**Embedded in Nature: A Comprehensive Review of The Development, Difficulties and Promise of Organic Agriculture and Fertilizers in Agro-ecosystems**

**Abstract**

Over the past century, organic farming-which has its roots in conventional agricultural methods-has undergone significant change. From a grassroots movement against agricultural industrialization to a global enterprise, organic farming is now essential to tackling today's issues with sustainability, food safety, and environmental health. Organic farming has difficulties even if consumer demand for organic products and market access is rising. This essay explores the history and development of organic farming, focusing on the various kinds of organic fertilizers, their advantages, and their drawbacks. The slow-release characteristic of organic fertilizer and nutrient variability frequently fail to fulfil crop needs, which can significantly lower yield. Manure and bio solids are two examples of organic fertilizers that can increase productivity, but they also pose health and environmental hazards. In organic farming, controlling weeds and pests can be expensive and time-consuming. Rapid changeover and ineffective organic farming planning can also lead to food insecurity. It demonstrates how organic farming's all-encompassing philosophy goes beyond productivity, incorporating tactics like cutting down on food waste and creating self-sufficient farming communities. By lessening their negative effects on the environment and boosting regional economy, these methods help create a more sustainable farming system. The development of targeted organic fertilizers may benefit from future technical advancements, particularly in precision agriculture and bio-physicochemical models.

**Keywords:** Organic certification, fertilizers, Manure, Environmental health, Sustainable

**Introduction**

In order to support resource cycle, ecological balance, and biodiversity protection, organic production systems combine mechanical, biological, and cultural processes. Consumer demand for fresh organic food is on the rise due to growing health and environmental concerns.

Research indicates that farmers who use environmentally friendly organic agricultural practices make more money than those who use more chemicals (Kennedy et al., 2013). This profitability results from the fact that conventional farmers mainly rely on outside inputs to produce high crop yields, while organic farmers primarily rely on ecosystem services (Crowder, and Reganold, 2015). This profitability results from the fact that conventional farmers mainly rely on outside inputs to produce high crop yields, while organic farmers primarily rely on ecosystem services (Reganold and Wachter, 2016). In total organic production, 30% of producers present in India in the world manor 2.30 million hectares, 27, 59,660 farmers, 1730 total producers and 745 total traders in India (FiBL, survey 2021). Although the impact on consumers is still up for question, premium pricing for organic food are another way that the higher advantages can offset the lower yields. Organic farming is not without its difficulties, despite its widespread use and financial success. Farmers need in-depth understanding of crop and soil management and must deal with problems including insect pests, diseases, restricted nutrient contents of organic fertilizers, and the sourcing of organic nutrients (Larkin 2020). According to Huntley et al. (1997), organic fertilizers are mineral sources that exist naturally and require little human involvement, mostly physical extraction. They fall into three general categories: plant, animal, and mineral and rock products. Their nutritional availability can be inconsistent, though, and they frequently release nutrients slowly. For example, only 1-3 percent of the total nitrogen (N) in composted organic materials is released each year (Claassen and Carey, 2007). Commercial fast-releasing organic fertilizers and a range of organic substrates are now available on the market to allay these worries. For example, vermicompost offers more nutrients than conventional compost (Lim et al., 2015). However, there is a glaring lack of awareness among farmers regarding these products in areas like availability, cost, selection, scalability, and, to some extent, the anticipated impact on crop output. Crop productivity increases and more closely matches human demands in greater populations when agrochemicals are used during agricultural operations. Using agricultural chemicals consistently and without judgment harms the wellbeing of people, threatens biodiversity and harms the ecosystem (Elahi et al 2019). Apart from providing a comprehensive examination of the organic fertilizer sources often used in crop production, this study aims to provide a comprehensive overview of the organic farming system, including its challenges and history. The author's viewpoint on organic farming and its wider ramifications are also included in this paper.

