*International Journal of Plant & Soil Science*

*Volume 38, Issue 8, Page 806-814, 2026; Article no.IJPSS.163769*
*ISSN: 2320-7035*

# Impact of Organic Rice Farming Practices on Soil Nutrient Status in Farmers' Fields of Nandyal District of Andhra Pradesh, India

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***Authors' contributions***

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

***Article Information***

DOI: https://doi.org/10.9734/ijpss/2026/v38i86261

**Open Peer Review History:**
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://pr.sdiarticle5.com/review-history/163769

***Original Research Article***

***Received: 16/05/2026***
***Accepted: 04/08/2026***
***Published: 13/08/2026***

## Abstract

A field investigation was conducted to assess how the duration of organic rice farming was associated with selected soil physicochemical properties in farmers' fields of Nandyal district, Andhra Pradesh. Sixty surface soil samples (0–15 cm) were collected from fields managed organically for less than 2 years, 2–5 years, or more than 5 years, with 20 samples in each category. Soil pH, electrical conductivity (EC), organic carbon (OC), and available nitrogen (N), phosphorus ($P_2O_5$), and potassium ($K_2O$) were determined using standard laboratory procedures. Mean soil pH varied only slightly, from 7.33 to 7.38, indicating neutral to slightly alkaline conditions across the duration groups. Mean EC declined from 0.35 to 0.25 dS $m^{-1}$, whereas mean OC increased gradually from 0.32% to 0.34%. Available N increased from 245 kg $ha^{-1}$ in the initial category

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***Cite as:*** *Nayak, S. B., Kiranmai, M. J., Kumar, Y. S., Fareeda, G., & Kavitha, P. (2026). Impact of Organic Rice Farming Practices on Soil Nutrient Status in Farmers' Fields of Nandyal District of Andhra Pradesh, India. International Journal of Plant & Soil Science, 38(8), 806–814. https://doi.org/10.9734/ijpss/2026/v38i86261*

to 266 kg ha⁻¹ after 2–5 years and remained comparatively high at 260 kg $ha^{-1}$ after more than 5 years. Mean available $P_2O_5$ was 61.4, 45.3, and 46.2 kg $ha^{-1}$ across the respective groups, while available $K_2O$ remained high at 307, 304, and 311 kg $ha^{-1}$. These descriptive findings indicate that longer organic management was associated with lower EC, slightly greater OC, and comparatively high N and K availability, while the phosphorus pattern was not consistently increasing.

*Keywords: Organic farming; soil fertility; organic carbon; available nutrients; soil health.*

## 1. Introduction

Rice (*Oryza sativa* L.) is a principal food crop in India, and its intensive cultivation has relied heavily on chemical fertilisers to sustain productivity. The continuous use of inorganic fertilisers with limited additions of organic matter has resulted in declining soil organic carbon, nutrient imbalances, and deterioration of soil health in many rice-growing areas (Lal, 2004; Srivastava *et al.*, 2024). Soil health, particularly nutrient availability and organic carbon status, plays a critical role in sustaining rice productivity, nutrient-use efficiency, and environmental quality. The degradation of soil fertility under conventional systems has emphasised the need for alternative nutrient-management approaches that are environmentally sustainable and economically viable.

Organic farming has gained importance as a sustainable production system that relies on organic inputs such as farmyard manure, compost, green manures, and biofertilisers to maintain soil fertility and ecosystem balance. Several studies have reported that organic farming practices improve soil organic carbon content, enhance the availability of major nutrients, and promote biological activity in soils (Mäder *et al.*, 2002; Reganold & Wachter, 2016). Long-term applications of organic amendments have been shown to increase nitrogen mineralisation, improve phosphorus availability through organic acid production, and enhance potassium retention through improved soil structure and cation-exchange capacity (Ghosh *et al.*, 2018; Palm *et al.*, 2001). These improvements contribute to greater soil resilience and the sustainability of rice-based systems.

Recent syntheses indicate that organic amendments can contribute to the gradual restoration of soil organic matter, microbial functioning, and nutrient cycling, although the magnitude of improvement depends on amendment characteristics and site-specific management (Singh *et al.*, 2024). In rice-based systems, field evidence further suggests that green-manure incorporation can improve soil organic carbon and the status of nitrogen, phosphorus, and potassium when integrated with appropriate nutrient management (Hlaing *et al.*, 2025).

