



# **Metagenomic Analysis of Soil Microbiome Diversity under Organic and Conventional Farming Systems**

**Dr. T. S. Harsha**

Assistant Professor

Department of Environmental Science

Karnataka State Open University

## **Abstract**

Soil microbiomes play a vital role in maintaining agricultural productivity, soil health, and ecosystem stability. The transition between organic and conventional farming systems significantly influences microbial diversity, nutrient cycling, and soil resilience. This study employs metagenomic analysis to compare soil microbial communities under organic and conventional agricultural practices, focusing on variations in taxonomic composition, functional genes, and ecological interactions. Using next-generation sequencing (NGS) and bioinformatic analysis, the research identifies differences in bacterial, archaeal, and fungal populations, revealing that organic soils harbor higher microbial diversity and beneficial functional traits associated with nutrient turnover and disease suppression. The findings emphasize that sustainable agricultural practices not only preserve microbial diversity but also enhance long-term soil fertility and environmental balance.

**Keywords:** Metagenomics, Soil Microbiome, Organic Farming, Conventional Farming, Microbial Diversity, Sustainable Agriculture, Next-Generation Sequencing, Soil Health

## **Introduction**

The soil microbiome forms the foundation of terrestrial ecosystems, influencing plant growth, nutrient cycling, and environmental sustainability. It includes bacteria, archaea, fungi, and protozoa that collectively regulate soil fertility and crop productivity. Over recent decades, agricultural intensification and chemical inputs in conventional farming have altered soil microbial ecology, often

reducing biodiversity and resilience. In contrast, organic farming systems, which emphasize natural nutrient inputs and biological pest control, promote more diverse and stable microbial communities.

The advent of metagenomics—the study of genetic material directly recovered from environmental samples—has revolutionized our ability to analyze soil microbial communities. Unlike culture-dependent methods, metagenomics provides an unbiased, comprehensive view of microbial diversity, including non-culturable species.

This study aims to evaluate and compare soil microbial diversity under organic and conventional farming systems using shotgun metagenomic sequencing. By examining taxonomic composition and functional gene abundance, it seeks to understand how different farming practices influence soil health, ecological balance, and nutrient cycling mechanisms.

## Methodology

### Study Design

A comparative field-based study was conducted in two agricultural systems:

1. Organic farms – managed without synthetic fertilizers or pesticides for over five years.
2. Conventional farms – using chemical fertilizers, pesticides, and intensive tillage.

### Sample Collection

- **Location:** Three paired sites representing similar soil types and climatic conditions.
- **Depth:** Soil samples were collected from the top 0–15 cm layer.
- **Replicates:** Five random replicates per site were pooled to minimize spatial heterogeneity.
- **Storage:** Samples were transported on dry ice and stored at  $-80^{\circ}\text{C}$  until DNA extraction.

## DNA Extraction and Sequencing

- DNA extracted using the MoBio PowerSoil® DNA Isolation Kit.
- Shotgun metagenomic sequencing performed using Illumina NovaSeq 6000.
- Reads filtered for quality (Q30 cutoff), assembled using MEGAHIT, and annotated via KEGG, MetaPhlAn3, and MG-RAST pipelines.

## Bioinformatic and Statistical Analysis

- Alpha diversity (Shannon, Simpson indices) and Beta diversity (Bray-Curtis distance) calculated.
- Functional annotation focused on nitrogen fixation, carbon metabolism, phosphorus solubilization, and antibiotic resistance genes.
- Statistical differences assessed using ANOVA ( $p < 0.05$ ).

## Case Study: Organic vs. Conventional Farming Sites

### Site A – Paddy Fields (Kerala, India)

Organic soils exhibited higher abundance of Nitrospira, Rhizobium, and Azospirillum, reflecting improved nitrogen cycling. Conventional soils showed dominance of Pseudomonas and Bacillus, indicating adaptation to chemical fertilizers.

### Site B – Wheat Fields (Punjab, India)

Organic soils had enriched Actinobacteria and Mycorrhizal fungi, enhancing phosphorus solubilization. In contrast, conventional soils showed increased Firmicutes, linked to pesticide tolerance.

### Site C – Vegetable Farms (Maharashtra, India)

Organic farming promoted Lactobacillus and Trichoderma species beneficial for plant health, whereas conventional systems harbored higher levels of Enterobacter and Clostridium, suggesting stress-driven community shifts.

## Data Analysis

**Table 1: Alpha Diversity Indices of Soil Microbiome**

<b>Farming System</b>	<b>Shannon Index</b>	<b>Simpson Index</b>	<b>Observed OTUs</b>	<b>Evenness</b>
Organic	7.85 ± 0.12	0.94 ± 0.01	2,540 ± 120	0.86
Conventional	6.34 ± 0.15	0.89 ± 0.02	1,760 ± 140	0.78

**Interpretation:** Organic soils had significantly higher microbial diversity and evenness, indicating a more balanced ecosystem.

