Fertilisers for Enhanced Soil Fertility and Crop Production: A Review

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Abstract: The escalating demand for food, driven by a growing global population, necessitates more intensive farming on limited arable land. Unfortunately, the appropriate approach to replenish the lost soil nutrients is overlooked, leading to a decline in natural fertility that hinders healthy crop growth. To address this issue and ensure sustainable yields, it is vital to enhance soil fertility through the strategic application of fertilisers that can boost agricultural productivity. Effective fertiliser use is crucial for enhancing food security and boosting rural incomes. However, in sub-Saharan Africa, particularly in Nigeria, the adoption of inorganic fertilisers remains alarmingly low, with few smallholder farmers utilising them. This low adoption rate poses significant challenges to agricultural sustainability and productivity. The obstacles associated with inorganic fertilisers include high costs, a lack of knowledge, and cultural barriers. Conversely, while organic fertilisers can improve soil health, they often fall short in delivering the rapid nutrient boost needed for high-yield crops in nutrient-deficient soils. This review explores the advantages and disadvantages of both organic and inorganic fertilisers in enhancing soil fertility and increasing crop production. This review recognises that the success of fertiliser application in improving or maintaining crop yields is closely tied to effective weed management. Weeds compete with crops for nutrients, water, and light; therefore, managing them is critical to maximising any fertiliser strategy. A comprehensive approach that integrates both fertiliser and weed management is identified as a prerequisite for achieving sustainable crop productivity.
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1. Introduction

Soil fertility is a critical determinant of agricultural productivity, underpinning global food security in an era of increasing population and environmental challenges (Henry et al., 2018). With the world population projected to reach 9.7 billion by 2050, the pressure to enhance crop yields, while preserving soil health has intensified (Bezboruah et al., 2024). Soil degradation, driven by intensive farming, nutrient depletion, and climate change, threatens agricultural sustainability. Climate change exacerbates these issues through altered precipitation patterns, rising temperatures, and increased frequency of extreme weather events, which disrupt soil nutrient cycles and reduce crop resilience (Raza et al., 2024). Fertile soils, rich in essential nutrients, organic matter, and microbial activity, are vital for supporting robust plant growth (Henry et al., 2018; Jaswal et al. 2021). Fertilisers, as key tools for replenishing soil nutrients, play an indispensable role in addressing these challenges.

Fertilisers are substances applied to soils or plants to supply essential nutrients, including macronutrients like nitrogen (N), phosphorus (P), and potassium (K), and micronutrients such as zinc (Zn), iron (Fe), and manganese (Mn), which are critical for plant physiological processes like photosynthesis, root development, and stress resistance (Ahmed et al., 2020). Historically, organic materials such as manure, compost, and crop residues were the primary means of maintaining soil fertility. The Green Revolution, marked by the widespread adoption of synthetic fertilisers, transformed agriculture by doubling or tripling crop yields, as noted by John and Babu (2021). However, the overuse of chemical fertilisers has contributed to environmental issues, including soil acidification, nutrient runoff, and greenhouse gas emissions, which exacerbate climate change (Pahalvi et al., 2021). For instance, nitrous oxide (N_2O) emissions from nitrogen fertilisers contribute significantly to global warming, with agriculture accounting for approximately 50-60% of global N_2O emissions (Kudeyarov, 2020). Climate change, in turn, affects soil fertility by accelerating organic matter decomposition and altering nutrient availability, necessitating adaptive fertiliser strategies.

Fertilisers are broadly classified into organic, inorganic (synthetic), and biofertilisers, each offering unique benefits in the context of climate change. Organic fertilisers, derived from natural sources like animal manure and plant residues, enhance soil organic carbon, improve water retention, and support microbial activity, which is critical for climate resilience (Arfat et al., 2022). Research by Lal (2021) shows that organic amendments increase soil carbon sequestration, mitigating climate change by reducing atmospheric CO_2. Inorganic fertilisers provide immediate nutrient availability, enabling rapid crop responses to changing climatic conditions, but their production and application are energy-intensive and contribute to carbon emissions (Ma et al., 2024). Biofertilisers, containing microorganisms like *Rhizobium* and *Azospirillum*, promote nutrient cycling and enhance plant resilience to drought and heat stress, as demonstrated by Chaudhary et al. (2022). These biological agents are particularly valuable in climate-vulnerable regions where soil degradation is pronounced.

