JOURNAL OF AGRICULTURE AND LIVESTOCK FARMING
Jan-Mar 2026, VOL. 3, ISSUE 1, pp. 16-22
https://doi.org/10.61577/jalf.2026.100003

RESEAPRO JOURNALS

REVIEW

OPEN ACCESS

Critical role of physico-chemical attributes in determining soil quality and fertility

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ABSTRACT

Soil is a dynamic and multifunctional natural resource that underpins terrestrial ecosystems and agricultural productivity. Its ability to sustain plant growth and ecosystem services is governed by key physico-chemical properties, including pH, texture, moisture, temperature, electrical conductivity (EC), and soil organic matter (SOM). Soil pH regulates nutrient solubility and microbial processes; texture controls water retention and nutrient-holding capacity; moisture and temperature influence biochemical reactions and plant development; EC reflects soluble salt status; and SOM enhances aggregation, nutrient storage, and biological activity. This review synthesizes the dynamics of essential macronutrients (N, P, K, and S) and micronutrients (Zn and B), emphasizing how their availability and mobility are strongly influenced by soil chemical and physical conditions. Nitrogen transformations are microbially mediated, phosphorus availability depends on organic matter and fixation processes, potassium behavior is linked to clay mineralogy, sulfur mobility is associated with sulfate leaching, and micronutrient availability is highly sensitive to soil pH and texture.

The impacts of intensive agricultural practices and excessive agrochemical use on soil degradation and nutrient imbalance are critically discussed. Sustainable approaches such as integrated nutrient management, organic amendments, and biofertilizers are highlighted as effective strategies to restore soil health. Overall, maintaining balanced soil physico-chemical properties is essential for long-term productivity, environmental sustainability, and global food security.

KEY WORDS

Electrical Conductivity; Macronutrients; Micronutrients; Soil Organic Matter; Soil pH; Sustainable Soil Management

ARTICLE HISTORY

Received 10 February 2026; Revised 02 March 2026; Accepted 10 March 2026

Introduction

Soil represents one of the most fundamental and indispensable resources of the natural environment, serving as the primary substrate that sustains virtually all terrestrial life. Every living organism, either directly or indirectly, relies on plants for its essential daily needs, including nutrition, shelter, and other life-sustaining requirements, and these plants, in turn, are entirely dependent on the soil for their growth, development, and productivity. Soils provide the indispensable medium through which crops are cultivated, enabling the production of food, fiber, and other plant-derived materials crucial for human survival and socioeconomic development. Beyond its undeniable significance in agriculture, soil serves a broader ecological function and is invaluable for all living organisms, acting as a reservoir of nutrients, moisture, and energy that sustains terrestrial ecosystems. As a vital component of the terrestrial ecosystem, soil performs a myriad of functions, many of which are essential for the maintenance and sustainability of plant growth, productivity, and ecological balance [1]. The recognition of soil as a critical repository of nutrients and moisture for the production of forage and other plant species dates back to the early development of forest management as a scientific discipline, highlighting its enduring importance in ecological and agricultural systems [2]. Almost every portion of the Earth's surface that supports vegetation is covered by soil, and the distribution, density, and diversity of vegetation are intricately linked to the chemical, physical, and biological characteristics of the underlying soil [3]. The process of soil formation is both constructive and destructive, encompassing a wide range of dynamic geological, chemical, and biological interactions [4]. Soil originates from the fragmentation of parent rock material, which undergoes extensive alteration through weathering, erosion, and other chemical and mechanical processes. It is not merely a collection of mineral particles, but rather a highly complex system that integrates inorganic minerals, organic matter, living microorganisms, and other biotic and abiotic components. This complexity enables soil to perform multiple essential functions that benefit human society, plants, animals, and the broader ecosystem [5]. Factors such as climate, topography, biological activity, and parent material interact in intricate ways to influence the characteristics and formation of soil, resulting in significant spatial and temporal variability. Contrary to the common perception of soil as an inert or lifeless material, a healthy soil is vibrant and dynamic, teeming with microorganisms that drive nutrient cycling, organic matter decomposition, and various biochemical transformations necessary for ecosystem functionality. The uppermost layer of soil, often enriched in nutrients and organic matter, supports the

