg/kg. These readings exceeded the regulatory body's established goal values, the Department of Petroleum Resources (DPR). Additionally, the oil and grease showed significant contamination, with one plot having a concentration of up to 840 mg/kg. This was demonstrated by the absence of plant development that was observed in the research region due to the NPK values running out below what was required to meet USDA standards for plant growth. The project's greatest level of contamination of various physicochemical parameters and heavy metals underlines the importance of exercising caution when handling drilling cutting discharges.

Abdulmajeed Mlitan, Abdullah Abofalga, and Abdelaziz Swalem [8] investigated the effect of treated wastewater on soil chemical and physical properties. A field experiment was conducted in the Misurata region in central Libya with water treatments of wastewater. Industrial waste water is treated using soil physicochemical characteristics such pH, water content, total soluble salts, and the addition of cadmium, zinc, lead, copper, and iron. The findings show that several test sites were contaminated by industrial waste water. The range of the soil's water content was 7.68 to 19.56%. With no discernible variations between places, soil pH ranged from 7.7 to 8.0 and total soluble salts ranged from 272.6 to 300 ppm. With the exception of iron, all of the tested metals increased from the first to the third position. Total soluble salts and the microbial flora were significantly impacted by the irrigation method. Four fungus genera belonging to the Aspergillus, Penicillium, Rizopus, and Fusarium families make up the isolated microbial flora. Due to its numerous colonies isolated from the water-contaminated metals area and its close resemblance to one of the Aspergillus spices (Aspergillus sp3), the latter and Aspergillus sp3 may be considered one of the resistant fungi in industrial waste water.

Sanjoli Mobar, Pallavi Kaushik and Pradeep Bhatnagar [9]. Carried out work on impacted and non-impacted soil of two areas i.e. Sanganer and Durgapura respectively, of Jaipur district. By estimating physicochemical parameters like pH, electrical conductivity (EC), water holding capacity, texture analysis, organic carbon, organic matter, total hardness, sodium, and potassium concentrations, as well as sodium adsorption ratios (SAR) and cation exchange capacities (CEC), the soil quality was analysed. The findings indicated a substantial difference in both soil's pH, EC, water holding capacity, total hardness, SAR, and CEC, indicating the influence of industrial effluent on soil quality. Control of this industrial contamination, which can be ensured by planned development, therefore assumes more significance to maintain the declining soil quality.

Prakash L. Patel, Nirmal P. Patel, Prakash H. Patel, Anita Gharekhan [10] correlated the chemical parameters of agricultural soil of different villages of Kutch district of Gujarat state in Western India. Their main goal was to investigate the mung bean crop using 30 samples of medium dark soil that were randomly chosen. Soil samples were taken by authorised farmers who had received local training under the Gujarati government's Soil Health Card Program and brought to the Soil Test Laboratory in Bhuj for analysis. The analysis of the soil quality employed standard methodologies. By employing correlation analysis, this work aims to investigate and assess the relationship between soil characteristics and macronutrients (P, K, C, and S). The current study comes to the conclusion that the statistical technique known as "correlation analysis" can offer a scientific foundation for managing agricultural soil fertility.

A.M. Shivanna and G. Nagendrappa [11] carried out work on the soil fertility status of selected command areas of three lakes- Eachanur, V. Mallenahalli and Halkurke in Tiptur Taluk. The variables tested included pH, EC, OC, N, P, and K. According to the study, the pH of the soil samples ranged from 7.07 to 7.87, was somewhat alkaline but still within the range of 6.5-8.5 that is best for crops. The soils' low salinity status was indicated by EC values that ranged from 0.26 dSm-1 to 0.485 dSm-1 and were below the threshold of 0.8 dSm-1. All of the samples had OC contents that varied from 0.50% to 0.67% and were rated as medium. Samples lacked phosphorus and nitrogen, with available nitrogen ranging from 5.33 kg/ha to 10.79 kg/ha and available phosphorous from 5 kg/ha to 85 kg/ha, respectively. Except for one sample that had a high potassium rating, samples ranged in rating from 156.18 kg/ha to 434.38 kg/ha.

Conclusion

For the analysis and sustainability of soil ecosystems, maintaining or improving soil quality is a more crucial criterion Establishing a precise standard for land quality, however, is a difficult task because the functions and ensuing values provided by soil ecosystems are variable and depend on the interaction of soil physical, chemical, and biological properties as well as cognitive processes, which frequently vary significantly across spatial and temporal scales. The choice of a uniform set of particular soil characteristics as measures of soil quality can be difficult and may differ between soil systems. The analysis of the review papers led researchers to the conclusion that many metrics can be used to investigate soil quality. The majority of the metrics fall inside or outside the permissible ranges.

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