Community and Ecology (2024) Volume 2 Issue 1
doi: 10.59429/ce.v2i1.6296

ARTS AND SCIENCE
ARTS AND SCIENCE PRESS PTE. LTD

REVIEW ARTICLE

Assessment of soil chemical characteristics in the context of Bangladesh: A comprehensive review

Shoma Hore

Post Graduate Student, Bangladesh University of Engineering and Technology, Bangladesh

*** Corresponding author:** Shoma Hore, shoma.acc17@gmail.com

ABSTRACT

This study presents a thorough examination of the chemical properties inherent to soil, with a focus on the unique context of Bangladesh. Soil functions are intricately linked to its chemical composition, which plays a vital role in determining agricultural productivity and ecological vitality. The soil within Bangladesh's geographical boundaries is characterized by its richness and fertility, contributing significantly to its agricultural output and overall ecosystem health. By delving into the chemical properties of Bangladeshi soil, this review aims to enhance our understanding of this dynamic ecosystem. Insights gained from this exploration can shed light on factors influencing soil fertility, nutrient availability, and overall ecosystem health, thereby informing strategies for sustainable land management and agricultural practices in Bangladesh and beyond.

Keywords: comprehensive examination; interconnected; chemical properties; agricultural output; ecological resilience; profound understandings

1. Introduction

The tropical nation of Bangladesh is situated within the expansive deltas formed by the Ganges and Brahmaputra rivers. Situated within the expansive deltas formed by the Ganges and Brahmaputra rivers, Bangladesh, a tropical and subtropical nation, spans approximately 144,000 square kilometers of diverse topography. Over 79% of its land consists of recent floodplains, hosting various habitats like sandy beaches, estuary floodplains, and meander floodplains. Additionally, basin areas and piedmont alluvial plains contribute to this rich landscape. The remaining 13% of the land features Tertiary-shaped hills in the north and east, while Madhupur and Barind tracts are characterized by Pleistocene terraces, as described by Morgan, McIntire, and Wadia in the mid-20th century[2].

At the heart of Bangladesh’s agricultural system lies fertile soil, providing the essential foundation for robust crop growth. Soil, rich in organic matter and minerals, acts as a natural source of vital nutrients necessary for plant development. Organic matter, resulting from decomposed plant and animal components, not only aids in soil aggregation but also sustains soil-dwelling organisms while enhancing water retention. Thus, soil plays a fundamental role in sustaining life on Earth.

Current review initiatives in Bangladesh focus on comprehensively characterizing its soils by analyzing

ARTICLE INFO
Received: 23 May 2024 | Accepted: 16 August 2024 | Available online: 20 September 2024

CITATION
Hore S. Assessment of Soil Chemical Characteristics in the Context of Bangladesh: A Comprehensive Review. *Community and Ecology* 2024; 2(1): 6296. doi: 10.59429/ce.v2i1.6296

COPYRIGHT
Copyright © 2024 by author(s). *Community and Ecology* is published by Arts and Science Press Pte. Ltd. This is an Open Access article distributed under the terms of the Creative Commons Attribution License (https://creativecommons.org/licenses/by/4.0/), permitting distribution and reproduction in any medium, provided the original work is cited.

their morphological and mineralogical attributes. The primary objective is to understand the general physico-chemical characteristics of all general Soil Types, complemented by detailed macro- and micro-morphological descriptions. This endeavor aims to shed light on the intricate interplay between geology, climate, and soil diversity, unraveling the dynamic terrain of Bangladesh.

Geography of Bangladesh

Bangladesh, situated on the edge of the Indian subcontinent in South Asia, is bordered by India to the west, north, and east and Myanmar to the southeast. The southern boundary of Bangladesh is shaped by the Bay of Bengal, marked approximately at 23.6850 degrees North latitude and 90.3563 degrees East longitude. Its predominantly low-lying terrain is chiefly formed by the expansive Ganges-Brahmaputra Delta, making it prone to annual flooding, particularly during the monsoon season. The intricate network of rivers and canals, such as the Ganges, Brahmaputra, and Meghna, plays a pivotal role in transportation, irrigation, and daily life.

In the southwest region lies the renowned Sundarbans mangrove forest, the largest of its kind globally and honored as a UNESCO World Heritage Site. This crucial ecosystem provides habitat to the iconic Royal Bengal tigers and acts as a vital natural barrier against storms and coastal erosion. Bangladesh's 580-kilometer coastline along the Bay of Bengal is essential for agricultural and fisheries activities, yet it faces threats from cyclonic disturbances and rising sea levels due to climate change[1].