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highest levels of biological productivity, including crop growth and bio-farming activities. Soil profile characteristics, including depth, color, texture, and chemical composition, exhibit distinct variations across different regions, influenced by local environmental and ecological conditions. Soil is a natural body composed of mineral and organic materials, differentiated into horizons that vary systematically in physical, chemical, and biological properties. The mineral composition of soil, the quantity and quality of organic matter it contains, and the surrounding environmental factors are all fundamentally determined by the chemical properties of the soil [6]. Soil depth also varies widely, with differences in morphology, constitution, physical attributes, chemical characteristics, and biological composition relative to the underlying parent material [7]. Soil chemistry encompasses all chemical reactions and processes occurring within the soil that directly impact plant growth, animal development, and human well-being [8]. A comprehensive understanding of soil chemical reactions and the various processes occurring within the soil matrix is indispensable for the development of innovative strategies in resource management, as well as for understanding, predicting, and regulating the behavior of terrestrial ecosystems at both regional and global scales [9]. Soil chemistry governs the availability and transformation of nutrients, the retention of moisture, and the cycling of organic and inorganic compounds, all of which directly influence ecosystem productivity and resilience. The modern conception of soil quality encompasses not only the ability of soil to sustain plant and animal productivity, but also its capacity to enhance water and air quality and contribute positively to plant and animal health [10]. This notion of soil health has continuously evolved over time, driven by increasing insights into the complex interactions among soil chemical, physical, and biological attributes, and their collective influence on overall soil functionality [11]. Recognized as one of the most valuable natural resources of any country, a detailed understanding of soil characteristics is essential for formulating optimal land-use plans aimed at maximizing agricultural productivity while maintaining ecological balance [12]. Agriculture, defined as the art and science of cultivating plants from the soil, remains one of the most economically significant activities for human societies [13].

Soil fertility constitutes a critical determinant of plant growth and productivity. It depends on the concentration and availability of macronutrients such as nitrogen (N), phosphorus (P), and potassium (K), along with organic and inorganic matter, micronutrients, and soil moisture. In general, deficiencies in these essential nutrients, along with suboptimal chemical fertility, are major contributors to soil degradation and declining productivity [14]. Nutrient deficiency has emerged as a significant constraint to soil productivity, stability, and long-term sustainability [15]. The structural integrity of soil aggregates deteriorates rapidly under repeated cropping of annuals that contribute minimal organic matter, necessitate extensive cultivation, and provide inadequate vegetative cover [16]. Soil nutrient cycling encompassing the addition, transformation, and loss of nutrients is critical to maintaining a balanced composition of organic and inorganic soil constituents. In recent decades, the widespread application of organic and inorganic fertilizers, alongside pesticides, has become a common practice among farmers to enhance crop yield and quality. The productivity and nutritional quality of crops are strongly dependent on the appropriate use of fertilizers and the availability of micronutrients. Consequently, the condition of soil, as the universal medium for plant growth, plays a pivotal role in supplying essential nutrients to cultivated plants [17]. However, excessive fertilizer application has altered the physico-chemical status of many soils, leading to imbalances that are difficult to manage and potentially harmful to soil health, plant productivity, and human and animal health [18].

The interaction of various farming practices, environmental factors, and soil characteristics gives rise to the specific properties observed in different soils. Physico-chemical properties vary spatially and temporally due to factors such as topography, climate, weathering processes, vegetation cover, microbial activity, and a range of biotic and abiotic influences [19]. These differences contribute to the formation of distinct soil types, each with unique characteristics that have significant implications for agricultural management and productivity [20]. Land-use changes, particularly the conversion of forested areas to agricultural land, can lead to the deterioration of soil physico-chemical properties, ultimately resulting in infertile or barren soils incapable of supporting normal vegetation growth for extended periods [5,21]. While industrialization and intensified agricultural practices are essential to meet the growing food demands of human populations, it is equally important to ensure environmental sustainability [22]. Ultimately, both food productivity and environmental quality are intimately linked to the physico-chemical properties of soil, underscoring the necessity of developing a thorough understanding of soil characteristics to ensure sustainable agricultural practices and long-term ecosystem health.

Role of Physico-Chemical Properties in Soil Quality

pH

Soil pH represents one of the most critical physical and chemical parameters influencing the overall quality and fertility of soils. It has a profound effect on solute concentration, nutrient availability, and absorption mechanisms within the soil matrix [23]. For farmers and gardeners, monitoring and managing soil pH is essential because different plants and soil organisms exhibit preferences for either acidic or alkaline environments [24]. Soils with a pH below 6 are classified as acidic, those with a pH ranging from 6 to 8.5 are considered neutral or normal, and soils with a pH above 8.5 are categorized as alkaline. In the study conducted by Sumit Kumar et al., the pH of cotton-growing soils was observed to range between 7.5 and 8.4, indicating near-alkaline conditions [25]. Soil pH serves as a reliable indicator of nutrient balance and availability; essential micronutrients such as Fe, Mn, Zn, and Cu are generally more soluble and accessible in acidic soils compared to alkaline soils [26]. Moreover, pH regulation plays a pivotal role in maintaining soil fertility and guiding the application of amendments for soil amelioration [27]. It also reflects the equilibrium among nutrients, cation exchange capacity, organic matter content, and overall soil health [28]. Williams studied the effects of pH on nutrient balance and found that elevated pH levels can significantly reduce the availability of micronutrients in soils, while lower pH enhances their solubility [29]. Typically, soil pH increases with depth, and extreme deviations either highly acidic or highly alkaline can impair crop growth due to imbalances in

https://doi.org/10.61577/jalf.2026.100003

ionic strength [25]. High soil pH levels are often attributed to the infiltration of alkaline effluents from industries such as cement production, as elevated sodium content contributes to alkalinity [30]. In addition, soil infiltration and water movement are frequently compromised under high-pH conditions. For example, soils in the Vidharbha region of Maharashtra exhibited neutral to moderately alkaline reactions, with pH values ranging from 7.15 to 8.03 [31].

