

Review Article

Sustainable Nutrient Management in Natural Farming: A Mini Review

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Abstract

Natural farming is a holistic, environmentally sustainable, and commercially feasible organic agricultural system that protects the soil's reproductive and regenerative abilities. According to modern agricultural principles, we should concentrate on improving production with the fewest number of inputs. Natural farming is an inexpensive agriculture practice that is closely tied to nature. It is based on four principles: no cultivation, no weeding with tillage or herbicides, no use of synthetic fertilisers, and no dependence on chemicals. As the world's population grows, so does the need for nutritious, organic foods. However, because of the use of chemical inputs in intensive farming, soil erodes fast, and dangerous microorganisms, as well as poisonous hazardous chemicals, build in soil media. As a result, plants absorb these harmful compounds, and when we consume this grain, this material enters our bodies and activates our metabolic pathways. These necessitate the emergence of chemical-free diversified agriculture-based farming practices with a greater emphasis on affordable native resources and management practices as a generic term "Natural Farming" in which the use of externally purchased inputs is avoided or minimised and the use of native resources with agro-ecological principles, people participation, and common resource management is largely focused for the benefit of farmers and communities. This strategy promotes multi-cropping and diversification of micro/macro flora. Thus, the low-cost, ecologically friendly farming approach must be used countrywide in order to maintain environmental harmony, minimise fertilizer consumption, and assist the farmers by increasing crop yields and profit margins. However, these are preliminary results, and further study is needed to establish the benefits for all crops across all environmental circumstances.

Keywords

Natural Farming, Synthetic Fertilizer, Multi-Cropping, Micro/Macro Flora

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1. Introduction

Sustainable Nutrient Management entails optimizing the use of natural and renewable resources to preserve soil fertility and production, mitigating environmental damage, and maintaining long-term agricultural profitability. Unfortunately, the current generation of humans has abused nature in order to reap the advantages of wealth via economic progress and agricultural scientific advances. Eventually, agricultural mechanization created a higher hazard to the natural environment [25]. Because traditional agriculture is mostly based on synthetic chemicals and petroleum energy, the excessive use of chemical fertilizers and pesticides has resulted in environmental pollution and degradation, compromised food safety and quality, and had a negative impact on human and animal health. According to FAI (2020), fertilizer use in India grew around 13 times between 1970 and 2020 [8]. This has had a negative influence on crop response ratios and caused nutritional imbalances in the soil. The crop response ratio has dropped from 58% during the previous three decades. Eventually, the optimal ratio of the three essential plant nutrients, nitrogen, phosphorus, and potassium, 4:2:1, is interrupted [16]. Furthermore, it has significantly increased the concentration of greenhouse gases in the atmosphere. Furthermore, it leads to unpredictable output in an unsustainable agroecosystem. Increased farmer debt owing to expensive agricultural inputs such as chemical fertilizers, pesticides, and herbicides, as well as higher cultivation costs and poor farm product prices, have exacerbated the country's agriculture problem. Concerns about such difficulties threatening

the country's environmental and agricultural sustainability spurred scientists and politicians to explore adequate alternative solutions to enable more sustainable food production in a pollution-free environment. Natural farming, with the least amount of external inputs and the use of nutritional supplements, has been shown in studies to promote multi-cropping and micro and macro flora diversification. Labour and manufacturing expenses are also minimized and therefore, it is quite considered as environmentally benign and sustainable [9].

Nutrient management is a key component of natural farming, which prioritizes sustainability, ecological balance, and low dependence on synthetic inputs [20]. Natural farming, as opposed to conventional farming, which frequently relies largely on chemical fertilizers, optimizes nutrient availability via the use of organic inputs and biological processes. This strategy protects soil health while also increasing biodiversity and encouraging environmental sustainability. Interestingly, the theory behind natural farming differs significantly from that of organic farming (Table 1). Natural farming promotes minimal intervention and is hence known as regenerative agriculture. Organic farming, on the other hand, requires very little intervention, such as the use of natural inputs and techniques to maintain soil health and fertility [20]. This review has emphasized into the ideas and techniques of nutrient management in natural farming, providing an in-depth analysis supported by scientific data and practical solutions.

Table 1. Natural farming versus organic farming.