While flatlands dominate much of Bangladesh’s landscape, the southeast region, known as the Chittagong Hill Tracts, presents a distinct terrain with hills, forests, and diverse indigenous communities. Within this low-lying expanse sits Dhaka, the bustling capital city and one of the world's most densely populated urban centers include Chittagong (Chattogram), Khulna, Rajshahi, and Sylhet. The country experiences a tropical monsoon climate characterized by distinct wet and dry seasons, with heavy rainfall spanning from June to October and a drier period from November to April. The **Figure 1** illustrates the general soil types of Bangladesh, as delineated by the Bangladesh Agricultural Research Council (BARC) in 2005.

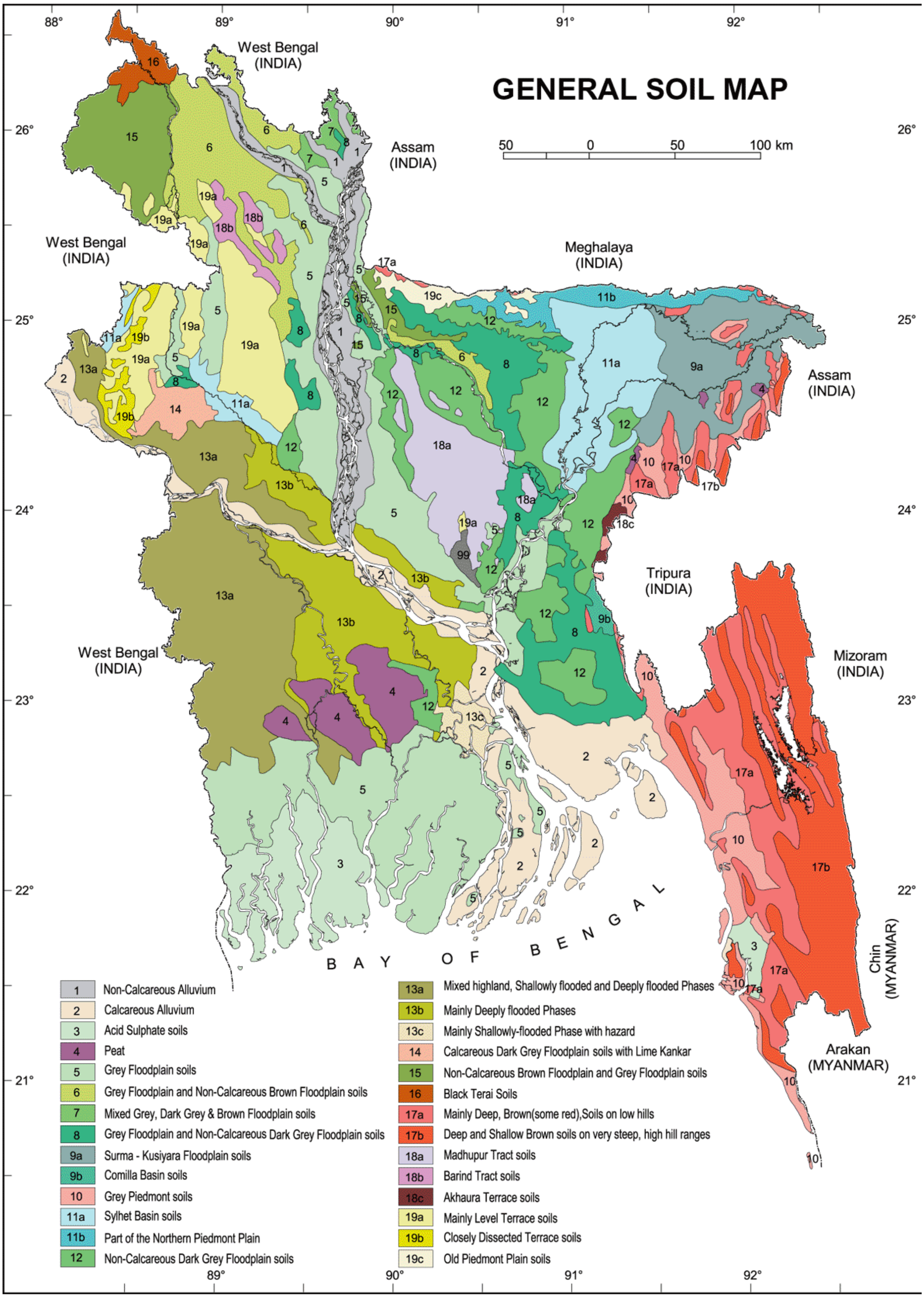

Figure 1. General soil types of Bangladesh (BARC, 2005).

