

REVIEW PAPER

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Short-term effects of tillage, manure and inorganic fertilizer on soil properties, agronomic characteristics and yield of rice: A review

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Key words: Tillage, Manure, Inorganic fertilizer, Soil properties, Agronomic characteristics, Yield, Rice

DOI: <https://dx.doi.org/10.12692/ijb/27.5.83-105>

Published: November 10, 2025

ABSTRACT

There is currently a demand to grow more crops in less area as a result of urbanization's reduction of agricultural land. Consequently, soil fertility is gradually declining. To maintain soil fertility, various management methods are used in modern times. By maintaining soil structure with conservational tillage, biological processes are frequently improved, and microbial biodiversity is increased. Tillage intensity influences soil physical properties through disruption or residue management especially bulk density, soil moisture, air filled porosity etc. and crop yield significantly. Soil health is the capacity of the soil to provide an environment for optimum growth and development of plants, while also ensuring the health of animals and humans. Manure is the major source of plant nutrients that also influences bulk density and yield of rice. Manure improves soil fertility and nutrient content. Tillage and manure application can improve rice yield and soil characteristics, with studies showing that a combination of appropriate tillage, like deeper plowing, and manure application significantly increases grain yield, plant height, and effective tillers per hill. Combination of manure and tillage practices can improve physical soil properties, increase yield, and enhance soil nutrient status, sometimes more effectively than applying either alone. Optimal practices often involve a synergistic approach, but the specific best treatment can vary depending on soil type, climate, and management practices. The result highlights that combination of conservational tillage and manure are much better than association of conventional tillage and manure application for soil quality and different aspects of different tillage and their interaction. This review helps to understand the role of tillage and manure in increasing rice production by maintaining soil fertility. In terms of manure and tillage management, our main goal is to improve crop yield while minimizing harm to the soil's health.

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INTRODUCTION

Rice (*Oryza sativa* L.) is the primary food source for an estimated 3.5 billion people globally, which contributes up to 50% of the daily caloric intake for Asian populations (Mohidem *et al.*, 2022). More than half of the world's population relies on rice as a staple diet, making it the second most extensively produced cereal crop (Giri *et al.*, 2022). It is also a frontrunner in the struggle against global poverty and hunger as well as the primary staple food and a significant source of income for worldwide populations (Hashim *et al.*, 2024). In this regard, rice is crucial to the economy and those with lower incomes in promoting agricultural growth and reducing poverty (Hashim *et al.*, 2024). Furthermore, rice is a significant source of zinc and other essential micronutrients for millions across Asia, given its prevalent consumption compared with other cereals (Fukagawa *et al.*, 2019; Kumari *et al.*, 2020). Rice grain has influenced the culture, economy of billions of people worldwide, a huge impact on socio-economic growth, and ensuring its sustainability and optimal utilization is vital (Hashim *et al.*, 2024).

Soil fertility deterioration has become a major constraint to higher rice production in the worldwide (Kumar *et al.*, 2022; Romadhon *et al.*, 2023; Bhatia and Sindhu, 2024). The increasing land use intensity without adequate and balance use of chemical fertilizers and with little or no use of organic manures have caused severe fertility deterioration of our soils resulting in stagnating or even declining of crop productivity (Bashar *et al.*, 2025a; Mondal *et al.*, 2025; Bashar *et al.*, 2025b).

The use of inorganic fertilizer in rice cultivation has been progressively increasing since its introduction. However, available reports indicate that the repeated use of chemical fertilizer alone fails to sustain desired yield, impairs soil physical condition and exhausts organic matter (OM) content leads to environmental degradation and soil health especially due to their continuous use (Bashar *et al.*, 2025a; Mondal *et al.*, 2025; Bashar *et al.*, 2025b). Application of excess inorganic fertilizer leads to higher pest and disease

attacks and also destroys the soil microorganisms. Hence, sustainable farming looks for making the best use of natural resources without damaging the environment and indigenous agricultural knowledge is a vital part of the process of making agriculture sustainable (Kharel *et al.*, 2022).

Most of the cultivated soils have less than low organic matter, whereas good agricultural soil should contain of least 2% organic matter. Bashar *et al.*, 2025a, Mondal *et al.*, 2025 and Bashar *et al.*, 2025b reviewed that integrated use of organic manure and NPK fertilizers would be quite promising not only in providing greater stability in production, but also in maintaining higher soil fertility status. Organic matter takes an important role in maintaining soil fertility and productivity (Hussain *et al.*, 2023; Srivastava *et al.*, 2024; Naveen, 2025). The problem of nutrient deficiencies as well as nutrient mining caused by intensive cropping with HYV (High Yielding Variety) of rice and nutrient imbalance can be minimized by judicious application of nutrients through organic manures (HASAN, 2021; Bashar *et al.*, 2025a; Mondal *et al.*, 2025; Bashar *et al.*, 2025b). Losses of soil organic matter can only be replenished in the short term by application of organic matter such as manures (Napoletano, Bellino and Baldantoni 2025). Cow dung and poultry manure are the most popular and promising bulky organic manures produced from liquid excreta of farm animals, which contain considerable amounts of essential nutrient elements required for plant growth. These are one kind of store house of nutrients of plants.

Hence an improvement and addition of a good amount of manure to the crop field is essential for fertility and productivity and maintenance of this soil (Li *et al.*, 2023; Liu *et al.*, 2024).

Application of organic fertilizer with chemical fertilizer stimulates microbial activity, promotes efficiency in the use of nutrients and increases accessibility of the surrounding nutrients, resulting in adequate nutrient uptake by plants (Sun *et al.*, 2024; Bashar *et al.*, 2025a; Mondal *et al.*, 2025; Bashar *et*

al., 2025b). Therefore, in order to increase the soil productivity by supplying all the plant nutrients in readily available form and to maintain good soil health, it is necessary to use organic fertilizer in combination with inorganic fertilizers to obtain optimum yields (Culas, Anwar and Maraseni 2025; Topa *et al.*, 2025; Mondal *et al.*, 2025; Bashar *et al.*, 2025b). Organic fertilizers such as cow dung, poultry manure, organic waste, crop residues and compost will not only increase grain yields but also increase the efficiency of applied nutrients due to their favorable effect on the physical, chemical and biological properties of soil (Hussainy, 2019).

However, extensive application of nitrogen fertilizer, whether in the form of organic matter or chemicals, can negatively affect the soil because excess nitrogen is converted to nitrates which are detrimental to the soil and human health (Giordano, Petropoulos and Rouphael 2021; Awadelkareem *et al.*, 2023; Bhatt *et al.*, 2025).

Tillage practice, manure application, and cropping systems is essential to maintain soil fertility (Büchi *et al.*, 2018). As conservation tillage improve the physical condition of the soil (Botta *et al.*, 2022), the cropping system and application of manure removes the deficiency of any nutrient element in the soil (Shankar *et al.*, 2021). So far, many reviews on cropping systems, manure application, and tillage have been performed separately (Cuevas *et al.*, 2019; Peixoto *et al.*, 2020). But this review brings the three issues together and highlights the integrated role of tillage and manure with recommended inorganic fertilizer dose on soil, yield contributing characteristics, and yield of rice. People may easily understand the difference between existing cropping systems and which can cope with modern agriculture through this review. Our main target is to increase rice production with minimum damage to soil health from the perspective of cropping systems, application of manure with recommended inorganic fertilizer dose and tillage management. This review finds the best way and indicates the specific importance of tillage, application of manure with recommended

inorganic fertilizer dose and cropping systems to maintain soil health and increase rice production.

Positive effect of tillage, manure, and inorganic fertilizer on soil properties, agronomic characteristics and yield of rice

Positive effect of tillage, manure, and inorganic fertilizer on soil properties during the cultivation of rice

Tillage affects soil structure and can lead to oxidation of organic matter. Tillage affects rice soil properties by changing its structure, organic matter content, and nutrient availability. Conservation tillage methods like zero tillage help improve soil physical properties like bulk density and porosity, increase organic matter, and enhance nutrient retention. It preserves soil structure by minimizing disturbance, which helps maintain porosity and field capacity. It reduces soil compaction by avoiding heavy machinery use. It increases soil organic matter and improves nutrient retention. It maintains higher levels of available total nitrogen, phosphorus, potassium, and sulfur. Besides, it can improve water infiltration rates and water storage capacity.

Manure adds essential nutrients like N, P, K, Ca, Mg, and S, increases soil organic matter content, improves soil structure, and enhances water-holding capacity. It also supports soil organisms and nutrient cycling. Nutrient availability to plants is composed of several processes in the soil-plant system before a nutrient is absorbed or utilized by a plant. These processes include the application of nutrient to soil or nutrient existing in the soil, transport from soil to plant roots, absorption by plant roots, transport to plant tops and finally utilization by the plant in producing economic parts or organs (Ahmed *et al.*, 2024). Addition of OM such as crop residues, composts, and farmyard manure (FYM) to the soil is known to improve the chemical, physical and biological properties, and enhance the availability of nutrients and their uptake by crops (Khambalkar *et al.*, 2025; Bashar *et al.*, 2025a; Mondal *et al.*, 2025; Bashar *et al.*, 2025b).

Organic matter and soil organisms play important roles in conserving and improving soil properties that

are related to soil resilience (Wang *et al.*, 2024; Xing *et al.*, 2025). Application of soil OM resulted with increasing of soil buffering capacity, nutrient availability and water holding capacity and supply micronutrients which may not be provided by commercial fertilizers (Mgxaji *et al.*, 2025; Bashar *et al.*, 2025a; Mondal *et al.*, 2025; Bashar *et al.*, 2025b). It is well known that the application of OM amendments to soil increases soil fertility (Ali *et al.*, 2025). Organic matter such as compost has many essential roles to play in maintaining soil fertility, source of macro and micronutrients for plant growth and alkaline substances which counteract soil acidification (Piccolo and Drosos, 2025).

Organic inputs, including compost, animal manure, crop residues, and green manure, are a good method of enhancing both soil physical, chemical and biological properties and crop performance (Khan *et al.*, 2024). It also increases the capacity of the soil to buffer changes in pH and cation exchange capacity (CEC) and serves as a reservoir of nutrients such as N, S, P and many minor elements (Yoni, 2024; Nasreen *et al.*, 2025). Soil OM encourages granulation, increases CEC and is responsible for up to 90% adsorbing power of the soils and cations such as Ca^{2+} , Mg^{2+} and K^{+} are produced during decomposition (Mintesinot, 2022). In general, it may be concluded that OM such as application of compost increased soil pH, electrical conductivity (EC), OM, Ca^{2+} , Mg^{2+} , K^{+} , and P while C: N ratio was narrowed in acidic soil. Hence, there was a general increase in nutrient supplying capacity of soils by OM application and OM such as compost application was a good strategy for enhancing fertility status of depleted soils (Gil-Martínez *et al.*, 2025).