Natural Farming	Organic Farming
Relies on natural processes without using any external inputs	Avoids synthetic chemicals, relying on natural inputs, crop rotation, and biodiversity
No external inputs; relies purely on nature's cycle	Uses natural and organic inputs, like organic composts and natural pesticides
Soil fertility is maintained through natural processes like mulching and microbial activity	Soil fertility is enhanced using organic composts, manures, and green manuring
Pest management through beneficial insects and natural predators	Uses organic, non-synthetic pesticides and encourages beneficial insects for managing pests
Low cultivation cost, as known for being low-cost, especially in "zero budget" approaches	Might involve some costs for organic inputs, certification, and labour
Can be less time-intensive due to fewer interventions	Might be more time-consuming due to specific organic practices and rotations
Adopts the philosophy of "work in harmony with nature"	Emphasizes avoiding synthetic chemicals while actively managing farm health

2. Challenges in Conventional Nutrient Management in Agriculture

The use of modern, highly specialized agricultural machinery is often associated with cultivation of plants in large-scale monocultures requiring significant transformation of the agricultural landscape, including regulation of soil water conditions, surface leveling, removing woodlots, hedges and field margins. In many countries such a unified landscape is nowadays a dominant form of agricultural management. However, the mentioned landscape transformations lead to the destruction of natural habitats of many plant and animal species, resulting in a significant depletion of biodiversity in agricultural areas. Many studies show a significant loss of the diversity of wild plants, invertebrates and birds in heavily managed agricultural areas [3, 24]. Depletion of flora and fauna species, and thus the disturbance of the natural balance in agrarian ecosystems promote the spread of pests and weeds, pushing farmers to the use of intensive chemical control on their fields. In addition, frequent use of heavy agricultural machinery in intensive farming is not only associated with high consumption of fuel, but also causes damage to the natural soil structure and increases its susceptibility to erosion. The results of numerous studies suggest that the biological activity of the soil, organic matter content, the stability of the structure and the associated erosion resistance, but also the yield per unit of applied fertilizer, decrease as a result of the use of intensive agricultural production methods [14]. Improper use of chemical pesticides also poses a considerable threat to the environment, both because of their high toxicity, and the possibility of accumulation. Residues of many of these compounds contaminate ground and surface waters [23] and climb to the top of the food chains by accumulating in tissues of living organisms.

In addition, the development of industrial, globalized agriculture, the aim of which was to ensure global food security, has led instead to a deepening of the problems related to providing access to food for the inhabitants of many regions of the world, especially developing countries. The rules of global trade and international structures that control the production and distribution of food, reduce significantly food sovereignty of many regions, inhibiting their growth and reducing access to food for their citizens. The described consequences of modern intensive agriculture definitely question the possibility of its further development. Therefore, the challenge we face is how to ensure food security of the growing human population (which, according to the present forecasts, could reach 9-10 billion people by 2050), while maintaining the current values of the environment and protecting non-renewable resources [10]. All these aforementioned challenges have piqued the interest in alternative systems of agricultural production.

3. Principles of Nutrient Management in Natural Farming

Nutrient management in natural farming revolves around maintaining soil health, enhancing biodiversity, and utilizing organic inputs to sustain crop productivity. The core principles are rooted in ecological balance and sustainability, ensuring long-term soil fertility without relying on synthetic fertilizers. According to Mokichi Okada, a Japanese philosopher, the principles of nature farming must fulfill five requirements: (1) produce safe and nutritious food that ensures good health; (2) be economically and spiritually beneficial to both producers and consumers; (3) be sustainable and easily practiced; (4) conserve and protect the environment; and (5) produce sufficient food of high quality for an expanding world population [26]. With the aim of these perspectives, natural farming is anticipated to improve soil health and fertility and creates a sustainable foundation for productive and resilient agricultural systems.

3.1. Soil Health and Fertility

Soil health is the bedrock of successful natural farming. Healthy soil is characterized by a rich composition of organic matter, diverse microbial communities, and balanced nutrient levels [2]. A key principle of nutrient management in natural farming is maintaining and enhancing soil health through the addition of organic matter. This includes practices such as composting, mulching, and the use of green manures which improve soil structure, water retention, and nutrient availability.

Maintaining and enhancing soil health is fundamental to nutrient management in natural farming. Healthy soil is the cornerstone of sustainable agriculture, as it supports robust plant growth, efficient nutrient cycling, and resilience against pests and diseases. Here are some key practices that focus on improving soil health through the addition of organic matter.

