**Studies on soil physicochemical properties of different crop ecosystems for future cropping and soil management strategies in Jorhat district, India**

**ABSTRACT:**

Soil physicochemical properties are key indicators of soil fertility and agricultural sustainability, yet they are profoundly influenced by land use practices. This investigation was undertaken to evaluate the influence of different land use systems on soil physicochemical properties in Jorhat district, Assam. The study encompassed five representative land use types: barren land, paddy, flower crops, fruit-based homestead, and rice-vegetable systems. Surface soil samples (0–15 cm depth) were collected under each system with three replications. Laboratory analyses were conducted to determine bulk density, particle density, porosity, pH, electrical conductivity (EC), available nitrogen (N), available phosphorus (P₂O₅), available potassium (K₂O), and organic carbon (OC). Results from one-way analysis of variance (ANOVA) indicated statistically significant differences (p < 0.05) among land use systems for most parameters, with the exception of porosity and EC. Tukey’s Honest Significant Difference (HSD) test further elucidated pairwise variations among the land uses. The findings revealed that fruit-based homestead and rice-vegetable systems significantly enhanced soil quality indicators such as organic carbon and nutrient availability, whereas barren land and monocropped paddy fields exhibited relatively poor fertility status. These results underscore the importance of diversified and organic-input-rich cropping systems in promoting soil health and long-term agricultural sustainability in the Upper Brahmaputra Valley Zone of Assam.

***Keywords:*** *Land use systems, soil physiochemical properties, ANOVA, Tukey HSD, organic carbon, nitrogen, phosphorus, potassium*

1. **INTRODUCTION**

Soil is a vital natural resource that forms the foundation of terrestrial ecosystems and serves as a key determinant of agricultural productivity and environmental quality. It is a dynamic and complex system composed of mineral particles, organic matter, water, air, and a diverse population of microorganisms derived from the decomposition of plant and animal residues (Bhuyan et al., 2023). Referred to as the “skin of the Earth,” soil plays a critical role in regulating essential ecosystem functions, including nutrient cycling, water retention, carbon storage, and biological activity (Cornish et al., 2020).

Among the various properties that influence soil functionality, fertility status remains central to sustaining crop productivity and ecological balance. Plants derive nutrients from two primary sources in the soil—organic matter and minerals. Organic matter, through decomposition, not only contributes to nutrient supply but also improves soil structure and enhances its capacity to retain moisture and support microbial life (Parida, 2022). Key indicators commonly used to assess soil fertility and health include pH, electrical conductivity (EC), cation exchange capacity (CEC), and concentrations of essential nutrients such as nitrogen (N), phosphorus (P), potassium (K), and organic carbon (OC) (Borah et al., 2024; Bhuyan et al., 2023). Soil pH, in particular, regulates the solubility and availability of nutrients, with most nutrients being optimally accessible at neutral pH values. EC reflects salinity levels, which influence crop tolerance and yield, while CEC represents the soil’s ability to retain and exchange nutrient cations essential for plant growth (Das et al., 2020; Chakravarty et al., 2023).

Land use practices are known to exert significant influence on the physicochemical and biological properties of soils. Changes in land use—such as the conversion of forests to croplands, adoption of intensive agriculture, or development of settlements—can lead to shifts in soil structure, nutrient availability, microbial dynamics, and overall soil fertility (Mahmud et al., 2022; Dutta et al., 2021). Repeated tillage, deforestation, and unsustainable land management practices have been linked to soil degradation, nutrient depletion, and a decline in organic matter content, thereby compromising soil productivity and long-term agricultural sustainability (Lal, 2006). As such, understanding the relationship between land use systems and soil fertility is essential for promoting sustainable land management and ensuring the resilience of agricultural ecosystems (Chakravarty et al., 2023; Bhuyan et al., 2023).

While numerous studies have investigated the impact of land use on soil fertility in various agro-ecological regions globally and across India, there is a notable lack of region-specific data for northeastern India, particularly in the soils of Assam. The Jorhat district, located in the Upper Brahmaputra Valley Zone, represents an agriculturally significant region where diverse land use systems coexist. However, limited research has been conducted to evaluate how these varying land uses affect soil fertility status in this specific context. In view of this gap, the present study was undertaken to assess the effect of different land use systems on the fertility status of soils in Jorhat district. The objective is to generate empirical data that can inform sustainable land use planning, soil health management, and long-term agricultural development in the region.