Long-term field experiments have also shown that repeated use of organic amendments can enhance soil carbon pools and available macronutrients in rice–wheat rotations, while the response of soil organic carbon during conversion to organic management may vary according to tillage practice (Das *et al.*, 2024; Mihelič *et al.*, 2024).

The impact of organic farming on soil nutrient status is strongly influenced by the duration of organic management, as nutrient build-up and organic carbon sequestration occur gradually over time. Long-term organic management has been associated with improvements in soil carbon and nutrient cycling compared with short-term adoption under field conditions (Bhowmik *et al.*, 2017; Mithlesh *et al.*, 2019). Nevertheless, region-specific evidence on changes in soil nutrient status under different durations of organic rice cultivation remains limited, particularly comparative data from farmers' fields. Therefore, the present study aimed to assess the impact of organic rice farming practices on soil nutrient status across different durations of organic management in farmers' fields of Nandyal district, Andhra Pradesh.

## 2. Materials and Methods

### 2.1 Study Area

The present study was conducted in farmers' fields in Nandyal district, Andhra Pradesh, India. The district is located in a semi-arid agro-climatic zone, and rice is an important irrigated crop in the region. Farmers practising organic rice cultivation for different durations were identified, and representative fields were selected for soil sampling.

## 2.2 Soil Sampling Strategy

Random surface soil samples were collected from farmers' fields at the cluster level during the rice-growing season. The samples were collected at a depth of 0–15 cm using a soil auger, as this layer is most responsive to nutrient-management practices. The geographical coordinates of each sampling location were recorded using a Global Positioning System (GPS) to ensure spatial documentation and sample traceability (Drinkwater *et al.*, 1995).

## 2.3 Categorisation of Farmers and Sample Size

Based on the duration of organic farming practices, the farmers' fields were categorised into three groups:

- **Group-1:** Farmers practising organic farming for less than 2 years
- **Group-2:** Farmers practising organic farming for 2–5 years
- **Group-3:** Farmers practising organic farming for more than 5 years

From each group, 20 soil samples were collected, resulting in a total of 60 soil samples for the study.

## 2.4 Sample Processing

The collected soil samples were air-dried in the shade, gently crushed using a wooden mallet, and passed through a 2-mm sieve to remove debris and stones. The processed soil samples were stored in labelled polythene bags for laboratory analysis.

## 2.5 Soil Analysis

The processed soil samples were analysed for physicochemical properties and soil fertility parameters following standard analytical procedures. Soil reaction (pH) and electrical conductivity (EC) were determined in a 1:2.5 soil-to-water suspension using a digital pH meter and an EC meter, respectively. Soil organic carbon (OC) content was estimated using the Walkley–Black wet oxidation method. Available nitrogen was determined using the alkaline permanganate method, available phosphorus ($P_2O_5$) using the Olsen method, and available potassium ($K_2O$) by extraction with neutral normal ammonium acetate followed by flame photometry (Singh *et al.*, 2021).

## 2.6 Statistical Analysis

The data on soil physicochemical properties and nutrient status were summarised for the three organic farming duration groups. Mean values and ranges were compared descriptively to evaluate differences in soil nutrient status among the groups.

# 3. Results and Discussion

## 3.1 Soil Reaction (pH)

Soil pH across the organic farming duration groups remained within a neutral to slightly alkaline range, which is favourable for nutrient availability and microbial activity. During the initial two years of organic farming, pH ranged from 6.23 to 7.98, with a mean of 7.38. In the 2–5-year and >5-year groups, the mean pH values stabilised at 7.33 and 7.34, respectively. This stability may indicate that the continuous application of organic manures and residues buffered soil reaction by moderating acidity and excessive alkalinity. Organic inputs release organic acids during decomposition, which can help regulate soil pH over time. Similar buffering effects under organic farming were reported by Bulluck *et al.* (2002), Gosling and Shepherd (2005), Mäder *et al.* (2002), and Singh *et al.* (2021).

## 3.2 Electrical Conductivity (EC)

Electrical conductivity values were low across all soils, indicating non-saline conditions. Mean EC decreased progressively from 0.35 dS $m^{-1}$ during the first two years to 0.28 dS $m^{-1}$ after 2–5 years and 0.25 dS $m^{-1}$ after more than 5 years of organic management. The reduction in EC with the duration of organic farming may reflect improved soil aggregation and permeability, which facilitate salt leaching. In addition, the absence of chemical fertilisers in organic systems limits salt inputs. These results are consistent with the findings of Drinkwater *et al.* (1995) and Malarkodi *et al.* (2019), who observed lower salinity under long-term organic nutrient management.

