Ecofarming (e-Magazine)

Agriculture

Ecofarming
e-Magazine for Agriculture and Allied Sciences
http://www.ecofarming.rdagriculture.in
e-ISSN: 2583-0791

Plastic Pollution and Soil Fertility

Emerging Threats to Sustainable Agriculture

Suneel Kumar[1]*, Ashutosh Kumar Rai[1], Devesh Pathak[2], Raisen Pal[3] and Manoj Kumar[4]
[1]ICAR- Indian Institute of Farming System Research, Modipuram, Meerut- 250110, U.P.
[2]Krishi Vigyan Kendra, Amethi, (ANDUAT, Kumarganj, Ayodhya).
[3]Rani Awanti Bai Lodhi College of Agriculture and Research Station, Chhuikhadan, IGKV, Raipur, 491884, Chhattisgarh.
[4]Deen Dayal Upadhyaya Gorakhpur University, Gorakhpur- 273009, U.P.
*Email: sssp447ag@gmail.com

Received: June, 2026; Accepted: June, 2026; Published: July, 2026

Introduction

Plastic pollution has become one of the most serious environmental problems worldwide, affecting terrestrial, aquatic, and atmospheric ecosystems. Due to rapid industrialization, urbanization, population growth, and increased use of synthetic materials, the production and disposal of plastic waste have increased dramatically over recent decades. Plastics are widely used because of their durability, flexibility, lightweight nature, and low cost. However, these same properties make plastics highly persistent in the environment. In agricultural systems, plastics are extensively used in mulching, greenhouse films, irrigation pipes, seedling trays, pesticide containers, and fertilizer packaging. Continuous and improper disposal of plastic materials has resulted in the accumulation of plastic residues in agricultural soils, thereby threatening soil fertility, ecosystem stability, and sustainable crop production.

Unlike organic materials, plastics do not decompose easily. Over time, larger plastic materials break down into smaller particles called microplastics (less than 5 mm) and nano plastics, which persist in soil for long periods. These particles alter the physical, chemical, and biological properties of soil and negatively influence soil fertility and agricultural productivity. Soil fertility refers to the ability of soil to provide essential nutrients, water, aeration, and a favourable environment for plant growth. Plastic contamination interferes with these processes and affects the overall functioning of soil ecosystems.

Sources of Plastic Pollution in Agricultural Soils

Agricultural soils receive plastic contamination from multiple sources. One of the major sources is the use of plastic mulch films for moisture conservation and weed control. Although mulching improves crop productivity, improper removal of plastic films leaves residues in the soil. Greenhouse coverings, drip irrigation pipes, plastic bags, pesticide bottles, and fertilizer packaging materials also contribute significantly to plastic accumulation.

Another important source is sewage sludge and compost prepared from municipal solid waste. These materials often contain microplastic particles that enter agricultural fields during application. Industrial waste, wastewater irrigation, urban runoff, and atmospheric deposition further increase plastic contamination in soils. Continuous use of these contaminated inputs results in long-term accumulation of plastic particles in agricultural ecosystems.

Effects of Plastic on Soil Physical Properties

Plastic pollution significantly affects the physical properties of soil. Soil structure, porosity, bulk density, aeration, aggregation, and water movement are highly sensitive to plastic contamination. Microplastics can block soil pores and reduce soil permeability, thereby affecting water infiltration and gaseous exchange.

Plastic particles interfere with soil aggregation by disrupting the natural binding of soil particles. Stable aggregates are essential for maintaining soil structure, root growth, and water retention. Disturbance in aggregation reduces soil stability and increases susceptibility to erosion. Microplastics alter soil bulk density and negatively influence soil physical functioning. Plastic contamination may also increase soil compaction and reduce root penetration. Changes in soil porosity and aggregation affect water-holding capacity and hydraulic conductivity. As a result, plants experience moisture stress even under irrigated conditions. Reduced infiltration and increased runoff further contribute to soil degradation and nutrient loss.

Impact on Soil Chemical Properties

Plastics influence several chemical properties of soil, including pH, nutrient availability, cation exchange capacity, and organic matter dynamics. Microplastics can adsorb toxic chemicals, pesticides, heavy metals, and persistent organic pollutants from the environment. These contaminants may later be released into the soil solution and affect nutrient availability and plant growth. Plastic particles also interfere with the decomposition of organic matter and nutrient cycling processes. Essential nutrients such as nitrogen, phosphorus, potassium, calcium, and magnesium become less available due to disturbed microbial activity and reduced organic matter transformation. Long-term plastic accumulation may therefore decrease soil fertility and crop productivity.

Certain plastic additives and chemicals released during degradation can also create toxic effects on soil organisms and plants. These substances may alter soil chemistry and contribute to environmental pollution.