Electrical Conductivity (EC)

Electrical conductivity is a rapid, cost-effective, and widely used indicator of soil health, reflecting the concentration of soluble ions present in the soil solution. Higher ion concentrations increase the EC, which is influenced by soil depth, texture, drainage, and rainfall patterns [32]. In upland soils, EC variability tends to be lower, likely due to leaching of alkaline and basic ions facilitated by slope and high permeability. EC correlates closely with soil properties including texture, cation exchange capacity, organic matter, drainage, and salinity [33]. It serves as a practical tool for estimating soluble salt concentrations, assessing soil salinity, and monitoring nutrient availability [34-35]. Putman and Alt also reported that leveling of soils alters the salt concentrations within the root zone [36]. The EC of soils depends on moisture content; soils with higher water content generally show higher conductivity. EC values below 1 dS/m indicate normal soil, values between 1–2 dS/m are critical for seed germination, 2–3 dS/m affect growth of salt-sensitive crops, and values exceeding 3 dS/m are considered severely injurious to crop development [30]. EC thus provides a valuable, integrated measure of soil chemical status and its potential constraints for agricultural productivity.

Texture

Soil texture, defined by the relative proportions of sand, silt, and clay particles, plays a fundamental role in determining the physical, chemical, and biological behavior of soil. Texture directly affects water retention, aeration, root penetration, and the overall nutrient dynamics of the soil. Electrical conductivity often reflects soil texture; clayey soils exhibit higher conductivity, while sandy soils are comparatively poor conductors [37]. In different regions, soil textures vary: black soils are typically loamy to clayey, red soils range from silty clay to loamy, and yellow soils often display a loamy clay composition [38]. The textural class of soil influences nutrient availability, water retention, and cation exchange capacity. Sandy soils, characterized by low nutrient content, minimal moisture retention, and low buffering capacity, are highly permeable, making them prone to nutrient leaching and deficiencies [39]. They also contain limited organic matter. Al-Omran demonstrated that the addition of clay deposits to sandy-textured soils enhanced squash crop productivity [40]. Sandy loam soils allow easier root penetration but may not support deep-rooted crops effectively [1]. Conversely, clayey soils retain moisture for longer periods due to low permeability, which can be detrimental for crops intolerant to prolonged wet conditions [41]. The high organic matter content of clay soils, coupled with substantial cation exchange and pH buffering capacities, makes them resilient to water and wind erosion [39]. Clay is also exploited commercially in cosmetic applications, where its color and mineral content determine its use in beauty spas [42]. Loamy topsoil overlying clayey subsoil can be highly susceptible to severe degradation if erosion diminishes the depth of the topsoil [1]. Variability in soil texture can influence other soil functions and potential threats, such as erosion, compaction, and waterlogging, thereby impacting overall soil health and productivity [43].

Soil temperature

Soil temperature is another key parameter influencing the chemical, physical, and biological processes that underpin plant growth. It fluctuates with seasonal changes, diurnal cycles, and local climatic conditions, with solar radiation being the primary source of heat, supplemented by heat generated through biological and chemical reactions within the soil [44]. Rising soil temperatures accelerate chemical reactions, reduce gas solubility, and can decrease soil pH, thereby affecting nutrient availability and microbial dynamics [45]. Temperature also governs seed germination, biomass accumulation, and microbial activity, directly impacting plant productivity and ecosystem function [46]. Variations in soil temperature are largely driven by energy exchange processes occurring at the soil surface [45]. For example, Bahuguna et al. reported that soil temperatures in Uttarakhand, India, ranged between 38°C and 43°C, reflecting both climatic influences and soil characteristics [47].

Moisture

Soil moisture is a key physical property that directly affects nutrient availability and uptake by plants. The water content of soil is closely related to its texture, structure, and organic matter content, and is influenced by factors such as void ratio, particle size, clay mineralogy, and groundwater levels. Soils with higher porosity, such as clay-rich soils, generally hold more water than coarser-textured sandy soils [48]. The capacity of soil to retain water is indicative of its physical condition and fertility, providing essential insights for evaluating regional soil water balance and irrigation management [49-50]. Thakare et al. reported maximum water-holding capacities for red and black soils, highlighting the variability of soil moisture retention across different textural classes [51]. Sandy soils can be rapidly recharged with water but are unable to retain moisture as efficiently as soils with heavier textures [38]. Oseni et al. observed higher soil moisture levels, ranging from 13.81% to 26.27%, in rainforest and plantation soils in Ondo State, Nigeria [52]. These observations highlight the significant spatial variability in soil moisture influenced by climatic conditions, soil texture, and vegetation cover. Soil moisture not only governs the uptake of essential nutrients but also plays a fundamental role in regulating microbial activity, decomposition processes, and overall soil fertility.

