STM JOURNALS

Research & Reviews: Journal of
Ecology

https://journals.stmjournals.com/rrjoe

ISSN: 2278-2230
Volume 15, Issue 2, 2026
May–August
DOI (Journal): 10.37591/RRJOE

Research RRJOE

Microplastics in Terrestrial Ecosystems: Impacts on Soil Biodiversity, Plant Growth, and Nutrient Cycling

Kishwar Jamal*

Abstract

Microplastics, defined as plastic particles smaller than 5 mm, have emerged as a widespread environmental contaminant in terrestrial ecosystems. Although their impacts in aquatic environments have received considerable attention, the occurrence and ecological consequences of microplastics in soil ecosystems are increasingly recognized as an important environmental concern. Agricultural practices, plastic mulching, sewage sludge application, wastewater irrigation, compost, atmospheric deposition, and the fragmentation of larger plastic materials are major pathways through which microplastics enter and accumulate in soils. Once present in soil, these particles can undergo weathering, fragmentation, and redistribution, thereby influencing soil physical, chemical, and biological properties. This review examines the sources, occurrence, transport, and fate of microplastics in terrestrial ecosystems, with particular emphasis on their ecological effects. Microplastics can alter soil structure, porosity, water-holding capacity, nutrient availability, and microbial activity. They may also affect soil microorganisms and fauna, including bacteria, fungi, earthworms, nematodes, and arthropods, through physical and chemical mechanisms. In plants, exposure to microplastics has been associated with changes in seed germination, root development, nutrient uptake, photosynthesis, and oxidative stress. Furthermore, microplastics can interact with pesticides, heavy metals, and other persistent contaminants, potentially acting as carriers and modifying their environmental fate and toxicity. Despite rapid advances in this field, significant knowledge gaps remain regarding long-term effects under realistic field conditions, interactions among multiple environmental stressors, the behavior of nanoplastics, and consequences for ecosystem functioning. Future research should, therefore, focus on standardized analytical methods, long-term field investigations, ecological risk assessment, and effective strategies for reducing plastic contamination in soils. Understanding these processes is essential for protecting soil biodiversity, maintaining ecosystem services, and developing sustainable terrestrial ecosystem management practices.

Keywords: Microplastics, soil pollution, soil biodiversity, soil microorganisms, terrestrial ecosystems, plant growth, nutrient cycling, ecological risk

***Author for Correspondence**
Kishwar Jamal
E-mail: shaimajamal7@gmail.com

Student, Department of Botany, University of Allahabad, Allahabad, Uttar Pradesh, India

Received Date: September 11, 2026
Accepted Date: September 16, 2026
Published Date: September 17, 2026

Citation: Kishwar Jamal Microplastics in Terrestrial Ecosystems: Impacts on Soil Biodiversity, Plant Growth, and Nutrient Cycling. Research & Reviews: Journal of Ecology. 2026; 15(2): 44–50p.

INTRODUCTION

Microplastics are plastic particles smaller than 5 mm that have emerged as a major environmental concern due to their persistence and widespread distribution. Although research has traditionally focused on marine and freshwater environments, increasing evidence shows that terrestrial ecosystems, particularly soils, can act as important reservoirs of microplastics. Agricultural activities, plastic mulching, wastewater irrigation, sewage sludge, compost, atmospheric deposition, and the degradation of larger plastic materials are important sources of microplastics in soil [1].

Once present in soil, microplastics can alter physical, chemical, and biological properties and interact with soil microorganisms, earthworms, nematodes, and plants. They may influence soil structure, nutrient cycling, microbial activity, plant growth, and soil biodiversity. In addition, microplastics can adsorb pollutants, such as pesticides and heavy metals, potentially affecting their mobility and toxicity [2].

Despite growing research interest, significant gaps remain regarding the long-term effects of microplastics under natural field conditions and their interactions with other environmental stressors. Therefore, understanding their sources, fate, ecological impacts, and potential risks is essential for developing effective strategies to protect soil health and maintain sustainable terrestrial ecosystems [3].