However, the composition of OM is strongly dependent on the type of vegetation, kinds of soils, depth of sampling and cultural practices which is the sources of both macro and micronutrients for crop growth (Sahu *et al.*, 2024). Some of the soil OM decomposes and mineralizes organic S into SO_4^{2-} form which plants take up by which returning

crop residue to the soil adds S to the organic pool (Sanchez, 2019). Even compared to other sources of OM, the poultry manure is relatively a cheap source of both macronutrients (N, P, K, Ca, Mg, S) and micronutrients such as Cu, Fe, Mn and boron (B) and can increase soil C and N content, soil porosity and enhance soil microbial activity (Agbede, 2025). Soil OM contributes substantially to the productivity of the land as it is a source of plant nutrients and it improves the physical conditions of the soil. Low OM contents may lead to severe limitations in plant growth and to the deterioration of cropland.

Almost all life in the soil is dependent on OM for nutrients and energy. The labile fraction of soil OM consists of any readily degradable materials from the plant and animal residues, and readily degradable microbial products which are an important reservoir of nutrients because the nutrients are rapidly recycled in the soil ecosystem (Cheng *et al.*, 2025). Organic matter is often the critical soil constituent that is needed to restore adequate conditions for root growth. Although human interventions that change the environmental conditions may have drastic effects on soil OM contents, in many soils, it is one of the major soil attributes that control the sustainability of agricultural systems. Soil OM maintenance is the key issue in low input agricultural systems.

Inorganic fertilizers are good for the rapid growth of plants because the nutrients are already water soluble. Therefore, the effect is usually immediately and fast, contains all necessary nutrients that are ready to use. Inorganic fertilizers are quite high in nutrient content and only relatively small amounts are required for productivity. The correct amount of applications of inorganic fertilizer can increase soil organic matter through higher levels of root mass and crop residues (Dhaliwal *et al.*, 2023; Quddus *et al.*, 2025; Xu *et al.*, 2025; Bashar *et al.*, 2025a).

Inorganic fertilizer provides readily available nutrients for quick plant uptake, supporting rapid growth.

Practices that are combined with other nutrient management techniques can have varied effects on soil properties. Combining organic and inorganic fertilizers creates a more balanced and sustained nutrient supply. This approach has been shown to improve soil organic matter, total nitrogen, available phosphorus, and cation exchange capacity (CEC). The addition of manure improves soil structure, while the combination with inorganic fertilizers helps to build soil fertility, leading to a more favorable environment for rice roots. Integrated approaches can lead to positive nutrient balances over time, as opposed to the negative balances for some nutrients seen with the exclusive use of inorganic fertilizers. Integrated nutrient management often results in higher rice yields compared to control plots or those treated with inorganic fertilizers alone.

The use of both organic and inorganic sources helps to optimize nutrient availability and plant growth.

Yadav *et al.* (2017) conducted a study to assess the effects of agronomic modification of traditional farming practices on productivity and sustainability of rice (wet season)–rice (dry season) system (RRS). Treatment T₅ recorded significantly lower soil bulk density (ρ_b) and higher pH than the T₂ after three years of the experiment. Further, treatment T₅ increased total soil organic carbon (2.8%), total soil organic carbon stock (2.8%), carbon sequestration rate (336.5 kg ha⁻¹ year⁻¹), cumulative carbon stock (142.9%) and carbon retention efficiency (141.0%) over T₂ of 0–20 cm depth after three years. The soil microbial biomass carbon concentration was significantly the highest under T₅. Similarly, the dehydrogenase activity was the maximum under T₅. Adoption of conservation tillage and nutrient management practice involving no-till (NT) and integrated nutrient management (INM) along with residue retention can enhance the system productivity, and C and N sequestration in paddy soils is thereby contributing to the sustainability of the RRS.

Bashar *et al.* (2025a) carried out a research to assess the effect of tillage intensity, use of poultry manure and chemical fertilizer on soil and yield attributes of

Boro rice [cv. BRRI (Bangladesh Rice Research Institute) Dhan28]. The experiment was organized in a randomized complete block design with three replications. The treatments were: T₁+P+C = one passing of power tiller + poultry manure @ 5 t ha⁻¹ + chemical fertilizer, T₂+P+C = two passing of power tiller + poultry manure @ 5 t ha⁻¹ + chemical fertilizer and T₃+P+C = three passing of power tiller + poultry manure @ 5 t ha⁻¹ + chemical fertilizer. The results revealed that soil physical parameters were significantly influenced by tillage, poultry manure and chemical fertilizer treatments. Three passing of power tiller in combination with poultry manure and chemical fertilizer showed significantly lower ($p < 0.01$) bulk density than all other treatments. The highest soil moisture content of 54.73% was measured in T₃+P+C treatment which was significantly higher ($p < 0.01$) than all other treatments which were statistically different. The highest air-filled porosity of 14.93% was measured in T₃+P+C treatment which was significantly higher ($p < 0.01$) than T₁+P+C and T₂+P+C treatments where they were statistically different. Considering the soil health T₃+P+C treatment proved the best treatments. It was concluded that judicious application of tillage, poultry manure, and chemical fertilizer improved the physical properties of soil during the cultivation of BRRI Dhan28.

Barus *et al.* (2021) conducted a research to increase land conservation to maintain sustainable land productivity. The treatments were arranged in a factorial randomized block design with three replications. The treatment in the main plot was the method of tillage whereas the subplot was organic fertilizers. The tillage methods were: (1) Maximum tillage and without ditch, (2) Minimum tillage with ditch. The organic fertilizer treatments were control, bio urine plus 10 L ha⁻¹, bio urine plus 20 L ha⁻¹, biodecomposer 10 L ha⁻¹, and biodecomposer 20 L ha⁻¹. The results showed that the minimum soil tillage with ditch provided a higher soil water content than the maximum tillage. Likewise, the application of liquid organic matter from local microorganisms (biodecomposer) increased soil water content compared to the control.

Baki *et al.* (2015) carried out field experiment to study the impact of tillage intensity, fertilizer and manuring on soil physical properties, water conservation and yield of rice. The experiment was laid out in a split-plot design with three tillage treatments in main plot and four fertilizer and manuring treatments in sub plots and replicated thrice. The maximum bulk density of 1.61 g cm and the 3 minimum bulk density of 0.87 g cm were observed in P at 10-20 cm depth and by P at 0-10 cm soil depth. The highest soil moisture content of 51.68% was found under P at 0-10 cm depth and the lowest value of 3 37.91% in P at 10-20 cm depth. The highest air-filled porosity of 12.16% was found under P at 0-10 cm soil depth. The soils were manipulated with different tillage operations thereby reduced compactness of soil and increased the number of pore spaces, which decreased soil bulk density.

Ali *et al.* (2023) carried out a field experiment to find out the suitable tillage operation as well as proper doses of farmyard manure (FYM) for increasing yield of rice under natural salinity condition. The experiment was laid out in split plot design assigning tillage operations in the main plot and FYM in the sub plot with three replications. Four tillage operations and six doses of FYM were used. The effect of tillage 20 cm depth five times and FYM 5.0 t ha⁻¹ enhanced the fertility and productivity of soil.

Qiu *et al.* (2023) conducted a study to reduce nitrogen leaching and nitrogen use efficiency in fragrant rice cultivation practices. The four experimental treatments included the following: conventional tillage with regular fertilization (T1), conventional tillage with simultaneous deep fertilization (T2), reduced tillage with simultaneous deep fertilization (T3), and no-tillage with simultaneous deep fertilization (T4). Our results indicate that the T4 treatment exhibited higher nitrogen leaching rates and potential nitrogen losses throughout the entire rice growth cycle, with a 4.51% increase in total mineral nitrogen leaching (TMNL) and a 1.86% increase in potential nitrogen leaching compared to T1 treatment. In contrast, the T2

treatment demonstrated the lowest nitrogen leaching rate, resulting in a 6.01% reduction in TMNL and a 9.57% decrease in potential nitrogen leaching compared to T1, demonstrating the most optimal performance.

Therefore, this study suggests that conventional tillage combined with deep fertilizer application can be considered as an effective agricultural strategy to reduce nitrogen leaching.

Dugan *et al.* (2024) carried out a research to decrease soil degradation, soil erosion and increase soil quality through the application of different tillage and manure. Soil water content did not show significant differences, whereas bulk density and penetration resistance yielded significantly higher values at 15–30 cm depth compared to 0–15 cm depth. Also, the conservation tillage recorded lower bulk density and penetration resistance values than conventional tilled treatments. Water-stable aggregates and soil organic matter were severely affected by manure addition and yielded an increase after harvest. Hydrological response was delayed for the treatments with manure addition. The results of this study show the positive aspects of conservation tillage, especially with manure addition, where soil quality is preserved or even increased.

Karki *et al.* (2017) carried out a field experiment to see the effect of tillage, residue and nutrient management practices on soil properties. Three factors each with two levels i.e. tillage (with or without), residue (with or without) and nutrient management (recommended dose (RD) with 100:60:30 NPK kg ha⁻¹ and farmer's doses (FD) with 5Mt ha⁻¹ of FYM+50:23:0 NPK kg ha⁻¹. Thus, altogether eight treatment combinations were evaluated under strip-split plot design with three replications. Higher soil organic matter was recorded in residue kept (5.73%) than the residue removed plots. Exchangeable potassium was found higher in no tillage (110.52 kg ha⁻¹) than the conventional tillage (76.77 kg ha⁻¹). Therefore, untilled direct seeded rice with residue and recommend doses of nutrients seem

promising in Terai region of Nepal. The findings of this study revealed that no tillage with residues kept and recommended dose of fertilizers were more efficient for improving soil properties.