- 1) **Composting:** Composting is the process of decomposing organic waste materials, such as plant residues, kitchen scraps, and animal manure, into humus-rich compost. This compost is rich in essential nutrients and beneficial microorganisms, which enhance soil fertility and structure.
- 2) **Nutrient Enrichment:** Compost provides a balanced supply of macronutrients (nitrogen, phosphorus, potassium) and micronutrients (iron, manganese, zinc) that are slowly released, reducing the risk of nutrient leaching and promoting steady plant growth [13].
- 3) **Microbial Activity:** The organic matter in compost supports a diverse and active microbial community, which is crucial for nutrient cycling and soil health. These microbes break down organic materials, releasing nutrients in forms that plants can absorb.
- 4) **Soil Structure:** Compost improves soil structure by increasing its organic matter content, enhancing its ability

to retain water and air. This leads to better root penetration and plant growth.

5) **Mulching:** Mulching involves covering the soil surface with organic materials like straw, leaves, grass clippings, or wood chips. This practice offers several benefits for soil health like-

- a. **Moisture Conservation:** Mulch reduces water evaporation from the soil surface, maintaining consistent soil moisture levels and reducing the need for irrigation.
- b. **Temperature Regulation:** Mulch helps regulate soil temperature, keeping it cooler in the summer and warmer in the winter, thus creating a more stable environment for plant roots and soil microorganisms.
- c. **Weed Suppression:** By blocking sunlight, mulch helps suppress the growth of weeds, reducing competition for nutrients and water.
- d. **Organic Matter Addition:** As mulch decomposes, it gradually adds organic matter to the soil, improving soil fertility and structure over time.

6) **Green Manuring:** Green manuring involves growing cover crops, such as legumes, clover, or buckwheat, and then incorporating them into the soil. These cover crops provide multiple benefits:

- a. **Nitrogen Fixation:** Leguminous cover crops fix atmospheric nitrogen through symbiotic relationships with nitrogen-fixing bacteria, enriching the soil with this essential nutrient [6].
- b. **Soil Structure Improvement:** The root systems of cover crops enhance soil structure by creating channels that improve water infiltration and root penetration.
- c. **Erosion Control:** Cover crops protect the soil from erosion by wind and water, maintaining soil integrity and preventing nutrient loss.
- d. **Organic Matter Addition:** When cover crops are turned into the soil, they decompose and add organic matter, which improves soil fertility and supports microbial activity.

3.2. Natural Fertilizers

Natural fertilizers, including manure, bone meal, and blood meal, provide essential nutrients without the negative environmental impacts associated with synthetic fertilizers. These fertilizers release nutrients gradually, improving nutrient use efficiency and reducing the risk of leaching.

- 1) **Animal Manure:** Animal manure is a rich source of nitrogen, phosphorus, and potassium. It also enhances soil microbial activity and organic matter content, contributing to overall soil fertility [17].
- 2) **Bone Meal:** Bone meal is an excellent source of phos-

phorus and calcium, essential for root development and flowering. Its slow-release nature ensures a steady supply of nutrients to plants.

- 3) **Blood Meal:** Blood meal is high in nitrogen, promoting vigorous plant growth and lush green foliage. It is particularly useful for leafy vegetables and nitrogen-demanding crops.

3.3. Crop Rotation and Diversity

Crop rotation and diversity are pivotal strategies for sustainable nutrient management. Rotating crops helps break pest and disease cycles, enhances soil structure, and optimizes nutrient use by different plant species.

- 1) **Legume Crops:** Including legumes in crop rotations boosts soil nitrogen levels through biological nitrogen fixation, reducing the need for synthetic nitrogen fertilizers [11].
- 2) **Diverse Planting:** Growing a variety of crops increases biodiversity, enhancing ecosystem resilience and reducing dependency on external inputs [1].

4. Practical Strategies for Nutrient Management

Crops need nutrients to grow and thrive, but effective nutrient management is not one-size-fits-all. A nutrient management plan is specific to the particular land, the crops grown in the land, and many other factors that change over time. Natural farming relies on practices like crop rotation, cover cropping, adding compost or manure, green manures, crop residues, and approved amendments to optimize soil health and nutrient supply.

