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Enhancing soil fertility and microbial diversity through natural farming inputs: A review

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Abstract

Natural farming practices have emerged as sustainable alternatives to conventional agriculture, addressing concerns about soil degradation, biodiversity loss, and environmental pollution. By integrating organic and natural inputs, these practices enhance soil fertility and microbial diversity while reducing dependency on chemical fertilizers and pesticides. Natural inputs such as compost, biochar, green manures, and microbial inoculants promote nutrient recycling, improve soil structure, and foster a balanced ecosystem for soil microbes.

This review explores the principles and methods of natural farming, focusing on their role in enhancing soil health and microbial diversity. The paper discusses the mechanisms through which natural inputs influence soil physical, chemical, and biological properties. Comparative studies on the effectiveness of natural versus chemical inputs are presented, along with case studies illustrating successful implementations.

Future prospects for natural farming, including its potential to mitigate climate change and enhance food security, are highlighted. By adopting natural farming practices, farmers can achieve sustainable productivity while preserving ecological balance.

Keywords: Natural farming, soil fertility, microbial diversity, sustainable agriculture, organic inputs, ecosystem health

1. Introduction

Conventional agricultural practices, which rely heavily on synthetic fertilizers and pesticides, have led to significant environmental challenges, including soil degradation, water pollution, and biodiversity loss. These issues threaten the sustainability of global food systems and necessitate the adoption of alternative farming practices that can restore ecological balance ^[1, 2].

Natural farming has emerged as a promising approach to address these challenges. By prioritizing the use of organic and natural inputs, such as compost, biochar, green manures, and microbial inoculants, this method focuses on improving soil health, enhancing microbial diversity, and fostering long-term sustainability. Unlike conventional methods, natural farming avoids synthetic chemicals, relying instead on ecologically harmonious techniques to maintain productivity ^[3].

The benefits of natural farming extend beyond environmental preservation. Enhanced soil fertility promotes better water retention and nutrient availability, leading to improved crop yields ^[4, 5]. Furthermore, the promotion of microbial diversity contributes to healthier soils, which are more resilient to diseases and climate variability. By integrating traditional knowledge with modern science, natural farming practices support both environmental and economic sustainability ^[5, 6].

2. Natural Farming Inputs

2.1 Compost

Compost is a nutrient-rich organic material produced through the decomposition of plant and animal waste. It improves soil structure, increases water retention, and supplies essential nutrients like nitrogen, phosphorus, and potassium (NPK) ^[7, 8].

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Benefits of Compost

- Enhances soil organic matter.
- Promotes beneficial microbial activity.
- Improves water-holding capacity.

Nutrient Composition in Compost (Approximate Values)	
Nutrient	Content (%)
Nitrogen (N)	1.5–3.5
Phosphorus (P)	0.5–1.5
Potassium (K)	1.0–2.0
Calcium (Ca)	1.5–2.5
Magnesium (Mg)	0.5–1.5
Sulfur (S)	0.2–0.8

2.2 Biochar

Biochar is a specialized material derived from the process of pyrolysis, where biomass is heated in a low-oxygen environment to produce a carbon-rich substance [9, 10]. This material plays a pivotal role in improving soil health by enhancing its cation exchange capacity, which allows soil to retain essential nutrients more effectively [11, 12]. Additionally, biochar provides structural benefits to the soil by improving aeration and water retention. Its porous nature creates an ideal habitat for beneficial soil microorganisms, further enriching the soil ecosystem and promoting sustainable farming practices [13, 14].

Benefits of Biochar

- Improves soil aeration and structure [15].
- Retains nutrients and water [15].
- Provides a habitat for beneficial microorganisms [17].
- Increases soil pH, reducing acidity [38].
- Sequesters carbon, contributing to climate change mitigation [38, 17].
- Enhances cation exchange capacity, improving nutrient retention and availability [38, 17].

2.3 Green Manures

Definition: Green manures refer to plants that are specifically cultivated and subsequently plowed into the soil while still green to enhance its organic matter content, supply nutrients, and improve its structure and microbial activity [18, 19].

Green manures are cover crops grown with the primary purpose of being incorporated back into the soil to enrich it with organic matter and essential nutrients. These crops, often leguminous or fast-growing plants, act as natural fertilizers by improving soil fertility and health through various mechanisms [20, 21].