The mechanisms by which fertilisers enhance soil fertility and crop production are complex, involving nutrient supply, soil structure improvement, and microbial interactions (Singh and Ryan, 2015). Nitrogen supports leaf growth and photosynthesis, phosphorus aids root development, and potassium enhances water regulation, all of which are critical for crops facing climate-induced stresses like drought or heat (Oyebamiji et al., 2024). Organic fertilisers improve soil structure, increasing its capacity to retain water and nutrients under erratic rainfall patterns (Timsina, 2018). Biofertilisers foster symbiotic relationships, enhancing nutrient uptake and plant resilience (Chaudhary et al., 2022). However, excessive or poorly timed fertiliser application can lead to nutrient leaching, particularly under heavy rainfall events associated with climate change, causing eutrophication and greenhouse gas emissions (Barłóg et al., 2022). Precision agriculture techniques, such as soil testing and variable-rate application, are essential for optimising fertiliser use in a changing climate (Getahun et al., 2024).

Recent innovations in fertiliser technology address both productivity and climate change mitigation. Controlled-release fertilisers and Slow Release Fertilisers reduce nutrient losses under variable weather conditions, with studies by Li and Zhang (2023) reporting up to 35% improved nitrogen use efficiency. Nanotechnology-based fertilisers deliver nutrients efficiently, minimising environmental impacts, while biochar-based fertilisers enhance soil carbon storage and nutrient retention, as noted by Sheokand et al. (2023) and Singh et al. (2024). The adoption of integrated nutrient management is particularly critical in the context of global agricultural challenges. Integrated nutrient management (INM), combining organic, inorganic, and biofertilisers, offers a sustainable approach to maintaining soil fertility under climate variability (Panta and Parajulee, 2021). Research by Raza et al. (2024) indicates that INM can boost yields, while reducing emissions, aligning with climate-smart agriculture goals. The global fertiliser market reflects this shift, with Freyer et al. (2024) reporting increased demand for sustainable products, driven by policies promoting eco-friendly fertilisers in regions like Europe and Africa. This review aims to evaluate the role of organic, inorganic, and biofertilisers in enhancing soil fertility and crop production, with a focus on their efficacy in mitigating the adverse impacts of climate change on agricultural systems.

2. **Inorganic Fertiliser**

Inorganic fertiliser refers to fertiliser produced through industrial processes or extracted from mineral deposits and can be derived from organic or synthetic organic substances. These fertilisers are designed to meet the immediate nutritional needs of crops, enabling farmers to achieve high yields in a short time frame (Lazewski, 2024). Applying inorganic fertiliser has been shown to maintain crop yield, improve nutrient cycling, and enhance soil productivity (Roba, 2018). Farmers use it to correct nutrient deficiencies in the soil. Experience indicates that chemical fertiliser is one of the most dependable means of improving agricultural productivity. According to FAO (2024) world fertiliser use for urea and NPK, an increase from 82.41 to 88.31 million tonnes was recorded between 2012 and 2022, respectively, suggesting the intensification of land for the production of food. However, the current use of the fertilisers in sub-Saharan Africa remains low, with only about 5% of small-scale farmers utilising them, and application rates ranged from 0-10 kg ha^{-1}, while the average fertiliser use in Nigeria was 6.2 kg ha^{-1}. This the world average of 100 kg ha^{-1} as indicated in Figure 1 and consederably low compared to 50-300 kg ha^{-1} used in North America and 100-300 kg ha^{-1} in western Europe (FAO, 2025). Bi (2023) found that soil organic matter in farmland is a major contributor to the soil's cation exchange capacity and nitrogen content. As soils become degraded and weathered, inorganic fertilisers become the primary method for replenishing soil nutrients. Research has consistently demonstrated a clear link between increased inorganic fertiliser consumption and increased crop production in Nigeria. Inorganic fertilisers have been used to enhance yields of crops like cassava and maize. For example, Nwokoro (2021) recommended specific application rates of nitrogen (N), phosphorus (P_2O_5), and potassium (K_2O) for cassava and maize production in Southwestern Nigeria. To accelerate agricultural production and productivity. Nigeria has implemented strategic policies to promote the efficient production, distribution, and use of inorganic fertilisers, resulting in a rapid increase in their consumption. The government's involvement in the production, procurement, and distribution of inorganic fertilisers is considered essential to ensure availability at fair prices and to encourage increased use through extension services (Benson et al., 2018). However, the inadequacies of public sector control over procurement and distribution have become apparent as fertiliser consumption has increased. These inadequacies include issues such as losses during transit, cross-border trade, late or non-deliveries, artificial scarcity, and the unsustainable burden of subsidies on the government. Furthermore, due to the long distances and challenging road conditions in Africa, farmers often face the highest fertiliser prices globally.