Soil Organic Matter (SOM)

Soil organic matter is a fundamental property of soils, influencing their physical, chemical, and biological functions. Soils deficient in organic matter are more susceptible to erosion, reduced fertility, and poor water retention, whereas soils rich in organic matter are highly suitable for agricultural practices. Organic matter can be added through animal manures, composts, crop residues, and other organic amendments, enhancing nutrient content and soil structure. Higher organic matter content is associated with reduced soil pH, increased cation exchange capacity, and improved nutrient retention [53].

https://doi.org/10.61577/jalf.2026.100003

Soil organic matter tends to decrease with depth, as surface layers are richer due to organic inputs and microbial activity, whereas subsoils are often nutrient-depleted [54]. SOM increases water retention at field capacity, enhances available water content in sandy soils, and improves air and water flow through fine-textured soils [55]. It serves as a reservoir of essential nutrients, including nitrogen, phosphorus, and sulfur, and supports the growth and activity of soil microorganisms [57]. By maintaining soil structure, organic matter also influences infiltration rates, water-holding capacity, and overall fertility, thus enhancing the agricultural potential of soils. The presence of adequate SOM ensures nutrient supply, improves soil moisture retention, and facilitates optimal plant growth, making it indispensable for sustainable land management and crop productivity.

Nitrogen

Nitrogen is one of the most essential macronutrients for plant growth, playing a central role in cellular structure, metabolism, and photosynthetic activity. Plants readily respond to nitrogen fertilization, typically absorbing it in the form of nitrate (NO_3^-) and ammonium (NH_4^+) ions [5]. Nitrogen promotes above-ground vegetative growth, enhances chlorophyll production, and imparts a deep green coloration to leaves, while also being integral to proteins, enzymes, nucleic acids, and energy transfer mechanisms [58]. The nitrogen cycle, which includes mineralization, immobilization, and leaching, is predominantly driven by microbial processes and is intimately linked to soil organic carbon levels [59].

While nitrogen is indispensable for plant growth, excessive application of inorganic nitrogen fertilizers can lead to soil acidification, negatively affecting soil health and long-term sustainability. For example, Jain and Singh, measured total nitrogen in soils from Madhya Pradesh, India, and reported values ranging from 172 ± 2.1 to 193.3 kg ha^{-1} in red and brown soils, 197 ± 4.9 to 215 ± 21 kg ha^{-1} in black soils, and 183 ± 19 kg ha^{-1} in yellow soils [38]. This underscores the importance of careful nitrogen management to balance crop productivity with soil conservation, mitigate environmental risks, and maintain ecosystem health.

Phosphorus

Phosphorus is an essential macronutrient present in every living plant cell and plays a pivotal role in various physiological and biochemical processes crucial for plant growth and development [44]. As a key component of nucleic acids and energy storage molecules such as ATP, phosphorus facilitates energy transfer within plants, thereby regulating growth, respiration, and reproductive processes [56]. It is especially critical during early plant development, seed germination, flowering, and fruit formation, and its deficiency often manifests as purpling of stems and leaves, reduced fruit yield, and overall stunted growth [13]. Phosphorus also contributes to maintaining a balanced uptake of other nutrients, ensuring optimal crop development and productivity. According to Wagh et al., phosphorus is a major determinant of plant metabolism and overall soil fertility, influencing processes such as photosynthesis, formation of oils, sugars, starches, and other biochemical constituents necessary for plant vitality [34].

The availability of phosphorus in soils varies with topographic position, organic matter content, and leaching patterns. Topographically elevated soils tend to have higher available phosphorus than lower-lying soils, primarily due to differences in erosion, runoff, and deposition [56]. Soils rich in organic matter supply greater amounts of organic phosphate, which is more accessible to plants compared to soils with low organic content [58]. Adequate phosphorus levels promote early plant growth, hasten maturity, and enhance yield potential. Soils with minimal leaching typically retain higher phosphorus concentrations compared to highly leached soils [8]. In practical terms, most agricultural soils with available phosphorus above 10 mg/kg are considered suitable for crop cultivation [59]. Thus, phosphorus management is critical not only for ensuring crop productivity but also for sustaining soil fertility over time.

Potassium

Potassium, although not a structural component of plant cells like nitrogen or phosphorus, plays an essential role in regulating a wide array of physiological processes required for plant growth, metabolism, and stress resistance [5]. It contributes to enzyme activation, protein synthesis, carbohydrate metabolism, lignin and cellulose formation, photosynthesis, sugar translocation, and maintenance of water balance within plants [33]. Potassium is primarily absorbed in its ionic form (K^+) and influences plant processes such as cell elongation, stomatal regulation, disease resistance, and tolerance to environmental stresses including drought and frost [56].

