

Earthworms as Key Drivers of Soil Health and Sustainable Agriculture

Barath Gowda, H. ⁽¹⁾, Nihash, V. L. ⁽²⁾ and Spandana, B. M. ⁽³⁾

⁽¹⁾Ph. D scholar, Department of Agronomy, University of Agricultural Sciences, GKVK, Bengaluru-560065.

⁽²⁾Research scholar, Department of Farm Machinery and Power Engineering, College of Agricultural Engineering, GKVK, UAS Bengaluru-560065.

⁽³⁾Research scholar, Department of Processing and Food Engineering, College of Agricultural Engineering, GKVK, Bengaluru- 560065.

Corresponding Author: bharathgowdah6@gmail.com

Abstract

Human driven overconsumption has intensified pressure on natural resources, necessitating sustainable agricultural practices. Vermicomposting, a bio-technology integrating earthworms and microbes, offers an efficient solution for recycling biodegradable waste into nutrient rich vermicompost. Earthworms enhance decomposition by aerating and fragmenting organic matter, improving nutrient availability and soil structure. Vermicompost enriches soil with plant available nutrients, growth hormones, and beneficial microbes. Modern agricultural practices have degraded soil health and biodiversity, but earthworms help restore ecological balance, improve fertility, and support sustainable crop production. Thus, vermiculture provides an economical, eco-friendly pathway toward resilient and productive agricultural systems.

Keywords: Earthworms, Vermicomposting, Sustainable agriculture, Soil fertility, Soil biodiversity, Nutrient cycling, Vermicast

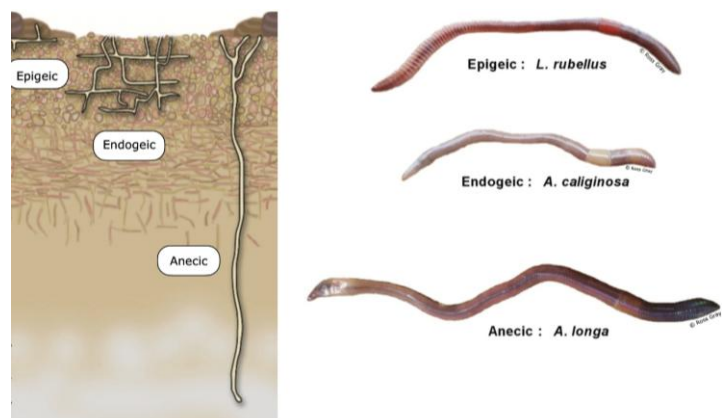
Introduction

Sustainable agriculture aims to maintain productivity while preserving environmental quality and resource efficiency. However, excessive use of chemical fertilizers and pesticides during the green revolution has led to soil degradation, biodiversity loss, and reduced soil fertility. In this context, earthworms play a crucial role in restoring soil health and ecological balance. Through vermicomposting, earthworms convert organic waste into nutrient rich vermicast, improving soil structure, aeration, and microbial activity. Their interaction with microorganisms accelerates decomposition and enhances nutrient availability. Earthworms also contribute to soil biodiversity, regulate harmful organisms, and promote plant growth through the release of growth hormones. As eco-friendly and cost-effective agents, they offer a practical solution to recycle waste and improve soil productivity (Patangray, 2014). Therefore, integrating earthworms into farming systems is a key strategy for achieving sustainable and long-term agricultural development. Additionally, earthworms enhance soil water retention and reduce erosion

by improving soil aggregation and porosity. Their continuous activity supports long-term soil resilience, making farming systems more stable and productive under changing environmental conditions.

Earthworms are classified into three categories based on their ecological distribution in soil (Bouche, 1997):

1. **Epigeic earthworms:** These are small-sized worms with uniform body coloration that live on surface litter or dung and can tolerate a wide range of temperatures. They have a minor role in humus formation but are highly suitable for vermicomposting. Examples include *Eisenia fetida*, *Dendrobaena rubida*, *Perionyx excavatus*, and *Eudrilus eugeniae*.
2. **Anecic earthworms:** These are large-sized worms with pigmentation mainly at the anterior and posterior ends. They are mostly phytophagous and play an important role in mixing nutrients from deeper soil layers to the surface through casting. Examples include *Lampito mauritii*, *Aporrectodea longa*, and *Lumbricus terrestris*.
3. **Endogeic earthworms:** These worms may be small or large in size and have weak pigmentation. They are geophagous and live within the soil, feeding on organic and mineral matter. Examples include *Metaphire posthuma*, *Octochaetona thurstoni*, *Allolobophora caliginosa*, *Aporrectodea rosea*, and *Octolasion cyaneum*. 977, Bouche



Earthworms can be classified into two groups based on their feeding habits (Lee, 1985):

1. **Detritivorous earthworms:** These earthworms feed at or near the soil surface, mainly consuming plant litter, dead roots, and animal dung. They play an important role in the decomposition of organic matter. Examples include *Eisenia fetida*, *Lampito mauritii*, *Perionyx excavatus*, and *Eudrilus eugeniae*.
2. **Geophagous earthworms:** These earthworms feed deeper below the soil surface and ingest large quantities of organically rich soil. They contribute to nutrient cycling and soil formation. Examples include *Metaphire posthuma* and *Octochaetona thurstoni*.