The acidity of soils, resulting from parent materials, weathering, and leaching, is exacerbated by the continuous use of acid-forming fertilisers like sulfate of ammonia, urea, and ammonium nitrate. This highlights the need for alternative nutrient sources that are less detrimental to the soil. While chemical fertilisers undeniably increase yields, their high cost remains a significant problem (Freyer et al., 2024). Inefficient distribution systems often hinder fertiliser availability at the farm level, and subsidy programmes have sometimes disproportionately benefited intermediaries, leaving farmers to pay high prices. Because crops like cassava and maize are primarily grown by poor farmers, the high cost of fertiliser is a major constraint. Furthermore, inefficient distribution systems at the farm level often result in higher prices and low yields that do not justify the purchase price of the fertiliser (Freyer et al., 2024). Potential profitability is also frequently affected by issues such as high application rates without soil testing. This can negatively impact the soil's chemical and physical properties, leading to nutrient imbalances, increased soil bulk density, and reduced water infiltration, all of which impede nutrient uptake by plants. Mineral fertilisers alone are not sufficient to sustain crop yields on acidic and poorly buffered Alfisols, as they can accelerate the decline in soil pH and exchangeable cations.

Therefore, there's a growing emphasis on agro-ecological technologies in agricultural production, as they require less capital and labour. Organic matter technologies are becoming important alternatives for enhancing soil fertility and crop yields in sub-Saharan Africa.

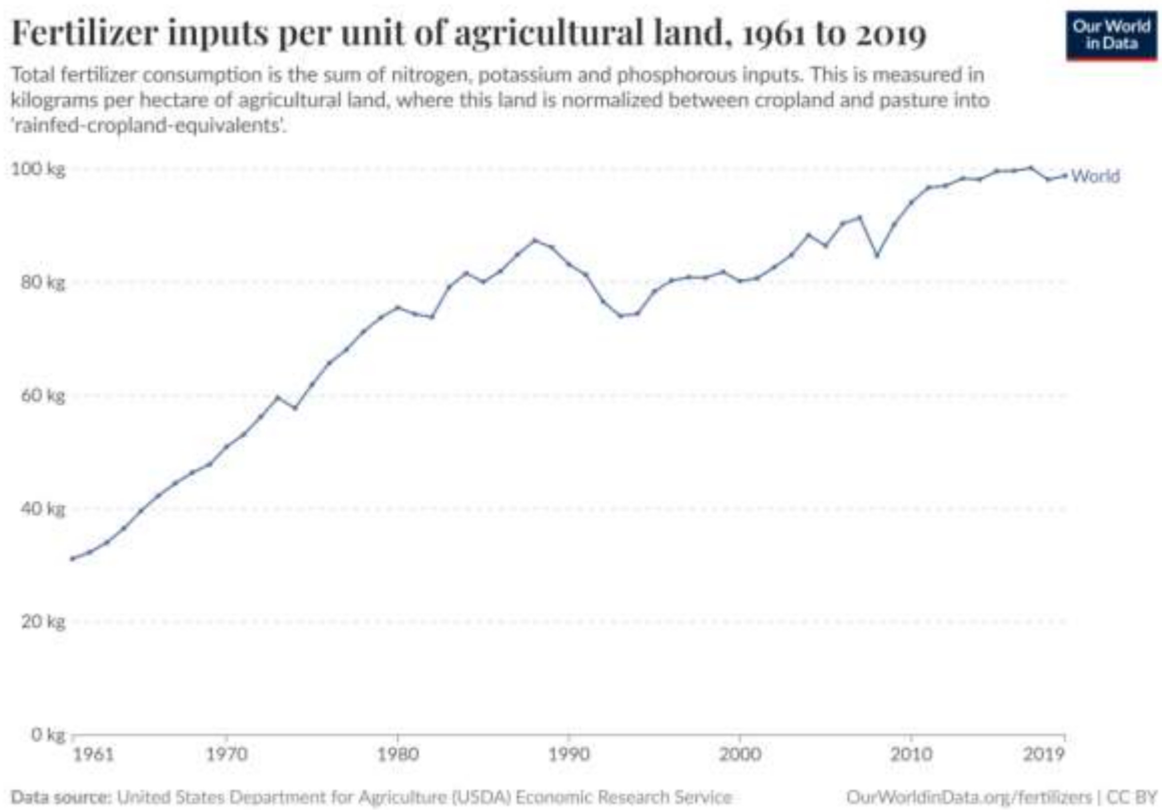

Figure 1: World fertiliser input per hectare of agricultural land area (Source: FAO, 2025)

3. **Organic Fertiliser**

Organic fertiliser refers to fertilisers derived from non-synthetic organic materials, including sewage sludge, animal manure, and plant residues (Arfat et al., 2022). Organic fertilisers are produced through processes like drying, composting, chopping, grinding, and fermenting. These processes enhance the availability of nutrients. Organic fertilisers are considered a viable alternative for supplying crop nutrients. Many researchers have advocated for the use of animal manures, as they provide essential nutrients such as nitrogen (N), phosphorus (P), potassium (K), zinc (Zn), iron (Fe), copper (Cu), manganese (Mn), and boron (B). In Southwestern Nigeria, various organic fertilisers are abundant, including pig manure, goat dung, cattle dung, and poultry manure (Timsina, 2018; Akinrinola and Salawu, 2025). Poultry manure, in particular, has been extensively studied. These manures, especially poultry manure, are rich in organic matter, which improves soil productivity (Wato et al., 2024). However, their limitations can hinder optimal food production for sustainable agriculture. Factors such as the rising cost of animal feeds, transportation challenges, and farmers' limited interest in animal husbandry restrict the use of animal manure as fertilisers (Lim et al., 2023). Additionally, the large quantities of organic waste required for field crop production and the difficulties in handling them make them unsuitable as a complete substitute for mineral fertilisers. The nutrient composition of manure varies depending on its source and handling. For example, Ashworth et al. (2020) found that poultry manure in large amount is required in correcting zinc deficiency in soils. These requirements make manure less appealing to farmers.