Surface soils often exhibit higher potassium concentrations due to the application of potassium-rich fertilizers and organic manures [60]. Potassium fixation occurs in dry soils, where K^+ ions become trapped between clay layers, making them less available to plants; availability typically decreases with soil depth [61]. Adequate potassium ensures rapid plant development, enhanced tolerance to pathogens and pests, and improved quality of fruits and grains. Pal reported that increasing potassium availability in kaolinitic soils significantly enhanced winter sorghum grain yield. Muhar et al. categorized soils based on potassium content, noting that 25% of samples were low (<125 kg ha^{-1}), 67.5% medium (125–300 kg ha^{-1}), and 2.5% high (>300 kg ha^{-1} K_2O) [61]. Potassium also interacts synergistically with nitrogen, helping to balance plant nutrient uptake and optimize overall growth.

Sulfur

Sulfur, like potassium, plays a vital role in plant nutrition, though its behavior in soil differs significantly. In soils, sulfur is mainly present in the sulfate (SO_4^{2-}) form, which is the form readily available for plant uptake. Elemental sulfur (S) can also be applied as a fertilizer source; however, it must first be biologically oxidized into sulfate. This oxidation process is carried out by bacteria such as Thiobacillus, and it generates considerable acidity. For this reason, elemental sulfur is sometimes deliberately applied to lower soil pH. In contrast, fertilizers that already contain sulfate do not significantly acidify the soil, although a temporary and slight decline in pH may occur due to salt effects [62].

Because sulfate is negatively charged (an anion), it is not strongly held by soil particles and can be easily leached, particularly in coarse-textured soils. In the past, sulfur deficiencies were relatively rare, largely because atmospheric emissions from coal- and oil-based industries supplied substantial amounts of sulfur to agricultural soils. Additionally, traditional fertilizers such as ordinary superphosphate contained appreciable quantities of sulfur. However, with the growing use of high-analysis fertilizers like urea and triple

https://doi.org/10.61577/jalf.2026.100003

superphosphate, which contain minimal sulfur, sulfur deficiencies have become increasingly common in many agricultural systems [17].

Zinc

Globally, zinc (Zn) production is largely derived from ores rich in zinc sulfide minerals. Although more than 80 zinc-bearing minerals have been identified, only a limited number possess commercial significance. The zinc content within minerals varies considerably, depending on factors such as zinc concentration in the original magma, characteristics of the parent rock before metamorphism, and the capacity of the mineral crystal lattice to incorporate zinc ions [62]. Extractable zinc generally shows positive correlations with total zinc content, organic matter, clay fraction, and cation exchange capacity (CEC). Conversely, it is negatively associated with free calcium carbonate ($CaCO_3$), higher soil pH, and base saturation. Soil pH plays a particularly critical role in determining zinc availability: as pH rises, zinc availability decreases, and vice versa. Research findings indicate that liming acidic soils can sharply reduce extractable zinc for example, increasing soil pH from 4.3 to 5.0 significantly lowered available zinc in one study, while raising pH to 6.1 severely limited zinc supply to forage crops in another experiment [20].

Zinc availability is also typically lower in organic soils and in mineral soils containing high levels of organic matter. In some regions, such as North Carolina, soil test interpretations for zinc are adjusted according to soil classification and organic matter content to better predict plant-available zinc levels [62].

Boron

Boron (B) is naturally present in the earth's crust mainly as calcium and sodium borates formed from mineral sources. The average boron concentration in the earth's crust is approximately 10 ppm. Sedimentary rocks typically contain higher boron levels than igneous rocks, and certain marine sedimentary formations may contain 500 ppm or more. The boron content of soils largely reflects the concentration in the parent material and the extent of weathering processes. Generally, total boron in soils ranges between 2 and 100 ppm [14]. Soils developed from acidic igneous rocks, freshwater sedimentary deposits, and coarse-textured materials with low organic matter commonly exhibit low boron content. In contrast, boron concentrations are often greater in surface soils, where organic matter accumulation is higher. In soils, boron exists in four principal forms: water-soluble, adsorbed on soil particles, organically bound, and fixed within clay and mineral lattices [62].

In coarse-textured soils with low clay and organic matter content, boron is highly mobile and prone to leaching losses, which may result in reduced surface concentrations under such conditions. Soil pH also plays an important role in regulating boron availability. In general, boron becomes more available to plants as soil pH decreases, whereas higher pH levels tend to reduce its availability [18].

Study Limitations

This review highlights the role of soil physico-chemical properties and nutrient dynamics but has some limitations. Much of the data are from studies in varied regions and soil types, which may not fully represent local conditions in Barishal and Jhalokathi, Bangladesh. Interactions among soil properties, nutrients, and microbes are complex, and the focus here is mainly on chemical and physical attributes, with less emphasis on biological aspects. Some referenced studies are laboratory-based, which may not reflect field variability. Limited long-term monitoring and inconsistent methods also restrict definitive conclusions. Future research should integrate field-based, long-term studies considering chemical, physical, and biological soil parameters to better support sustainable management.