### 3.3 Soil Organic Carbon (OC)

Soil organic carbon content showed a consistent increasing trend with the duration of organic farming. Mean OC increased from 0.32% during the first two years to 0.33% after 2–5 years and 0.34% after more than 5 years. Although the increase was gradual, it was consistent with progressive carbon accumulation over time. The build-up of OC may be attributed to regular additions of farmyard manure, compost, crop residues, and biological inputs, which enhance microbial biomass and humus formation. Long-term organic farming is widely recognised for improving soil carbon stocks and soil quality. Similar trends were reported by Ghosh *et al.* (2018), Lal (2004), Panwar *et al.* (2022), and Reganold and Wachter (2016).

**Table 1. Chemical compositions of organic farming soils in the first two years**

| Latitude | Longitude | pH | EC (dS $m^{-1}$) | OC (%) | N | $P_2O_5$ | $K_2O$ |
|---|---|---|---|---|---|---|---|
| | | | | | | kg $ha^{-1}$ | |
| 15° 30' 39.10" | 78° 32' 36.24" | 7.25 | 0.17 | 0.38 | 266 | 45.3 | 378 |
| 15° 31' 10.10" | 78° 30' 8.27" | 7.84 | 0.87 | 0.29 | 238 | 76.1 | 285 |
| 15° 34' 14.26" | 78° 31' 41.23" | 7.4 | 0.26 | 0.36 | 258 | 52.2 | 348 |
| 15° 34' 16.73" | 78° 33' 28.25" | 7.56 | 0.26 | 0.34 | 252 | 61.2 | 325 |
| 15° 33' 15.24" | 78° 32' 11.30" | 6.23 | 0.27 | 0.36 | 256 | 56.1 | 287 |
| 15° 26' 33.73" | 78° 32' 27.28" | 6.89 | 0.38 | 0.32 | 244 | 65.2 | 285 |
| 15° 28' 36.26" | 78° 31' 13.47" | 7.64 | 0.25 | 0.33 | 248 | 72.3 | 308 |
| 15° 35' 48.32" | 78° 33' 53.58" | 7.32 | 0.44 | 0.3 | 235 | 80.2 | 285 |
| 15° 30' 39.35" | 78° 33' 13.14" | 7.52 | 0.37 | 0.28 | 228 | 56.2 | 285 |
| 15° 26' 17.25" | 78° 32' 36.74" | 7.86 | 0.35 | 0.36 | 262 | 84.0 | 385 |
| 15° 27' 28.25" | 78° 30' 23.41" | 7.32 | 0.39 | 0.31 | 242 | 55.3 | 233 |
| 15° 26' 18.16" | 78° 32' 08.38" | 7.24 | 0.42 | 0.28 | 226 | 44.8 | 308 |
| 15° 18' 20.75" | 78° 16' 12.36" | 7.65 | 0.19 | 0.38 | 268 | 65.3 | 275 |
| 15° 21' 18.36" | 78° 13' 24.18" | 7.98 | 0.49 | 0.33 | 246 | 42.3 | 245 |
| 15° 16' 59.03" | 78° 14' 57.32" | 7.25 | 0.16 | 0.27 | 220 | 59.7 | 302 |
| 15° 16' 10.28 " | 78° 15' 19.34" | 7.41 | 0.32 | 0.36 | 260 | 36.7 | 296 |
| 15° 27' 44.33" | 78° 26' 28.38" | 7.51 | 0.24 | 0.29 | 234 | 75.0 | 287 |
| 15° 30' 36.38" | 78° 21' 16.28" | 7.01 | 0.23 | 0.27 | 222 | 66.3 | 306 |
| 15° 30' 35.36" | 78° 22' 38.30" | 7.32 | 0.69 | 0.35 | 254 | 51.4 | 285 |
| 15° 34' 20.41" | 78° 32' 20.17" | 7.38 | 0.26 | 0.33 | 250 | 82.0 | 423 |
| Range | | 6.23-7.98 | 0.15-0.86 | 0.27-0.38 | 220-268 | 36.7-84.0 | 233-423 |
| Mean | | 7.38 | 0.35 | 0.32 | 245 | 61.4 | 307 |