**Organic Farming Overview**

Despite being seen as a modern movement, organic farming has historical origins that are firmly ingrained in antiquated farming methods. Many farming practices before the agricultural revolution of the 20th century naturally fit the definition of "organic" as we use it now. Because synthetic chemicals and genetically modified organisms (GMOs) had not yet been produced, traditional agriculture practices naturally adapted to organic ways (Twarog 2023). But with the start of the Industrial and Green Revolutions in the 20th century, things took a significant turn. A major shift from these traditional methods was brought about by the development of synthetic fertilizers, pesticides, and contemporary machinery (Harwood, 1990).

After evolving from conventional methods, organic farming is now acknowledged as a sustainable and feasible substitute for conventional farming (Lockeretz, 2007). As the organic market developed, it expanded its product line to include processed meals, textiles, cosmetics, and more in addition to basic vegetables. Talks on standardizing organic laws among nations gained prominence as the world's organic goods trade grew (Paull, 2023). With issues like global food security and climate change, the benefits of sustainable and organic farming methods are becoming increasingly clear (Rhodes, 2012). Organic farming has evolved over the last century from a specialized movement to a worldwide industry. Its guiding ideals-natural production, sustainability, and environmental well-being-remain relevant and are gradually influencing the conversation about agriculture's future despite its fair share of difficulties and criticisms (Horlings and Marsden, 2011).

Sustainable agriculture is a production practice of animals and plants with the application of site specificity, that will progress over time i.e., satisfy the need for human food and fibre, enhance the quality of the environment, sustain the farm operational economic viability and increase the way of life of farmers and the state of society (Bhaumik et al., 2024).

**The environmental benefits of organic farming**

Organic farming offers numerous environmental advantages since it is based on ecologically balanced agricultural concepts. Groundwater contamination is considerably less likely on organic farms as they don't use artificial fertilizers and pesticides. An extensive research conducted in Europe, for example, discovered that groundwater in regions with intense organic farming had 40% less nitrate than that of conventional farming (Stolze et al., 2000). Because they contain more organic matter, soils that are treated organically have greater water-holding capacity and infiltration rate (Colla et al., 2000). Approximately 22% of the world's anthropogenic greenhouse gas emissions come from agriculture, making it a significant contributor to climate change. Total GHG emissions per unit area have been demonstrated to decrease under organic management (Seufert and Ramankutty, 2017).

**Organic farming's health benefits**

Produced without the use of artificial pesticides or genetically modified organisms, organic foods satisfy consumers' growing need for pure and unadulterated foods. Generally speaking, studies have shown that organic crops have higher antioxidant concentrations, lower cadmium (Cd) levels, and a lower incidence of compared to crops produced conventionally, pesticide residues (Barański et al., 2011). For example, it was discovered that, on average, organic tomatoes have higher levels of vitamin C than normal tomatoes (Mitchell et al., 2007). The possible health hazards associated with pesticide residues are also reduced by organic farming, which uses fewer synthetic chemicals. The prevalence of several chronic illnesses and ailments may decline with this strategy (Forman and Silverstein, 2012).

**Obstacles in Organic Farming**

Although organic farming has many benefits for the environment, human health, and sustainability, it also faces many obstacles that may affect its effectiveness and rate of adoption. The various difficulties faced by organic farmers are examined in this section, which also explains the external variables that affect the practice's implementation as well as the method's intrinsic complexity.

**Sources of Organic Nutrients**

The procurement and use of organic nutrients is one of the main issues facing organic farmers. Organic farmers are limited in their options compared to conventional farmers, who have access to a large variety of synthetic fertilizers made to satisfy particular nutrient requirements. To maintain balanced soil fertility, these organic inputs—such as compost, manure, and bone meal—need to be carefully managed because their nutrient contents might vary greatly and may not be in the same proportion as what plants require (Gosling and Shepherd, 2005).