Bhattacharya *et al.* (2023) conducted an experiment to evaluate the effects of minimum tillage and integrated nutrient management on soil health. Conventional tillage (CT) direct seeded rice-lentil, Minimum tillage (MT) direct seeded rice-lentil, MT transplanted rice-lentil and MT direct seeded rice-lentil were kept as main plot treatments and control (without any fertilizer), 100% RDF, 75% nitrogen + FYM, 75% nitrogen + FYM + *Azospirillum* and 75% Nitrogen + FYM + *Azospirillum* sp. + Zinc Sulphate were kept as subplot treatments during the study. Soil organic carbon was marginally improved by both tillage and nutrient treatments, while soil microbial biomass carbon, dehydrogenase activity and microbial count were significantly influenced. The combination of MT_{DSR-L} and 75% Nitrogen + FYM + *Azospirillum* sp. + Zinc Sulphate (N₅) treatment showed the maximum values for all soil biological parameters leading to improve soil health. The results of the experiment concluded that the practice of minimum tillage and integrated nutrient management may be recommended to enhance the stability of rice-lentil cropping systems in sandy clay loam soil of a new alluvial zone of eastern India.

Nandan *et al.* (2019) carried out a field experiment to assess the impact of four tillage based crop establishment treatments [puddled transplant rice followed by conventional tillage in wheat/maize (CTTPR–CT), non–puddled transplant rice followed by zero–tillage in wheat/maize (NPTPR–ZT), zero–till transplant rice followed by zero–tillage in wheat/maize (ZTTPR–ZT), zero–tillage direct seeded rice followed by zero–tillage in wheat/maize (ZTDSR–ZT)], two residue management treatments [residue removal, residue retention (~33%)], and two cropping systems [rice–wheat, rice–maize] on soil aggregation, carbon pools, nutrient availability, and crop productivity. The constructive changes in soil properties following conservation tillage and crop

residue retention led to increased crop productivity over conventional CTTPR–CT.

Therefore, conservation tillage (particularly ZTTPR–ZT and ZTDSR–ZT) and crop residue retention could be recommended in tropical rice–based cropping systems for improving soil quality and production sustainability.

Mondal *et al.* (2025) conducted a research to study the effects of cotton oil cake with recommended fertilizer dose on soil during the cultivation of rice. The research was set up using a Randomized Complete Block Design (RCBD) with 3 replicates. There were seven treatments such as T1: Control, T2: Recommended Fertilizer Dose (RFD), T3: 90% of RFD + 10% of Cotton Oil Cake (COC), T4: 80% of RFD + 20% of COC, T5: 70% of RFD + 30% of COC, T6: 60% of RFD + 40% of COC and T7: 50% of RFD + 50% of COC. The findings discovered obviously showed that in order to enhance the crop yield and maintain soil good health, treatments T5 may be practiced instead of treatments T2. Consequently, bearing in mind the importance of organic manures and sustain soil good health, cotton oilcake should be regarded for implementation in combination with chemical fertilizers for yield enlargement of rice.

Bashar *et al.* (2025b) carried out a study to evaluate the impact of tillage intensity and use of organic and chemical fertilizer on soil during the cultivation of Boro rice (cv. BRRI Dhan97).

The study was conducted in a randomized complete block design with 3 replications. The treatments were: T1 +C = 1 passing of power tiller + poultry manure with chemical fertilizer, T2 +C = 2 passing of power tiller + poultry manure with chemical fertilizer, and T3 +C = 3 passing of power tiller + poultry manure with chemical fertilizer. The results revealed that soil physical parameters were substantially affected by tillage and poultry manure with chemical fertilizer treatments. Three passing of power tiller in combination with poultry manure with chemical fertilizer presented substantially lower ($p < 0.01$) bulk

density than all other treatments. T₁+C and T₂+C treatments are significantly higher than T₃+C treatment. The maximum soil moisture content of 49.78% was measured in the T₃+C treatment which was significantly higher ($p<0.01$) than all other treatments were statistically different. The highest air-filled porosity of 11.95% was measured in the T₃+C treatment which was substantially higher ($p<0.01$) than T₁+C and T₂+C treatments where they were statistically different. Considering the soil and rice yield attributes T₃+C treatment proved the best results.

The integrated application of tillage, manure, and inorganic fertilizer is a sustainable approach to rice cultivation that improves soil health and productivity (Fig. 1). It balances the benefits of readily available nutrients from inorganic fertilizers with the long-term soil health improvements provided by organic matter from manure, leading to better soil properties and higher crop yields compared to using inorganic fertilizer alone.

Positive effect of tillage, manure, and inorganic fertilizer on agronomic characteristics and yield of rice

The integrated use of tillage, manure, and inorganic fertilizer positively impacts rice agronomic characteristics and yield by improving soil health and providing a balanced nutrient supply, which increases tillers, grain weight, and overall yield. Tillage creates a better seedbed, while manure improves soil physical properties and provides nutrients, and inorganic fertilizers supply readily available nutrients. Conservation tillage can improve soil physical properties like moisture content and bulk density, especially when used with Integrated nutrient management (INM). The interactive effects among tillage methods, manure with recommended inorganic fertilizer application levels can lead to superior results in yield-contributing parameters and yield of rice.

Bashar *et al.* (2025) conducted a field experiment to assess the effect of tillage intensity, use of poultry

manure and chemical fertilizer on soil and yield attributes of Boro rice (cv. BRRI Dhan28). The experiment was organized in a randomized complete block design with three replications. The treatments were: T₁+P+C = one passing of power tiller + poultry manure @ 5 t ha⁻¹ + chemical fertilizer, T₂+P+C = two passing of power tiller + poultry manure @ 5 t ha⁻¹ + chemical fertilizer and T₃+P+C = three passing of power tiller + poultry manure @ 5 t ha⁻¹ + chemical fertilizer. The results revealed that considering the plant attributes, the maximum number of effective tillers hill⁻¹ (18.23) and 1000 grain weight (22.82 g) were observed in T₃+P+C treatment which was significantly higher ($p<0.05$). The highest grain (8.67 t ha⁻¹) and straw (10.66 t ha⁻¹) yields were recorded in T₃+P+C treatment which was significantly higher ($p<0.01$) than other treatments. Considering the rice yield attributes T₃+P+C treatment proved the best treatments. It was concluded that judicious application of tillage, poultry manure, and chemical fertilizer increased the yield of BRRI Dhan28.

Manir *et al.* (2025) conducted a field experiment to evaluate the effect of different tillage practices on productivity and profitability of rice. There was no discernible difference in grain yield across treatments, regardless of season. In both the seasons the highest gross margin was obtained from herbicide application followed by one ploughing and laddering treatment hence the cost of per kg of rice was lowest in herbicide application followed by one ploughing and laddering treatment. For land preparation, four to five ploughings followed by laddering were not necessary in Bangladesh's clay loam soils.

Yang *et al.* (2024) carried out a field experiment to investigate the impact of seven tillage methods on the yield of ratoon rice crop. The managements included winter ploughing + rotary 2 times (PTw + RT₂) or 3 times (PTw + RT₃), spring ploughing + rotary 2 times (PTs + RT₂) or 3 times (PTs + RT₃), no ploughing + rotary 2 times (Po + RT₂) or 3 times (Po + RT₃) and no tillage (NT). PTw + RT₃ had the highest total rice yield. In terms of main season rice yield, the order of ranking was PTw > PTs ≈ NT ≈

Po, while for ratoon rice yield, the ranking was NT > PTw $\approx$ PTs > Po. Generally, the root function ranked as PTw > PTs > Po > NT. The photosynthetic capacity of the main season rice always maximized in PTw, those of the ratoon rice all maximized in NT, and those of both the main season rice and ratoon rice always minimized in Po. In the three tillage modes (PTw, PTs, Po), an additional rotary tillage did not affect the growth or yield of rice. PTw + 3RT was the highest yielding tillage management, but it is still necessary to explore other PTw + 3RT methods and more economical tillage management to increase the yield of ratoon rice.

Bitew *et al.* (2024) conducted a study to determine the effects of farmyard manure and nitrogen fertilizer on yield and yield components of lowland rice. The treatments were laid out as factorial combination of three levels of FYM (0, 5, and 7.5 t ha⁻¹) and four levels of Nitrogen (0, 46, 92, and 184 kg ha⁻¹). The experiment was arranged at (RCBD) with three replications. Analysis of the results revealed that application of FYM at 7.5 t ha⁻¹ combined with 92 kg N ha⁻¹ increased grain yield by 218.25% compared to the negative controls. The highest rice grain yield (7533.1 kg ha⁻¹), biomass yield (14553.1 kg ha⁻¹), number of grains per panicle (153.27) and harvest index (51.89%) were obtained from the application of 7.5 t ha⁻¹ FYM with 92 kg ha⁻¹ N. Therefore, combined applications of 7.5 t ha⁻¹ FYM with 92 kg ha⁻¹ N is the recommended treatment that economically feasible for rice production.

Qiu *et al.* (2023) conducted an experiment to improve grain yield and nitrogen use efficiency in fragrant rice cultivation practices. The four experimental treatments included the following: conventional tillage with regular fertilization (T₁), conventional tillage with simultaneous deep fertilization (T₂), reduced tillage with simultaneous deep fertilization (T₃), and no-tillage with simultaneous deep fertilization (T₄). Our study involved the cultivation of two fragrant rice varieties, 'Meixiangzhan2' (MX) and 'Xiangyaxiangzhan' (XY), and the results revealed some interesting insights. For MX, the T₁ treatment

resulted in lower daily grain outputs compared to the other treatments, with disparities ranging from 5.35% to 9.94%. Similarly, for XY, the T₁ treatment yielded significantly lower daily grain outputs compared to the other treatments, with discrepancies ranging from 6.26% to 10.81% during the late season of 2019. Therefore, this study suggests that conventional tillage combined with deep fertilizer application can be considered as an effective agricultural strategy to enhance fragrant rice yields.

Kumar *et al.* (2023) conducted a research to study the effect of tillage and nutrient management strategies on rice productivity and nutrient uptake in Eastern Indo Gangetic Plains (EIGP) of India. The experiment was laid out in split-plot design with three replications. Nine treatment combinations comprising of three tillage methods in the main plots viz., Conventional tillage, Zero tillage and Zero tillage + Residue management and three nutrient management practices viz., recommended dose of fertilizer (RDF), Site - Specific Nutrient Management (SSNM) based on Nutrient expert and 60 % Recommended dose of nitrogen (RDN) + green seeker guided N application (GSGN) + 100% Recommended dose of phosphorus (RDP) + 100% RDN in the subplot. The results of the study revealed that residue management with zero tillage practice resulted in 14.03 % and 9.27 % higher grain and straw yield than conventional tillage respectively. Zero tillage with residue management increased nutrient uptake to the maximum of 86.71 kg N, 24.62 kg P and 99.99 kg K/ha as compared to conventional tillage. Among nutrient management, SSNM based on Nutrient expert exhibited the highest grain (4.5 t/ha) and straw yields (6.4 t/ha), while 60 % RDN+ GSGN + 100% RDP + 100% Recommended dose of potassium (RDK) showed at par of these values. Adoption of SSNM based on Nutrient expert resulted in maximum N, P and K uptake. Thus, zero tillage and residue management with SSNM based on Nutrient expert is a viable management practice for improving productivity under Direct seeded rice (DSR) in EIGP of India.