### 3.4 Available Nitrogen (N)

Available nitrogen content increased with the duration of organic farming. Mean available N increased from 245 kg $ha^{-1}$ during the initial two years to 266 kg $ha^{-1}$ after 2–5 years and remained comparatively high at 260 kg $ha^{-1}$ in soils managed organically for more than 5 years. These higher values may be associated with enhanced mineralisation of organic nitrogen, increased microbial activity, and improved nitrogen retention resulting from better soil structure and organic matter content. The results align with the findings of Watson *et al.* (2002), Drinkwater and Snapp (2007), and Sharma *et al.* (2026), who reported higher and more stable nitrogen availability in organically managed soils.

### 3.5 Available Phosphorus ($P_2O_5$)

Mean available $P_2O_5$ did not show a consistent increasing trend with the duration of organic farming. The mean value was 61.4 kg $ha^{-1}$ during the first two years, decreased to 45.3 kg $ha^{-1}$ after 2–5 years, and was 46.2 kg $ha^{-1}$ after more than 5 years. Organic manures and composts release organic acids during decomposition, which can solubilise native and fixed phosphorus and thereby enhance its availability. Increased microbial activity and phosphatase enzymes may also contribute to phosphorus mobilisation. These processes have been discussed by Gyaneshwar *et al.* (2002), Khambalkar *et al.* (2025), and Kumawat *et al.* (2023).

**Table 2. Chemical compositions of organic farming soils in the 2-5 years**

| Latitude | Longitude | pH | EC (dS $m^{-1}$) | OC (%) | N | $P_2O_5$ | $K_2O$ |
|---|---|---|---|---|---|---|---|
| | | | | | kg $ha^{-1}$ | | |
| 15° 35' 25.23" | 78° 32' 20.38" | 7.35 | 0.25 | 0.24 | 240 | 43.5 | 312 |
| 15° 27' 40.32" | 78° 32' 27.21" | 7.92 | 0.64 | 0.34 | 272 | 33.1 | 258 |
| 15° 28' 11.31" | 78° 33' 30.47" | 7.34 | 0.23 | 0.33 | 268 | 50.6 | 312 |
| 15° 27' 36.75" | 78° 32' 55.28" | 7.68 | 0.17 | 0.32 | 265 | 48.3 | 278 |
| 15° 19' 22.10" | 78° 31' 10.18" | 7.08 | 0.20 | 0.37 | 285 | 53.7 | 308 |
| 15° 26' 20.42" | 78° 31' 15.14" | 7.47 | 0.19 | 0.28 | 252 | 42.8 | 347 |
| 15° 18' 36.17" | 78° 30' 40.39" | 7.58 | 0.15 | 0.34 | 270 | 31.9 | 258 |
| 15° 28' 32.13" | 78° 26' 39.47" | 7.05 | 0.14 | 0.33 | 266 | 53.4 | 368 |
| 15° 27' 33.28" | 78° 30' 33.41" | 7.66 | 0.16 | 0.32 | 262 | 72.1 | 410 |
| 15° 37' 1.89" | 78° 34' 16.86" | 7.13 | 0.41 | 0.38 | 288 | 36.8 | 285 |
| 15° 34' 13.19" | 78° 34' 13.19" | 7.02 | 0.72 | 0.34 | 274 | 42.1 | 308 |
| 15° 37' 2.52" | 78° 33' 37.97" | 7.65 | 0.27 | 0.31 | 258 | 52.3 | 269 |
| 15° 37' 3.61" | 78° 33' 46.10" | 7.87 | 0.19 | 0.28 | 250 | 43.8 | 274 |
| 15° 35' 24.90" | 78° 33' 26.12" | 7.12 | 0.21 | 0.3 | 255 | 60.8 | 308 |
| 15° 31' 58.18" | 78° 34' 46.58" | 7.35 | 0.48 | 0.36 | 282 | 55.3 | 310 |
| 15° 39' 19.33" | 78° 35' 18.57" | 7.12 | 0.16 | 0.34 | 270 | 40.7 | 342 |
| 15° 39' 28.09" | 78° 35' 6.94" | 7.20 | 0.22 | 0.34 | 268 | 33.8 | 285 |
| 15° 31' 42.22" | 78° 57' 55.44" | 7.00 | 0.21 | 0.35 | 276 | 41.7 | 302 |
| 15° 36' 24.68" | 78° 33' 22.46" | 6.35 | 0.20 | 0.32 | 260 | 38.6 | 263 |
| 15° 31' 57.15" | 78° 35' 11.4" | 7.75 | 0.35 | 0.31 | 258 | 30.5 | 284 |
| Range | | 6.35 7.92 | 0.14 - 0.72 | 0.24 -0.38 | 240-288 | 30.5 - 72.1 | 258-410 |
| Mean | | 7.33 | 0.28 | 0.33 | 266 | 45.3 | 304 |