There is increasing interest in using plant residues as sources of plant nutrients, particularly phosphate and potash fertilisers. Versino et al. (2020) reported that the slow release of nitrogenous fertilisers from plant residues positively affected cassava growth and yield. Compared to mineral fertilisers, these plant residues are less likely to have adverse effects on the soil's physical and chemical properties. However, their low nutrient content and the time it takes for them to decompose and release nutrients limit their use, as large quantities are needed to meet crop nutritional demands. Examples of plant residues include cocoa pod husks, kola husks, neem leaves, Gliricidia, oil palm bunches, and sunflower residues, Siam weed, Tithonia (Anyaoha et al., 2018; Akinrinola and Ojo, 2024). In Nigeria, about 800,000 tonnes of cocoa pod husks are generated annually, much of which goes to waste. Research indicates that many farmers apply two to three times more nitrogen fertiliser than their crops require. One reason for this over-application is that farmers often do not account for the nutrient contribution from manure (Sharara et al., 2022).

4. Biofertilisers

Biofertilisers are natural inputs derived from living microorganisms that enhance soil fertility and promote plant growth without the environmental toll of synthetic fertilisers. These microbes (including nitrogen-fixing bacteria like Rhizobium and Azotobacter, phosphate-solubilising bacteria, and mycorrhizal fungi) work symbiotically with plants to unlock essential nutrients. By fixing atmospheric nitrogen, breaking down insoluble phosphorus, or improving nutrient uptake, biofertilisers offer a nature-friendly alternative to chemical inputs, fostering healthier ecosystems and more resilient crops (Anli et al., 2020). Their rise in popularity reflects a growing awareness of the need for farming practices that balance productivity with ecological stewardship.

The mechanism behind biofertilisers is both simple and profound. Nitrogen-fixing bacteria, for instance, convert atmospheric nitrogen into ammonia, a form plants can readily use, effectively reducing the need for synthetic nitrogen fertilisers (Anli et al., 2020). Rhizobium, which forms nodules on legume roots, is a classic example, of boosting crops like soybeans and peas. Similarly, phosphate-solubilising bacteria release bound phosphorus in the soil, making it accessible to plants, while mycorrhizal fungi extend root systems, enhancing water and nutrient absorption (Chaudhary et al., 2022). These processes not only feed plants but also enrich the soil's microbial community, improving its structure, water retention, and long-term fertility. Unlike chemical fertilisers, which can degrade soil over time through acidification or nutrient depletion, biofertilisers nurture the soil's natural vitality, making them a linchpin of organic and regenerative farming.

One of the standout benefits of biofertilisers is their environmental impact or lack thereof. The excessive use of synthetic fertilisers often leads to nutrient runoff, polluting waterways and causing algal blooms, while their production is energy-intensive, contributing to greenhouse gas emissions (Paramesh et al., 2023; Lazewski, 2024). Biofertilisers, by contrast, are low-energy, biodegradable inputs that reduce pollution risks and promote biodiversity in the soil. They also help mitigate the overuse of chemical fertilisers, which can disrupt microbial ecosystems and reduce soil resilience. For small-scale farmers, biofertilisers are a cost-effective solution, often produced locally or even on-farm, cutting down on the expense of imported chemicals (Freyer et al., 2024). In regions with degraded soils, such as parts of sub-Saharan Africa, biofertilisers have shown promise in restoring fertility and boosting yields, offering a lifeline to communities reliant on agriculture (Anli et al., 2020).

However, biofertilisers are not without challenges. Their effectiveness depends on factors like soil type, climate, and crop species, which can make results inconsistent. For example, Rhizobium requires specific legume hosts to thrive, and mycorrhizal fungi may struggle in heavily disturbed soils. Application can also be tricky—microbes must be stored and applied correctly to remain viable, and improper handling can render them ineffective. Additionally, biofertilisers often work more slowly than chemical fertilisers, which may deter farmers from seeking quick results. To address this, many advocate for INM, combining biofertilisers with organic or inorganic inputs to balance immediate and long-term needs (Kushwah et al., 2023). Education and training are critical to help farmers adopt these practices effectively, as misunderstanding or misapplication can undermine benefits.