**2. MATERIALS AND METHODS**

**2.1 Study Area:** The study was carried out in the Jorhat district of Assam, located in the Upper Brahmaputra Valley Zone (UBVZ), which lies between 26°45′N to 27°15′N latitude and 93°15′E to 94°15′E longitude. The area experiences a humid subtropical climate, receiving average annual rainfall between 2000–2500 mm and temperatures ranging from 7°C in winter to 36°C in summer. The predominant soil types are alluvial with loamy to clayey textures (Dutta et al., 2021; Borah et al., 2024).

**2.2 Experimental Design and Sampling:** Five different land use systems were selected based on field survey and land use classification: barren land, paddy fields, flower crops, fruit-based homesteads, and rice-vegetable cropping systems. Soil samples were collected from the surface layer (0–15 cm) using a random sampling method, with six replications per land use type. Each composite sample was formed by mixing five subsamples taken within a 10 m × 10 m plot. Samples were air-dried, ground, and sieved using a 2 mm mesh sieve before laboratory analysis (Chakravarty et al., 2023; Parida, 2022)

**2.3 Soil Physicochemical Analysis:** Bulk density was determined using the core method and particle density by pycnometer (Blake &Hartge, 1986). Porosity was calculated using the formula: Porosity (%) = [1 - (BD/PD)] × 100. Soil pH and EC were measured in a 1:2.5 soil-water suspension using a digital pH meter and EC meter (Jackson, 1973). Available nitrogen was determined by the alkaline KMnO₄ method (Subbiah &Asija, 1956), phosphorus by Olsen’s method (Olsen et al., 1954), potassium via flame photometry using 1N NH₄OAc extraction (Pratt, 1965), and organic carbon using Walkley and Black’s method (Walkley & Black, 1934).

**2.4 Statistical Analysis:** Data were subjected to one-way ANOVA to test the significance of variations among land use types. Tukey’s HSD post hoc test was applied to determine the group-wise differences. Analysis was conducted using SPSS version 26.0 with a confidence level of 95% (p < 0.05).

**3. RESULTS AND DISCUSSION**

Soil physicochemical properties play a pivotal role in determining soil health, productivity, and sustainability. The assessment of parameters such as bulk density, particle density, porosity, pH, electrical conductivity, organic carbon, and available nutrients provides essential insights into the effects of land use practices on soil quality (Lal, 2006; Bünemann et al., 2018). The differences in soil physicochemical properties among the various land use systems are summarized in Table 1 and visually represented in Figure 1.

Table 1: Soil physico-chemical properties under different land use systems

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Land Use System** | **BD (g/cm³)** | **Porosity (%)** | **pH** | **EC (dS/m)** | **N (kg/ha)** | **P₂O₅ (kg/ha)** | **K₂O (kg/ha)** | **OC (%)** |
| Barren Land | 1.58 ± 0.02 **a** | 37.5 ± 1.14 **b** | 5.39 ± 0.18 **ab** | 0.036 ± 0.009 **a** | 101.64 ± 6.89 **d** | 16.07 ± 1.29 **d** | 113.5 ± 4.17 **c** | 0.62 ± 0.04 **d** |
| Paddy | 1.25 ± 0.09 **c** | 46.5 ± 2.01 **a** | 5.07 ± 0.12 **b** | 0.036 ± 0.009 **a** | 330.37 ± 30.61 **a** | 25.38 ± 1.89 **c** | 104.9 ± 17.78 **c** | 1.32 ± 0.06 **c** |
| Flower Crops | 1.57 ± 0.06 **a** | 38.9 ± 4.00 **b** | 5.97 ± 0.28 **a** | 0.033 ± 0.007 **a** | 115.56 ± 27.79 **d** | 42.11 ± 2.56 **a** | 218.6 ± 3.08 **a** | 1.57 ± 0.09 **b** |
| Fruit-based Homestead | 1.40 ± 0.06 **b** | 39.6 ± 2.79 **b** | 5.63 ± 0.32 **ab** | 0.086 ± 0.008 **a** | 326.71 ± 15.43 **a** | 31.43 ± 1.14 **b** | 149.6 ± 6.94 **b** | 2.02 ± 0.06 **a** |
| Rice-Vegetable | 1.32 ± 0.12 **bc** | 40.3 ± 3.99 **b** | 5.41 ± 0.27 **ab** | 0.191 ± 0.12 **a** | 348.04 ± 18.16 **a** | 32.05 ± 2.56 **b** | 148.3 ± 4.93 **b** | 1.66 ± 0.03 **b** |