Kumar *et al.* (2023a) conducted an experiment in 'split-plot design' with tillage practices under main plot treatments and nutrient management practices as subplot treatments. The results revealed that yield attributes such as no. of panicles per square metre and no. of grains per panicle were significantly influenced by both tillage and nutrient management practices with higher values of both the yield attributes were recorded in Zero tillage + Residue management (239; 122) among tillage practices and site specific nutrient management (SSNM) based on Nutrient expert® (228; 119) respectively among nutrient management treatments whereas, panicle length, test weight and harvest index were not significantly influenced by any of the tillage or nutrient management practices. Zero tillage + Residue management and Zero tillage increased the grain and straw yield of direct seeded rice to the tune of 14.03% (grain); 9.27% (straw) and, 10.15%(grain); 6.1% (straw) over Conventional tillage, respectively. While SSNM based on Nutrient expert® and 60% Recommended dose of nitrogen (RDN) + GSGN + 100% PK of, Recommended dose of fertilizers (RDF) increased grain and straw yield of direct seeded rice to the tune of 14.91%; 7.73% and 12.07%; 5.52% over RDF, respectively. Zero tillage + Residue management among tillage practices and SSNM based on Nutrient expert® among nutrient management treatments resulted in maximum gross returns (₹ 91451, ₹ 91321 /ha); net returns (₹ 59050, ₹ 59313 /ha) and Benefit cost ratio (BCR) (1.83, 1.86) respectively.

Gong *et al.* (2023) laid out a research to explore the effects of different tillage depths on yield and quality of rice. The experimental treatments were comprised of four tillage depths i.e., 14 cm [TD (Tillage Depth) 14] as the control, 17 cm (TD17), 20 cm (TD20), and 23 cm (TD23) by using a tractor- mounted hydraulic-adjustable. Results indicated that the TD17 treatment substantially improved the breaking resistance by 39.45–72.37% and decreased the lodging index by 11.73–29.94% of first to third node attribute, increased the stem diameter and unit length dry weight and decreased the internode length, compared

with control. The TD17 treatment also reduced the chalkiness, chalkiness rate by 26.23% and 32.30%, respectively.

Moreover, the viscosity value and cooking and eating quality of rice in TD17 treatment were improved 27.30% and 12.33%, respectively, compared to control. Moreover, the TD20 treatment enhanced the grain yield by 9.18% owing to the higher panicle number and grain number per panicle. The highest photosynthetic rate was also found in the TD20 treatment, which was significant higher 15.57% than TD14 treatment. Overall, the 17–20 cm was found the optimum tillage depth and therefore recommended to the farmers to get improved rice yield with minimum lodging in the rice production systems of the Northeast China.

Ren *et al.* (2021) conducted a study by three treatments (CK: conventional tillage; T1: minimum tillage; T2: no-tillage) to assess the effects of conservation tillage on the aroma, yield and quality of mechanical-transplanting fragrant rice. T1 and T2 treatments improved yield components, increased the photosynthetic matter accumulation, and increased yields. T1 and T2 treatments also resulted in a higher head milled rice rate and significant changes in protein content of mechanical-transplanting fragrant rice. Overall, conservation tillage practices were beneficial to increase the 2-AP content, quality and yield of mechanical-transplanting fragrant rice.

Barus, Pujiharti and Novitasari (2021) conducted a research in a factorial randomized block design with three replications. The tillage methods were: (1) Maximum tillage and without ditch, (2) Minimum tillage with ditch. The organic fertilizer treatments were control, bio urine plus 10 L ha⁻¹, bio urine plus 20 L ha⁻¹, biodecomposer 10 L ha⁻¹, and biodecomposer 20 L ha⁻¹. Application of bio urine plus 20 L ha⁻¹ significantly increased plant height and yield. The highest dry grain was obtained in the treatment of minimum tillage and biodecomposer 20 L ha⁻¹.

Baki *et al.* (2015) carried out an experiment to study the impact of tillage intensity, fertilizer and manuring on agronomic and yield of rice. The experiment was laid out in a split-plot design with three tillage treatments in main plot (P1: One passing of a power tiller, P2: Two passing of a power tiller, and P3: Three passing of a power tiller) and four fertilizer and manuring treatments in sub plots [FMO (Recommended dose of fertilizers @ 85 kg N, 14 kg P, 32 kg K, 8 kg S, 2 kg Zn ha⁻¹ as Urea, TSP, MOP, Gypsum and ZnSO₄.2H₂O (BARC, 2005)), FM1 (60% of N plus rest of recommended dose of fertilizers + Cowdung @ 5 t ha⁻¹), FM2 (60% of N plus rest of recommended dose of fertilizers + rice straw @ 5 t ha⁻¹), and FM3 (60% of N plus rest of recommended dose of fertilizers + Cowdung @ 2.5 t ha⁻¹ + rice straw @ 2.5 t ha⁻¹) and replicated thrice. Considering tillage treatment, the highest number of tillers hill⁻¹ (11.80), number of grains panicle⁻¹ (106.97), 1000-grain weight (21.58 g) and grain yield (4.40 t ha⁻¹) were observed in P3 treatment. The lowest straw yield (4.18 t ha⁻¹) and grain yield (3.64 t ha⁻¹) was found in P2 treatment. As a result, yield of rice increased.

Urmi *et al.* (2022) conducted a research to quantify the effects of integrated nutrient management on rice yield and nutrient use efficiency in cultivated land. The experiment was designed with seven treatments comprising of a zero input control, recommended inorganic fertilizers (RD), poultry manure (PM) (5 t ha⁻¹) + 50% RD, PM (2.5 t ha⁻¹) + 75% RD, vermicompost (VC) (5 t ha⁻¹) + 50% RD, VC (2.5 t ha⁻¹) + 75% RD, and farmers' practice (FP) with three replications that were laid out in a randomized complete block design. The highest grain yield (6.16–6.27 t ha⁻¹) was attained when VC and PM were applied at the rate of 2.5 t ha⁻¹ along with 75% RD. Uptake of nutrients and their subsequent use efficiencies appeared higher and satisfactory from the combined application of organic and inorganic fertilizers. Therefore, organic and inorganic fertilizers might help to ensure agricultural sustainability.

Lamichhane *et al.* (2022) conducted an experiment to study the effect of sole application of farm yard

manure (FYM) and combined application of chemical fertilizers and FYM on the growth and yield traits of rice (Variety: Ramdhan). The seven treatments were studied in a randomized complete block design with four replications: T1: 100% recommended dose of inorganic fertilizer (RDIF) (i.e., 100:60:40 NPK kg ha⁻¹); T2: 50% RDIF+ FYM @ 9.9 Mt ha⁻¹; T3: 50% RDIF+ FYM @ 31.3 Mt ha⁻¹; T4: 50% RDIF+ FYM @ 11.05 Mt ha⁻¹; T5: FYM @ 19.83 Mt ha⁻¹. The results indicated that combined application of chemical fertilizers and farmyard manure was found to have a significant effect on the number of effective tillers per m⁻² and grain yield of rice. There was no significant interaction between thousand grain weight and sterility percent.

The highest grain yield of 3,453.69 kg ha⁻¹ and the highest number of effective tillers per m⁻² (299) were found in the application of 50% RDIF+ FYM @ 31.3 Mt ha⁻¹. The highest values of available soil organic carbon (34.67 Mt ha⁻¹), available soil nitrogen (1.24 Mt ha⁻¹), and available soil phosphorus (39.57 kg ha⁻¹) at a depth of 0–15 cm was found with the application of FYM @ 62.5 Mt ha⁻¹. The findings of this study suggest that farmers can apply 50% RDIF + FYM @ 31.3 Mt ha⁻¹ to have the higher grain yield of rice.

Bhosale *et al.* (2021) conducted a study to assess the effects of inorganic fertilizers and organic manures on crop productivity. The application of Integrated Nutrient Management (INM) increase grain yield (25.07, 22.87 to 57.52, 57.87 q ha⁻¹) and straw yield (30.65, 28.14 to 68.36, 67.94 q ha⁻¹) in Kharif rice and Rabi-hot weather Rice respectively.

Alam *et al.* (2021) carried out a study to evaluate the efficacy of different organic and inorganic fertilizers on the growth and yield of boro rice (BRRI dhan29). The experiment had eight treatments with three replications as follows; T0: Control, T1: 100% N75P12K45S9 kg/ha (Recommended dose), T2 : 50% NPKS + 6 t cowdung ha⁻¹, T3 : 75% NPKS + 3 t cowdung ha⁻¹, T4: 50% NPKS + 6 t poultry manure ha⁻¹, T5: 75% NPKS + 3 t poultry manure ha⁻¹, T6: 50% NPKS + 6 t vermicompost ha⁻¹ and T7: 75%

NPKS + 3 t vermicompost ha⁻¹. At harvest stage, the tallest plant (94.37 cm) and the highest number of total tillers per hill (22.10) was recorded from T4. The longest panicle (26.48 cm), maximum number of total grains per plant (178.3), the highest weight of 1000 seeds (21.96 g), the maximum grain yield (10.33 t ha⁻¹) and straw yield (15.67 t ha⁻¹) was also recorded in T4 treatment. Although the highest biological yield was recorded from T4 treatment but statistically similar result was found from T5 treatment. The findings of the study showed that the performance of the treatment T4 was the best among all treatments in terms of growth and yields. So, the recommendation of this study is amendment of soil with 50% NPKS + 6 t poultry manure ha⁻¹ might be an efficient practice for achieving sustainable higher boro rice (BRRI dhan29) production.