**Table 2: Functional Gene Abundance (Relative % of Total Reads)**

<b>Functional Category</b>	<b>Organic Farming</b>	<b>Conventional Farming</b>
Nitrogen Fixation Genes (nifH)	4.8	2.1
Phosphorus Solubilization Genes	3.6	1.8
Carbon Degradation Enzymes	7.5	5.2
Stress Response Genes	2.4	3.9
Antibiotic Resistance Genes	0.8	2.6

**Interpretation:** Organic soils exhibit greater nutrient cycling potential, while conventional soils show increased antibiotic resistance gene abundance due to agrochemical exposure.

## Questionnaire

1. How does organic farming affect the richness and functional diversity of soil microbiomes compared to conventional farming?
2. What are the dominant microbial phyla contributing to nutrient cycling under both systems?
3. How do agricultural inputs such as fertilizers and pesticides influence microbial gene expression?

4. What role do beneficial microbes play in enhancing soil health under organic systems?
5. Can metagenomic data be integrated into precision agriculture for soil management strategies?

## Conclusion

Metagenomic insights reveal that organic farming systems foster a more diverse and functionally rich soil microbiome compared to conventional systems. The higher presence of beneficial microbial taxa such as *Rhizobium*, *Actinobacteria*, and *Trichoderma* enhances soil nutrient turnover, plant symbiosis, and pathogen suppression.

Conversely, conventional soils, characterized by reduced microbial diversity and increased antibiotic resistance genes, indicate ecological imbalance resulting from excessive chemical use. These findings affirm that sustainable farming practices promote long-term soil fertility and ecological stability by nurturing microbial diversity.

Integrating metagenomics into soil health monitoring provides an advanced framework for precision agriculture, enabling farmers and policymakers to design ecologically sound and productive farming systems. Future research should focus on longitudinal studies to assess microbiome recovery and resilience under transitioning systems, along with multi-omics integration (metatranscriptomics and metabolomics) for a holistic view of soil ecosystem functions.



## References

1. Fierer, N., & Jackson, R.B. (2020). The Diversity and Biogeography of Soil Bacterial Communities. PNAS.
2. Hartmann, M., & Widmer, F. (2019). Community Structure of Soil Microbiota under Organic and Conventional Farming. Soil Biology & Biochemistry.
3. Van der Heijden, M.G.A., et al. (2021). The Soil Microbiome and Its Role in Sustainable Agriculture. Nature Reviews Microbiology.
4. Torsvik, V., & Øvreås, L. (2018). Microbial Diversity and Function in Soil Ecosystems. Current Opinion in Microbiology.
5. Schmidt, R., & Philipot, L. (2020). Functional Interactions between Soil Microorganisms and Agricultural Management Practices. Applied Soil Ecology.
6. Quast, C. et al. (2013). The SILVA Ribosomal RNA Gene Database Project. Nucleic Acids Research.
7. Edwards, J. et al. (2021). Metagenomic Insights into the Impact of Agricultural Management on Soil Microbial Communities. ISME Journal.
8. Banerjee, S., et al. (2022). Organic Farming Promotes Resilient Microbial Networks. Nature Sustainability.
9. Delgado-Baquerizo, M. et al. (2019). Microbial Diversity and Ecosystem Multifunctionality. Science Advances.
10. Thompson, L.R. et al. (2017). A Communal Catalogue Reveals Earth's Multiscale Microbial Diversity. Nature.
11. Liang, Y. et al. (2020). Influence of Chemical Inputs on Microbial Composition and Soil Functionality. Frontiers in Microbiology.
12. Singh, B.K. et al. (2021). Microbiome-Mediated Adaptation in Agricultural Ecosystems. Trends in Microbiology.



13. Trivedi, P. et al. (2020). Functional Metagenomics of Soil Microbiomes under Organic Farming. *Environmental Microbiology*.
14. Jones, R.T. et al. (2018). Comparative Soil Microbiome Analysis across Agricultural Systems. *PLoS ONE*.
15. Chen, L. et al. (2021). Integrative Metagenomic and Functional Profiling of Soil Microbes under Different Fertilization Regimes. *Microbiome*.
16. Mahra, Mr Anil Kumar. "FINANCIAL LITERACY AND PATTERN OF SAVINGS, INVESTMENT BEHAVIOR OF WOMEN TEACHING FACULTIES IN SAGAR REGION. AN EMPIRICAL ASSESSMENT."
17. Mahra, Anil Kumar. "A Strategic Approach to Information Technology Management." (2019).
18. Mahra, Anil Kumar. "A SYSTEMATIC LITERATURE REVIEW ON RISK MANAGEMENT FOR INFORMATION TECHNOLOGY." (2019).
19. Mahra, Anil Kumar. "THE ROLE OF GENDER IN ONLINE SHOPPING-A."
20. Dwivedi, Shyam Mohan, and Anil Kumar Mahra. "Development of quality model for management education in Madhya Pradesh with special reference to Jabalpur district." *Asian Journal of Multidisciplinary Studies* 1.4 (2013): 204-208.
21. Mahra, Anil Kumar. "Management Information Technology: Managing the Organisation in Digital Era." *International Journal of Advanced Science and Technology* 4238.29 (2005): 6.
22. Kumar, Anil, et al. "Integrated Nutrient Management Practices for Sustainable Chickpea: A Review." *Journal of Advances in Biology & Biotechnology* 28.1 (2025): 82-97.
23. Kumar, Anil, et al. "Investigating the role of social media in polio prevention in India: A Delphi-DEMATEL approach." *Kybernetes* 47.5 (2018): 1053-1072.