\* Values are **mean ± SE**. Means sharing the **same letter** in a column are **not significantly different** at p ≤ 0.05

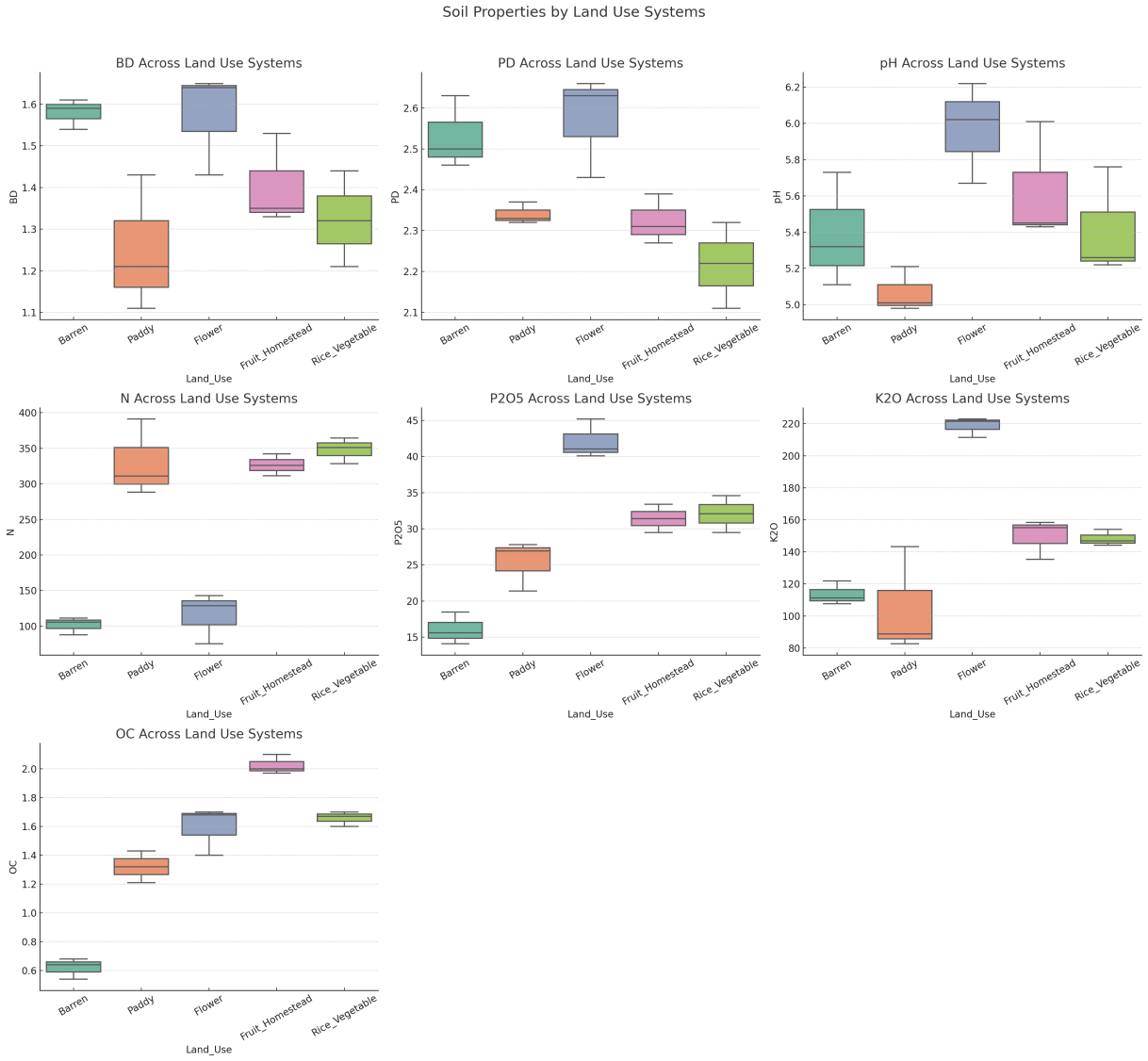


Figure 1 Boxplots showing soil physico-chemical properties across different land use systems (BD-Bulkdensity (g cm-3), PD Particle density (g cm-3), N-Available Nitrogen (kg ha-1), P2O5 Available phosphorus (kg ha-1), K2O-Available Potassium (kg ha-1), OC-Soil organic carbon (%).

**3.1 Bulk and Particle Density**Bulk density (BD) and particle density (PD) are physical properties that influence porosity, root penetration, and water retention. High BD indicates compacted soil with lower pore space, while PD reflects the mineralogical composition of soil particles (Brady & Weil, 2017). In the present study, significant variations were observed across land use types (p = 0.0207 for BD and p = 0.0028 for PD) (Table 1). Paddy systems exhibited the lowest bulk density (1.25 g/cm³), likely due to puddling and high organic matter inputs that reduce soil compaction (Panagos et al 2024). Waterlogging in paddy fields causes breakdown of soil aggregates and displaces air, lowering soil mass per unit volume (Kaur et al., 2019). Conversely, flower crop systems recorded the highest particle density, possibly due to greater mineral content and frequent tillage operations that disturb soil structure (Li et al., 2025).

**3.2 Soil pH and Electrical Conductivity (EC)** Soil pH is a master variable influencing nutrient availability, microbial activity, and chemical reactions in the soil (Paul, 2015). It is sensitive to fertilization practices, crop residues, and liming. In this study, pH differed significantly among systems (p = 0.0285)( Table 1), ranging from acidic in paddy fields (5.07) to near-neutral in flower crop systems (5.97). The relatively higher pH in flower beds may reflect lime applications or organic residues with alkaline characteristics like vermicompost with banana pseudo stem as raw material. Acidification in paddy soils is likely due to anaerobic conditions and continuous use of ammonium-based fertilizers (Guo et al., 2010; Goulding, 2016). EC, which indicates soluble salt content, showed no significant difference (p = 0.3782) (Table 1), with all values within acceptable agricultural thresholds (Figure 1). This aligns with previous reports documenting stable EC values across different cropping systems (Brady & Weil, 2017), suggesting negligible salinity stress.

**3.3 Available Nutrients (N, P, K)** Nutrient availability is a key determinant of soil fertility. Nitrogen is essential for vegetative growth, phosphorus for root development and energy transfer, and potassium for water regulation and disease resistance (Havlin et al., 2014; Marschner, 2012; Awe et. al., 2018). Highly significant differences were found in available nitrogen (p < 0.00001), phosphorus (p < 0.00001), and potassium (p = 0.00006) (Table 1). Fruit-based homestead and rice-vegetable systems had the highest values for all three nutrients. This can be attributed to regular addition of organic inputs such as compost and tree litter, which enhance mineralization and nutrient cycling (Drinkwater & Snapp, 2007; Blanco - Canqui & Lal, 2009). In contrast, nutrient depletion in barren lands and monocropped paddy fields could be due to erosion, nutrient leaching, and lack of organic amendments (Lal, 2006; Tilman et al., 2002). Monoculture reduces below ground biomass and limits nutrient replenishment through residues (McDaniel et al., 2014).

**3.4 Organic Carbon (OC)** Soil organic carbon is a vital component of soil organic matter and contributes to nutrient cycling, aggregation, and biological activity (Devi, 2021). OC varied significantly across systems (p < 0.00001), ranging from 0.62% in barren land to 2.02% in fruit-based systems. The high carbon stock in fruit-based systems is likely due to sustained input from root biomass, leaf litter, and minimal soil disturbance that protects organic matter from decomposition (Mendoza et al 2025; Bünemann et al., 2018). Crop diversification enhances microbial carbon use efficiency and promotes carbon sequestration in soil aggregates (Jiang et. al., 2025).