Anisuzzaman *et al.* (2021) conducted a pot experiment aimed to test the effect of organic and inorganic fertilizers on the growth and yield components of 65 rice genotypes during the period of February to June 2019 and August to December 2019 in a randomized complete block design (RCBD) with three replications. There were three treatment combinations *viz.* T1: 5 t ha⁻¹ chicken manure (CM), T2: 2.5 t ha⁻¹ CM + 50% CFRR, T3: 100% (150 N: 60 P₂O₅: 60 K₂O kg ha⁻¹) and chemical fertilizer recommended rate (CFRR). Grain and straw samples were collected for chemical analysis, and physical parameters were measured at the harvest stage. Results showed that most of the growth and yield components were significantly influenced due to the application of organic manure with chemical fertilizer. The application of chemical fertilizer alone or in combination with organic manure resulted in a significant increase in growth, yield component traits, and nutrient content (N, P and K) of all rice genotypes. Treatment of 2.5 t ha⁻¹ CM + 50% CFRR as well as 100% CFRR showed a better performance than the other treatments. It was observed that the yield of rice genotypes can be increased substantially with the judicious application of organic manure with chemical fertilizer. The benefits of the mixed fertilization (organic + inorganic) were not only the

crop yields but also the promotion of soil health, the reduction of chemical fertilizer input, etc.

Sunarpi *et al.* (2021) carried out a study to determine the effect of a combination of organic and inorganic fertilizers on the growth and yield of rice. The three treatments used in this study were P₀N₀ with no organic and inorganic fertilizers; P₀N₁₀₀ with a dose of 100% inorganic fertilizer and P₅₀N₅₀ with a dose of 50% organic fertilizer and 50% inorganic fertilizer. The results showed that the combination of organic fertilizers (50%) and inorganic fertilizers (50%) can increase the growth and yield of rice in the screen house compared to control plants and plants which given only 100% inorganic fertilizers. In summary, the combination of organic and inorganic fertilizers can reduce the use of inorganic fertilizers.

Chakraborty *et al.* (2020) conducted an experiment during the boro season of December 2016 to May 2017 to evaluate the effect of integrated nutrient management on two boro rice cultivars. The varieties were BRRI dhan28 and BRRI dhan29 and eight kinds of nutrient management *viz.*, control (no fertilizers), recommended dose of inorganic fertilizers (120-60-40 N, P₂O₅, K₂O kg ha⁻¹ + gypsum 60 kg ha⁻¹ and ZnSO₄ @ 10 kg ha⁻¹), full dose of poultry manure @ 5 t ha⁻¹, cowdung @ 10 t ha⁻¹, poultry manure @ 2.5 t ha⁻¹ + 50% prilled urea and full dose of other inorganic fertilizers, cowdung @ 5 t ha⁻¹ + 50% prilled urea and full dose of inorganic fertilizers, poultry manure @ 2.5 t ha⁻¹ + 75% prilled urea and full dose of inorganic fertilizers, and cowdung @ 5 t ha⁻¹ + 75% prilled urea and full dose of other inorganic fertilizers. The experiment was laid out in a split plot design with three replications. Result showed that, yield and yield components of boro rice were significantly influenced by variety, nutrient management and interaction of variety and nutrient management. In respect of grain yield, BRRI dhan29 produced the maximum yield (5.46 t ha⁻¹). BRRI dhan28 showed poor performance with all characters and gave the minimum yield (4.07 t ha⁻¹). In case of nutrient managements, the highest yield and yield component were obtained from poultry manure @ 2.5 t ha⁻¹ + 50% prilled urea and

full dose of inorganic fertilizers and produced the maximum grain yield (5.70 t ha^{-1}).

In the interaction of variety and integrated nutrient management, the highest grain yield (6.83 t ha^{-1}) and straw yield (7.61 t ha^{-1}) was obtained from poultry manure @ 2.5 t ha^{-1} + 50% prilled urea and full dose of inorganic fertilizers with BRRI dhan29 variety. So, BRRI dhan29 with 2.5 t ha^{-1} poultry manure + 50% prilled urea and full dose of the recommended inorganic fertilizers might be a promising practice for boro rice cultivation.

Kakar *et al.* (2020) carried out a research to elucidate the efficacy of different fertilizers' application on growth attributes, yield potential, and grain quality of rice. The treatments included the traditional application rate of nitrogen and phosphorus (RD), animal manure (AM), animal manure with 50% nitrogen and phosphorus of the traditional application rate (AMRD), sawdust (SD), and sawdust with 50% nitrogen and phosphorus of the traditional application rate (SDRD). Growth parameters, grain yield and its components, physicochemical properties, and morphological observation using scanning electron microscopy were recorded. The results revealed that the greatest panicle number, spikelet number, and grain yield were recorded in AMRD and SDRD treatments.

Hossain, Ahmmed and Billah (2023) conducted an experiment to investigate the effect of combining organic and inorganic fertilizers on rice growth and yield. The experiment consisted of five treatments: T1 100% STB ($\text{N}_{90}\text{P}_{15}\text{K}_{75}\text{S}_{12}\text{Zn}_2$), T2 (85% CF+ 5 t/ha cow dung), T3 (85% CF+ 4 t/ha vermicompost), T4 (70% CF+ 5 t/ha cow dung), and T5 (70% CF+ 2 t/ha vermicompost). The study found that combining inorganic fertilizer with 2 t/ha of vermicompost resulted in the highest yield. Chemical fertilizer (CF) with organic sources increased yield. The tallest plants were in T1 (104.9 cm), while the shortest was in T4. The highest grain yield was in T3 (5.9 t/ha), and lowest in T4 (4.7 t/ha). When combining 4 t/ha of vermicompost with 85% CF (77 kg N , 13 kg P , 64 kg K , 12 kg S , 2 kg Zn),

the parameters of tillers per plant, panicle length, filled grains per panicle, 1000-grain weight, grain yield, and straw yield were maximized. Based on these findings, it can be concluded that Using high-quality rice varieties and incorporating compost, alone or with chemical fertilizers, increases yields compared to full inorganic fertilizer. The study emphasizes the importance of judicious organic and chemical fertilizer application for significantly enhancing rice yields.

Mondal *et al.* (2025) conducted a research to study the effects of cotton oil cake with recommended fertilizer dose on agronomic characteristics and yield of rice. The research was set up using a Randomized Complete Block Design (RCBD) with 3 replicates. There were seven treatments such as T1: Control, T2: Recommended Fertilizer Dose (RFD), T3: 90% of RFD + 10% of Cotton Oil Cake (COC), T4: 80% of RFD + 20% of COC, T5: 70% of RFD + 30% of COC, T6: 60% of RFD + 40% of COC and T7: 50% of RFD + 50% of COC. The grain, straw, and biological yield of BRRI dhan29 were all substantially impacted by the various treatments.

The maximum grain yield of 5.21 t ha^{-1} was recorded for the treatment T2 which was statistically identical to those recorded for the treatments T5 (5.10 t ha^{-1}), T6 (5.13 t ha^{-1}), and T7 (5.18 t ha^{-1}). The maximal features of nutrient concentration in grain and straw, as well as absorption by grain, straw, and overall were likewise greater for treatment T2, whereas T5 produced substantially equivalent findings. Plant length, active tillers hill^{-1} , panicle length, filled grains panicle^{-1} , unfilled grains panicle^{-1} and 1000-grain weight were also greater for the treatment T2. Grain yield enhanced with raising nutrient absorption through BRRI dhan29. The implementation of treatment T5 suggestively influenced the yield contributing characters, nutrient content and nutrient absorption through grain and straw of BRRI dhan29 but remained statistically similar to that of the results revealed due to the treatment T2. The findings discovered obviously showed that in order to enhance the crop yield, treatments T5 may be practiced instead of treatments T2.

Bashar *et al.* (2025b) carried out a study to evaluate the impact of tillage intensity and use of organic and chemical fertilizer on yield attributes of Boro rice (cv. BRRI Dhan97). The study was conducted in a randomized complete block design with 3 replications. The treatments were: T1 +C= 1 passing of power tiller + poultry manure with chemical fertilizer, T2 +C= 2 passing of power tiller + poultry manure with chemical fertilizer, and T3 +C= 3 passing of power tiller + poultry manure with chemical fertilizer. Considering the plant attributes, the maximum number of effective tillers hill⁻¹ (16.84) and 1000 grain weight (22.58 g) were observed in T3+C treatment which was significantly higher ($p < 0.05$). The maximum grain (7.33 t ha⁻¹) and straw (9.83 t ha⁻¹) yields were documented in T3+C treatment which was substantially higher ($p < 0.01$) than other treatments. Considering the soil and rice yield attributes T3+C treatment proved the best results.

The combination of conservation tillage, organic manure, and inorganic fertilizer provides a synergistic effect where the benefits of each are amplified (Fig. 1). A balanced approach helps maintain soil fertility over time, whereas long-term use of only inorganic fertilizers can degrade soil physical properties. Partially substituting inorganic with organic fertilizers can reduce production costs while maintaining high yields. Optimal results are achieved by combining these inputs rather than using them in isolation, although specific optimal ratios vary.

Negative effect of tillage, manure, and inorganic fertilizer on soil properties, agronomic characteristics and yield of rice

Soil tillage is among the important factors affecting soil properties and crop yield. Among the crop production factors, tillage contributes up to 20% (Datta *et al.*, 2025) and affects the sustainable use of soil resources through its influence on soil properties (Francaviglia *et al.*, 2023). The judicious use of tillage practices overcomes edaphic constraints, whereas inopportune tillage may cause a variety of undesirable outcomes, for example, soil structure destruction,

accelerated erosion, loss of organic matter and fertility, and disruption in cycles of water, organic carbon, and plant nutrient (Fig. 1). Reducing tillage positively influences several aspects of the soil whereas excessive and unnecessary tillage operations give rise to opposite phenomena that are harmful to soil. Conventional tillage creates a fine, loose structure and can increase nutrients in the short term; it often leads to reduced organic matter, soil compaction, lead to long-term soil degradation, and a loss of soil structure over time (Fig. 1). It can increase soil compaction due to heavy machinery, especially under wet conditions. It accelerates the breakdown of soil organic matter, leading to a loss of nutrients. It can initially increase nutrient availability due to increased aeration, but this is often short-lived.