4.1. Integrated Nutrient Management (INM)

Integrated Nutrient Management (INM) combines organic and inorganic sources of nutrients to maintain soil fertility and sustain crop productivity. In natural farming, INM focuses predominantly on organic inputs but may incorporate minimal inorganic amendments when necessary (Figure 1).

- 1) **Organic Amendments:** Compost, green manures, and crop residues are used to maintain soil organic matter and nutrient levels. These amendments improve soil structure, enhance microbial activity, and provide a slow-release source of nutrients [21].
- 2) **Microbial Inoculants:** Beneficial microbes, such as mycorrhizal fungi and nitrogen-fixing bacteria, are introduced to enhance nutrient availability and uptake, supporting plant health and growth [22].

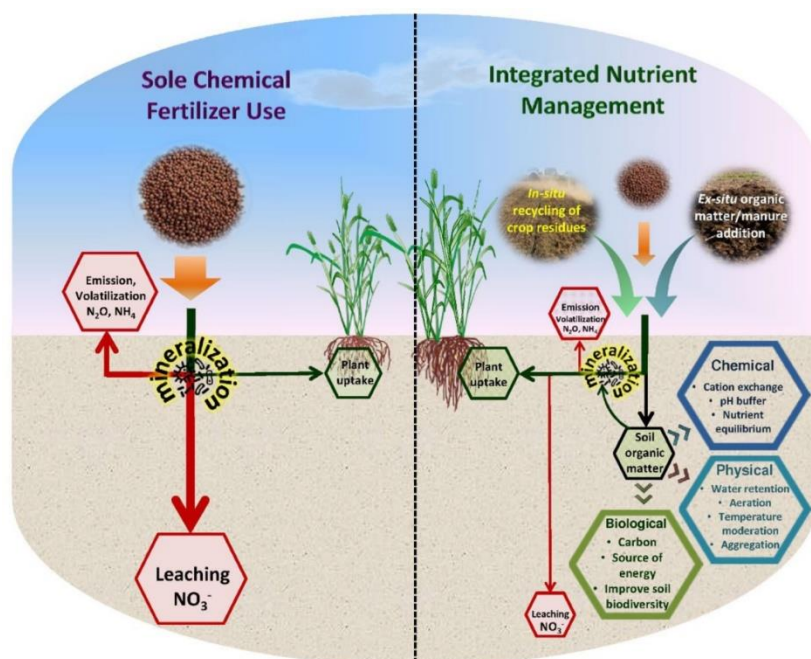


Figure 1. Integrated nutrient management minimizes nutrient leaching and improves nutrient utilization more effectively than using chemical fertilizers alone.

4.2. Soil Testing and Analysis

Regular soil testing is a critical component of effective nutrient management. Soil tests provide essential information on nutrient levels, pH, and organic matter content, guiding farmers in making informed decisions about nutrient applications.

- 1) Soil Sampling: Soil samples should be collected from various locations and depths within a field to obtain a representative analysis. Proper sampling ensures accurate assessment of soil fertility and nutrient status.
- 2) Laboratory Analysis: Soil samples are analyzed for macronutrients (nitrogen, phosphorus, potassium), micronutrients (iron, manganese, zinc, copper), pH, and organic matter content. This data helps tailor nutrient management practices to the specific needs of the soil and crops [7].

4.3. Biodynamic Preparations

Biodynamic farming, a subset of natural farming, employs specific preparations made from fermented herbs and minerals to enhance soil fertility and plant health.

- 1) Preparation 500 (Horn Manure): This preparation is made from cow manure fermented in a cow horn buried in the soil. It is believed to improve soil structure, enhance microbial activity, and stimulate root growth.
- 2) Preparation 501 (Horn Silica): Made from ground quartz crystal fermented in a cow horn, this preparation is used to enhance photosynthesis and overall plant growth by increasing light absorption and utilization.

5. Modern Technology in Natural Farming across Different Countries

Effective nutrition management is essential in the contemporary context to maintain equilibrium between the dietary needs of an expanding global populace and the diminishing availability of arable land. Conventional nutrient management practices are insufficient for producing adequate high-quality food for the global population due to significant soil fertility degradation caused by the excessive extraction of nutrients by high-yielding varieties and the neglect to replenish the soil. Furthermore, the unrestrained use of synthetic fertilizers, neglecting organic alternatives as a soil nutrient regimen, significantly deteriorates the nutritional quality of food products and disrupts the physical, chemical, and biological balances of the soil [4, 15]. The sustainable development goals (SDGs) ultimately fail due to hunger and malnutrition. All these rising concerns intentionally drive agricultural research to include creative concepts and technically robust methodologies for improved nutrient management.