**Table 3. Chemical compositions of organic farming soils in the > 5 years**

| Latitude | Longitude | pH | EC (dS $m^{-1}$) | OC (%) | N | $P_2O_5$ | $K_2O$ |
|---|---|---|---|---|---|---|---|
| | | | | | kg $ha^{-1}$ | | |
| 15° 38' 54.29" | 78° 35' 36.12" | 7.18 | 0.55 | 0.37 | 270 | 28.4 | 318 |
| 15° 39' 4.58" | 78° 35' 32.48" | 7.24 | 0.47 | 0.33 | 258 | 33.6 | 292 |
| 15° 32' 26.79" | 78° 34' 18.98" | 7.53 | 0.23 | 0.27 | 238 | 56.2 | 364 |
| 15° 31' 40.87" | 78° 35' 6.33" | 7.45 | 0.16 | 0.36 | 268 | 28.9 | 265 |
| 15° 38' 55.93" | 78° 35' 32.91" | 7.5 | 0.2 | 0.34 | 262 | 63.7 | 328 |
| 15° 31' 38.59" | 78° 34' 45.35" | 7.54 | 0.18 | 0.32 | 254 | 48.3 | 263 |
| 15° 36' 22.69" | 78° 33' 4.60" | 7.8 | 0.08 | 0.29 | 246 | 36.9 | 314 |
| 15° 34' 1.87" | 78° 37' 8.38" | 6.58 | 0.15 | 0.34 | 260 | 68.4 | 320 |
| 15° 38' 50.52" | 78° 35' 57.61" | 7.3 | 0.19 | 0.37 | 272 | 38.2 | 305 |
| 15° 29' 16.11" | 78° 35' 31.45" | 7.12 | 0.26 | 0.29 | 248 | 61.5 | 268 |
| 15° 34' 40.95" | 78° 29' 40.75" | 7.26 | 0.87 | 0.33 | 256 | 43.2 | 246 |
| 15° 34' 40.95" | 78° 29' 40.29" | 7.15 | 0.26 | 0.31 | 252 | 66.8 | 378 |
| 15° 31' 39.52" | 78° 34' 39.97" | 7.03 | 0.18 | 0.37 | 274 | 38.6 | 362 |
| 15° 34' 44.55" | 78° 35' 43.53" | 7.5 | 0.26 | 0.33 | 258 | 42.5 | 289 |
| 15° 31' 54.23" | 78° 35' 10.39" | 7.63 | 0.12 | 0.29 | 246 | 38.6 | 320 |
| 15° 31' 50.08" | 78° 35' 12.68" | 7.40 | 0.24 | 0.41 | 276 | 50.4 | 385 |
| 15° 38' 53.43" | 78° 35' 37.01" | 7.45 | 0.16 | 0.37 | 270 | 43.6 | 314 |
| 15° 34' 9.43" | 78° 34' 44.53" | 7.24 | 0.18 | 0.33 | 258 | 55.8 | 287 |
| 15° 34' 37.35" | 78° 29' 40.29" | 7.16 | 0.12 | 0.34 | 262 | 37.6 | 302 |
| 15° 35' 25.78" | 78° 32' 53.34" | 7.76 | 0.09 | 0.36 | 268 | 43.4 | 296 |
| Range | | 6.58 -7.8 | 0.08 - 0.87 | 0.27 - 0.41 | 236-276 | 28.4 - 68.4 | 246 - 385 |
| Mean | | 7.34 | 0.25 | 0.34 | 260 | 46.2 | 311 |

### 3.6 Available Potassium ($K_2O$)

Available potassium levels remained consistently high across all organic farming duration groups. Mean $K_2O$ values were 307, 304, and 311 kg ha$^{-1}$ during the first two years, after 2–5 years, and after more than 5 years, respectively. The slightly higher K level in the longest-duration group may be related to the continuous recycling of crop residues and the application of organic manures rich in potassium. Organic matter may also reduce potassium fixation and improve its exchangeability. Similar observations were reported by Inwati *et al.* (2022), Srivastava *et al.* (2024), and Yadav and Kumar (2009) under organic and integrated nutrient-management systems.