Potentially pathogenic improperly-processed organic fertilizers may contain pathogens that are harmful to humans or plants because organic fertilizers are derived from a substance like animal feces or plant/animal matter contaminated with pathogens (Samaddar *et al.*, 2021). Limited Nutrient Availability: they are relatively low in nutrient content, so larger volume is needed to supply enough nutrients for plant growth. Hence, large-scale agriculture without use inorganic fertilizers it is difficult (Babajani *et al.*, 2023; Panday *et al.*, 2024). Accurate application is tie due to the composition of organic fertilizers highly variable, so that the accurate application of nutrients to match plant production is difficult.

Over-application can result in negative effects such as leaching, pollution of water, acidification and reduces the availability of the trace element or alkalization of the soil. Chemical fertilizer enhances the decomposition of soil organic matter, which leads to degradation of soil structure and decrease in soil aggregation results in nutrients are easily lost from soils through fixation, leaching, gas emission and can lead to diminishing fertilizer efficiency (Jote, 2023; Titirmare *et al.*, 2023; Xing *et al.*, 2025). Over treatments of chemical fertilizers can destroy

decomposers and other soil organisms, reduce the colonization of plant roots with mycorrhiza and inhibit symbiotic N-fixation by rhizobia due to high N-fertilization (Yuan *et al.*, 2025). This showed that over treatments Chemical fertilizer causes problems

not only to the soil health but also to the human health and physical environment. However, relying solely on inorganic fertilizers can lead to potential nutrient imbalances and negative balances for some nutrients.



Fig. 1. Short-term effects of tillage, manure, and inorganic fertilizer on soil properties, agronomic characteristics, and yield of rice

Finally, it is important to remember that the application of conventional tillage, potentially pathogenic improperly-processed organic fertilizers, and over doses of chemical fertilizer not only affects soil health but also reduces rice growth and yield at an alarming rate.

How to achieve optimal outcomes

Integrated approach: An integrated nutrient management approach that combines both organic and inorganic fertilizers is often the most beneficial for both rice yield and long-term soil fertility.

Adjust for local conditions: The optimal rates for organic and inorganic fertilizers will vary based on specific soil types, rice varieties, and environmental conditions.

Consider soil properties: Soil analysis is crucial to determine nutrient deficiencies and apply fertilizers accordingly.

Monitor yield and soil health: Long-term studies are beneficial to understand the cumulative effects of

different management practices on both yield and the sustainability of the soil ecosystem.

CONCLUSION

Soil health is a broad term that speaks to the capacity of the soil to function as an ecosystem that supports the plant, animal, and human life. This review shows that manure contributes to creating this ecosystem in supplying nutrients and improving various soil properties. On the other hand, tillage is a substantial input to agricultural activities that alters the soil's chemical, physical, and microbiological composition. The consequences of various soil tillage techniques frequently vary depending on the crop type, location, time of tillage, and past cropping history.

At present, population problems and environmental issues are getting worse, while farming practices are getting simpler. Due to this, it is a burning question, how current cropping systems will work in the future in terms of resilience, adaptability to climate change, multifunctionality of the agricultural landscape.

supply of ecosystem services, and biodiversity. As the major concern of the modern world is to produce more crops in limited resources of soil so the fertility and biodiversity of soil decrease day by day which induces low crop production in the future. All the ways to increase crop yield as well as maintain soil health are discussed in detail in this review.

This review identifies the best suitable cropping system for the individual crops which helps to increase crop production with minimum effect on soil health and also highlights the benefit aspect of conservation tillage compared to conventional tillage to maintain soil fertility.

Moreover, the large amounts of manure that must be applied to get equal quantities of nutrients as synthetic fertilizers, make its application to land unappealing from a labor and cost perspective. Finally, if manure is to become an attractive amendment to farmers for soil improvement, the economic sustainability of manure-based cropping systems and opportunities to improve their profitability must be explored. Therefore, more research is currently needed to analyze different tillage methods, application of manure, and develop new cropping systems that will increase the production of various crops and make the future world self-sufficient in food.

REFERENCES

Agbede TM. 2025. Poultry manure improves soil properties and grain mineral composition, maize productivity and economic profitability. *Scientific Reports* **15**(1), 16501.

<https://doi.org/10.1038/s41598-025-00394-8>

Ahmed N, Zhang B, Chachar Z, Li J, Xiao G, Wang Q, Hayat F, Deng L, Narejo MU, Bozdar B, Tu P. 2024. Micronutrients and their effects on horticultural crop quality, productivity and sustainability. *Scientia Horticulturae* **323**, 112512. <https://doi.org/10.1016/j.scienta.2023.112512>

Alam MM, Arifunnahar M, Khatun MM, Sumon MA, Rahman MA, Islam MJ. 2021. Effect of different organic and inorganic fertilizers on the growth and yield of boro rice (BRRI dhan29). *International Journal of Research in Science and Innovation (IJRSI)* **8**(1), 176-180.

<https://d1wqtxts1xzle7.cloudfront.net/108445892/176-180-libre.pdf>

Ali M, Rahul F, Ali S, Subhan U, Saleem Z, Quratulain, Waseem M, Hussain M, Ali MA, Mehdi MM. 2025. Impact of organic amendments on soil structure, fertility and growth of plants. In: Kausar R, Nisa ZU, Jamil M, Bashir I (eds). *Integrated Health and Sustainability: Plants, Wildlife, and Genetic Resilience*. Unique Scientific Publishers, Faisalabad, Pakistan, pp. 183-189.

<https://doi.org/10.47278/book.HH/2025.295>

Ali MI, Islam MS, Hossain MS, Azad MA. 2023. Tillage operation and fertilizer management effect on yield of boro rice in saline prone zone of Bangladesh. *Bangladesh Journal of Nuclear Agriculture* **37**(1), 51-62.

<https://doi.org/10.3329/bjnag.v37i1.69928>

Anisuzzaman M, Rafii MY, Jaafar NM, Izan Ramlee S, Ikbali MF, Haque MA. 2021. Effect of organic and inorganic fertilizer on the growth and yield components of traditional and improved rice (*Oryza sativa* L.) genotypes in Malaysia. *Agronomy* **11**(9), 1830. <https://doi.org/10.3390/agronomy11091830>

Awadelkareem W, Haroun M, Wang J, Qian X. 2023. Nitrogen interactions cause soil degradation in greenhouses: Their relationship to soil preservation in China. *Horticulturae* **9**(3), 340.

<https://doi.org/10.3390/horticulturae9030340>

Babajani A, Muehlberger S, Feuerbacher A, Wieck C. 2023. Drivers and challenges of large-scale conversion policies to organic and agro-chemical free agriculture in South Asia. *International Journal of Agricultural Sustainability* **21**(1), 2262372.

<https://doi.org/10.1080/14735903.2023.2262372>

- Baki MZ, Haque M, Amin R, Matin MA.** 2015. Impact of tillage intensity, fertilizer and manuring on yield contributing characters of rice. *Scientia Agriculturae* **10**(1), 22-30.
<https://doi.org/10.15192/PSCP.SA.2015.10.1.2230>
- Barus J, Pujiharti Y, Novitasari E.** 2021. Effect of differences in soil tillage and application of organic fertilizers on soil water content and yield of upland rice. *IOP Conference Series: Earth and Environmental Science* **648**(1), 012153.
<https://doi.org/10.1088/1755-1315/648/1/012153>
- Bashar MKI, Islam Z, Jahangir MM, Islam MT, Zulfiqar M, Kumar A, Hasan SM, Rahman ME.** 2025a. Effects of synergistic application of tillage, poultry manure, and chemical fertilizer on soil and yield attributes of BRRI dhan28. *Asian Journal of Research in Crop Science* **10**(2), 33-47.
<https://doi.org/10.9734/ajrcs/2025/v10i2349>
- Bashar MKI, Islam Z, Rahman ME, Mahmud MK, Bashar MA, Zulfiqar M, Islam MT, Mondal MM, Kumar A.** 2025b. Effects of tillage and fertilizers on soil and yield characteristics of BRRI dhan97 rice. *International Journal of Agronomy and Agricultural Research* **27**(4), 11-20.
<https://doi.org/10.12692/ijaar/27.4.11-20>
- Bhatia T, Sindhu SS.** 2024. Sustainable management of organic agricultural wastes: Contributions in nutrients availability, pollution mitigation and crop production. *Discover Agriculture* **2**(1), 130.
<https://doi.org/10.1007/s44279-024-00147-7>
- Bhatt R, Moulick D, Bárek V, Brestic M, Gaber A, Skalicky M, Hossain A.** 2025. Sustainable strategies to limit nitrogen loss in agriculture through improving its use efficiency—Aiming to reduce environmental pollution. *Journal of Agriculture and Food Research* **101957**.
<https://doi.org/10.1016/j.jafr.2025.101957>
- Bhattacharya U, Naskar MK, Venugopalan VK, Sarkar S, Bandopadhyay P, Maitra S, Gaber A, Alsuhaibani AM, Hossain A.** 2023. Implications of minimum tillage and integrated nutrient management on yield and soil health of rice-lentil cropping system—being a resource conservation technology. *Frontiers in Sustainable Food Systems* **7**, 1225986.
<https://doi.org/10.3389/fsufs.2023.1225986>
- Bhosale SS, Jondhale DG, Khobragade NH, Dahiphale AV, Bhagat SB, Bedse TJ, Mhaskar NV.** 2021. Impact of integrated nutrient management on physical properties of inceptisols under rice–rice cropping system in North Konkan coastal zone of Maharashtra. *The Pharma Innovation Journal* **10**(1), 500-505.
<https://www.thepharmajournal.com/archives/2021/vol10issue1/PartG/10-1-56-640.pdf>
- Bitew B, Molla E, Tadesse T, Bekis D.** 2024. Effects of farmyard manure and nitrogen fertilizers on yield and yield components of lowland rice (*Oryza sativa* L.) on Vertisols of Fogera District, Northwestern Ethiopia. *Journal of Chemical, Environmental and Biological Engineering* **8**(2), 37-51.
<https://www.sciencepublishinggroup.com/article/10.11648/j.jcebe.20240802.11>
- Botta GF, Antille DL, Nardon GF, Rivero D, Bienvenido F, Contessotto EE, Ezquerra-Canalejo A, Ressia JM.** 2022. Zero and controlled traffic improved soil physical conditions and soybean yield under no-tillage. *Soil and Tillage Research* **215**, 105235.
<https://doi.org/10.1016/j.still.2021.105235>
- Büchi L, Wendling M, Amossé C, Necpalova M, Charles R.** 2018. Importance of cover crops in alleviating negative effects of reduced soil tillage and promoting soil fertility in a winter wheat cropping system. *Agriculture, Ecosystems & Environment* **256**, 92-104. <https://doi.org/10.1016/j.agee.2018.01.005>