Conclusion

Soil is a resource whose physico-chemical properties pH, texture, moisture, temperature, EC, and organic matter govern nutrient availability, microbial activity, and crop productivity. Conventional reliance on chemical fertilizers and pesticides may boost short-term yields but can degrade soil and ecosystems over time. Sustainable practices, including organic amendments, biofertilizers, biopesticides, and integrated nutrient management, restore soil health, balance nutrient dynamics, and support long-term productivity, environmental sustainability, and global food security.

Acknowledgement

I hereby declare that I have used AI tools in the preparation of our manuscript. The use of such tools was limited to assistance (such as language improvement, structuring, or editing), and the core research work, data interpretation, and conclusions are entirely my/our original work. I take full responsibility for the accuracy, integrity, and authenticity of the submitted manuscript.

Disclosure Statement

No potential conflict of interest was reported by the author.

Reference

1. Nwachokor MA, Uzu FO, Molindo WA. Variations in physicochemical properties and productivity implications for four soils in the derived savannah of southern Nigeria. Am Eurasian J Agron. 2009;2(3):124-129.
2. Amos-Tautua BM, Onigbinde AO, Ere D. Assessment of some heavy metals and physicochemical properties in surface soils of municipal open waste dumpsite in Yenagoa, Nigeria. Afr J Environ Sci Technol. 2014;8(1):41-47. https://doi.org/10.5897/AJEST2013.1621
3. Kardol P, Martijn Bezemer T, Van Der Putten WH. Temporal variation in plant–soil feedback controls succession. Ecol Lett. 2006;9(9):1080-1088. https://doi.org/10.1111/j.1461-0248.2006.00953.x
4. Pujar KG, Hiremath SC, Pujar AS, Pujeri US, Yadawe MS. Analysis of physico-chemical and heavy metal concentration in soil of Bijapur Taluka, Karnataka. Sci Revs Chem Commun. 2012;2(1):76-79.
5. Sumithra S, Ankalaiah C, Rao D, Yamuna RT. A case study on physicochemical characteristics of soil around industrial and agricultural area of Yerraguntla, Kadapa district, AP, India. Int J Geo Earth and Environ Sci. 2013;3(2):28-34.
6. Joffe JS. Pedology. New Brunswick (NJ): Pedology Publications; 1949.