Description of Soil

Soils are categorized into organic and mineral types depending on the presence of organic matter. Mineral soils, constituting the majority of farmland worldwide, contain varying amounts of organic matter, typically up to 30 percent[2]. Soil chemistry plays a crucial role in supporting all aspects of soil ecology. **Figure 2** shows the Composition of Soil. To delve into the intricacies of soil ecosystems, a thorough grasp of soil chemistry is indispensable. Let's explore the chemical attributes inherent in soils[3].

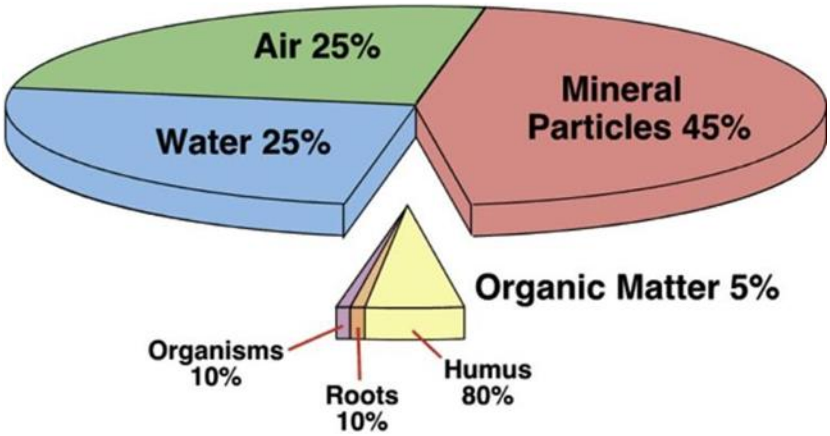

Figure 2. Composition of Soil (Talukder, 2023).

Soil Formation

The formation of soil is a result of the interplay among regional climate, parent material, terrain, relief, biological processes, and the passage of time. The initial characteristics of soil are set by the parent material and the landform, while the pace of soil development is influenced by the climate and biological factors[5-8]. As depicted in **Figure 3** below, the progression of soil-forming processes is contingent upon the passage of time.

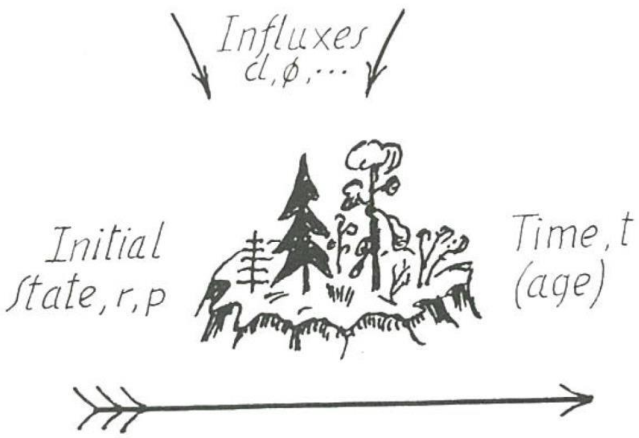

Figure 3. Factors that determine soil formation. Source: Hans 1980.

Inorganic particles in soil are classified based on their size, which includes gravel or stone, sand, silt, or clay, each influencing the soil's texture. The solid rock, known as bedrock, constituting the inorganic component of soil, is a product of gradual formation from the Earth's crust over an extended period[8-12]. This bedrock can be grouped into various categories:

1. Sedimentary rock: Formed when worn fragments of other rocks accumulate and cement together, including limestone, sandstone, mudstone, shale, dolomite, and conglomerates.
2. Igneous rock: Resulting from the solidification of volcanic lava, examples include granite and basalt.
3. Metamorphic rock: Examples such as gneiss, schist, quartzite, slate, and marble form when igneous or sedimentary rocks undergo intense heat or pressure.

Through weathering, the original bedrock undergoes erosion, producing parent material for mineral soils. As weathering progresses, fragments separate, transforming into mineral particles exposed to further weathering. Over time, these mineral particles diminish in size due to continuous weathering, also releasing soluble chemicals[12-17]. Notably, some of these soluble convert into nutrients for plants, as depicted in **Figure 4**.