**Pest and Pathogen Management**

Because organic farming does not rely on synthetic pesticides and herbicides, controlling weeds, diseases, and insect pests becomes more difficult. Furthermore, this scenario is made more difficult by the variation in environmental circumstances and pest behaviours. A more complex approach is required for the organic method, which includes crop rotation, companion planting, biological controls, and occasional tillage. Although these techniques can be useful, they frequently need for a more sophisticated knowledge and occasionally produce less predictable results than chemical controls (Altieri, 1999).

**Soil and Crop Management**

It can be difficult to control soil fertility in organic farming, especially when using organic fertilizers. Organic fertilizers lack a specific source of nutrients and have lower nutritional contents than inorganic fertilizers. Rather, they are a combination of many organically accessible nutrients that must be mineralized in order for plants to absorb them. Consequently, maintaining the necessary and suggested nutrient levels can be challenging, particularly for crops that require a lot of nutrients (Burnett and Stack, 2009). When producers create greenhouse crops with longer growing seasons, like cucumber, tomato, and sweet pepper, this would be even more important. Over the course of their growth stages, these crops require a steady and uninterrupted supply of nutrients (Bergstrand, 2022).

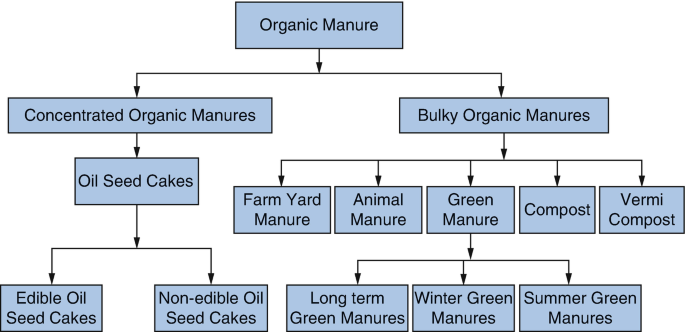
**Yield Gap and Issues with Economics and Logistics**

Despite its advantages for the environment and human health, organic farming usually struggles with the "yield gap," or lower yields as compared to conventional farming. According to studies, the average yield of organic crops in developed countries is between 5% and 34% less than that of conventional crops   
(Seufert et al ., 2012).

Organic farming produces lower yields because it is less flexible in modifying nutrient availability in response to crop needs than conventional farming, which uses synthetic fertilizers. Furthermore, because organic farming does not use synthetic herbicides, weeds must be removed by hand or by machine, which can be time-consuming and expensive. This method may not be able to handle aggressive weed species (Melander, 2013).Financial resources may be stretched by the costs of organic certification, infrastructural changes, and the possibility of lower yields during the transition period, which are some of the major economic obstacles associated with switching to organic farming. Further complicating matters for farmers are the logistical difficulties of obtaining organic seeds and overseeing prolonged agricultural rotations (Lampkin and Padel, 1994).

**Organic Fertilizers: Categories and Characterization**

Manure is categorized as having high quality nutrients that are easily absorbed by plants and utilized in fields to increase soil fertility and plant health. Organic manure refers to Manure, which is the waste materials of animals and plants that are used in order to give plant nutrients (Chhonkar 2002). Utilizing organic Manure, organic farming makes a substantial contribution to the growth of agricultural sustainability. (Jiang et al., 2022). Directly, organic manure serves to promote the growth of the crop due to the supply of things that are humic and increases the availability of microorganisms, improving soil productivity (Aisha et al., 2014). Depending on the concentration of nutrients, organic manure has two groups, e.g., bulky organic Manure and concentrated organic Manure (Reddy & Reddy, 2021).



**Figure 1: Classification of Organic manure**

**Organic Fertilizer: Nutrient Profile, Application, and Challenges**

It's crucial to understand that controlling nutrient budgets with organic sources might be difficult when investigating the usage of organic fertilizer. Their complex organic compositions, variable mineralization kinetics, and poor nutrient profile provide this difficulty. Their manufacturing, outsourcing, shelf life, and environmental effects are further difficulties. The nutrient composition, utilization, and difficulties of the most widely accessible and utilized organic nutrient sources are covered in this section. Table 1 gives specific details about the nutritional makeup of organic fertilizers.