**3.5 Tukey HSD analysis**

Tukey’s HSD test revealed distinct groupings among land use types for all significant soil parameters (Table 1). Barren land consistently formed a separate group with notably lower nutrient and organic carbon levels, whereas fruit-based and rice-vegetable systems clustered together, exhibiting the highest concentrations. Similar trends have been documented by studies showing that greater plant diversity and perennial systems enhance soil health indicators, including nutrient cycling and organic carbon stocks, due to sustained organic inputs and reduced disturbance (Blanco-Canqui & Lal 2008; Cong et al. 2015; Tiemann et al. 2015). Diversified and perennial cropping systems foster enhanced biological activity, maintain continuous ground cover, and improve microclimatic conditions, all of which contribute to increased nutrient retention and soil carbon sequestration (Lal 2004; McDaniel et al. 2014).

Overall, the results highlight the importance of integrated and biologically enriched systems in maintaining soil fertility and ecological balance. These systems not only enhance nutrient availability and carbon content but also promote microbial health, structural stability, and resilience to environmental stress (Bünemann et al., 2018; Onemayin et al 2020).

**4. CONCLUSION**

The findings of this study clearly establish that land use practices exert a profound influence on soil physicochemical properties in the Jorhat district of Assam. Systems integrating perennial vegetation, organic recycling, and crop diversification—such as fruit-based homesteads and rice-vegetable rotations—significantly improve key soil quality indicators, including organic carbon, nutrient availability, and reduced bulk density. These systems create favorable conditions for microbial activity, enhance soil structure, and support long-term sustainability of agricultural productivity. On the contrary, barren and intensively monocropped lands like paddy fields exhibit depleted fertility and lower organic matter status, thereby compromising soil resilience. Given the challenges posed by climate variability and land degradation in the northeastern region, adopting integrated land use models becomes essential. Such systems not only improve soil health but also contribute to biodiversity conservation, carbon sequestration, and enhanced livelihood opportunities for smallholder farmers. Therefore, it is imperative for policymakers, researchers, and development agencies to prioritize the promotion of ecologically sound, socially acceptable, and economically viable land use strategies for sustainable agricultural intensification in the region.

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Details of the AI usage are given below:

1. GPT-3.5 : prompts : Find some literatures related to the topic

**References**

Awe O, G., O. Nurudeen, O., O. Omotoso, S., A. Amiola, A., Ojeniyi, D., & Tutuola, T. (2018). Soil Physico-chemical Properties Changes under Different Crops in Ado Ekiti, Nigeria. Asian Soil Research Journal, 1(2), 1–15. <https://doi.org/10.9734/asrj/2018/v1i2653>

Bhuyan, S., Patgiri, D. K., Medhi, S. J., Chutia, D., Meena, R. S., & Sandillya, M. (2023). Spatial distribution of soil nutrient status of Biswanath district, Assam, North East India. International Journal of Plant & Soil Science, 35(8), 145–157. <https://doi.org/10.9734/IJPSS/2023/v35i82891>

Blake, G. R., & Hartge, K. H. (1986). Bulk density. In A. Klute (Ed.), Methods of Soil Analysis: Part 1. Physical and Mineralogical Methods (2nd ed., pp. 363–375). American Society of Agronomy.

Blanco-Canqui, H., & Lal, R. (2008). Crop residue removal impacts on soil productivity and environmental quality. Critical Reviews in Plant Sciences, 27(1), 1–16.

Blanco-Canqui, H., & Lal, R. (2009). Crop residue removal impacts on soil productivity and environmental quality. Critical Reviews in Plant Sciences, 28(3), 139–163.

Borah, N., Chetia, S. K., Pathak, P. K., Sarma, A., Saikia, M., & Pathak, K. (2024).  
Soil fertility, crop productivity, cropping intensity and livelihood enhancement in Titabar, Assam, India: A participatory approach through Farmer FIRST Programme. *Journal of Scientific Research & Reports, 30*(12), 341–349.