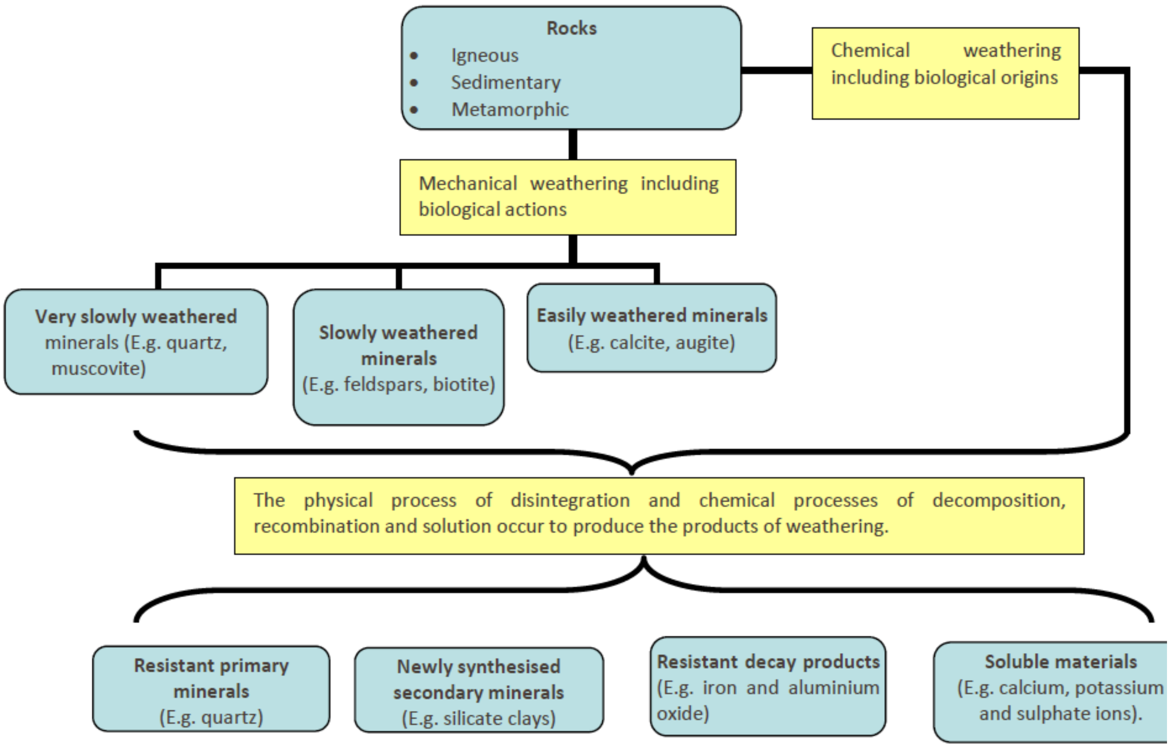

Figure 4. Trends in weathering conditions that take place under acid conditions common in humid-temperate regions. Source: Adapted from Buckman and Brady (1960).

Decomposition Soil by organic matter (SOM)

The bulk of organic matter found in soil originates from plant tissues, which typically contain 60 to 90 percent moisture content. The remaining dry matter consists of carbon (C), oxygen (O), and hydrogen (H), along with trace amounts of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg). Despite their scarcity, these nutrients play a crucial role in regulating soil fertility[2].

Soil organic matter is broadly categorized into two groups:

(i) Fresh or partially decomposed plant and animal wastes, retaining identifiable physical characteristics from their source.

(ii) Humus, a colloidal breakdown product known for its increased resistance to decomposition.

Both living and deceased organic materials contribute to the organic fraction of soil. While sandy and arid soils typically contain minimal organic matter (one percent or less), peaty soils can harbor concentrations as high as 90 percent. Upon the death of plants and animals, decomposition ensues, yielding various organic materials or compounds[4].

The initial components undergo decomposition, giving rise to humus, characterized by its deep brown color. Additionally, living microbes contribute to soil organic matter through metabolic waste. Organic matter is predominantly soluble in alkaline solutions, with only a small portion being water-soluble[18-25]. **Figure 5** illustrates the Soil Physiography map of Bangladesh.