**Table 1.** Nutrient composition of various organic fertilizers and soil amendments

|  |  |  |  |
| --- | --- | --- | --- |
| **Material** | **% Nitrogen** | **% Phosphate** | **% Potash** |
| Alfalfa hay | 2–3 | 0.5–1 | 1–2 |
| Bone meal | 1–6 | 11–30 | 0 |
| Blood meal | 12 | 1–2 | 0–1 |
| Cottonseed meal | 6 | 3 | 1 |
| Composts | 1–3 | 1–2 | 1–2 |
| Feather meal | 12 | 0 | 0 |
| Fish meal | 6–12 | 3–7 | 2–5 |
| Grass clippings | 1–2 | 0–0.5 | 1–2 |
| Hoof/horn meal | 12–14 | 1.5–2 | 0 |
| Kelp | 1–1.5 | 0.5–1 | 5–10 |
| Leaves | 1 | 0–0.5 | 0–0.5 |
| Legumes | 2–4 | 0–0.5 | 2–3 |
| Manures: cattle | 2–3 | 0.5–1 | 1–2 |
| Horse | 1–2 | 0.5–1 | 1–2 |
| Swine | 2–3 | 0.5–1 | 1–2 |
| Poultry | 3–4 | 1–2 | 1–2 |
| Sheep | 3–4 | 0.5–1 | 2–3 |
| Pine needles | 0.5 | 0 | 1 |
| Sawdust | 0–1 | 0–0.5 | 0–1 |
| Sewage sludge | 2–6 | 1–4 | 0–1 |
| Seaweed extract | 1 | 2 | 5 |
| Straw/corn stalks | 0–0.5 | 0–0.5 | 1 |
| Wood ashes | 0 | 1–2 | 3–7 |

**Animal-Based Fertilizers**

**Manure**

An essential part of organic farming is manure, a natural fertilizer made from animal urine and excrement combined with hay or straw that has several advantages for crops and soil. This can be broadly divided into dung from cows, horses, sheep, chickens, pigs, goats, and rabbits, each of which has a different amount of nutrients (NPK and other nutrient values). For example, N concentrations in cow manure usually range from 0.5% to 3%, P concentrations from 0.3% to 0.6%, and K values from 0.5% to 3%. Particularly high in nutrients, chicken manure contains 1.5% to 3.5% N, 1.5% to 3% P, and 0.8% to 2.5% K. The food of the animals, the age of the manure, and its storage all affect the concentrations of nutrients.

**Blood Meal**

Blood meal, a popular organic fertilizer derived from dried and ground animal blood, is a cost-effective and efficient source of N for plants, particularly high-N-demanding vegetables such as lettuce, spinach, kale, tomatoes, peppers, cucumbers, and okra. Despite its high N content (10–13%) compared to other organic sources, it is also a slow-release fertilizer. Blood meal is mainly composed of haemoglobin (globular protein) and is characterized by the presence of a prosthetic group (protoporphyrin) containing iron (Fe).

**Bone Meal**

A common organic fertilizer made from finely powdered animal bones, bone meal is high in calcium (22–33%) and phosphorus (15–27%). A tiny quantity of N (1–4%) and trace minerals, like as collagens, are also included in bone meal. Although they are advantageous in many situations, bone meals are not always appropriate. It might not be the best option for plants that require a lot of nitrogen or for use in highly acidic soils. The delayed conversion of bone meal into soluble P in acidic environments is the cause. In P-deficient soils, this trait can be helpful in promoting plant development. Bone meal, on the other hand, tends to transform into a stable form of phosphorus in soils that already contain enough of it, providing no extra advantages to the plants.