SOURCES OF MICROPLASTICS IN SOIL

Microplastics enter soil ecosystems through several direct and indirect pathways, with agricultural activities, wastewater irrigation, sewage sludge, compost, atmospheric deposition, and plastic waste being major sources. The use and improper disposal of plastic mulch films, irrigation pipes, greenhouse materials, and other agricultural plastics can result in their gradual fragmentation into smaller particles. Wastewater and sewage sludge may transport microplastics from domestic and industrial sources into agricultural soils, while contaminated compost and organic fertilizers can introduce additional plastic particles. Atmospheric deposition also contributes microplastic fibers and fragments to agricultural, forest, and urban soils. Furthermore, poorly managed plastic waste and landfill activities can release microplastics into surrounding environments through wind, runoff, and leaching. Tire and road-wear particles generated by vehicle traffic are another important source, particularly in soils located near roads. The continuous input of microplastics from these diverse sources can lead to their accumulation in soil and may influence soil properties, biodiversity, and ecosystem functioning [4].

Occurrence, Distribution, and Accumulation of Microplastics in Soil

Microplastics are increasingly detected in agricultural, urban, forest, and other terrestrial soils worldwide. Their distribution depends on factors such as land use, proximity to pollution sources, soil characteristics, rainfall, wind, and agricultural practices. Agricultural soils often show higher microplastic concentrations due to the repeated use of plastic mulch, irrigation with wastewater, application of sewage sludge, and contaminated compost. Microplastics can accumulate mainly in surface soil but may also move into deeper soil layers through rainfall, irrigation, soil disturbance, and the activity of soil organisms such as earthworms [5]. Their persistence and continuous input from different sources may result in long-term accumulation. The abundance and distribution of microplastics also vary according to their size, shape, polymer type, and density. Therefore, understanding their occurrence and movement within soil profiles is important for assessing their ecological risks and potential effects on soil health [6].

Fate and Transport of Microplastics in Soil

Once introduced into soil, microplastics can undergo weathering, fragmentation, redistribution, and interactions with soil components. Sunlight, temperature changes, mechanical forces, and microbial activity can gradually alter their physical and chemical properties. Their movement within soil is influenced by particle size, shape, density, soil texture, organic matter, moisture, and rainfall. Microplastics may be transported from the soil surface to deeper layers through water infiltration, irrigation, runoff, and soil disturbance. Soil organisms, particularly earthworms and other burrowing fauna, can also contribute to their vertical and horizontal movement. During their environmental persistence, microplastics may develop biofilms and interact with organic matter, minerals, heavy metals, and other pollutants. These processes influence their distribution, bioavailability, and potential ecological effects, making the fate and transport of microplastics an important aspect of terrestrial pollution assessment [7].

EFFECTS OF MICROPLASTICS ON SOIL PROPERTIES

The presence of microplastics can influence the physical, chemical, and biological properties of soil. Due to differences in particle size, shape, and density, microplastics may alter soil structure, porosity, bulk density, water-holding capacity, and water movement. Their interaction with soil organic matter and minerals can also affect nutrient availability and soil aggregation. Microplastics may influence soil pH, carbon dynamics, and the activities of soil enzymes involved in nutrient cycling [3]. Changes in these properties can subsequently affect microbial communities, decomposition processes, nutrient availability, and plant growth. However, the magnitude of these effects depends on factors such as polymer type, particle size, and concentration, soil characteristics, and duration of exposure. Therefore, the accumulation of microplastics may contribute to changes in soil quality and ecosystem functioning [8].

Effects of Microplastics on Soil Microorganisms

Soil microorganisms play an essential role in decomposition, nutrient cycling, and maintenance of soil fertility, and their communities can be affected by microplastic contamination. Microplastics may alter the abundance, diversity, and activity of soil bacteria and fungi by changing soil structure, moisture conditions, nutrient availability, and microbial habitats. Their surfaces can also provide new sites for microbial colonization and biofilm formation, potentially changing the composition of microbial communities. Microplastics may influence soil enzyme activities and processes involved in carbon and nitrogen cycling, thereby affecting nutrient transformation and decomposition [9]. In addition, additives released from plastics and pollutants associated with microplastic surfaces may contribute to microbial stress. The magnitude of these effects varies with microplastic type, concentration, particle characteristics, soil properties, and environmental conditions. Consequently, microplastic contamination may influence soil microbial functioning and, in turn, broader ecosystem processes [10].

Effects of Microplastics on Soil Fauna

Microplastics can affect a wide range of soil fauna, including earthworms, nematodes, collembolans, mites, and other soil invertebrates that play important roles in decomposition, nutrient cycling, soil formation, and food–web interactions. Soil organisms may be exposed to microplastics through direct contact with contaminated soil or through ingestion during feeding. Among soil fauna, earthworms are particularly important because of their close interaction with soil particles and organic matter. During feeding and burrowing, earthworms may ingest microplastics and subsequently redistribute them within the soil profile, thereby contributing to their vertical transport. Exposure to microplastics has been associated with changes in feeding behavior, growth, reproduction, energy metabolism, and physiological condition in some soil organisms. Ingested particles may cause physical abrasion or blockage of the digestive tract, reduce feeding efficiency, and interfere with nutrient absorption. Microplastics may also induce oxidative stress by increasing the production of reactive oxygen species, which can damage cells and tissues when antioxidant defenses are insufficient [11].