- Chakraborty S, Rahman A, Salam MA.** 2020. Effect of integrated nutrient management on the growth and yield of Boro rice (*Oryza sativa* L.) cultivars. Archives of Agriculture and Environmental Science **5**(4), 476-481.
https://www.researchgate.net/publication/347939593_Effect_of_integrated_nutrient_management_on_the_growth_and_yield_of_boro_rice_Oryza_sativa_L_cultivars
- Cheng R, Du L, Ye S, Wang S.** 2025. Soil organic carbon and labile organic carbon fractions drive the dynamics of aggregate composition and stability in a chronosequence of tea plantations. Agronomy **15**(2), 501. <https://doi.org/10.3390/agronomy15020501>
- Cuevas J, Daliakopoulos IN, del Moral F, Hueso JJ, Tsanis IK.** 2019. A review of soil-improving cropping systems for soil salinization. Agronomy **9**(6), 295. <https://doi.org/10.3390/agronomy9060295>
- Culas RJ, Anwar MR, Maraseni TN.** 2025. A framework for evaluating benefits of organic fertilizer use in agriculture. Journal of Agriculture and Food Research **19**, 101576.
<https://doi.org/10.1016/j.jafr.2024.101576>
- Datta S, Mazumdar SP, Majumdar B, Alam NM, Chattopadhyay L, Ghosh S, Saha D, Saha AR, Kar G.** 2025. Impact of integrated nutrient management on soil microbiome diversity and health in rice-based cropping system: Insights from long-term agricultural practices. Rhizosphere **33**, 101048.
<https://doi.org/10.1016/j.rhisph.2025.101048>
- Dhaliwal SS, Sharma V, Shukla AK, Gupta RK, Verma V, Kaur M, Behera SK, Singh P.** 2023. Residual effect of organic and inorganic fertilizers on growth, yield and nutrient uptake in wheat under a basmati rice–wheat cropping system in North-Western India. Agriculture **13**(3), 556.
<https://doi.org/10.3390/agriculture13030556>
- Dugan I, Pereira P, Kisić I, Matisić M, Bogunović I.** 2024. Analyzing the influence of conservation tillage and manure on soil parameter modulations in croplands. Plants **13**(5), 607.
<https://doi.org/10.3390/plants13050607>
- Francaviglia R, Almagro M, Vicente-Vicente JL.** 2023. Conservation agriculture and soil organic carbon: Principles, processes, practices and policy options. Soil Systems **7**(1), 17.
<https://doi.org/10.3390/soilsystems7010017>
- Fukagawa NK, Ziska LH.** 2019. Rice: Importance for global nutrition. Journal of Nutritional Science and Vitaminology **65**(Supplement), S2–S3.
<https://doi.org/10.3177/jnsv.65.S2>
- Gil-Martínez M, Madejón P, Madejón E, de Sosa LL.** 2025. Compost and vegetation cover drive soil fertility, microbial activity, and community in organic farming soils. Plant and Soil **26**, 1–23.
<https://doi.org/10.1007/s11104-025-07720-z>
- Giordano M, Petropoulos SA, Rouphael Y.** 2021. The fate of nitrogen from soil to plants: Influence of agricultural practices in modern agriculture. Agriculture **11**(10), 944.
<https://doi.org/10.3390/agriculture11100944>
- Giri D, Dhital M, Chaudhary B, Pandey R, Bastakoti B, Shrestha S.** 2022. Effect of different nitrogen levels on yield and yield attributes of different rice varieties in DDSR condition at Kanchanpur, Nepal. Archives of Agriculture and Environmental Science **7**(3), 310–317.
<https://doi.org/10.26832/24566632.2022.070302>
- Gong D, Dai G, Chen Y, Yu G.** 2023. Optimal tillage depths for enhancing rice yield, quality and lodging resistance in the rice production systems of northeast China. PeerJ **11**, e15739.
<https://doi.org/10.7717/peerj.15739>

Hasan J. 2021. Effect of organic and inorganic fertilizer application on rice production (BRRI dhan29). A thesis on Master of Science (MS) in Soil Science. Sher-e-Bangla Agricultural University Library, Sher-e-Bangla Nagar, Dhaka-1207, 1–65. <http://archive.saulibrary.edu.bd:8080/xmlui/bitstream/handle/123456789/4956/19-10321.pdf?sequence=1>

Hashim N, Ali MM, Mahadi MR, Abdullah AF, Wayayok A, Kassim MS, Jamaluddin A. 2024. Smart farming for sustainable rice production: An insight into application, challenge, and future prospect. *Rice Science* **31**(1), 47–61. <https://doi.org/10.1016/j.rsci.2023.08.004>

Hossain MF, Ahmmed F, Billah M. 2023. The combined effect of organic and inorganic fertilizers on the growth and yield of T. Aman rice in the T. aman–mustard–boro cropping pattern. *International Journal of Agronomy and Agricultural Research* **23**(2), 34–39. Available at: <https://innspub.net/wp-content/uploads/2023/11/IJAAR-V23-No2-p34-39.pdf>

Hussain A, Bashir H, Zafar SA, Rehman RS, Khalid MN, Awais M, Sadiq MT, Amjad I. 2023. The importance of soil organic matter (SOM) on soil productivity and plant growth. *Biological and Agricultural Sciences Research Journal* **2023**(1), 11. <https://doi.org/10.54112/basrj.v2023i1.11>

Jote CA. 2023. The impacts of using inorganic chemical fertilizers on the environment and human health. *Organic and Medicinal Chemistry International Journal* **13**(3), 555864. https://www.researchgate.net/profile/Chali-Jote/publication/376601166_The_Impacts_of_Using_Inorganic_Chemical_Fertilizers_on_the_Environment_and_Human_Health/links/658004a232bc453821f7b04f/The-Impacts-of-Using-Inorganic-Chemical-Fertilizers-on-the-Environment-and-Human-Health.pdf

Kakar K, Xuan TD, Noori Z, Aryan S, Gulab G. 2020. Effects of organic and inorganic fertilizer application on growth, yield, and grain quality of rice. *Agriculture* **10**(11), 544. <https://doi.org/10.3390/agriculture10110544>

Karki S, Karki TB, Shah SC, Yadav R, Yadav RK, Dhaka R, Pandit M. 2017. Effect of tillage, residue and nutrient management on soil qualities and yield parameters of rice. *Journal of Experimental Sciences* **8**, 16–20. <https://pdfs.semanticscholar.org/1b72/aba69781804f39a742f06a8d52dff367063d.pdf>

Khambalkar PA, Agrawal S, Dhaliwal SS, Yadav SS, Sadawarti MJ, Singh A, Yadav IR, Yadav K, Prasad D, Singh A, Afreen N. 2025. Sustainable nutrient management balancing soil health and food security for future generations. *Applied Food Research* **101087**. <https://doi.org/10.1016/j.afres.2025.101087>

Khan MT, Aleinikovienė J, Butkevičienė LM. 2024. Innovative organic fertilizers and cover crops: Perspectives for sustainable agriculture in the era of climate change and organic agriculture. *Agronomy* **14**(12), 2871. <https://doi.org/10.3390/agronomy14122871>

Kharel M, Dahal BM, Raut N. 2022. Good agriculture practices for safe food and sustainable agriculture in Nepal: A review. *Journal of Agriculture and Food Research* **10**, 100447. <https://doi.org/10.1016/j.jafr.2022.100447>

Kumar N, Chhokar RS, Meena RP, Kharub AS, Gill SC, Tripathi SC, Gupta OP, Mangrauthia SK, Sundaram RM, Sawant CP, Gupta A. 2022. Challenges and opportunities in productivity and sustainability of rice cultivation system: A critical review in Indian perspective. *Cereal Research Communications* **50**(4), 573–601. <https://doi.org/10.1007/s42976-021-00214-5>

Kumar PM, Roy DK, Ranjan S, Sow S. 2023. Influence of tillage and nutrient management strategies on rice (*Oryza sativa* L.) productivity, nutrient uptake and soil properties. *Oryza – An International Journal on Rice* **60**(3), 448–456.

<https://epubs.icar.org.in/index.php/OIJR/article/view/143154>

Kumar PM, Roy DK, Singh SK, Kumar M. 2023a. Effect of different tillage and nutrient management practices on yield attributes and economics of direct seeded rice. *International Journal of Plant & Soil Science* **35**(19), 1300–1306.

<https://doi.org/10.9734/IJPSS/2023/v35i193670>

Kumari S, Kumar R, Kumar R, Kumari A, Shabana AP. 2020. Effect of zinc levels and moisture regimes on growth and nutrient uptake of direct seeded rice. *International Journal of Chemical Studies* **8**(2), 120–1240.

<https://doi.org/10.22271/chemi.2020.v8.i2b.8756>

Lamichhane S, Khanal BR, Jaishi A, Bhatta S, Gautam R, Shrestha J. 2022. Effect of integrated use of farmyard manure and chemical fertilizers on soil properties and productivity of rice in Chitwan. *Agronomy Journal of Nepal* **6**(1), 200–212.

<https://doi.org/10.3126/ajnl.v6i1.47994>

Li X, Qiao L, Huang Y, Li D, Xu M, Ge T, Meersmans J, Zhang W. 2023. Manuring improves soil health by sustaining multifunction at relatively high levels in subtropical area. *Agriculture, Ecosystems & Environment* **353**, 108539.

<https://doi.org/10.1016/j.agee.2023.108539>

Li Y, Xiao J, Chen L, Huang X, Cheng Z, Han B, Zhang Q, Wu C. 2018. Rice functional genomics research: Past decade and future. *Molecular Plant* **11**(3), 359–380.

[https://www.cell.com/molecular-plant/fulltext/S1674-2052\(18\)30027-3?sf184077616=1](https://www.cell.com/molecular-plant/fulltext/S1674-2052(18)30027-3?sf184077616=1)

Liu Y, Lan X, Hou H, Ji J, Liu X, Lv Z. 2024. Multifaceted ability of organic fertilizers to improve crop productivity and abiotic stress tolerance: Review and perspectives. *Agronomy* **14**(6), 1141.

<https://doi.org/10.3390/agronomy14061141>

Manir MR, Halder KP, Rashid MM, Begum S, Salaududdin AK, Hasan K. 2025. Effect of tillage operation on the productivity and profitability of rice cultivation. *Asian Journal of Advances in Agricultural Research* **25**(7), 158–165.