Examples

- Leguminous crops like clover and alfalfa.
- Non-leguminous crops like mustard and rye.

Benefits

- Fix nitrogen through symbiotic relationships with Rhizobium bacteria.
- Prevent soil erosion and suppress weeds.

2.4 Microbial Inoculants

Microbial inoculants are formulations containing beneficial microorganisms, including nitrogen-fixing bacteria, phosphorus-solubilizing bacteria, and mycorrhizal fungi, which play a pivotal role in enhancing soil fertility and plant health. These inoculants are applied to the soil or seeds to establish a symbiotic relationship with plants, leading to improved nutrient uptake and soil microbial diversity [22, 23].

Types of Microbial Inoculants

1. **Nitrogen-Fixing Bacteria:** Convert atmospheric nitrogen into forms usable by plants. Example: Rhizobium for legumes [24].
2. **Phosphorus-Solubilizing Bacteria:** Release bound phosphorus in the soil, making it available for plant uptake. Example: Bacillus specie [25, 26].
3. **Mycorrhizal Fungi:** Form symbiotic associations with plant roots, enhancing water and nutrient absorption, particularly phosphorus and micronutrients [27, 28].
4. **Potassium-Mobilizing Microbes:** Solubilize insoluble potassium compounds, improving potassium availability [29, 30]. Example: Frateuria aurantia.
5. **Biocontrol Agents:** Suppress soil-borne pathogens and diseases through competition and production of antimicrobial compounds [29]. Example: Trichoderma species.

Benefits

- Enhance nutrient cycling and availability.
- Improve plant growth and yield.
- Increase resistance to biotic and abiotic stresses.
- Promote soil microbial diversity and ecosystem stability.
- Reduce dependency on chemical fertilizers, contributing to sustainable farming.

3.1 Soil Fertility Enhancement

Natural farming inputs significantly improve soil fertility by addressing the physical, chemical, and biological components of soil health:

1. **Recycling Nutrients:** Compost and green manures recycle organic waste into plant-available nutrients, creating a sustainable nutrient loop [22, 23]. This reduces dependency on synthetic fertilizers and enhances the availability of macro- and micronutrients.
2. **Cation Exchange Capacity (CEC):** Biochar and organic matter improve the soil's ability to retain cations such as potassium, magnesium, and calcium. Enhanced CEC ensures that plants have access to essential nutrients over extended periods [24].
3. **Soil Organic Matter (SOM):** Adding compost and biochar increases SOM, improving soil structure, water retention, and aeration. It also promotes the aggregation of soil particles, reducing erosion and enhancing plant root penetration [21, 22].
4. **Microbial Biomass:** Natural inputs provide the energy source for beneficial microorganisms, boosting soil microbial activity, which is critical for nutrient mineralization and plant health [23, 24].

3.2 Microbial Diversity

Natural farming inputs create a conducive environment that fosters a diverse and balanced microbial ecosystem, which directly contributes to soil health and plant growth:

1. **Nutrient Cycling:** Beneficial microorganisms such as nitrogen-fixing bacteria, phosphate-solubilizing microbes, and mycorrhizal fungi enhance the availability of essential nutrients. These microbes transform complex organic compounds into forms that plants can readily absorb [22, 23].
2. **Disease Suppression:** A diverse microbial community suppresses harmful pathogens through competitive exclusion and the production of antimicrobial substances. For instance, Trichoderma species act as biocontrol agents, reducing the incidence of soil-borne diseases [24, 25].

3. **Improved Soil Structure:** Microbial secretions like polysaccharides and glomalin promote soil aggregation, increasing porosity and water infiltration. This also supports root growth and plant stability ^[26, 27].
4. **Resilience to Stresses:** A rich microbial ecosystem buffers plants against abiotic stresses such as drought and salinity, enhancing overall productivity ^[22, 23].
5. **Symbiotic Relationships:** Mycorrhizal fungi establish mutualistic associations with plant roots, improving the uptake of phosphorus and other immobile nutrients, while plants provide carbohydrates for fungal growth ^[24, 25].