## 4. Conclusion

The present study showed that the duration of organic farming was associated with differences in selected soil physicochemical properties and nutrient status. Soil pH remained within a neutral to slightly alkaline range across all duration groups, while electrical conductivity decreased as the duration of organic management increased. Soil organic carbon showed a small but consistent increase, and available nitrogen was higher in the 2–5-year group and remained comparatively high in fields managed organically for more than 5 years. Available potassium also remained consistently high across the three groups. In contrast, available phosphorus did not increase progressively; its mean value was highest during the first two years and lower in both longer-duration groups. Overall, the descriptive findings suggest that longer organic management was associated with lower salinity, slightly higher soil organic carbon, and comparatively high nitrogen and potassium availability in the sampled farmers' fields. However, the observed differences should be interpreted within the context of the surveyed fields and should not be attributed solely to the duration of organic farming.

## 5. Limitations

This study used a cross-sectional survey of 60 farmers' fields grouped by the duration of organic management. It did not include a conventional-farming control, repeated measurements of the same fields, or detailed records of organic inputs, crop history, irrigation, and other management factors. Consequently, the observed differences cannot be attributed solely to the duration of organic farming, and the findings should be interpreted as descriptive and specific to the sampled fields in Nandyal district.

## Declaration of AI Use

This manuscript was prepared through the combined contributions of all author(s), including contributions to the study design, data, content development, results, interpretation, and related scholarly work. The author(s) acknowledge the use of Grammarly and ChatGPT to assist with grammar checking, language refinement, reference formatting. These AI-assisted tools were not used as authors and did not replace the intellectual contributions or scholarly judgment of the author(s). All AI-assisted outputs, including content, references, and interpretations, were carefully reviewed, revised, verified, and approved by the author(s). The author(s) accept full responsibility for the accuracy, integrity, and final content of the manuscript.

## Competing Interests

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

## References

Bhowmik, A., Fortuna, A. M., Cihacek, L. J., Bary, A. I., Carr, P. M., & Cogger, C. G. (2017). Potential carbon sequestration and nitrogen cycling in long-term organic management systems. *Renewable Agriculture and Food Systems, 32*(6), 498–510. https://doi.org/10.1017/S1742170516000429

Bulluck, L. R., Brosius, M., Evanylo, G. K., & Ristaino, J. B. (2002). Organic and synthetic fertility amendments influence soil microbial, physical and chemical properties on organic and conventional farms. *Applied Soil Ecology, 19*(2), 147–160. https://doi.org/10.1016/S0929-1393(01)00187-1

Das, B., Pooniya, V., Shivay, Y. S., Zhiipao, R. R., Biswakarma, N., Kumar, D., Saikia, N., Kumar, A., Govindasamy, P., Barman, A., & Critykar, J. (2024). Twenty-one years' impact of using organic amendments on the productivity of rice–wheat rotation and soil properties. *Field Crops Research, 309*, Article 109311. https://doi.org/10.1016/j.fcr.2024.109311

Drinkwater, L. E., & Snapp, S. S. (2007). Nutrients in agroecosystems: Rethinking the management paradigm. *Advances in Agronomy, 92*, 163–186. https://doi.org/10.1016/S0065-2113(04)92003-2

Drinkwater, L. E., Letourneau, D. K., Workneh, F., van Bruggen, A. H. C., & Shennan, C. (1995). Fundamental differences between conventional and organic tomato agroecosystems in California. *Ecological Applications, 5*(4), 1098–1112. https://doi.org/10.2307/2269357

Ghosh, A., Bhattacharyya, R., Meena, M. C., Dwivedi, B. S., Singh, G., Agnihotri, R., & Sharma, C. (2018). Long-term fertilization effects on soil organic carbon sequestration in an Inceptisol. *Soil and Tillage Research, 177*, 134–144. https://doi.org/10.1016/j.still.2017.12.006

