Volume 4, Issue 8
August I 2026

Agri Roots
e- Magazine

www.agrirootsmagazine.in

ISSN: 2583-9071

How Nutrient Cycling Keeps Soil Healthy and Productive

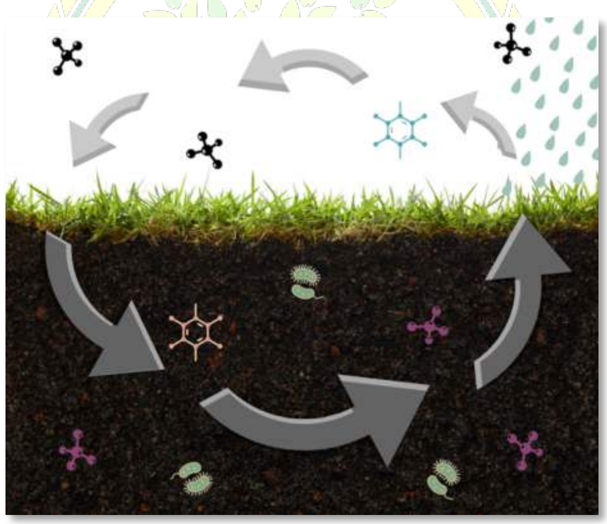
ARTICLE ID: 0405

Iliya Hassan Abubakar[1], Adiba Afrin[2]

[1]M.Sc. Agronomy Student, School of Agriculture, Sanskaram University, Jhajjar, Haryana–124108, India

[2]M.Sc. Student, Department of Entomology, Bangladesh Agricultural University, Mymensingh–2202, Bangladesh

Nutrient cycling, often described as nature's recycling system, is the continuous movement and reuse of essential nutrients among soil, plants, animals, microorganisms, water, and the atmosphere. In agricultural systems, plants take up nutrients such as nitrogen, phosphorus, and potassium from the soil for their growth and development. These nutrients are gradually returned to the soil when leaves fall, crop residues remain in the field, or organisms die and decompose. Soil microorganisms, particularly bacteria and fungi, play an important role in decomposing organic matter and releasing nutrients in forms that plants can absorb again (Schroder et al., 2016).



Nutrient cycling is important because it helps maintain soil productivity and minimizes the loss of essential nutrients from agricultural systems. If this natural recycling process did not occur, soils would gradually become depleted, resulting in reduced crop yields and increased dependence on external inputs such as inorganic fertilizers. Efficient nutrient cycling supports agricultural production by maintaining the availability of nutrients for plant uptake (Reicosky, 2018). Major nutrient cycles include the nitrogen, phosphorus, potassium, and carbon cycles. Each cycle represents the movement and transformation of nutrients within an ecosystem. For example, nitrogen can be fixed from the atmosphere, absorbed by plants, and eventually returned to the soil through the decomposition of organic matter. This continuous process supports biological activity and contributes to ecological balance.

Healthy soils are characterized by active nutrient cycling. Soils rich in organic matter provide suitable habitats for beneficial microorganisms and tend to recycle nutrients more efficiently, thereby improving soil fertility and supporting healthy plant growth. Therefore, understanding nutrient cycling is important not only for farmers but also for everyone concerned with sustainable food production and environmental conservation.

Why Healthy Soil Matters in Agriculture

Soil health can be defined as the capacity of soil to function as a living system within ecosystem and land-use boundaries, supporting plant and animal production, maintaining or improving water and air quality, and promoting plant and animal health. Healthy soil is essential for sustainable agriculture because it supports biological activity, organic matter decomposition, nutrient cycling, suppression of soil-borne pathogens, water storage, and the transformation and retention of nutrients (Tahat et al., 2020).

Healthy soils provide several important ecosystem services, including high water-holding capacity, improved soil aggregation, enhanced nutrient availability, and efficient nutrient cycling. For example, effective nitrogen cycling allows nitrogen to be retained in the soil and made available for plant uptake when required (Doran & Zeiss, 2000). In contrast, degraded soils often have poor structure, reduced biological activity, limited nutrient availability, and lower water-holding capacity. Maintaining soil health is therefore essential for achieving stable crop production while reducing the environmental impacts associated with excessive use of external inputs.

How Nutrients Move in Nature

The movement of nutrients through nature occurs through a continuous process known as nutrient cycling. The process begins when plants absorb essential nutrients such as nitrogen, phosphorus, and potassium from the soil through their roots. These nutrients support plant growth, flowering, grain and fruit development, and other physiological functions.

When plants shed leaves, crop residues remain in the field, or organisms die, the organic matter is decomposed by soil microorganisms such as bacteria and fungi. During decomposition, nutrients are released into the soil in forms that can once again be taken up by plants, thereby completing the nutrient cycle.

Some nutrients may be lost from the soil through leaching, runoff, erosion, or gaseous emissions. Nitrogen, in particular, can enter or leave the atmosphere through biological and chemical processes (Hayashi, 2022). Soils containing diverse and active microbial communities can support efficient nutrient cycling through the continuous transformation and recycling of nutrients. This natural process helps reduce nutrient losses, maintain soil fertility, and support sustainable crop production. Protecting soil biodiversity and adopting appropriate agricultural practices can therefore promote efficient nutrient circulation within the soil–plant system (Banerjee & van der Heijden, 2023).

Simple Ways Farmers Can Improve Soil Fertility

Farmers do not always need to spend large amounts of money to maintain soil fertility. Simple and sustainable management practices can significantly improve soil health and crop productivity. One of the most effective approaches is the addition of organic materials such as compost, farmyard manure, and crop residues. These materials increase soil organic matter, improve soil structure, enhance microbial activity, and provide a gradual supply of nutrients to crops (Vanlauwe et al., 2010).