The future of biofertilisers lies in innovation and accessibility. Advances in microbial technology, such as developing more resilient strains or biofertiliser formulations tailored to specific crops and soils, could broaden their impact. Governments and agricultural organisations can play a role by subsidising production and providing training to farmers, particularly in developing nations. As climate change pressures mount, biofertilisers offer a path to sustainable intensification—producing more food with fewer resources while preserving the planet's ecosystems. Their ability to enhance soil health, reduce environmental harm, and support resilient agriculture makes them a vital tool in the global shift toward sustainability (Chaudhary et al., 2022).

Below are findings from recent research on fertilizers for enhanced soil fertility and crop production (Tables 1, 2 and 3). The tables focus on fertilizer types, their effects on soil and crop outcomes, and associated challenges, drawing from relevant studies.

Table 1: Types of Fertilizers and Their Mechanisms

Fertilizer Type	**Nutrient Release Mechanism**	**Key Benefits**	**Challenges**
Slow-Release Fertilizers (SRF)	Biological, chemical, or biochemical slow release	Reduced nutrient loss, improved nutrient use efficiency (NUE)	Limited control over release rates, higher cost
Controlled-Release Fertilizers (CRF)	Physical mechanisms (coatings, encapsulation)	Synchronized nutrient release with crop demand, reduced environmental impact	High production costs, variable performance across soil types
Nanofertilizers	Nanoparticle-based delivery, pH-triggered release	Enhanced nutrient uptake, targeted delivery	Limited field data, lack of standardized testing protocols
Biofertilizers	Microbial activity (e.g., PGPR, mycorrhizal fungi)	Eco-friendly, promotes soil health, enhances abiotic stress tolerance	Crop and environment-specific efficacy, technical application challenges
Organic Fertilizers	Gradual nutrient release via decomposition	Improves soil structure, organic matter, microbial activity	Potential nutrient imbalances, risk of P and N leaching

Table 2: Impact on Soil Fertility and Crop Production

Fertilizer Type	**Soil Fertility Impact**	**Crop Production Impact**	**Study Reference**
Slow-Release Fertilizers	Enhances nutrient retention, reduces leaching	Increases yield by 10-20% in some crops	Chaudhary et al. (2023)
Controlled-Release Fertilizers	Improves nutrient availability, reduces soil acidification	Up to 84.91% N and 13.40% P utilization in bok choy	Blanco-Canqui, & Ruis (2018
Nanofertilizers	Improves nutrient bioavailability, reduces soil nutrient depletion	Potential yield increase, limited large-scale data	Maaz et al. (2025)
Biofertilizers	Increases soil microbial diversity, enhances nutrient cycling	Enhances rice yield via potassium solubilization (>70%)	Bünemann et al. (2018)
Organic Fertilizers	Increases SOM, improves soil structure and water-holding capacity	Up to 51% yield increase in barley with MSWC/SSC amendments	Shang et al. (2014)

Table 3: Environmental and Economic Considerations

Fertilizer Type	Environmental Benefits	Environmental Risks	Economic Considerations	Study Reference
Slow-Release Fertilizers	Reduces nutrient runoff, lowers GHG emissions	Soil pH decrease with sulfur-coated urea	Higher cost than conventional fertilizers	Liang et al. (2024)
Controlled-Release Fertilizers	Minimizes nutrient loss, reduces eutrophication	Coating material degradation concerns	Scalable but costly production	Wang et al. (2024)
Nanofertilizers	Reduces fertilizer overuse, lowers environmental footprint	Unknown long-term ecological impacts	High initial R&D costs, commercialization challenges	Shanmugavel et al. (2023)
Biofertilizers	Eco-friendly, reduces chemical fertilizer dependency	Limited efficacy in low microbial activity soils	Cost-effective but requires technical expertise	Mahmud et al. (2021)
Organic Fertilizers	Enhances soil health, reduces chemical pollution	Risk of nutrient leaching, water quality impact	Limited by availability of organic materials	Liu et al. (2024)

5. Integrated Soil Nutrient Management: A Balanced Approach

Integrated Soil Nutrient Management (ISNM) is an approach to managing soil fertility in a sustainable and cost-effective manner. It aims to optimise the use of inherent soil nutrient reserves, locally available soil amendments, and environmentally friendly agro-wastes, combined with limited amounts of mineral fertilisers, to increase land productivity while maintaining or improving soil fertility (Kushwah et al., 2023; Adeola et al., 2024). The ISNM represents a shift from traditional fertiliser trials that focused solely on increasing production. Instead, ISNM aims to develop comprehensive solutions that consider various factors such as weather, weeds, pests, diseases, soil characteristics, land-use history, and spatial variations in soil fertility. According to Paramesh et al. (2023), ISNM involves soil fertility-enhancing methods such as improved crop management practices, livestock integration, erosion and leaching control, and measures to improve soil organic matter content. The strategies include combining the use of soil amendments, organic materials, and mineral fertilisers to replenish soil nutrient pools and enhance the efficiency of external inputs (Delgado et al., 2016). This synergy can enhance crop yields by ensuring a steady supply of nutrients throughout the growing season while improving soil health over time.