5. Comparative Analysis of Natural and Chemical Inputs

Parameter	Natural Inputs	Chemical Inputs
Environmental Impact	Minimal	High (soil degradation, pollution)
Soil Organic Matter	Increased	Depleted
Microbial Diversity	Enhanced	Reduced
Cost	Low (in long term)	High

5. Case Studies

Case Study: Zero-Budget Natural Farming (ZBNF) in Andhra Pradesh, India

Introduction

The Zero-Budget Natural Farming (ZBNF) program in Andhra Pradesh serves as a transformative model for enhancing soil fertility and microbial diversity through natural farming practices. Launched on 2 June 2018, the initiative aims to transition 6 million farms and 8 million hectares of agricultural land to natural farming methods by 2024, positioning Andhra Pradesh as India’s first 100% natural farming state. This case study highlights how ZBNF contributes to soil rejuvenation, microbial diversity, and sustainable agricultural practices ^[30].

Background and Objectives

ZBNF is a climate-resilient, regenerative agricultural model designed to reduce dependency on synthetic chemicals and promote the use of natural ^[16], in-situ resources. Led by the Rythu Sadhikara Samstha (RySS) in partnership with the Sustainable India Finance Facility (SIFF), ZBNF integrates agroecological principles to achieve the following objectives:

- Enhance soil fertility by rejuvenating soil ecosystems with organic inputs.
- Promote microbial diversity to sustain natural nutrient cycles.
- Reduce farmers' costs by eliminating external inputs.
- Restore ecosystem health through multi-layered, biodiverse cropping systems.
- Achieve Sustainable Development Goals (SDGs), particularly those related to poverty alleviation, clean water, responsible production, and biodiversity conservation.

Key Components of ZBNF

1. Natural Farming Inputs

- **Jeevamrutham:** A microbial inoculant made from cow dung, cow urine, jaggery, and pulse flour, which enriches the soil with beneficial microorganisms and nutrients.
- **Bijamrutham:** A seed treatment solution to protect crops from diseases and pests while boosting germination.
- **Mulching and Moisture Conservation:** Organic mulching techniques to enhance soil moisture retention and temperature regulation.
- **Cover Crops and Crop Rotation:** These practices foster

biodiversity and improve soil structure and fertility.

2. Farmers’ Participation and Knowledge Dissemination

- Creation of self-help groups and farmers’ federations to facilitate collective action.
- Training programs to empower farmers as agents of knowledge creation and dissemination.

3. Scaling Efforts

With investments totaling US\$ 2.3 billion over six years, SIFF supports the large-scale implementation of ZBNF, ensuring financial sustainability and cross-sectoral collaboration.

Impact on Soil Fertility and Microbial Diversity

1. Enhanced Soil Fertility

- The use of Jeevamrutham and Bijamrutham has significantly improved organic matter content, leading to enhanced soil structure and nutrient availability.
- Mulching practices contribute to reduced soil erosion and better moisture conservation, essential for arid and semi-arid regions.

2. Increased Microbial Diversity

- Natural farming inputs promote the proliferation of beneficial soil microorganisms, including nitrogen-fixing bacteria, mycorrhizal fungi, and decomposers.
- Diverse cropping systems reduce monoculture-induced soil degradation and support a balanced microbial ecosystem.

3. Climate Resilience and Ecosystem Restoration

- By reducing chemical contamination and fostering natural nutrient cycles, ZBNF enhances the resilience of soils against climate-induced stresses such as drought and salinity.
- The regenerative model contributes to carbon sequestration, reducing greenhouse gas emissions from agriculture.

Global and Local Implications

The success of ZBNF in Andhra Pradesh demonstrates the viability of transitioning to sustainable agricultural systems that prioritize soil health and biodiversity. As 14 of the 17 SDGs rely on the health of natural resources, ZBNF provides a blueprint for inclusive agricultural development that can be adapted to diverse agro-climatic conditions globally ^[30].

This model also aligns with global efforts to combat climate change, ensuring food security while promoting the well-being of smallholder farmers. The integration of social capital, including community-driven approaches and farmer-led innovations, ensures that the program fosters inclusive growth (30).

6. Challenges and Future Prospects

Challenges

1. Lack of Awareness and Knowledge

- Farmers, especially smallholders, often lack the technical knowledge and understanding of natural farming practices ^[31].
- Misconceptions about the productivity and reliability of natural farming compared to conventional methods persist ^[31].