Nematodes and other microscopic soil organisms may also be affected by changes in soil structure, moisture, microbial communities, and food availability caused by microplastic contamination. Since many soil invertebrates depend on microorganisms as a food source, alterations in microbial communities may indirectly affect their abundance and activity. Similarly, changes in populations of earthworms, nematodes, springtails, and other decomposers can influence litter decomposition, organic matter turnover, and nutrient cycling. Microplastics may, therefore, have both direct effects on individual organisms and indirect effects mediated through changes in soil habitat and food-web interactions [12].

The ecological effects of microplastics can be further complicated by their ability to interact with other contaminants. Microplastic surfaces may adsorb pesticides, heavy metals, and persistent organic pollutants, potentially increasing the exposure of soil organisms to these substances. In addition, chemical additives released from plastic materials during weathering may contribute to toxic effects. Aging and weathering can modify the surface properties of microplastics and may increase their ability to interact with microorganisms, organic matter, and chemical pollutants [13].

The severity of microplastic effects on soil fauna depends on several factors, including particle size, shape, polymer type, concentration, exposure duration, and environmental conditions. Smaller particles may be more easily ingested, while irregular or sharp particles may cause greater physical damage. However, responses observed under laboratory conditions may differ from those occurring under natural field conditions because environmental concentrations are often lower and organisms are exposed to multiple interacting factors. Long-term studies under environmentally realistic conditions are, therefore, needed to better understand the effects of microplastics on soil fauna and their broader consequences for soil biodiversity and ecosystem functioning.

EFFECTS OF MICROPLASTICS ON PLANTS

Microplastics can influence plants by altering the physical and chemical conditions of the soil surrounding their roots. Their presence may affect soil porosity, water availability, nutrient movement, and root–soil interactions, thereby influencing plant growth and development. Microplastics can directly or indirectly affect different stages of plant development, including seed germination, root growth, shoot development, and biomass production. Changes in soil structure caused by microplastic particles may modify water infiltration and retention, while their interaction with soil nutrients can influence the availability and uptake of essential elements by plants. In some cases, exposure to microplastics has been associated with reduced germination and root elongation, whereas other studies have reported neutral or even stimulatory responses depending on particle characteristics and experimental conditions [14].

Roots are particularly important in microplastic–plant interactions because they are directly exposed to contaminated soil. Microplastics may accumulate around the root surface and influence root architecture, including root length, branching, and biomass. Changes in the root environment can subsequently affect water and nutrient uptake. Some microplastics may also enter plant tissues through damaged root surfaces or very small particles may interact closely with root cells, although the extent and ecological significance of internalization remain subjects of ongoing research. Once associated with plant tissues, microplastics or plastic-derived chemicals may potentially influence physiological and biochemical processes.

Microplastic exposure can also induce physiological stress in plants. One important response is the production of reactive oxygen species (ROS).

EFFECTS OF MICROPLASTICS ON SOIL NUTRIENT CYCLING

Soil nutrient cycling is a fundamental ecological process that maintains soil fertility and supports plant growth and ecosystem productivity. Microplastic contamination can influence nutrient cycling by modifying soil physical properties, microbial communities, enzyme activities, and the decomposition of organic matter. Changes in soil structure, porosity, moisture, and aggregation caused by microplastics can alter the availability and movement of nutrients within the soil. In addition, microplastics may influence the activity and composition of microorganisms responsible for important biogeochemical processes.

Microplastics can affect carbon cycling by altering microbial decomposition and the breakdown of organic matter. Changes in microbial activity may influence carbon mineralization and the release of carbon dioxide from soil. Similarly, microplastics can interfere with nitrogen cycling by affecting microorganisms involved in processes such as ammonification, nitrification, and denitrification. Such changes may alter the availability of nitrogen forms required for plant growth. Microplastic contamination may also influence phosphorus cycling by changing microbial activity and interactions between phosphorus and soil minerals or organic matter [5].