https://doi.org/10.61577/jalf.2026.100003

7. Rai MM. Principles of soil science. Macmillan; 2002;38-91.
8. Ashraf M, Bhat GA, Dar IY, Ali M. Physico-Chemical Characteristics of the Grassland Soils of Yusmarg Hill Resort (Kashmir, India). Ecologia Balkanica. 2012;4(1). https://www.cabidigitallibrary.org/doi/full/10.5555/20123239293
9. Schnitzer M. Binding of humic substances by soil mineral colloids. Interact Soil Miner Nat Org Microbes. 1986;17:77-101. https://doi.org/10.2136/sssaspecpub17.c4
10. Doran JW, Zeiss MR. Soil health and sustainability: managing the biotic component of soil quality. Appl Soil Ecol. 2000;15(1):3-11. https://doi.org/10.1016/S0929-1393(00)00067-6
11. Chaudhari PR, Ahire DV, Ahire VD. Correlation between Physico-chemical properties and available nutrients in sandy loam soils of Haridwar. J Chem Biol and Phys Sc. 2012;2(3):1493.
12. Kumar P, Kumar A, Dhyani BP, Kumar P, Shahi UP, Singh SP, et al. Soil fertility status in some soils of Muzaffarnagar District of Uttar Pradesh, India, along with Ganga canal command area. Afr J Agric Res. 2013;8(14):1209-1217. https://doi.org/10.5897/AJAR12.1755
13. Wagh GS, Sayyed MR. Assessment of macro and micronutrients in soils from Panvel Area, Maharashtra, India. Univers J Environ Res Technol. 2013;3(1):72-78.
14. Hartemink AE. Land use change in the tropics and its effect on soil fertility. In19th world congress of soil science, soil solutions for a changing world 2010;1-6. https://edepot.wur.nl/174757
15. Bell RW, Dell B. Micronutrients for sustainable food, feed, fibre and bioenergy production. International Fertilizer Industry Association (IFA); 2008. https://researchportal.murdoch.edu.au/esploro/outputs/book/Micronutrients-for-sustainable-food-feed-fibre/991005543889907891
16. Harris RF, Chesters G, Allen ON. Dynamics of soil aggregation. Adv Agron. 1966;18:107-169. https://doi.org/10.1016/S0065-2113(08)60649-5
17. Narkhede SR, Bhirud SR, Patil NS, Chaudhari RR. Physico-chemical analysis of soil collected from Chorwad, Tehsil-Bhusawal, Dist. Jalgaon (MS). Int J Chem Sci. 2012;9(4):1973–1978. https://www.cabidigitallibrary.org/doi/full/10.5555/20123086682
18. Kamble PN, Kurhe AR, Pondhe GM, Gaikwad VB, Baath E. Soil nutrient analysis and their relationship with special reference to pH in Pravaranagar area, District Ahmednagar, Maharashtra, India. Int J Sci Technol Res. 2013;2(3):216-218.
19. Paudel S, Sah JP. Physiochemical characteristics of soil in tropical sal (Shorea robusta Gaertn.) forests in eastern Nepal. Himal J Sci. 2003;1(2):107-110.
20. Ahire DV, Chaudhari PR, Ahire VD, Patil AA. Correlations of electrical conductivity and dielectric constant with physico-chemical properties of black soils. Int J Sci Res Pub. 2013;3(2):1-6.
21. Jha AK, Singh JS. Spoil characteristics and vegetation development of an age series of mine spoils in a dry tropical environment. Vegetation. 1991;97(1):63-76.
22. Joshi N, Kumar A. Physico-chemical analysis of soil and industrial effluents of Sanganer region of Jaipur Rajasthan. Res J Agric Sci. 2011;2(2):354-356.
23. Akpoveta OV, Osakwe SA, Okoh BE, Otuya BO. Physicochemical characteristics and levels of some heavy metals in soils around metal scrap dumps in some parts of Delta State, Nigeria. J Appl Sci Environ Manag. 2010;14(4):57–60.
24. Pandeeswari N, Kalaiarasu S. Studies on the physico-chemical properties of the soil samples collected from different locations of tsunami affected soils of Cuddalore district of Tamil Nadu. Int J Current Res. 2012;4(7):143-145.
25. Kumar S, Iyer A, Agarwal S. Cotton yield in relation to physicochemical properties of cultivated soil of Rajkot region. Int J of Adv Engi Tech. 2011;2(3):52-55.
26. Deshmukh KK. Studies on chemical characteristics and classification of soils from Sangamner area, Ahmednagar district, Maharashtra, India. Rasayan J Chem. 2012;5(1):74-85.
27. Daji JA. A textbook of soil science. 1970.
28. Ellis B, Foth H. Soil fertility. CRC Press; 1996.
29. Brady NC, Weil RR. The nature and properties of soils 13th edition. Agroforest Syst. 2002;54(3):249.
30. Elango L, Ramachandran S, Chowdary YS. Groundwater quality in coastal regions of South Madras. Indian J Environ Health. 1992;34:318–325.
31. Gabhane VV, Jadhao VO, Nagdeve MB. Land evaluation for land use planning of a micro watershed in Vidarbha region of Maharashtra. J Indian Soc Soil Sci. 2006;54(3):307-315.
32. Datta M, Munna Ram MR. Status of some micronutrients in some soil series of Tripura. J Indian Soc Soil Sci. 1993;41(4):776–777.
33. Solanki HA, Chavda NH. 12. Physico-chemical analysis with reference to seasonal changes in soils of Victoria Park reserve forest, Bhavnagar (Gujarat). Life Sci Leafl. 2012;8:62-68.
34. Wagh GS, Chavhan DM, Sayyed MR. Physicochemical Analysis of Soils from Eastern Part of Pune City. Univers J Environ Res Technol. 2013;3(1):93-99.
35. Smith JL, Doran JW. Measurement and use of pH and electrical conductivity for soil quality analysis. Methods for assessing soil quality. 1997;49:169-185. https://doi.org/10.2136/sssaspecpub49.c10
36. Putman J, Alt K. Erosion control: How does it change farm income?. J Soil Water Conserv. 1987;42(4):265-267.
37. Marx ES, Hart J, Stevens RG. Soil testing interpretation guide. Corvallis (OR): Oregon State University; 1999. file:///C:/Users/Lenovo/Downloads/ec1478.pdf
38. Jain P, Singh D. Analysis the physic-chemical and microbial diversity of different variety of soil collected from Madhya Pradesh, India. Scholarly J Agric Sci. 2014;4(2):103-108. https://scholarlyjournals.org/sjas/archive/2014/February/pdf/Jain%20and%20Singh.pdf
39. Patnaik P, Dipti Raut DR, Lipika Behera LB, Saswati Mishra SM. Physico-chemical and heavy metal characterization of soil from industrial belt of Cuttack, Orissa Lipika. Asian J Exp Biol Sci. 2013;4(2):219–225.
40. Al-Omran AM, Sheta AS, Falatah AM, Al-Harbi AR. Effect of drip irrigation on squash (Cucurbita pepo) yield and water-use efficiency in sandy calcareous soils amended with clay deposits. Agric Water Manag. 2005;73(1):43-55. https://doi.org/10.1016/j.agwat.2004.09.019
41. Moody PW, Phan Thi Cong PT. Soil Constraints and Management Package (SCAMP): guidelines for sustainable management of tropical upland soils. 2008.