Environmental factors affecting earthworm population:

1. **Temperature:** Earthworms grow and reproduce best at 25–30°C. Very low (<10°C) or high temperatures reduce activity. They move deeper into soil during extreme conditions.
2. **Moisture:** Earthworms need 60–90% moisture (optimum ~80%). Too little causes drying, and too much forces them out of soil.
3. **Food supply:** Good quality organic matter (low C:N ratio, soft and decomposed) increases growth and reproduction. Poor-quality or insufficient food reduces population.
4. **pH:** They prefer neutral pH (~7). Very acidic soils (<4.5) are harmful and reduce their survival.
5. **Soil texture:** Loamy soils are best. Sandy soils dry quickly and can damage worms, while heavy clay may limit their population.
6. **Aeration and CO₂:** Earthworms need oxygen for respiration. Poor aeration and high CO₂ reduce their activity and survival.
7. **Ammonia:** High ammonia (>1 mg g⁻¹) is toxic and can kill earthworms. Proper composting helps reduce ammonia.

Role of Earthworms in Soil Improvement

Earthworms enhance soil quality by modifying its physical, chemical, and biological properties. They improve crop growth by increasing nutrient availability and interacting with soil components (Singh *et al.*, 2016). Their burrowing activity improves soil porosity and structure, while feeding and casting promote decomposition and mineralization of organic matter. Earthworm casts are nutrient-rich and boost microbial activity, making essential

nutrients like nitrogen, phosphorus, potassium, and magnesium more available. Overall, these processes increase soil fertility and support better plant growth.

Role of Earthworms in Natural and Agricultural Soils

Earthworms act as important colonizers in both natural and cultivated soils, helping maintain soil health and productivity. Human activities such as movement of soil and plant materials aid their distribution. Surface-dwelling (epigeic) earthworms disperse more easily but are more exposed to environmental stresses and agrochemicals, while deep-burrowing (anecic) species are less mobile. Practices like reduced tillage and addition of organic matter increase earthworm population and diversity. Earthworms improve soil structure, enhance nutrient cycling, and increase water regulation through their burrowing and feeding activities. They also support ecosystem services such as soil formation, plant production, climate regulation, and pollution control (Blouin *et al.*, 2013).

Earthworms in Soil Pollution Control (Bioremediation)

Earthworms and vermicompost help clean contaminated soil by breaking down pesticides and herbicides, removing up to 80% of harmful chemicals. They also aid in the accumulation and degradation of pollutants like polycyclic aromatic hydrocarbons (PAHs). Their burrowing and feeding activities improve soil aeration and support microbial processes, which enhance the breakdown of contaminants (Jing *et al.*, 2013). Although excessive pesticide use can harm earthworms, their presence promotes natural detoxification and soil stability. Overall, vermicomposting is a low-cost and eco-friendly method for improving soil quality and supporting sustainable agriculture.

Combined action of Earthworms and Microbes in Vermicomposting

Earthworms and microorganisms work together to speed up the decomposition of organic waste. Earthworms break down and mix organic matter, improving soil structure, porosity, and water movement, while also increasing microbial activity. Microorganisms further decompose the material and help release nutrients like carbon, nitrogen, and phosphorus. Earthworms, stimulate microbial growth and enzyme activity in their gut and casts, leading to faster nutrient release. Their interaction with fungi and bacteria enhances cellulose breakdown and overall composting efficiency. Together, they produce nutrient-rich vermicompost, improving soil fertility and supporting sustainable waste management.

Earthworms as Soil Ecosystem Builders

Earthworms are key soil organisms that improve soil fertility and sustainability, which is why they are called ecosystem engineers. Their burrowing and feeding activities enhance soil structure, porosity, and aggregation, while also helping in the incorporation and decomposition of organic matter. They convert low-quality organic materials into nutrient-rich forms through interaction with soil microbes, improving the availability of essential nutrients like nitrogen, phosphorus, and potassium. Earthworm activity also promotes humus formation, nutrient cycling, and overall soil productivity. Vermicast produced by earthworms improves water-holding capacity, aeration, and soil softness, reducing the need for tillage and irrigation. It is rich in nutrients, beneficial microbes, and plant growth regulators, and can also help suppress harmful pathogens (Datta *et al.*, 2016).

Importance of Earthworm Casts in Soil Fertility

Earthworm casts (vermicast) are nutrient-rich materials formed when earthworms digest soil and organic matter. These casts are more stable than normal soil and contain higher levels of nutrients like carbon, nitrogen, calcium, magnesium, and potassium, along with beneficial microbes. They improve soil structure, increase porosity, moisture retention, and enhance microbial activity, making nutrients more available to plants (Clause *et al.*, 2014). Vermicast is a better nutrient source compared to compost and chemical fertilizers and promotes plant growth, root development, and nutrient uptake. The quality of casts depends on the type of soil ingested and the earthworm species, but overall, they significantly improve soil fertility and productivity.