<https://doi.org/10.9734/ajaar/2025/v25i7655>

Mgxaji Y, Mutengwa CS, Mukumba P, Dzvene AR. 2025. Biogas slurry as a sustainable organic fertilizer for sorghum production in sandy soils: A review of feedstock sources, application methods, and agronomic impacts. *Agronomy* **15**(7), 1683.

<https://doi.org/10.3390/agronomy15071683>

Mintesinot D. 2022. Review on the integrated use of organic and inorganic fertilizers on production and soil fertility in Ethiopia. *Journal of Biology, Agriculture and Healthcare* **12**(3).

<https://d1wqtxts1xzle7.cloudfront.net/121530247/60090-libre.pdf>

Mohidem NA, Hashim N, Shamsudin R, Che Man H. 2022. Rice for food security: Revisiting its production, diversity, rice milling process and nutrient content. *Agriculture* **12**(6), 741.

<https://doi.org/10.3390/agriculture12060741>

Mondal MM, Hashem MA, Hoque MA, Rahman ME, Bashar MK, Islam Z, Hossain MS, Islam MR, Tauhid MT. 2025. Effects of cotton oil cake with recommended fertilizer dose on nutrient uptake, yield contributing characters, and yield of BRRI dhan29 rice. *Asian Journal of Research in Crop Science* **10**(4), 72–87.

<https://doi.org/10.9734/ajrcs/2025/v10i4393>

Nandan R, Singh V, Singh SS, Kumar V, Hazra KK, Nath CP, Poonia S, Malik RK, Bhattacharyya R, McDonald A. 2019. Impact of conservation tillage in rice-based cropping systems on soil aggregation, carbon pools and nutrients. *Geoderma* **340**, 104–114.

<https://doi.org/10.1016/j.geoderma.2019.01.001>

Napoletano M, Bellino A, Baldantoni D. 2025. Depletion and recovery of soil organic matter: Ecological, economic and social implications. *Ecological Civilization* **2**(2), 10002.

<https://doi.org/10.70322/ecolciviliz.2025.10002>

Nasreen S, Arshad R, Parveen K, Mansab S. 2025. Soil chemical properties, nutrient dynamics and fertility management. In *Soils and sustainable agriculture: Interplay of soil, plant, water and environmental systems for sustainable agriculture*, pp. 57–77. Cham: Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-91114-9_4

Naveen M. 2025. The role of organic matter in soil for improving crop productivity and soil health. *Journal of Experimental Agriculture International* **47**(2), 367–375. <https://doi.org/10.9734/jeai/2025/v47i23296>

Panday D, Bhusal N, Das S, Ghalegholabbehbahani A. 2024. Rooted in nature: The rise, challenges, and potential of organic farming and fertilizers in agroecosystems. *Sustainability* **16**(4), 1530. <https://doi.org/10.3390/su16041530>

Peixoto DS, da Silva LD, de Melo LB, Azevedo RP, Araújo BC, de Carvalho TS, Moreira SG, Curi N, Silva BM. 2020. Occasional tillage in no-tillage systems: A global meta-analysis. *Science of the Total Environment* **745**, 140887.

<https://doi.org/10.1016/j.scitotenv.2020.140887>

Piccolo A, Drosos M. 2025. The essential role of humified organic matter in preserving soil health. *Chemical and Biological Technologies in Agriculture* **12**(1), 21.

<https://doi.org/10.1186/s40538-025-00730-0>

Qiu X, Zhang X, Mo Z, Pan S, Tian H, Duan M, Tang X. 2023. Effects of different tillage and fertilization methods on the yield and nitrogen leaching of fragrant rice. *Agronomy* **13**(11), 2773. <https://doi.org/10.3390/agronomy13112773>

Quddus MA, Ahmed R, Islam M, Haque ME, Islam MA, Alam A, Rahman MZ, Fahad ZH, Islam MK, Gaber A, Bárek V. 2025. Organic and inorganic fertilizers influence the productivity, fruit quality and nutrient use efficiency of strawberry (*Fragaria × ananassa* Duch.). *Scientific Reports* **15**(1), 26252.

<https://www.nature.com/articles/s41598-025-10787-4>

Ren Y, Cheng S, Pan S, Tian H, Duan M, Wang S, Tang X. 2021. Effect of conservation tillage practices on aroma, yield and quality of mechanical-transplanting fragrant rice. *Journal of Plant Interactions* **16**(1), 522–532.

<https://doi.org/10.1080/17429145.2021.1999511>

Romadhon MR, Mujiyo M, Cahyono O, Maro'Ah S, Istiqomah NM, Irmawati V. 2023. Potential soil degradation of paddy fields through observation approaches from various sources of environmental diversity. In *IOP Conference Series: Earth and Environmental Science*. IOP Publishing **1241**(1), 012013.

<https://doi.org/10.1088/1755-1315/1241/1/012013>

Sahu H, Kumar U, Mariappan S, Mishra AP, Kumar S. 2024. Impact of organic and inorganic farming on soil quality and crop productivity for agricultural fields: a comparative assessment. *Environmental Challenges* **15**, 100903.

<https://doi.org/10.1016/j.envc.2024.100903>

Samaddar S, Karp DS, Schmidt R, Devarajan N, McGarvey JA, Pires AF, Scow K. 2021. Role of soil in the regulation of human and plant pathogens: soils' contributions to people. *Philosophical Transactions of the Royal Society B* **376**(1834), 20200179. <https://doi.org/10.1098/rstb.2020.0179>

Sanchez PA. 2019. Sulfur. In Properties and management of soils in the tropics, pp. 415–430. <https://www.cambridge.org/core/books/properties-and-management-of-soils-in-the-tropics/sulfur/8EB9D874700EA65D328992538A42293A>

Shankar T, Malik GC, Banerjee M, Dutta S, Maitra S, Praharaj S, Sairam M, Kumar DS, Dessoky ES, Hassan MM, Ismail IA. 2021. Productivity and nutrient balance of an intensive rice–rice cropping system are influenced by different nutrient management in the red and lateritic belt of West Bengal, India. *Plants* **10**(8), 1622. <https://doi.org/10.3390/plants10081622>

Srivastava RK, Purohit S, Alam E, Islam MK. 2024. Advancements in soil management: optimizing crop production through interdisciplinary approaches. *Journal of Agriculture and Food Research* **18**, 101528. <https://doi.org/10.1016/j.jafr.2024.101528>

Sun Q, Zhang Q, Huang Z, Wei C, Li Y, Xu H. 2024. Effect of organic fertilizer application on microbial community regulation and pollutant accumulation in typical red soil in South China. *Agronomy* **14**(9), 2150. <https://doi.org/10.3390/agronomy14092150>

Sunarpi H, Nikmatullah A, Sunarwidhi AL, Jihadi A, Ilhami BT, Ambana Y, Rinaldi R, Widyastuti S, Prasedya ES. 2021. Combination of inorganic and organic fertilizer in rice plants (*Oryza sativa*) in screen houses. *IOP Conference Series: Earth and Environmental Science* **712**(1), 012035. <https://doi.org/10.1088/1755-1315/712/1/012035>

Titirmare NS, Ranshur NJ, Patil AH, Patil SR, Margal PB. 2023. Effect of inorganic fertilizers and organic manures on physical properties of soil: a review. *International Journal of Plant and Soil Science* **35**(19), 1015–1023. <https://doi.org/10.9734/IJPSS/2023/v35i193638>

Țopa DC, Căpșună S, Calistru AE, Ailincăi C. 2025. Sustainable practices for enhancing soil health and crop quality in modern agriculture: A review. *Agriculture* **15**(9). <https://doi.org/10.3390/agriculture15090998>

Urmi TA, Rahman MM, Islam MM, Islam MA, Jahan NA, Mia MA, Akhter S, Siddiqui MH, Kalaji HM. 2022. Integrated nutrient management for rice yield, soil fertility, and carbon sequestration. *Plants* **11**(1), 138. <https://doi.org/10.3390/plants11010138>

Wang X, Chi Y, Song S. 2024. Important soil microbiota's effects on plants and soils: A comprehensive 30-year systematic literature review. *Frontiers in Microbiology* **15**, 1347745. <https://doi.org/10.3389/fmicb.2024.1347745>

Xing Y, Wang X, Mustafa A. 2025. Exploring the link between soil health and crop productivity. *Ecotoxicology and Environmental Safety* **289**, 117703. <https://doi.org/10.1016/j.ecoenv.2025.117703>

Xing Y, Xie Y, Wang X. 2025. Enhancing soil health through balanced fertilization: a pathway to sustainable agriculture and food security. *Frontiers in Microbiology* **16**, 1536524. <https://doi.org/10.3389/fmicb.2025.1536524>

Xu H, Mustafa A, Saeed Q, Jiang G, Sun N, Liu K, Kucerik J, Yang X, Xu M. 2025. Combined application of chemical and organic fertilizers enhances soil organic carbon sequestration and crop productivity by improving carbon stability and management index in a rice–rice cropping system. *Chemical and Biological Technologies in Agriculture* **12**(1), 1. <https://doi.org/10.1186/s40538-024-00721-7>

Yadav GS, Datta R, Imran Pathan S, Lal R, Meena RS, Babu S, Das A, Bhowmik SN, Datta M, Saha P, Mishra PK. 2017. Effects of conservation tillage and nutrient management practices on soil fertility and productivity of rice (*Oryza sativa* L.)–rice system in north eastern region of India. *Sustainability* **9**(10), 1816. <https://doi.org/10.3390/su9101816>

Yang T, Zhang H, Li F, Yang T, Shi Y, Gu X, Chen M, Jiang S. 2024. Optimized tillage method increased rice yield in rice ratooning system. *Agriculture* **14**(10), 1768.

<https://doi.org/10.3390/agriculture14101768>

Yoni M. 2024. Dynamic of CEC and exchangeable bases influenced by a soudanian forest in hydromorphic soil of western Burkina Faso. *International Journal of Innovation and Applied Studies* **44**(2), 435–449.

Yuan Y, Feng Z, Yan S, Zhang J, Song H, Zou Y, Jin D. 2025. The effect of the application of chemical fertilizer and arbuscular mycorrhizal fungi on maize yield and soil microbiota in saline agricultural soil. *Journal of Fungi* **11**(4), 319.

<https://doi.org/10.3390/jof11040319>