MICROPLASTIC–POLLUTANT INTERACTIONS

Microplastics can interact with a wide range of chemical contaminants present in soil, including heavy metals, pesticides, and persistent organic pollutants. Their relatively large surface area, hydrophobic properties, and surface functional groups allow them to adsorb and retain different chemical substances. Weathering and degradation can further modify the surface characteristics of microplastics and increase their ability to interact with surrounding pollutants. As a result, microplastics may influence the transport, distribution, persistence, and bioavailability of contaminants in soil.

Heavy metals – such as lead, cadmium, copper, zinc, and chromium – can associate with microplastic surfaces through adsorption and other physicochemical interactions. Similarly, pesticides and organic pollutants may accumulate on plastic particles because of hydrophobic interactions. Microplastics can, therefore, act as potential carriers, transporting associated contaminants through soil and increasing the possibility of exposure to plants and soil organisms. However, the direction and magnitude of these effects depend on the type of polymer, particle size, degree of aging, surface properties, contaminant characteristics, and environmental conditions [15].

The interaction between microplastics and pollutants may also influence their toxicity. In some circumstances, microplastics can reduce the freely available concentration of a contaminant by binding it to their surfaces, whereas under other conditions they may facilitate contaminant transport and increase exposure to organisms. Soil organisms – such as earthworms and microorganisms – may, therefore, experience combined exposure to microplastics and associated chemical pollutants. Plants may also be exposed to both microplastics and adsorbed contaminants through their root systems.

These interactions make environmental risk assessment more complex because the ecological effects of microplastics cannot always be considered independently from other pollutants. Most available studies have focused on individual contaminants or controlled laboratory conditions, while relatively few have examined long-term interactions under realistic field conditions. Further research is, therefore, required to understand the mechanisms of microplastic–pollutant interactions and their consequences for soil biodiversity, plant health, nutrient cycling, and overall terrestrial ecosystem functioning [7].

FACTORS INFLUENCING MICROPLASTIC TOXICITY

The ecological effects and toxicity of microplastics in soil are influenced by several physical, chemical, biological, and environmental factors. Particle size is an important factor because smaller particles generally have a greater surface area relative to their volume and may interact more closely with microorganisms, soil fauna, and plant roots. Particle shape can also influence toxicity, as irregular and fibrous particles may produce different physical effects compared with spherical particles. The polymer type determines the chemical properties, density, persistence, and potential release of additives from microplastics. In addition, the concentration and duration of exposure strongly influence biological responses, with prolonged exposure potentially producing effects that are not observed during short-term experiments.

The environmental history of microplastics is also important. Weathering caused by sunlight, oxidation, mechanical abrasion, and microbial activity can modify their surface properties and increase their ability to interact with soil components and other contaminants. Soil characteristics, including pH, texture, organic matter, moisture, nutrient availability, and microbial composition, can further influence the behavior and bioavailability of microplastics. Environmental factors – such as temperature, rainfall, irrigation, and land-use practices – can also affect their transport and persistence. Furthermore, the presence of pesticides, heavy metals, and other pollutants may produce combined effects that differ from exposure to microplastics alone. Therefore, microplastic toxicity should be evaluated by considering particle characteristics, exposure conditions, soil properties, and interactions with other environmental stressors rather than relying on a single factor [11].

CURRENT RESEARCH GAPS

Although research on microplastics in terrestrial ecosystems has increased rapidly, several important knowledge gaps remain. A major limitation is the lack of standardized methods for sampling, extracting, identifying, and quantifying microplastics in soil, making comparisons among studies difficult. Many studies have been conducted under laboratory conditions using relatively high concentrations of microplastics, which may not accurately represent environmental conditions. Therefore, the long-term effects of environmentally realistic concentrations under field conditions remain poorly understood. There is also limited information on the behavior and ecological effects of very small plastic particles, including nanoplastics, in soil. More research is needed to understand how microplastics interact with soil microorganisms, plants, soil fauna, and other pollutants over long periods. In addition, the effects of different polymer types, particle shapes, sizes, aging conditions, and chemical additives require further investigation. The consequences of microplastics for important ecosystem processes – such as carbon sequestration, nitrogen cycling, decomposition, and soil fertility – are also not fully understood. Another major gap is the limited understanding of how microplastic contamination may affect terrestrial food webs and the transfer of plastic particles or associated chemicals between different trophic levels. Addressing these gaps through standardized methods, long-term field experiments, and multidisciplinary research will improve ecological risk assessment and provide a stronger scientific basis for managing microplastic pollution in terrestrial ecosystems.