Despite its promise, integrating organic and inorganic fertilisers presents several challenges. Determining the optimal ratio of organic to inorganic inputs requires careful consideration of crop type, soil conditions, and agroecological context (Chivenge et al., 2009; Wato et al., 2024). Over-application or improper timing can lead to nutrient imbalances, reducing the effectiveness of the system. Additionally, the availability of high-quality organic materials can be a limiting factor, particularly in regions with intensive farming systems that generate limited organic residues (Palm et al., 1997). The labour-intensive nature of preparing and applying organic fertilisers, such as composting, may also deter adoption among farmers with limited resources (Timsina, 2018). Furthermore, the transition to integrated systems requires knowledge and technical expertise, necessitating robust extension services and farmer education programmes to ensure successful implementation.

The adoption of INM is particularly critical in the context of global agricultural challenges. Soil degradation, driven by intensive farming and monoculture practices, affects millions of hectares of farmland worldwide (FAO, 2017; Imran 2024). In many regions, declining soil fertility has led to stagnating crop yields, threatening food security (Henry et al., 2018). Climate change further exacerbates these challenges by altering rainfall patterns, increasing the frequency of extreme weather events, and affecting soil moisture availability (IPCC, 2014). Integrated fertiliser systems offer a pathway to build resilience in agricultural systems by improving soil health and reducing dependency on external inputs (Vanlauwe et al., 3023). Moreover, they align with global sustainability goals, such as those outlined in the United Nations' Sustainable Development Goals, particularly those related to zero hunger, climate action, and responsible production (United Nations, 2015).

The integration of organic and inorganic fertilisers is not a one-size-fits-all solution. Its success depends on tailoring practices to local conditions, including soil type, climate, cropping systems, and socio-economic factors. For example, in tropical regions with high rainfall, organic fertilisers may help reduce nutrient leaching, while in arid regions, their role in improving soil moisture retention is critical (Timsina, 2018). Similarly, the economic feasibility of integrated systems varies across contexts, with smallholder farmers benefiting from the use of locally available organic resources, while large-scale commercial farms may require mechanised systems for organic fertiliser application (Place et al., 2003). Research on INM has grown significantly, with studies demonstrating its efficacy across diverse crops and agroecosystems. Field trials have shown that combining organic and inorganic fertilisers can increase yields by 10–30% compared to using either alone, depending on the crop and soil conditions (Vanlauwe et al., 2010). These findings underscore the potential of INM to transform agricultural systems, but gaps in knowledge remain. For instance, long-term studies on the cumulative effects of integrated systems on soil carbon sequestration and microbial diversity are limited. Additionally, the scalability of these practices and their adaptability to different farming systems require further exploration.

The integration of inorganic, organic, and biofertilisers offers a more sustainable approach to agriculture that can mitigate the impacts of climate change (Imran. 2024). By combining the precision and rapid nutrient availability of inorganic fertilisers with the soil-enhancing properties of organic fertilisers, such as compost and manure, farmers can improve crop resilience to extreme weather while reducing greenhouse gas emissions (Paramesh et al., 2023). Biofertilisers, which utilise beneficial microorganisms to enhance nutrient uptake, further promote soil health and decrease reliance on synthetic inputs that contribute to carbon footprints. According to Imran (2024), this synergistic approach fosters soil carbon sequestration, improves water retention, and minimises environmental degradation, aligning agricultural practices with the urgent need to adapt to and combat climate change.

6. **Organomineral Fertiliser**

Combining organic and inorganic materials can mitigate the individual problems associated with each type of fertiliser and achieve better outcomes (Roba, 2018; Wato et al., 2024; Ibironke and Akinrinola, 2025) Relying solely on chemical fertiliser is not economically justifiable for peasant farmers in Nigeria, as it represents a significant expense. Integrated fertiliser management approaches can reduce costs by requiring only small quantities of chemical fertilisers when used with animal manure. Balanced NPK fertiliser combined with organic soil amendments can lead to high and stable crop yields (Timsina, 2018; Akinrinola and Ojo, 2024). The combined use of organic and inorganic fertilisers, known as organomineral fertiliser, offers advantages over using either type alone. Studies in Southwest Nigeria have recommended combinations of farmyard manure and NPK fertiliser for intercropping systems. Research has shown that this combination promotes high crop yields (Roba, 2018). Findings have consistently demonstrated that organomineral fertiliser results in higher and more sustainable crop yields compared to inorganic fertiliser or animal manure used alone (Chivenge et al., 2009). Nazir et al. (2021) found that combining ash and peanut residues reduced soil bulk density and increased aggregate stability and porosity. Applying poultry manure or a combination of both with reduced NPK levels showed that tomato performed better (Akinrinola and Tijani-Eniola, 2019). The application of combined use of Organic Based Fertiliser (OBF) and urea was superior to applying either fertiliser alone (Adekiya et al., 2019). Combining organic wastes (such as poultry manure and oil palm sludge) with urea increases soil pH, organic matter, total N, available phosphorus, and exchangeable magnesium (Mg) and potassium (K) levels, whereas mineral fertiliser reduces these soil properties (Anyaoha et al., 2018).