2. Transition Period Challenges

- The shift from chemical-intensive farming to natural

farming involves an initial transition period where soil fertility and yields may temporarily decline ^[31].

- Farmers may face economic constraints during this phase due to reduced income and additional labor requirements ^[32].

3. Scalability and Adoption

- Implementing natural farming practices on a large scale is challenging due to the diversity of agro-climatic conditions and cropping patterns ^[32].
- Resistance to change among farmers accustomed to synthetic fertilizers and pesticides hinders widespread adoption ^[31].

4. Availability of Natural Inputs

- Ensuring the availability of quality natural inputs like compost, biochar, and microbial inoculants is a logistical challenge ^[33].
- Limited infrastructure for producing and distributing these inputs adds to the complexity.

5. Policy and Institutional Support

- Insufficient policy incentives and lack of financial support deter farmers from adopting natural farming ^[34].
- Existing subsidies on chemical fertilizers and pesticides create an uneven playing field.

6. Market and Economic Viability

- Farmers practicing natural farming often struggle to find premium markets for their produce ^[34].
- Lack of certification mechanisms for natural farming products affects their marketability and price realization ^[34].

7. Climate Vulnerabilities

- Extreme weather events, such as droughts and floods, can disrupt natural farming systems.
- Lack of resilient infrastructure exacerbates the vulnerability of farmers practicing natural farming ^[35, 36].

Future Prospects

1. Policy Support and Incentives

- Governments and institutions should develop policies that promote natural farming through subsidies, grants, and training programs.
- Redirecting subsidies from synthetic inputs to natural farming inputs will encourage farmers to transition ^[31].

2. Capacity Building and Education

- Conducting extensive training and awareness campaigns to educate farmers about the benefits and techniques of natural farming ^[32].
- Incorporating natural farming principles into agricultural education and extension services.

3. Market Development:

- Creating certification systems for natural farming products to ensure premium market access and consumer trust ^[33].
- Developing local and international markets for natural farming produce to improve economic viability.

4. Infrastructure Development

- Establishing facilities for producing and distributing high-quality natural inputs, such as composting units and biochar plants ^[34].

- Investing in storage and transportation infrastructure to reduce post-harvest losses.

5. Technological Integration

- Leveraging modern technologies like drones, IoT, and AI to monitor soil health and optimize natural farming practices ^[36].
- Developing digital platforms to connect farmers with markets, input suppliers, and knowledge resources ^[37].

6. Research and Development

- Conducting long-term research on the impacts of natural farming on soil health, crop yields, and climate resilience.
- Developing region-specific natural farming models tailored to local agro-climatic conditions.

7. Climate Change Mitigation

- Promoting natural farming as a key strategy for sequestering carbon in soils and reducing greenhouse gas emissions.
- Integrating natural farming into national and global climate action plans ^[37].

8. Community-Based Approaches

- Encouraging the formation of farmer cooperatives and self-help groups to share knowledge and resources.
- Fostering community-led initiatives to promote natural farming as a collective effort.

9. Global Replication and Scaling

- Adopting successful models like Andhra Pradesh's ZBNF program as blueprints for other regions and countries.
- Facilitating international collaborations to exchange knowledge and best practices in natural farming.

10. Cross-Sectoral Collaboration

- Engaging stakeholders from academia, industry, government, and NGOs to promote natural farming.
- Developing partnerships to fund and implement large-scale natural farming projects.

Conclusion

Natural farming offers a sustainable and regenerative approach to agriculture by enhancing soil fertility, microbial diversity, and ecosystem health. By integrating organic inputs such as compost, biochar, green manures, and microbial inoculants, it addresses critical challenges posed by conventional chemical-intensive farming, including soil degradation, biodiversity loss, and environmental pollution. These natural inputs foster nutrient cycling, improve soil structure, and promote a balanced microbial ecosystem, resulting in resilient and productive agricultural systems.

The case studies, particularly the transformative Zero-Budget Natural Farming (ZBNF) initiative in Andhra Pradesh, demonstrate the potential of natural farming to achieve large-scale ecological and economic benefits. This approach not only reduces the dependency on synthetic inputs but also empowers farmers, enhances food security, and contributes significantly to climate change mitigation.