Role of Humic Substances in Vermicast

Humic substances in vermicast are formed from the breakdown of plant materials like lignin through microbial activity. They mainly include humic acid (HA) and fulvic acid (FA), which differ in solubility. HA is soluble in alkaline conditions, while FA is soluble at all pH levels. These substances contain both polar and non-polar components, allowing them to interact with various nutrients and compounds in soil. Fulvic acid has more active functional groups, making it highly reactive. Overall, humic substances improve nutrient availability, enhance soil fertility, and support better plant growth (Befrozfar *et al.*, 2013).

Benefits of Earthworms in Sustainable Agriculture

- Improve soil structure: Increase porosity, aeration, and water infiltration

- Enhance soil fertility: Casts are rich in nutrients like N, P, K, Ca, and Mg
- Increase nutrient cycling: Faster decomposition and mineralization
- Boost microbial activity: Support beneficial soil microbes
- Promote plant growth: Better root development and nutrient uptake
- Aid vermicomposting: Convert organic waste into nutrient-rich compost
- Reduce soil pollution: Help break down harmful chemicals
- Improve water retention: Soil holds moisture more effectively
- Lower chemical inputs: Reduce dependence on fertilizers
- Enhance biodiversity: Maintain a healthy soil ecosystem

Challenges and Limitations

- Sensitive to environmental conditions: Extreme temperature, moisture, or pH reduces survival
- Susceptible to chemicals: Pesticides and high ammonia levels can harm or kill earthworms
- Limited in dry or waterlogged soils: Cannot survive in very dry or highly saturated conditions
- Slow population buildup: Takes time to establish a stable earthworm population
- Species-specific performance: Not all species adapt well to all soil types or climates
- Dependence on organic matter: Require sufficient organic residues for survival and growth
- Predation and disturbances: Birds, rodents, and tillage practices reduce populations
- Management requirements: Proper moisture, aeration, and waste quality must be maintained
- Initial cost and effort: Vermicomposting setup and maintenance need investment
- Variable efficiency: Performance may vary depending on soil and environmental conditions

Future Research Directions

Future research should focus on identifying earthworm species that can tolerate high moisture and temperature conditions for effective management of urban

solid waste. It is also important to identify species that can withstand high levels of heavy metals for safe processing of industrial organic wastes. Additionally, studies should be conducted on the interactions between earthworms and microorganisms, including both beneficial microbes and soil-borne pathogens, to enhance soil health and improve compost quality.

Conclusion

Earthworms help maintain aerobic soil conditions through continuous mixing, which supports the breakdown of contaminants and improves soil quality. Vermicomposting plays an important role in bioremediation and enhances agricultural sustainability by boosting microbial and biochemical activities while reducing environmental risks. Earthworms and their casts act as key drivers of sustainable food production by improving soil fertility, promoting plant growth, enhancing nutrient quality, and protecting crops from pests and diseases. Overall, earthworms provide a natural, cost-effective solution for improving soil health and managing organic waste. Their use in vermitechology can reduce dependence on chemical inputs and support eco-friendly farming practices. Hence, integrating earthworms into agricultural systems is essential for long-term sustainability and environmental protection.

References

Befrozfar, M. R., Habibi, D., Asgharzadeh, A., Sadeghi-Shoae, M., & Tookaloo, M. R. (2013). Vermicompost, plant growth-promoting bacteria and humic acid effects on growth and essence of basil (*Ocimum basilicum* L.). *Annals of Biological Research*, 4, 8-12.

Blouin, M., Hodson, M. E., Delgado, E. A., Baker, G., Brussaard, L., Butt, K. R., Dai, J., Dendooven, L., Peres, G., Tondoh, J. E., Cluzeau, D., & Brun, J. J. (2013). A review of earthworm impact on soil function and ecosystem services. *European Journal of Soil Science*, 64, 161-182.

Bouché, M. B., & Al-Addan, F. (1997). Earthworms, water infiltration and soil stability: Some new assessments. *Soil Biology and Biochemistry*, 29, 441-452.

Clause, J., Barot, S., Richard, B., & Forey, E. (2014). Interactions between soil type and earthworm species determine the properties of earthworm casts. *Applied Soil Ecology*, 83, 149-158.

Datta, S., Singh, J., Singh, S., & Singh, J. (2016). Earthworm, pesticides and sustainable agriculture: A review. *Environmental Science and Pollution Research*, 23, 8227-8243.

Jing, Y. P., Liu, M. Q., Yin, Q. P., Li, H. X., & Hu, F. (2013). Effects of earthworms and ryegrass on the removal of fluoranthene from soil. *Pedosphere*, 23, 523-531.

Lee, K. E. (1985). *Earthworms: Their ecology and relationship with soil and land use*. Academic Press.

Patangray, A. J. (2014). Vermicompost: Beneficial tool for sustainable farming. *Asian Journal of Multidisciplinary Studies*, 2(8), 254-257.

Singh, S., Singh, J., & Vig, A. P. (2016). Earthworms as ecological engineers to change the physico-chemical properties of soil: Soil vs vermicast. *Ecological Engineering*, 90, 1-5.