CONCLUSION

Microplastics have emerged as an important and persistent contaminant of terrestrial ecosystems, particularly soils, where they can accumulate through agricultural activities, wastewater, sewage sludge, compost, atmospheric deposition, plastic waste, and other sources. Their presence can influence soil physical and chemical properties and may affect microorganisms, soil fauna, plants, nutrient cycling, and broader ecosystem processes. Microplastics can also interact with pesticides, heavy metals, and other contaminants, increasing the complexity of their ecological effects. However, the magnitude of these impacts depends on particle size, shape, polymer type, concentration, weathering, soil characteristics, and environmental conditions. Although considerable progress has been made in understanding microplastic pollution, important uncertainties remain regarding long-term effects, environmentally realistic exposure levels, nanoplastics, and ecosystem-level consequences. Future research should, therefore, emphasize standardized methods, long-term field studies, realistic exposure conditions, and integrated assessment of multiple environmental stressors. At the same time, reducing plastic inputs, improving waste management, promoting sustainable agricultural practices, and strengthening environmental monitoring are essential for controlling contamination. A better understanding of the sources, fate, ecological impacts, and management of microplastics will be crucial for protecting soil biodiversity, maintaining soil health, and ensuring the long-term sustainability of terrestrial ecosystems.

REFERENCES

1. de Souza Machado AA, Kloas W, Zarfl C, Hempel S, Rillig MC. Microplastics as an emerging threat to terrestrial ecosystems. Glob Chang Biol. 2018;24(4):1405–1416. doi: 10.1111/gcb.14020.
2. Rillig MC, Lehmann A. Microplastic in terrestrial ecosystems. Science. 2020;368(6498):1430–1431. doi: 10.1126/science.abb5979.
3. Boots B, Russell CW, Green DS. Effects of microplastics in soil ecosystems: Above and below ground. Environ Sci Technol. 2019;53:11496–11506. doi: 10.1021/acs.est.9b03304.
4. Huang D, Wang X, Yin L, Chen S, Tao J, Zhou W, et al. Research progress of microplastics in soil-plant system: Ecological effects and potential risks. Sci Total Environ. 2022;812:151487. doi: 10.1016/j.scitotenv.2021.151487.
5. Li J, Yu S, Yu Y, Xu M. Effects of microplastics on higher plants: A review. Bull Environ Contam Toxicol. 2022;109(2):241–265. doi: 10.1007/s00128-022-03566-8.
6. Azeem I, Adeel M, Ahmad MA, Shakoor N, Jiangcuo GD, Azeem K, et al. Uptake and accumulation of nano/microplastics in plants: A critical review. Nanomaterials. 2021;11(11):2935. doi: 10.3390/nano11112935.
7. Wang F, Wang X, Song N. Polyethylene microplastics and natural soil organic matter co-exist to affect plant growth and soil microbial community. Sci Total Environ. 2021;760:143430.

8. Jiang X, Chen H, Liao Y, Ye Z, Li M, Klobučar G. Ecotoxicity and genotoxicity of polystyrene microplastics on higher plants. Environ Pollut. 2019;250:831–838.
9. Bosker T, Bouwman LJ, Brun NR, Behrens P, Vijver MG. Microplastics accumulate on pores in seed capsule and delay germination and root growth of the terrestrial vascular plant Lepidium sativum. Chemosphere. 2019;226:774–781.
10. Allouzi MM, Tang JY, Xu X, Cheung SG, Rochman CM, Chan FT. Microplastics in soils: A review of sources, fate, distribution and potential effects on soil organisms. Sci Total Environ. 2021;780:146541.
11. Yu H, Liu X, Chen H, Zhang X, Zhao X, Zhou X, et al. Effects of microplastics on soil microbial communities and functions: A review. Environ Pollut. 2022;306:119375.
12. Yang Y, Liu Y, Chen X, Zhang Y, Wu S, Zhang Z, et al. Microplastics in soil: Sources, fate, transport, and ecological risks. J Hazard Mater. 2022;424:127750.
13. Li J, Liu HH, Chen JP. Microplastics in freshwater systems: A review on occurrence, environmental effects, and methods for detection. Water Res. 2018;137:362–374.
14. Jia L, Liu L, Zhang Y, Fu W, Liu X, Wang Q, et al. Microplastic stress in plants: Effects on plant growth and their remediations. Front Plant Sci. 2023;14:1226484. doi: 10.3389/fpls.2023.1226484.
15. Meng S, Zhang Z. Effects of microplastics on soil environment and land plant growth: A review. Environ Monit Assess. 2025;197(8):861. doi: 10.1007/s10661-025-14316-8.