Brady, N. C., & Weil, R. R. (2017). The nature and properties of soils (15th ed.). Pearson.

Bünemann, E. K., Bongiorno, G., Bai, Z., Creamer, R. E., De Deyn, G., de Goede, R., ... & Brussaard, L. (2018). Soil quality – A critical review. Soil Biology and Biochemistry, 120, 105–125. <https://doi.org/10.1016/j.soilbio.2018.01.030>

Chakravarty, M., Nath, D. J., & Sarma, U. J. (2023). Physicochemical properties of long‑term rice‑fallow cultivation and uncultivated soils of Nalbari, Assam, India. International Journal of Plant & Soil Science, 35(20), 1362–1369. <https://doi.org/10.9734/IJPSS/2023/v35i203936>

Cong, W. F., Raza, W., Oenema, O., et al. (2015). Intercropping enhances soil carbon and nitrogen. Global Change Biology, 21(4), 1715–1726.

Cornish, P. S., Kumar, A., & Das, S. (2020). Soil fertility along toposequences of the East India Plateau. SOIL, 6, 325–336. <https://doi.org/10.5194/soil-6-325-2020>

Das, A., Biswas, D. R., Sharma, V. K., Das, R., Ray, P., Ghosh, A., & Biswas, S. S. (2020). Soil potassium fractions under two contrasting land use systems of Assam. Indian Journal of Agricultural Sciences, 89(8). [Available via e-publications of ICAR-IARI]

Devi, N. B. (2021). Soil microbial biomass as an index of soil quality and fertility in different land use systems of Northeast India. In S. Das & P. Bhattacharya (Eds.), Microbiological activity for soil and plant health management (pp. 61–77). Springer. <https://doi.org/10.1007/978-981-16-2922-8_4>

Drinkwater, L. E., & Snapp, S. S. (2007). Nutrients in agroecosystems: Rethinking the management paradigm. Advances in Agronomy, 92, 163–186. <https://doi.org/10.1016/S0065-2113(07)92004-2>

Dutta, A., Dutta, S., & Karmakar, R. M. (2021). Characterization and classification of some alluvium‑derived soils under different land uses in Jorhat district of Assam. Journal of the Indian Society of Soil Science. [Available via ICAR-IARI Publications]

Goulding, K. W. T. (2016). Soil acidification and the importance of liming agricultural soils with particular reference to the United Kingdom. Soil Use and Management, 32(3), 390–399. <https://doi.org/10.1111/sum.12270>

Guo, J. H., Liu, X. J., Zhang, Y., Shen, J. L., Han, W. X., Zhang, W. F., ... & Zhang, F. S. (2010). Significant acidification in major Chinese croplands. Science, 327(5968), 1008–1010. <https://doi.org/10.1126/science.1182570>

Havlin, J. L., Tisdale, S. L., Nelson, W. L., & Beaton, J. D. (2014). Soil fertility and fertilizers: An introduction to nutrient management (8th ed.). Pearson.

Jackson, M. L. (1973). Soil chemical analysis. Prentice Hall of India.

Jiang, Y., Zhang, M., Ling, N., et al. (2025). Soil organic carbon thresholds control fertilizer effects on carbon accrual in croplands worldwide. Nature Communications, 16, 3009. <https://doi.org/10.1038/s41467-025-57981-6>

Kaur, G., Singh, G., Motavalli, P. P., Nelson, K. A., Orlowski, J. M., & Golden, B. R. (2019). Impacts and management strategies for crop production in waterlogged or flooded soils: A review. Agronomy Journal, 112(2), 1471–1488. <https://doi.org/10.1002/agj2.20093>

Lal, R. (2004). Soil carbon sequestration to mitigate climate change. Geoderma, 123(1–2), 1–22. <https://doi.org/10.1016/j.geoderma.2004.01.032>

Lal, R. (2006). Enhancing crop yields through restoration of soil organic carbon pool. Land Degradation & Development, 17(2), 197–209. <https://doi.org/10.1002/ldr.696>