References

1. Bonanomi G, De Filippis F, Cesarano G, La Stora A, Ercolini D, Scala F. Organic farming induces changes in soil microbiota that affect agro-ecosystem functions. *Soil Biol Biochem.* 2016 Dec 1;103:327-36.

2. Badiyal A, Mahajan R, Rana RS, Sood R, Walia A, Rana T, *et al.* Synergizing biotechnology and natural farming: pioneering agricultural sustainability through innovative interventions. *Front Plant Sci.* 2024 Mar 22;15:1280846.
3. Vashishth M, Maheshwari S, Garg R, Kaushal S. Soil microbial diversity in conventional and organic agricultural farming systems. *J Pharma Innov.* 2022;11(11):1331-7.
4. Bhagat R, Walia S. Microbial fertilizers for plant nutrition under organic and natural farming. In: *Plant-Microbial Interactions for Sustainable Agriculture.* 2024 Nov 13:108.
5. Pinto AP, Faria JM, Dordio AV, Carvalho AP. Organic farming – A sustainable option to reduce soil degradation. *Agroecol Approaches Sustain Soil Manag.* 2023 Aug 18:83-143.
6. Pinto AP, Faria JM, Dordio AV, Carvalho AP. Organic farming – A sustainable option to reduce soil degradation. *Agroecol Approaches Sustain Soil Manag.* 2023 Aug 18:83-143.
7. Lal R. Soils and sustainable agriculture. A review. *Agron Sustain Dev.* 2008 Mar;28:57-64.
8. Lal R. Soils and sustainable agriculture. A review. *Agron Sustain Dev.* 2008 Mar;28:57-64.
9. Vaja M, Kulshrestha K, Lakhani H. Natural farming in India: A sustainable alternative to conventional agricultural practices. *Farming Manag.* 2024 Jan 11;9(2):63-5.
10. Kaswan S, Kaswan V, Kumar R. Organic farming as a basis for sustainable agriculture – a review. *Agric Rev.* 2012;33(1):27-36.
11. Henneron L, Bernard L, Hedde M, Pelosi C, Villenave C, Chenu C, *et al.* Fourteen years of evidence for positive effects of conservation agriculture and organic farming on soil life. *Agron Sustain Dev.* 2015 Jan;35(1):169-81.
12. Hartmann M, Frey B, Mayer J, Mäder P, Widmer F. Distinct soil microbial diversity under long-term organic and conventional farming. *ISME J.* 2015 May;9(5):1177-94.
13. Singh JS, Pandey VC, Singh DP. Efficient soil microorganisms: a new dimension for sustainable agriculture and environmental development. *Agric Ecosyst Environ.* 2011 Mar 1;140(3-4):339-53.
14. Gupta A, Singh UB, Sahu PK, Paul S, Kumar A, Malviya D, Singh S, Kuppusamy P, Singh P, Paul D, Rai JP. Linking soil microbial diversity to modern agriculture practices: a review. *Int J Environ Res Public Health.* 2022 Mar 7;19(5):3141.
15. Asghar W, Kataoka R. Green manure incorporation accelerates enzyme activity, plant growth, and changes in the fungal community of soil. *Arch Microbiol.* 2022 Jan;204(1):7.
16. Kanagalabavi AC, PATIL D, HR P, MS A. Zeolite in agriculture: An amendment in improving physical and chemical properties of soil. *International Journal of Advanced Chemistry Research.* 2024;6(2):228-35.
17. Alshankiti A, Gill S. Integrated plant nutrient management for sandy soil using chemical fertilizers, compost, biochar, and biofertilizers – case study in UAE. *J Arid Land Stud.* 2016;26(3):101-6.
18. Kaur J. Effect of green manure and bio-inoculants on inter-relationship of soil biological properties of Kharif maize.
19. De Corato U. Governance of soil amendment to enhance suppression of soil-borne plant pathogens from a long-term perspective. *Appl Soil Ecol.* 2023 Feb 1;182:104721.
20. Singh TB, Ali A, Prasad M, Yadav A, Shrivastav P, Goyal D, Dantu PK. Role of organic fertilizers in improving soil fertility. In: *Contaminants in Agriculture: Sources, Impacts and Management.* 2020:61-77.