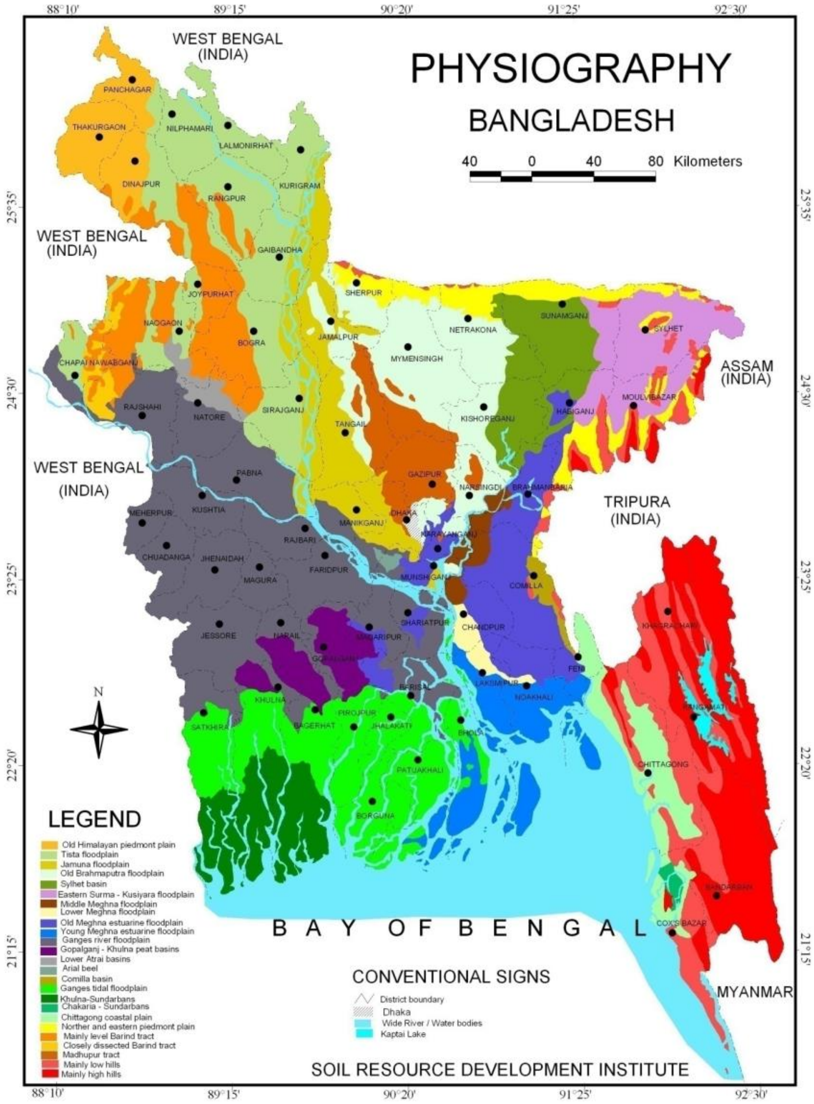

Figure 5. Soil Physiography map of Bangladesh (SRDI, 2007).

Peat, muck, and humus:

Muck consists of highly degraded organic waste, while peat originates from plant tissues that have not fully decomposed. Mucky peat represents an intermediate stage of decomposition between the two. Humus, responsible for the distinctive black or brown tint often observed in the upper layers of soil profiles, plays a pivotal role[26-35].

Humus, the most active component of organic matter, significantly influences soil characteristics. Gradual decomposition of humus darkens the soil, promotes soil aggregation and stability, enhances Cation Exchange Capacity (CEC) facilitating nutrient attraction and retention, and supplies essential nutrients such as nitrogen (N) and phosphorus (P). Microorganisms and other soil organisms utilize organic materials in the soil as a nutrient source[36-41].

Rate of decomposition of materials in soils:

Organic matter is further classified based on its rate of decomposition:

Rapidly decomposed: This category includes sugars, starches, proteins, and other readily ecomposable organic compounds.

Less rapidly decomposed: Hemicelluloses, celluloses, and other organic compounds that decompose at a slower rate compared to sugars and proteins fall into this group.

Very slowly decomposed: Fats, waxes, resins, lignins, and other complex organic compounds are categorized as very slowly decomposed, as they undergo decomposition at a significantly slower pace compared to sugars, starches, and proteins[42-43].

pH in Soil

Soil chemistry plays a pivotal role in shaping the physical characteristics of soil, particularly evident in soils rich in exchangeable salt. A substantial portion of global food production, around 40%, relies on irrigated soil. However, nearly one-fifth of these cultivated areas face reduced yields due to salt-related issues. It's essential to recognize that irrigation water naturally contains some level of salt, and the buildup of salts near a plant's root zone can hinder growth, diminish yields, and alter soil structure, leading to long-term land degradation[44-45].