Another useful practice is crop rotation. The inclusion of legumes such as cowpea, soybean, and groundnut in cropping systems can improve soil nitrogen status through biological nitrogen fixation. This can reduce dependence on inorganic nitrogen fertilizers and contribute to long-term soil fertility management (Havlin & Heiniger, 2020).

The combined use of biochar, microbial inoculants, organic amendments, and balanced fertilizer management can further improve soil fertility. Biochar is a carbon-rich material produced from organic materials under oxygen-limited conditions. It can improve soil structure, increase soil organic carbon, enhance water retention, and improve nutrient retention. Its porous structure can also provide a suitable habitat for beneficial microorganisms, thereby increasing biological activity and potentially reducing nutrient losses (Bolan et al., 2023).

Microbial inoculants such as *Rhizobium*, *Azotobacter*, phosphate-solubilizing bacteria (PSB), and arbuscular mycorrhizal fungi (AMF) can contribute to nutrient availability through biological nitrogen fixation, phosphorus solubilization, and improved nutrient uptake by plant roots. These biological inputs should not necessarily be viewed as complete substitutes for conventional soil-fertility management but can provide additional benefits when integrated with organic amendments and appropriate fertilizer practices. Such integrated soil management can improve nutrient-use efficiency, promote soil fertility, and contribute to sustainable crop production (Shahwar et al., 2023).

Farmers can also improve nutrient-use efficiency by applying inorganic fertilizers according to soil-test recommendations. This approach helps provide crops with the required nutrients in appropriate quantities while reducing nutrient losses and unnecessary production costs. In addition, practices such as mulching, cover cropping, and reduced tillage can conserve soil moisture, minimize erosion, improve soil structure, and enhance nutrient retention.

By adopting these practices, farmers can maintain healthy soils, improve crop productivity, reduce unnecessary dependence on external inputs, and build more sustainable agricultural systems for future generations.

Conclusion

Nutrient cycling is fundamental to maintaining soil health, fertility, and long-term agricultural productivity. The continuous movement and recycling of nutrients between soil, plants, microorganisms, and the atmosphere ensures that essential elements remain available for plant growth. Soil microorganisms, organic matter, crop residues, and diverse cropping systems all contribute to this process.

Farmers can strengthen nutrient cycling through practical approaches such as organic matter addition, crop rotation, balanced fertilizer application, biofertilizer use, mulching, cover cropping, and reduced tillage. Rather than relying solely on external inputs, an integrated approach to soil fertility management can improve nutrient-use efficiency and enhance the biological functioning of soil. Healthy and biologically active soils are therefore an important foundation for productive, resilient, and sustainable agriculture.

References

1. Banerjee, S., & van der Heijden, M. G. A. (2023). Soil microbiomes and one health. *Nature Reviews Microbiology, 21*, 6–20. https://doi.org/10.1038/s41579-022-00779-w
2. Bolan, S., Hou, D., Wang, L., Hale, L., Egamberdieva, D., Tammeorg, P., Li, R., Wang, B., Xu, J., Wang, T., Sun, H., Padhye, L. P., Wang, H., Siddique, K. H., Rinklebe, J., Kirkham, M., & Bolan, N. (2023). The potential of biochar as a microbial carrier for agricultural and environmental applications. *Science of the Total Environment, 886*, 163968. https://doi.org/10.1016/j.scitotenv.2023.163968
3. Doran, J. W., & Zeiss, M. R. (2000). Soil health and sustainability: Managing the biotic component of soil quality. *Applied Soil Ecology, 15*(1), 3–11.
4. Havlin, J. L., & Heiniger, R. W. (2020). Soil fertility management for better crop production. *Agronomy, 10*(9), 1349. https://doi.org/10.3390/agronomy10091349
5. Hayashi, K. (2022). Nitrogen cycling and management focusing on the central role of soils: A review. *Soil Science and Plant Nutrition, 68*(5–6), 514–525. https://doi.org/10.1080/00380768.2022.2125789
6. Reicosky, D. C. (2018). Nutrient cycling in soils. In R. Lal & B. A. Stewart (Eds.), *Managing Soil Health for Sustainable Agriculture*. CRC Press.
7. Schroder, J. J., Schulte, R. P. O., Creamer, R. E., Delgado, A., van Leeuwen, J., Lehtinen, T., Rutgers, M., Spiegel, H., Staes, J., Tóth, G., & Wall, D. P. (2016). The elusive role of soil quality in nutrient cycling: A review. *Soil Use and Management, 32*(4), 476–486. https://doi.org/10.1111/sum.12288
8. Shahwar, D., Mushtaq, Z., Mushtaq, H., Alqarawi, A. A., Park, Y., Alshahrani, T. S., & Faizan, S. (2023). Role of microbial inoculants as biofertilizers for improving crop productivity: A review. *Heliyon, 9*(6), e16134. https://doi.org/10.1016/j.heliyon.2023.e16134
9. Tahat, M. M., Alananbeh, K. M., Othman, Y. A., & Leskovar, D. I. (2020). Soil health and sustainable agriculture. *Sustainability, 12*(12), 4859. https://doi.org/10.3390/su12124859
10. Vanlauwe, B., Bationo, A., Chianu, J., Giller, K. E., Merckx, R., Mokwunye, U., Ohiokpehai, O., Pypers, P., Tabo, R., Shepherd, K. D., Smaling, E. M. A., Woomer, P. L., & Sanginga, N. (2010). Integrated soil fertility management: Operational definition and consequences for implementation and dissemination. *Outlook on Agriculture, 39*(1), 17–24. https://doi.org/10.5367/000000010791169998