21. Lei B, Wang J, Yao H. Ecological and environmental benefits of planting green manure in paddy fields. *Agriculture.* 2022 Feb 3;12(2):223.
22. Li T, Yan Z, Sun Y, Hu X, Peng C, Zhao S, *et al.* Inorganic and organic additives differently regulate compost microbiomes in response to heavy metals immobilization. *Chem Eng J.* 2024 Dec 15;502:158087.
23. Asghar W, Akça MO, Akça H, Tarf OJ, Kataoka R, Turgay OC. Alternative strategies to synthetic chemical fertilizers: revitalization of soil quality for sustainable agriculture using organic-based approaches. In: *New and Future Developments in Microbial Biotechnology and Bioengineering.* 2022 Jan 1 (p. 1-30). Elsevier.
24. Cardelli R, Becagli M, Marchini F, Saviozzi A. Effect of biochar, green compost, and vermicompost on the quality of a calcareous soil: A 1-year laboratory experiment. *Soil Sci.* 2017 Jul 1;182(7):248-55.
25. Cardelli R, Becagli M, Marchini F, Saviozzi A. Effect of biochar, green compost, and vermicompost on the quality of a calcareous soil: A 1-year laboratory experiment. *Soil Sci.* 2017 Jul 1;182(7):248-55.
26. Khan MT, Aleinikovienė J, Butkevičienė LM. Innovative organic fertilizers and cover crops: Perspectives for sustainable agriculture in the era of climate change and organic agriculture. *Agronomy.* 2024 Dec 1;14(12):2871.
27. Cardelli R, Becagli M, Marchini F, Saviozzi A. Effect of biochar, green compost, and vermicompost on the quality of a calcareous soil: A 1-year laboratory experiment. *Soil Sci.* 2017 Jul 1;182(7):248-55.
28. Wolna-Maruwka A, Piechota T, Niewiadomska A, Kamiński A, Kayzer D, Grzyb A, *et al.* The effect of biochar-based organic amendments on the structure of soil bacterial community and yield of maize (*Zea mays* L.). *Agronomy.* 2021 Jun 24;11(7):1286.
29. Bamdad H, Papari S, Lazarovits G, Berruti F. Soil amendments for sustainable agriculture: Microbial organic fertilizers. *Soil Use Manag.* 2022 Jan;38(1):94-120.
30. CREATE. CREATE ZBNF Rose Halstead Griffin. Available from: https://createsolutions.tufts.edu/wpcontent/uploads/2021/12/CREATE_ZBNF_Rose_Halstead_Griffin.pdf
31. Basilevac J. An analysis of factors affecting municipal biochar implementation in voluntary carbon markets.
32. Kiruba NJM, Saeid A. An insight into microbial inoculants for bioconversion of waste biomass into sustainable “bio-organic” fertilizers: a bibliometric analysis and systematic literature review. *Int J Mol Sci.* 2022 Oct 27;23(21):13049.
33. Vurukonda SS, Fotopoulos V, Saeid A. Production of a rich fertilizer base for plants from waste organic residues by microbial formulation technology. *Microorganisms.* 2024 Mar 7;12(3):541.
34. Bamdad H, Papari S, Lazarovits G, Berruti F. Soil amendments for sustainable agriculture: Microbial organic fertilizers. *Soil Use Manag.* 2022 Jan;38(1):94-120.
35. Sakhong R, Jaiswal P, Yosung L, Shukla YK, Kumari S. Technology innovation: A green approach to soil health. *Int J Plant Soil Sci.* 2024 Dec 30;36(12):613-22.
36. Freyer B, Ellssel P, Nyakanda F, Saussure S. Exploring the off-farm production, marketing, and use of organic and biofertilizers in Africa: A scoping study. Report to the European Commission. DeSIRA-LIFT European Union. 2024.
37. Schröder P, Sauvêtre A, Gnädinger F, Pesaresi P, Chmeliková L, Doğan N, *et al.* Discussion paper: Sustainable increase of crop production through improved technical strategies, breeding, and adapted management—A European perspective. *Sci Total Environ.* 2019 Aug

15;678:146-61.

38. Ierna A, Distefano M. Crop nutrition and soil fertility management in organic potato production systems. Horticulturae. 2024 Aug 21;10(8):886.