Accurate measurement of soil salt content and assessment of salt accumulation from irrigation are crucial for maintaining productivity on irrigated land. Among soil chemistry variables, soil pH stands out due to its profound influence on various chemical reactions involving essential plant nutrients, as well as hazardous substances and environmental contaminants. pH directly affects the solubility and availability of nutrients, the effectiveness of herbicides, and the decomposition of organic material, making it a critical indicator of soil functionality, quality, and environmental implications.

The interaction between soil pH, organic matter content, and plant nutrient availability significantly impacts soil functions and crop growth. pH regulates the solubility and availability of essential nutrients, the efficacy of herbicides, and the decomposition of organic material. Additionally, soil pH influences microbial activity and the release of inorganic carbonates, directly affecting the concentrations of crucial minerals such as phosphorus, calcium, magnesium, and potassium, as well as harmful compounds like manganese. Therefore, obtaining accurate spatial data on soil pH properties and understanding the factors influencing their distribution are essential for optimizing growing conditions and ensuring sustainable agricultural practices.

Buffering Properties:

Buffering in soil refers to its ability to resist changes in pH, akin to buffer solutions in chemistry. When acid or alkali is introduced, certain solutions maintain their pH, known as “buffer solutions.” Similarly, soils exhibit this buffering action, mitigating pH alterations.

Buffer solutions comprise a blend of weak acid salts and the acid itself, ensuring stability in pH. In agriculture, soil's buffering action is vital for the following reasons:

1. pH Stabilization: This shields higher plants and microorganisms from adverse effects resulting from abrupt shifts in soil reaction.
2. Amendment Efficiency: Soils with higher buffering capacities require less lime or sulfur to rectify acidity or alkalinity. Buffering action is influenced by factors such as the quantity and nature of clay and organic colloids in the soil, as well as the presence of salts and colloids associated with cations[2-3].

Conclusion

In conclusion, soils, as products of surface weathering processes, exhibit a porous nature and serve as complex biogeochemical systems comprising solids, liquids, and gases. The chemical composition of soil primarily results from the weathering of parent materials facilitated by water. The intricate interplay of various chemical constituents influences processes such as leaching, where contaminants may infiltrate deeper layers while insoluble compounds tend to persist in surface layers. Understanding the behavior of soil colloids is essential for comprehending the diverse chemical properties of soil. These fundamental concepts hold true for Bangladesh, underscoring the universal nature of soil chemistry attributes. This understanding is crucial for informing sustainable land management practices and agricultural strategies tailored to the unique ecosystem of Bangladesh and beyond.

Conflict of interest

Authors declare that there is no conflict of interest.

Reference

1. Alam, M. L., Saheed, S. M., Shinagawa, A., & Miyauchi, N. (1993). Chemical properties of general soil types of Bangladesh. Memoirs of the Faculty of Agricultural Kagoshima University, 29, 75-87.
2. Balasubramanian, A. (2017). Chemical Properties of Soils. Centre for Advanced Studies in Earth Science, University of Mysore, Mysore, 1-11.
3. Buckman, H.O. and Brady, N.C. (1960) The Nature and Properties of Soils. Soil Science, 90, 212. doi: 10.1097/00010694-196009000-00018
4. Zhou Y, Biswas A, Ma Z, Lu Y, Chen Q and Shi Z, 2016 Revealing the scale-specific controls of soil organic matter at large scale in Northeast and North China Plain Geoderma 271 pp 71-79.
5. Zhang Y, Shen H, Gao Q and Zhao L, 2020 Estimating soil organic carbon and pH in Jilin Province using Landsat and ancillary data Soil Science Society of America Journal 84(2) pp 556-567.
6. Roelofsen H D, van Bodegom P M, Kooistra L, van Amerongen J J and Witte J PM, 2015 An evaluation of remote sensing derived soil pH and average spring groundwater table for ecological assessments International journal of applied earth observation and geoinformation 43 pp 149-159.
7. Disale, A. S., Chavan, D. P., Alameen, A. S., & Undre, P. B. (2020, October). Soil Characterization Using Physical and Chemical Properties. In Journal of Physics: Conference Series (Vol. 1644, No. 1, p. 012026). IOP Publishing.
8. Campbell, I. B., & Claridge, G. G. C. (2004). Soil properties and relationships in Cryosols of the region of the Transantarctic Mountains in Antarctica. In Cryosols: Permafrost-Affected Soils (pp. 713-726). Berlin, Heidelberg: Springer Berlin Heidelberg.
9. Bathurst, R.J., Hatami, K. (1998). Seismic response analysis of a geosynthetic reinforced soil retaining wall. Geosynthetics International 5 (1–2), pp. 127–166. doi: 10.1680/gein.5.0117
10. Cengiz, C., &Guler, E. (2018). Shaking table tests on geosynthetic encased columns in soft clay. Geotextiles and Geomembranes, 46(6), pp. 748-758. doi: 10.1016/j.geotexmem.2018.07.009