https://doi.org/10.61577/jalf.2026.100003

42. Matike DM, Ekosse GI, Ngole VM. Physico-chemical properties of clayey soils used traditionally for cosmetics in Eastern Cape, South Africa. Int J Phys Sci. 2011;6(33):7557-7566.
43. Adhikari K, Guadagnini A, Toth G, Hermann T. Geostatistical analysis of surface soil texture from Zala County in western Hungary. InInternational Symposium on Environment, Energy and Water in Nepal: Recent Researches and Direction for Future 2009;(pp. 219-224).
44. Jain SA, Jagtap MS, Patel KP. Physico-chemical characterization of farmland soil used in some villages of Lunawada Taluka, Dist: Mahisagar (Gujarat) India. Int J of Sci Res Publi. 2014;4(3):1-5.
45. Nayana S, Malode SN. Municipal solid waste management: a survey and physicochemical analysis of contaminated soil from Sukali Compost and landfill depot, Batkuli Road, Amravati. Global J Bio-Sci Biotech. 2007;1(2):215.
46. Mora-Naranjo N, Meima JA, Haarstrick A, Hempel DC. Modelling and experimental investigation of environmental influences on the acetate and methane formation in solid waste. Waste Manag. 2004;24(8):763-773. https://doi.org/10.1016/j.wasman.2004.04.006
47. Bahuguna A, Lily MK, Munjal A, Singh RN, Dangwal K. A study on the physico-chemical analysis of automobile contaminated soil of Uttarakhand, India. Int J Environ Sci. 2011;2(2):380. https://indianjournals.com/api/article-view/ijes-2-2-001
48. Williams PT. Waste treatment and disposal. John Wiley & Sons; 2013.
49. Soffe RE. The agricultural notebook. 19th ed. Oxford: Blackwell Science; 1995.
50. Vanderlinden K, Giráldez JV, Van Meirvenne M. Soil water-holding capacity assessment in terms of the average annual water balance in Southern Spain. Vadose Zone J. 2005;4(2):317-328. https://doi.org/10.2136/vzj2004.0099
51. Thakre YG, Choudhary MD, Raut RD. Physicochemical characterization of red and black soils of Wardha region. Int J Chem Phys Sci. 2012;1(2):60-66.
52. Oseni OA, Ekperigin MM, Akindahunsi AA, Oboh G. Studies of physiochemical and microbial properties of soils from rainforest and plantation in Ondo state, Nigeria. Afr J Agric Res. 2007;2(11):605-609. https://journalbackups.lon1.digitaloceanspaces.com/uploads/main/article/article1380899019_Oseni%20et%20al.pdf
53. Tale KS, Ingole S. A review on role of physico-chemical properties in soil quality. Chem Sci Rev Lett. 2015;4(13):57-66. https://chesci.com/wpcontent/uploads/2016/10/V4i13_8_CS29204512.pdf
54. Hallberg GR, Wollenhaupt NC, Miller GA. A century of soil development in spoil derived from loess in Iowa. Soil Sci Soc Am J. 1978;42(2):339-343. https://doi.org/10.2136/sssaj1978.03615995004200020028x
55. Sree Ramulu US. Reuse of municipal sewage and sludge in agriculture. 2001.
56. Singh DP, Rathore MS. Available nutrient status and their relationship with soil properties of Aravalli mountain ranges and Malwa Plateau of Pratapgarh, Rajasthan, India. Afr J Agric Res. 2013;8(41):5096-5103. https://doi.org/10.5897/AJAR2013.7168
57. Patil SL, Sheelavantar MN, Nalatwadmath SK, Surkod VS, Mohan SM, Lamani VK. Correlation analysis among soil moisture, soil physico-chemical properties, nutrient uptake and yield of winter sorghum. Indian J Agric Res. 2005;39(3):177. https://indianjournals.com/article/ijar2-39-3-003
58. Miller RW, Donahue RL. Soils in our environment. 2001.
59. FAO. A framework for land evaluation. FAO Bulletin 32. Paris: FAO/UNESCO; 1976.
60. Miles RJ, Hammer RD. One hundred years of Sanborn field: Soil baseline data. Proceedings of the Sanborn Field Centennial, Publication No. SR-415, ed. JR Brown. 1989:100-108. file:///C:/Users/Lenovo/Downloads/agecon-missouri-022.pdf
61. Muhar GR, Datta NP, Shankara SN, Dever F, Lecy VK, Donahue RR. Soil testing in India,1963, USDA Mission to India.
62. Hodges SC. Soil fertility basics. Soil science extension, North carolina state university. 2010;22:46-59. http://www2.mans.edu.eg/projects/heepf/ilppp/cources/12/pdf%20course/38/Nutrient%20Management%20for%20CCA.pdf

https://doi.org/10.61577/jalf.2026.100003