Significant resources are often spent on liming acid soil without achieving substantial improvement. Therefore, the combined use of organic and inorganic fertilisers can help maintain a stable soil pH level (Roba,2018; Imran, 2024). However, integrating residue incorporation with judicious fertiliser use is likely the most effective and efficient way to maintain soil productivity and sustain crop yields in humid tropical environments (Akinrinola and Babajide, 2023). Neither mineral fertiliser nor manure is a complete solution for soil fertility management. Both play important roles, but neither can independently supply all the necessary nutrients and growth conditions for producing enough crops to feed the growing population (Jaswal et al. 2021). In Nigeria, studies have investigated the combined effects of cow dung, poultry manure, and swine manure with mineral fertilisers on soil chemical properties and gaarden egg and tomato yields (Akinrinola and Tijani-Eniola, 2019; Akinrinola and Salawu, 2025). These studies found more positive responses from the combined applications in Southern Nigeria. Uyobisere and Elemo (2002) conducted an experiment to evaluate the effect of locust bean (*Perkia biblogosa*) and neem (*Azadirachta indica*) foliage on soil fertility and the productivity of early maize (Singh et al. 2023). They combined locust bean or neem foliage with three rates of NPK fertiliser (0, ½, and ¼ of the optimum recommendation of 120-60-60) and reported that integrated application of locust bean or neem foliage at ½ the recommended rate increased early maize yield. Different organic wastes and inorganic fertilisers have also been combined with positive results. For example, Akinrinola and Ojo (2024), and Akinrinola and Tijani-Eniola (2019) found that combining cocoa pod husk ash poultry manure and NPK fertiliser had a positive effect on radish and tomato yields. Ipinmoroti et al. (2003) also reported more positive results with integrated application of organomineral fertiliser compared to single applications of fertilisers on *Amaranthus cruentus* L. in Southwestern Nigeria (Akinrinola et al., 2025a). The application of organic fertiliser alone resulted in the greatest depletion of soil organic matter (OM) and total nitrogen (N). However, complementary application of organic and inorganic fertilisers reduced the degree of depletion from 31.0 to 12.1 g kg^{-1} for OM and from 1.8 to 0.6 g kg^{-1} for total N (Erkossa et al., 2018). The organomineral fertilisers used in many research studies were compounded individually and manually, leading to inconsistencies in recommended application rates for farmers. In response, some state governments in Nigeria, such as Oyo and Ondo States, have initiated industrial production of organomineral fertilisers, marketed as Pacesetter and Sunshine Organomineral Fertilisers, respectively (Abdulraheem et al., 2023).

7. Fertilisers and Soil Microbial Population Changes

Soil microorganisms are vital components of terrestrial ecosystems, playing crucial roles in nutrient cycling, OM decomposition, and overall soil health. Fertilisers, both organic and inorganic, are widely used in agriculture to enhance crop production (Wato et al., 2024; Olowoake and Akinrinola, 2024). However, their application can significantly alter soil physiochemical properties, impacting the composition, diversity, and activity of soil microbial communities. This review examines the current literature on the effects of different types of fertilisers on soil microbial populations.

Inorganic fertilisers, also known as mineral or synthetic fertilisers, typically contain high concentrations of nitrogen (N), phosphorus (P), and potassium (K). Studies have shown that the short-term application of inorganic fertilisers can increase microbial biomass and activity due to the added nutrients (Li et al., 2020; Akinrinola et al., 2025b). However, long-term use often has negative impacts on soil microbial communities. For instance, the application of nitrogen fertilisers can lead to soil acidification, which can decrease bacterial diversity and favour fungal growth. High N inputs can also suppress the growth of beneficial microorganisms like nitrogen-fixing bacteria, disrupting natural nutrient cycling processes (Li et al., 2023). Phosphorus fertilisers on the other hand can affect microbial community structure, although the effects are less pronounced than those of nitrogen fertilisers. High P levels can alter the balance of microbial populations and influence the availability of other nutrients (Maharajan et al., 2021). However, potassium fertilisers generally have less impact on soil microbial communities compared to N and P fertilisers, its excessive K application can lead to salt stress, which may negatively affect certain microbial groups.