11. Chakraborty, S., Hore, R. Ahmed, F., Ansary, M. A., Soft ground improvement at the Rampal Coal Based Power Plant Connecting Road Project in Bangladesh, Geotechnical Engineering Journal of the SEAGS & AGSSEA, AIT December 2017.
12. Chakraborty, S., Hore, R., Shuvon, A. M., Ansary, M. A, Dynamic Responses of Reinforced Soil Model Wall on Soft Clay Foundation, Geotechnical and Geological Engineering, January 2021. doi: 10.1007/s10706-020-01665-z
13. Chakraborty, S., Hore, R., Shuvon, A. M., Ansary, M. A, Physical and numerical analysis of reinforced soil wall on clayey foundation under repetitive loading: effect of fineness modulus of backfill material, Arabian Journal of Geosciences, June 2021. doi: 10.1007/s12517-021-07317-7
14. Chakraborty, S., Hore, R., Shuvon, A.M. et al. Effect of Surcharge Pressure on Model Geotextile Wrapped-Face Wall Under Seismic Condition. Iran J Sci Technol Trans Civ Eng (2022). doi: 10.1007/s40996-022-00900-2
15. El-Emam, M. M., Bathurst, R. J. (2007). Influence of reinforcement parameters on the seismic response of reduced-scale reinforced soil retaining walls. Geotextiles and Geomembranes 25 (1), pp. 33–49. doi: 10.1016/j.geotexmem.2006.09.001
16. Gidday, B.G. & Mittal, S. (2020). Dynamic response of wrap-faced cement treated reinforced clayey soil retaining walls. Innov. Infrastruct. Solut. 5, 42, pp. 1-9. doi: 10.1007/s41062-020-00295-x
17. Guan, Y., Zhou, X., Yao, X., & Shi, Y. (2019). Seismic performance of prefabricated sheathed cold-formed thin-walled steel buildings: Shake table test and numerical analyses. Journal of Constructional Steel Research, p. 105837. doi: 10.1016/j.jcsr.2019.105837
18. Hore, R. & Ansary M. A., SPT-CPT Correlations for Reclaimed Areas of Dhaka, Journal of Engineering Science, JES, KUET, June 2018.
19. Hore, R., M. R. Arefin, Ansary, M. A., Development of Zonation Map Based on Soft Clay for Bangladesh, Journal of Engineering Science 10(1), 2019, 13-18
20. Hore, R., Chakraborty, S., Ansary, M. A., Field Investigation to Improve Soft Soils Using Prefabricated Vertical Drain, Transportation Infrastructure Geotechnology, September 2019. doi: 10.1007/s40515-019-00093-8
21. Hore, R., Chakraborty, S., Shuvon, A. M., Ansary, M. A., Effect of Acceleration on Wrap Faced Reinforced Soil Retaining Wall on Soft Clay by Performing Shaking Table Test, Proceedings of Engineering and Technology Innovation, 2020.
22. Hore, R., Chakraborty, S., Bari, M. F., Shuvon, A. M., Ansary, M. A., Soil Zonation and The Shaking Table Test of The Embankment on Clayey Soil, Geosfera Indonesia, August 2020. doi: 10.19184/geosi.v5i2.17873
23. Hore, R., Chakraborty, S., Ansary, M. A., Experimental Investigation of Embankment on Soft Soil Under Cyclic Loading: Effect of Input Surcharges, Journal of Earth Engineering (JEE) Vol. 5, No. 1, (2020).
24. Hore, R., Ansary, M. A., Different Soft Soil Improvement Techniques of Dhaka Mass Rapid Transit Project, Journal of Engineering Science 11(2), 2020, 37-44. doi: 10.3329/jes.v11i2.50896
25. Hore, R., Al-Mamun. S., Climate Change and its diverse impact on The Rural Infrastructures in Bangladesh, Disaster Advances, Vol. 13 (9) September (2020).
26. Hore, R., Chakraborty, S., Ansary, M. A., "Liquefaction Potential Analysis based on CPT and SPT" Geotechnical Engineering Journal of the SEAGS & AGSSEA, December 2020.
27. Hore, R., Chakraborty, S., Ansary, M. A., Seismic Response of Embankment on Soft Clay Based on Shaking Table Test, International Journal of Geosynthetics and Ground Engineering, March 2021. doi: 10.1007/s40891-020-00246-7
28. Hore, R., Chakraborty, S., Shuvon, A. M., Ansary, M. A., Dynamic Response of Reinforced Soil Retaining Wall Resting on Soft Clay, Transportation Infrastructure Geotechnology, February 2021. doi: 10.1007/s40515-021-00156-9