Lehmann, J., & Kleber, M. (2015). The contentious nature of soil organic matter. Nature, 528, 60–68. <https://doi.org/10.1038/nature16069>

Li, A., Cheng, J., Chen, D., et al. (2025). Spatial interpolation of cropland soil bulk density by increasing soil samples with filled missing values. Scientific Reports, 15, 8008. <https://doi.org/10.1038/s41598-025-91335-y>

Mahmud, M. A.-A., Hota, S., Mishra, V., Mourya, K. K., Giri, K., Kumar, D., ... & Ray, S. K. (2022). Land use, landform, and soil management as determinants of soil physicochemical properties and microbial abundance of Lower Brahmaputra Valley, India. Sustainability, 14(4), 2241–2258. <https://doi.org/10.3390/su14042241>

Marschner, P. (2012). Marschner’s mineral nutrition of higher plants (3rd ed.). Academic Press.

McDaniel, M. D., Tiemann, L. K., & Grandy, A. S. (2014). Does agricultural crop diversity enhance soil microbial biomass and organic matter dynamics? A meta-analysis. Ecological Applications, 24(3), 560–570. <https://doi.org/10.1890/13-0616.1>

Mendoza, O., De Neve, S., Deroo, H., Li, H., Françoys, A., & Sleutel, S. (2025). Soil organic carbon mineralization is controlled by the application dose of exogenous organic matter. SOIL, 11, 105–119. <https://doi.org/10.5194/soil-11-105-2025>

Olsen, S.R., Cole, C.V., Watanabe, F.S., & Dean, L.A. (1954). *Estimation of available phosphorus in soils by extraction with sodium bicarbonate*. USDA Circular No. 939.

Onemayin, J. J., Olayiwola, V. A., Abiodun, F. O., Musa, F. B., & Idris, R. S. (2020). Land Use Influence on Some Soil Physical and Chemical Properties of an Alfisol at Forestry Research Institute of Nigeria. International Journal of Plant & Soil Science, 32(4), 1–8. https://doi.org/10.9734/ijpss/2020/v32i430263

Panagos, P., De Rosa, D., Liakos, L., Labouyrie, M., Borrelli, P., & Ballabio, C. (2024). Soil bulk density assessment in Europe. Agriculture, Ecosystems & Environment, 364, Article 108366. <https://doi.org/10.1016/j.agee.2024.108366>

Parida, G. (2022). Soil characterization and organic carbon dynamics under different land use systems of Assam [Unpublished doctoral dissertation, ICAR-Indian Agricultural Research Institute]. KrishiKosh Repository.

Paul, E. A. (2015). Soil microbiology, ecology and biochemistry (4th ed.). Academic Press.

Pratt, P. F. (1965). Potassium. In C. A. Black (Ed.), Methods of Soil Analysis: Part 2. Chemical and Microbiological Properties (pp. 1022–1030). American Society of Agronomy.

Six, J., Conant, R. T., Paul, E. A., & Paustian, K. (2002). Stabilization mechanisms of soil organic matter: Implications for C-saturation of soils. Plant and Soil, 241, 155–176. <https://doi.org/10.1023/A:1016125726789>

Subbiah, B. V., & Asija, G. L. (1956). A rapid procedure for the estimation of available nitrogen in soils. Current Science, 25, 259–260.

Tiemann, L. K., Grandy, A. S., Atkinson, E. E., Marin-Spiotta, E., & McDaniel, M. D. (2015). Crop rotational diversity enhances belowground communities and functions in agroecosystems. Ecology Letters, 18(8), 761–771. <https://doi.org/10.1111/ele.12453>

Tilman, D., Cassman, K. G., Matson, P. A., Naylor, R., & Polasky, S. (2002). Agricultural sustainability and intensive production practices. Nature, 418(6898), 671–677. <https://doi.org/10.1038/nature01014>

USDA Natural Resources Conservation Service (NRCS). (2014). Soil electrical conductivity: Soil quality kit—Guidelines for educators. <https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/health/assess/?cid=nrcs142p2_053302>

Walkley, A., & Black, I. A. (1934). An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Science, 37, 29–38.