Organic fertilisers, derived from plant and animal sources, such as manure, compost, and crop residues, provide a more balanced supply of nutrients and OM to the soil. They generally have positive effects on soil microbial communities. Organic fertilisers enhance soil microbial biomass and diversity by providing a source of carbon and nutrients. The addition of OM improves soil structure, water-holding capacity, and aeration, creating a favourable environment for microbial growth (Arfat et al., 2022). The activity of beneficial microorganisms involved in nutrient cycling, such as nitrogen-fixing bacteria, mycorrhizal fungi, and decomposers is stimulated. This leads to improved nutrient availability, soil fertility, and plant health. Some organic fertilisers (particularly composted materials), can suppress soilborne pathogens due to the presence of antagonistic microorganisms and the release of inhibitory compounds during decomposition.

Sustainable agricultural practices that combine balanced fertiliser application strategies with soil health management are essential to maintain a healthy soil microbiome and ensure long-term agricultural productivity. Further research is needed to fully understand the complex interactions between fertilisers, soil microorganisms, and plant health, and to develop strategies that minimise the negative impacts of fertilisation on soil ecosystems.

8. **Fertilisers and Weed Infestation**

The benefits of fertiliser applications are closely linked to weed control. Applying fertiliser is labour-intensive (Zhou et al., 2023), often requiring farmers to apply it directly to plants by hand while bending over. Fertiliser application competes with other essential tasks like weeding and planting additional crops. Consequently, fertiliser application may be delayed or not done at all, reducing its effectiveness. Farmers sometimes over-irrigate and over-fertilise to compensate, inadvertently benefiting weeds as well as crops. Many weeds absorb nutrients more quickly and in larger quantities than crops (Little et al., 2021). Kaur et al., (2018) reported that weeds removed more potassium and nitrogen from the soil than maize. Maize trials have shown that increased fertiliser application in weedy plots can increase yield losses due to weeds (Kaur et al., 2018; Ibironke and Akinrinola, 2025). Fertiliser application can also increase labour demands during peak season (Prasad et al., 2017). Some weeds thrive in acidic conditions, while others prefer higher-pH soils. Applying OBF can increase soil pH, which, according to Ameena et al. (2024), can reduce the competitive advantage of certain weeds. Furthermore, herbicides tend to be most effective on weeds that are growing vigorously due to high nutrient levels (Varanasi et al., 2016). Hoe weeding, a common practice, can only be done when weeds reach a manageable size, typically 2-4 weeks after crop planting. During this period, weeds can take up significant amounts of fertiliser, depriving the crop. Without effective weed control, increased fertiliser application primarily benefits weeds, leading to the need for more labour to remove them. Farmers are often reluctant to increase fertiliser use because of the increased weeding burden (Zhou et al., 2023). African farmers may not increase their fertiliser use until weed problems are adequately managed. Fertiliser application does not make the site unsuitable for weeds; instead, it can give them a competitive advantage over cultivated plants. Applying fertiliser can sometimes exacerbate weed problems by increasing weed density. However, Akinrinola and Fagbola (2020) presented a contrasting view, reporting that fertiliser treatments in their study did not significantly influence weed density or dry weight.

9. **CONCLUSION**

Fertilisers remain a cornerstone of modern agriculture, addressing the critical need to enhance soil fertility and boost crop production amidst the challenges of climate change and a growing global population. This review has highlighted the diverse roles of organic, inorganic, and biofertilisers in sustaining agricultural productivity while navigating environmental constraints. Organic fertilisers enrich soil health and carbon sequestration, inorganic fertilisers provide rapid nutrient delivery, and biofertilisers promote sustainable nutrient cycling, each offering unique contributions to climate-resilient farming. However, their efficacy depends on judicious application to avoid adverse effects like nutrient runoff, soil degradation, and greenhouse gas emissions, which exacerbate climate change. Integrated soil nutrient management, which combines fertilisers, offers a sustainable and cost-effective strategy. This approach optimises the use of available resources, including soil amendments and agro-wastes, along with limited amounts of inorganic fertilisers. Emerging technologies, such as controlled-release fertilisers, nanotechnology, and INM, offer promising solutions to optimise nutrient use efficiency and minimise environmental impacts. Despite these advancements, challenges persist, particularly in resource-constrained regions where access to sustainable fertilisers and technologies is limited. Bridging this gap requires increased investment in research, farmer education, and policy support to promote equitable access to eco-friendly fertilisation practices. This review underscores the need for a balanced approach to fertiliser use, emphasising sustainability and resilience. Future research should focus on developing cost-effective, climate-adaptive fertilisers and scaling up INM to support global food systems. Ultimately, fertilisers, when used strategically, will continue to play a pivotal role in fostering sustainable agriculture, ensuring fertile soils and abundant harvests for generations to come.

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