29. Hore, R., Chakraborty, Kamrul, K. S., Shuvon, A. M. and Ansary, M. A., Numerical Verification for Seismic Response of Reinforce Soil Embankment on soft Clay foundation, Geotechnical Engineering Journal of the SEAGS & AGSSEA, 53(2), 18-28, June 2022.
30. Koerner, R. M. (1999). Designing with Geosynthetics, 4th edition, Prentice Hall, NJ, p. 761.
31. Kokusho, T., (1980). Cyclic triaxial test of dynamic soil properties for wide strain range. Soils and foundations 20, 45–60. doi: 10.3208/sandf1972.20.2_45
32. Latha, G. M., Manju, G. S. (2016). Seismic Response of Geocell Retaining Walls Through Shaking Table Tests.International Journal of Geosynthetics and Ground Engineering, 2(1), p.7. doi: 10.1007/s40891-016-0048-4
33. Latha, G. M., Nandhi Varman, A. M. (2014). Shaking table studies on geosynthetic reinforced soil slopes. International Journal of Geotechnical Engineering, 8(3), pp. 299-306. doi: 10.1179/1939787914Y.0000000043
34. Hossain, M. Hasan, T. et al. (2023). Stability analysis of rainfall-induced landslides: A case study of a hilly area in Bangladesh. Earthquake 1 (1).
35. Nova-Roessig, L., & Sitar, N. (1999). Centrifuge model studies of the seismic response of reinforced soil slopes. In Earthquake geotechnical engineering, pp. 679-684.
36. Reitherman, Robert (2012). Earthquakes and Engineers: An International History. Reston, VA: American Society of Civil Engineers. pp. 126–127. doi: 10.1061/9780784410714
37. Shoma Hore. (2023). Review of Phosphate Removal From Water by Various Sorbents. Web of Technology: Multidimensional Research Journal, 1(1), 15–24.
38. S. Sahoo, B. Manna. K. G. Sharma (2019), Seismic Response of a Steep Nailed Soil Slope: Shaking Table Test and Numerical Studies, Geotechnics for Transportation Infrastructure, pp. 611-623. doi: 10.1007/978-981-13-6701-4_39
39. Siavoshnia, M., Kalantari, F., &Shakiba, A. (2010). Assessment of geotextile reinforced embankment on soft clay soil. In Proceedings of The 1st International Applied Geological Congress, Department of Geology, Islamic Azad University, pp. 1779-1784.
40. Talukder, R., Hore, S. and Hore, R (2023). A Review of Soil Chemical Properties for Bangladesh Perspective. Western European Journal of Modern Experiments and Scientific Methods, 1(1), 52-65.
41. Talukder, R., Hore, S. and Hore, R. (2023). Systematic Approach of Earthquake Awareness Analysis in Bangladesh. Earthquake. 1 (1). doi: 10.1680/gein.3.0051
42. Sakaguchi, M., Muramatsu, M., Nagura, K. (1992). A discussion on reinforced embankment structures having high earthquake resistance. Proceedings of the International Symposium on Earth Reinforcement Practice, IS-Kyushu ’92, Fukuoka, Japan, Vol. 1, pp. 287–292.
43. Viswanadham, B. V. S., & Mahajan, R. R. (2007). Centrifuge model tests on geotextile-reinforced slopes. Geosynthetics International, 14(6), 365-379. doi: 10.1680/gein.2007.14.6.365
44. Arefin, S., Talukder, R., Hore, S. and Hore, R. (2023). A Novel Study on Present Situation of Infrastructure of Water, Sanitation and Hygiene of Rural People in Bangladesh. (2023). Western European Journal of Historical Events and Social Science, 1(1), 44-58.
45. Yazdandoust, M. (2017). Investigation on the seismic performance of steel-strip reinforced-soil retaining walls using shaking table test. Soil Dynamics and Earthquake Engineering, 97, pp. 216-232. doi: 10.1016/j.soildyn.2017.03.011