Currently, agriculture is becoming a high-tech trade. Ranchers and farmers are utilizing modern farming techniques to develop more crops and raise more animals on reduced land, controls pests and diseases, and utilize data to create speedier, superior decisions. Modern technology has revolutionized natural farming practices worldwide, enhancing productivity while preserving ecological balance [12]. In Japan, innovations such as automated weeders and precision irrigation systems are employed to optimize resource use and reduce labor demands. These technologies facilitate efficient

water and nutrient management, aligning with the low-intervention, sustainable principles advocated by natural farming pioneers like Masanobu Fukuoka. In India, drones are increasingly utilized for monitoring crop health and applying organic inputs, ensuring precise and timely interventions that boost crop yields and minimize environmental impact. In Europe, the adoption of smart sensors and Internet of Things (IoT) devices in natural farming has become widespread [19]. These technologies provide real-time data on soil moisture, temperature, and nutrient levels, enabling farmers to make informed decisions and implement adaptive management practices. In the United States, Geographic Information Systems (GIS) and remote sensing technologies enhance land use planning and biodiversity conservation within natural farming landscapes [18]. In addition, AI (artificial intelligence) is revolutionizing nutrient management nowadays. It's dynamic decision-making based on real-time data from sensors, drones, and satellites allows for pinpoint accuracy [5]. Timely preventive measures can be taken to

address deficiencies before they impact crops. This data-driven approach ensures crops receive the right nutrients at the right time, promoting sustainability and meeting food demand efficiently. Furthermore, AI can promote the use of alternative nutrient sources and organic fertilizers, contributing to sustainable agricultural practices. As AI continues to advance, its integration into crop nutrient management holds tremendous promise for addressing the challenges of feeding a growing global population while minimizing the environmental footprint of agriculture.

Hence, innovation could be a major instrument in social and economic development; especially, eco-friendly innovation stimulates not only production but an efficient utilization of natural resources as well. Such technological advancements not only support the ecological foundations of natural farming but also enhance its scalability and economic viability. Below is a pictorial diagram illustrating some innovative ideas which has accelerated the effectiveness of natural farming around the world (Figure 2).



Figure 2. Advancement in natural farming strategies is hoped to accelerate its effectiveness in order to level up agricultural performance.

6. Conclusion

Nutrient management in natural farming is a comprehensive strategy that prioritizes soil vitality, organic amendments, and ecological equilibrium. Amidst the ramifications of climate change, including rising temperatures, modified precipitation patterns, and inconsistent soil salinity, global food security is significantly compromised. Contemporary agricultural techniques, marked by excessive water and fertilizer use, particularly nitrogen (N), do not satisfy sustainability standards. Soil deterioration, the loss of soil organic car-

bon (SOC), and nutritional imbalances, particularly shortages in essential elements (N, P, K, S), have emerged as urgent issues. The prolonged use of fertilizers without nutrient recycling has resulted in diminished soil fertility, reduced production, and shortages in secondary and micronutrients. Consequently, alternative tillage and crop establishment methods focused on water saving, soil health maintenance, and environmental sustainability need the development of innovative technologies in contemporary times. Through the use of methods like composting, crop rotation, and the application of organic fertilizers, farmers may maintain soil fertility, improve agricultural yield, and promote environmental sustainability. These technologies are essential for maximiz-

ing natural resource conservation and optimizing input usage efficiency, ensuring a more resilient and sustainable future for global agriculture.

Understanding the scientific principles and practical strategies outlined in this review will equip students and practitioners with the knowledge to implement effective nutrient management practices in natural farming.

Abbreviations

FAI	Fertilizer Association of India
INM	Integrated Nutrient Management
SDG	Sustainable Development Goals
IOT	Internet of Things
GIS	Geographic Information Systems
AI	Artificial Intelligence
SOC	Soil Organic Carbon

Author Contributions

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Soham Barik: Formal Analysis, Visualization, Writing – review & editing

Kinjal Mondal: Conceptualization, Supervision, Validation, Visualization, Writing – review & editing

Conflicts of Interest

The authors declare no conflicts of interest.

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