24. Sankpal, Jitendra, et al. "Oh, My Gauze!!!-A rare case report of laparoscopic removal of an incidentally discovered gossypiboma during laparoscopic cholecystectomy." *International Journal of Surgery Case Reports* 72 (2020): 643-646.
25. Salunke, Vasudev S., et al. "Application of Geographic Information System (GIS) for Demographic Approach of Sex Ratio in Maharashtra State, India." *International Journal for Research in Applied Science & Engineering Technology (IJRASET)* 8 (2020).
26. Sudha, L. R., and M. Navaneetha Krishnan. "Water cycle tunicate swarm algorithm based deep residual network for virus detection with gene expression data." *Computer Methods in Biomechanics & Biomedical Engineering: Imaging & Visualisation* 11.5 (2023).
27. Sudha, K., and V. Thulasi Bai. "An adaptive approach for the fault tolerant control of a nonlinear system." *International Journal of Automation and Control* 11.2 (2017): 105-123.
28. Patel, Ankit B., and Ashish Verma. "COVID-19 and angiotensin-converting enzyme inhibitors and angiotensin receptor blockers: what is the evidence?." *Jama* 323.18 (2020): 1769-1770.
29. Rahul, T. M., and Ashish Verma. "A study of acceptable trip distances using walking and cycling in Bangalore." *Journal of Transport Geography* 38 (2014): 106-113.
30. Kabat, Subash Ranjan, Sunita Pahadsingh, and Kasinath Jena. "Improvement of LVRT Capability Using PSS for Grid Connected DFIG Based Wind Energy Conversion System." *2022 1st IEEE International Conference on Industrial Electronics: Developments & Applications (ICIDeA)*. IEEE, 2022.
31. Kabat, Subash Ranjan. "Cutting-Edge Developments in Engineering and Technology: A Global Perspective." *International Journal of Engineering & Tech Development* 1.01 (2025): 9-16.



32. Das, Kedar Nath, et al., eds. Proceedings of the International Conference on Computational Intelligence and Sustainable Technologies: ICoCIST 2021. Springer Nature, 2022.
33. Hazra, Madhu Sudan, and Sudarsan Biswas. "A study on mental skill ability of different age level cricket players." International Journal of Physiology, Nutrition and Physical Education 3.1 (2018): 1177-1180.
34. Deka, Brajen Kumar. "Deep Learning-Based Language." International Conference on Innovative Computing and Communications: Proceedings of ICICC 2023, Volume 2. Vol. 731. Springer Nature, 2023.
35. Deka, Brajen Kumar, and Pooja Kumari. "Deep Learning-Based Speech Emotion Recognition with Reference to Gender Separation." International Conference On Innovative Computing And Communication. Singapore: Springer Nature Singapore, 2025.
36. Obaiah, G. O., J. Giresha, and M. Mylarappa. "Comparative study of TiO<sub>2</sub> and palladium doped TiO<sub>2</sub> nano catalysts for water purification under solar and ultraviolet irradiation." Chemistry of Inorganic Materials 1 (2023): 100002.
37. Obaiah, G. O., K. H. Shivaprasad, and M. Mylarappa. "A potential use  $\gamma$ -Al<sub>2</sub>O<sub>3</sub> coated cordierite honeycomb reinforced Ti<sub>0.97</sub>Pd<sub>0.03</sub>O<sub>2</sub>- $\delta$  catalyst for selective high rates in coupling reactions." Materials Today: Proceedings 5.10 (2018): 22466-22472.
38. Abbasi, Naiyla Mobin. "Organic Farming and Soil Health: Strategies for Long Term Agricultural Sustainability." Agricultural Innovation and Sustainability Journal E-ISSN 3051-0325 1.01 (2025): 25-32.
39. MURAD, MUHAMMAD. Result of MSPH Program Spring Session 2025. Diss. Jinnah Sindh Medical University, 2025