**Plant-Based Fertilizers**

**Compost**

Agricultural residues, yard debris, and kitchen scraps all break down aerobically to produce compost, a crucial component of sustainable waste management. Microbial activity, water retention, and soil structure are all improved (Kranz et al., 2020). There are several types of composting depending on the ingredients and process, such as home composting, vermicomposting (which uses earthworms to speed up decomposition - Blouin et al., 2019) , bokashi   
(a fermentation-based method- Olle, 2021), and large-scale industrial composting. Benefits include improving soil aeration and moisture retention, enriching vital nutrients, assisting in carbon sequestration, and diverting organic waste from landfills to reduce greenhouse gas emissions. The challenges of home composting include space and upkeep, vermicomposting requires particular conditions, and bokashi composting requires an anaerobic atmosphere (Footer, 2013).

**Green Manure**

Green manure, which incorporates fresh plant material-particularly from cover crops that develop quickly-offers a sustainable way to improve the health and quality of soil. The purpose of planting crops like legumes like clover, vetch, and peas, as well as grasses like rye and barley, is to improve soil health rather than for harvest (Fageria, 2007). In particular, their incorporation into agricultural systems improves soil structure and organic matter content and aids in N fixation. Green manure application is not without its difficulties, though; for instance, it might be difficult to manage and time it precisely, and the growing period of these crops can occasionally clash with the main crop planting schedule. Furthermore, the addition of green manure to the soil needs to be carefully scheduled so that it happens before the plants are ready to seed. Despite being good for the health of the soil, this procedure can be time-consuming and requires the right agricultural tools. Additionally, water resource management becomes an important factor, particularly in arid regions where additional irrigation may be necessary (Cherr et al., 2006).

**Perspective and Future**

An increasing world population and high demand for products like corn, soybeans, and rice create both opportunities and challenges for organic farming, which places a strong focus on sustainability and environmental care. Although slow-release fertilizers are good for soil health and long-term sustainability, they may not be able to meet the high-yield crops' immediate nutritional needs. This is a major characteristic of organic farming. Because of this intrinsic nutrient restriction, organic systems may not be able to meet the anticipated growth rate required to feed the growing population. Long-term use of organic fertilizer, particularly manure, can increase the system's resilience to abiotic stresses like drought, greatly improve the organic matter and health of the soil, and maintain a more stable yield than inorganic fertilizers, even though organic farming may not be supplying the essential nutrients at the rate that crops require. But it's crucial to remember that organic farming takes a comprehensive approach to creating self-sufficient communities, encompassing more than just production techniques. Techniques like composting to reduce food waste and building networks of independent organic farmers are essential. As technology and scientific understanding grow, organic farming offers a plethora of chances to satisfy consumer needs while promoting environmental responsibility. Determining the timing of nutrient availability, creating accurate nutrient prescription plans, and comprehending how organic fertilizers behave in the soil system are important issues that must be resolved for organic farming to be established properly. It is possible to determine the rate of mineralization and nutrient intake using contemporary technology, such as isotope tracing. With metagenomics and metabolomics research, the impact of microbial activity on the mineralization dynamics of organic fertilizers may be assessed.



**Figure 2: A busy marketplace that supports sustainable agriculture**

**Conclusion**

Comprehensive strategies for sustainable agriculture that takes social, economic, and environmental factors into account. An active communal garden, a busy marketplace, and a productive composting area are all depicted. Through organic cultivation and biodiversity preservation, the garden represents environmental sustainability. By promoting the direct selling of locally farmed produce, the marketplace promotes economic sustainability, boosts the local economy, and cuts down on food miles. The composting area serves as a reminder of the need of nutrient recycling and waste reduction in sustainable resource management. Furthermore, by increasing community involvement, creating job possibilities, and raising inhabitants' standard of living generally, this arrangement promotes social sustainability. The soils chemical, physical and biological characteristics improved with the application of organic materials in the long term and farmer's income also increases. The most crucial element in creating sustainable agriculture is organic farming. I want everyone to practice organic farming.

**Disclaimer (Artificial intelligence)**

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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