Effects on Soil Biological Properties

Soil biological activity is one of the most important indicators of soil fertility. Soil microorganisms including bacteria, fungi, actinomycetes, algae, and earthworms play critical roles in decomposition, nutrient cycling, humus formation, and soil aggregation. Plastic pollution negatively affects these biological processes. Microplastics disturb microbial habitats and reduce microbial diversity and population density. Beneficial microorganisms responsible for nitrogen fixation, phosphorus solubilization, and decomposition decline under plastic-contaminated conditions. Reduced microbial activity leads to slower organic matter decomposition and poor nutrient availability. microplastics represent a major emerging threat to terrestrial ecosystems because they alter soil biological functioning. Soil enzyme activities such as dehydrogenase, urease, phosphatase, and β-glucosidase also decline under plastic pollution, indicating reduced biological health of soil.

Earthworms are particularly sensitive to plastic contamination. Ingestion of microplastics affects their feeding behaviour, reproduction, growth, and burrowing activity. Since earthworms contribute significantly to aeration, humus formation, and nutrient cycling, their reduction negatively impacts soil fertility and ecosystem functioning.

Impact on Plant Growth and Crop Productivity

Plastic contamination directly and indirectly affects plant growth and crop productivity. Microplastics influence seed germination, root development, nutrient uptake, photosynthesis, and biomass production. Plastic particles around plant roots may restrict root elongation and reduce water and nutrient absorption. Several studies have shown that microplastic contamination reduces chlorophyll content, plant height, root biomass, and yield parameters in crops. Plastic mulch residues negatively affected wheat growth and soil fertility under long-term agricultural conditions. Plastic-associated toxic substances may also accumulate in plant tissues and enter the food chain, posing risks to human and animal health. Therefore, plastic pollution not only threatens soil health but also food safety and environmental sustainability.

Plastic Burning and Environmental Hazards

Burning plastic waste in agricultural fields is another serious environmental concern. Farmers often burn used plastic materials after harvesting due to lack of proper disposal facilities. Burning plastics releases harmful gases such as dioxins, furans, carbon monoxide, sulphur dioxide, and greenhouse gases into the atmosphere. These emissions contribute to air pollution, climate change, respiratory diseases, and environmental toxicity. Residual ash from burnt plastics may also contaminate soils with toxic compounds and heavy metals.

Microplastics and Long-Term Soil Degradation

Microplastics persist in soils for many years because they degrade very slowly. Their long-term accumulation can alter soil ecosystem functioning and reduce agricultural sustainability. Continuous deposition of microplastics may lead to chronic soil degradation, biodiversity loss, and disruption of nutrient cycling processes. Scientists are increasingly concerned about the movement of microplastics through soil-water systems and their interaction with soil organisms and crops. Research has shown that microplastics can move into deeper soil layers and potentially contaminate groundwater systems.

Management Strategies to Reduce Plastic Pollution

Several management strategies can help reduce plastic pollution and protect soil fertility. Sustainable agricultural practices and environmentally friendly alternatives are essential for minimizing plastic contamination. Biodegradable plastics prepared from natural materials are gaining attention as sustainable alternatives to conventional plastics. Improved recycling technologies and waste management systems can also reduce plastic accumulation in soils.

Conclusion

Plastic pollution has emerged as a major threat to soil fertility, agricultural productivity, and environmental sustainability. Accumulation of plastics and microplastics in soils negatively affects soil physical, chemical, and biological properties, thereby disturbing nutrient cycling, microbial activity, water movement, and plant growth. Long-term plastic contamination reduces soil health and threatens sustainable agricultural production. Improper disposal, excessive use of agricultural plastics, and poor waste management practices have accelerated the spread of plastic pollution in terrestrial ecosystems. Soil microorganisms, earthworms, and beneficial soil fauna are highly vulnerable to plastic contamination, resulting in reduced soil biological functioning and ecosystem stability. Sustainable management practices such as biodegradable materials, recycling technologies, organic farming, proper waste disposal, and environmental awareness programs are essential for reducing plastic pollution and protecting soil fertility. Future agricultural systems must focus on environmentally sustainable practices that minimize plastic dependency and ensure long-term soil health and food security.

References

1. M. C. (2018). Impacts of microplastics on the soil biophysical environment. Environmental Science & Technology, 52(17), 9656–9665. https://doi.org/10.1021/acs.est.8b02212
2. Qi, Y., Yang, X., Pelaez, A. M., Huerta Lwanga, E., Beriot, N., Gertsen, H., Garbeva, P., & Geissen, V. (2020). Macro- and micro-plastics in soil-plant system: Effects of plastic mulch film residues on wheat growth. Science of the Total Environment, 645, 1048–1056. https://doi.org/10.1016/j.scitotenv.2018.07.229
3. Rillig, M. C. (2012). Microplastic in terrestrial ecosystems and the soil? Environmental Science & Technology, 46(12), 6453–6454. https://doi.org/10.1021/es302011r