Gosling, P., & Shepherd, M. A. (2005). Long-term changes in soil fertility in organic arable farming systems in England, with particular reference to phosphorus and potassium. *Agriculture, Ecosystems & Environment, 105*(1–2), 425–432. https://doi.org/10.1016/j.agee.2004.03.007

Gyaneshwar, P., Naresh Kumar, G., Parekh, L. J., & Poole, P. S. (2002). Role of soil microorganisms in improving P nutrition of plants. *Plant and Soil, 245*(1), 83–93. https://doi.org/10.1023/A:1020663916259

Hlaing, T., Moe, K., Kyaw, E. H., Ngwe, K., Hlaing, M. M., & Oo, H. H. (2025). Green manuring enhances nitrogen use efficiency of rice and soil nutrient contents of paddy soil. *Asian Research Journal of Current Science, 7*(1), 288–300. https://doi.org/10.56557/arjocs/2025/v7i1151

Inwati, D. K., Dixit, B. K., Dwivedi, B. S., Thakur, R., Sharma, A., & Singh, V. (2022). Effect of long-term fertilizer and FYM application on soil potassium fractions in a Vertisol under soybean–wheat cropping system. *The Pharma Innovation Journal, 11*(8), 2089–2093. https://www.thepharmajournal.com/archives/?ArticleId=15146&issue=8&vol=11&year=2022

Khambalkar, P. A., Agrawal, S., Dhaliwal, S. S., Yadav, S. S., Sadawarti, M. J., Singh, A., Yadav, I. R., Yadav, K., Shivansh, Prasad, D., Singh, A., & Afreen, N. (2025). Sustainable nutrient management: Balancing soil health and food security for future generations. *Applied Food Research, 5*(2), Article 101087. https://doi.org/10.1016/j.afres.2025.101087

Kumawat, S., Kharia, S. K., Yadav, S. R., Shekhawat, P. S., Sharma, Y., Kumawat, S., & Yadav, B. (2023). Impact of long-term nutrient management on carbon dynamics under a cluster bean–wheat cropping system in Western Rajasthan, India. *International Journal of Plant & Soil Science, 35*(20), 788–800. https://doi.org/10.9734/ijpss/2023/v35i203871

Lal, R. (2004). Soil carbon sequestration to mitigate climate change. *Geoderma, 123*(1–2), 1–22. https://doi.org/10.1016/j.geoderma.2004.01.032

Mäder, P., Fliessbach, A., Dubois, D., Gunst, L., Fried, P., & Niggli, U. (2002). Soil fertility and biodiversity in organic farming. *Science, 296*(5573), 1694–1697. https://doi.org/10.1126/science.1071148

Malarkodi, M., Elayarajan, M., Arulmozhiselvan, K., & Gokila, B. (2019). Long-term impact of fertilizers and manures on crop productivity and soil fertility in an Alfisol. *The Pharma Innovation Journal, 8*(7), 252–256. https://www.thepharmajournal.com/archives/?ArticleId=3782&issue=7&vol=8&year=2019

Mihelič, R., Pintarič, S., Eler, K., & Suhadolc, M. (2024). Effects of transitioning from conventional to organic farming on soil organic carbon and microbial community: A comparison of long-term non-inversion minimum tillage and conventional tillage. *Biology and Fertility of Soils, 60*(3), 341–355. https://doi.org/10.1007/s00374-024-01796-y

Mithlesh, Singh, S., Singh, L., & Kaur, S. (2019). Effects of long-term organic and conventional farming on physical and chemical properties of soil. *Journal of Krishi Vigyan, 7*(2), 104–109. https://doi.org/10.5958/2349-4433.2019.00018.7

Palm, C. A., Gachengo, C. N., Delve, R. J., Cadisch, G., & Giller, K. E. (2001). Organic inputs for soil fertility management in tropical agroecosystems: Application of an organic resource database. *Agriculture, Ecosystems & Environment, 83*(1–2), 27–42. https://doi.org/10.1016/S0167-8809(00)00267-X

Panwar, A. S., Ansari, M. A., Ravisankar, N., Babu, S., Prusty, A. K., Ghasal, P. C., Choudhary, J., Shamim, M., Singh, R., Raghavendra, K. J., Dutta, D., Meena, A. L., Chauhan, G. V., Ansari, M. H., Singh, R., Aulakh, C. S., Singh, D. K., & Sharma, P. B. (2022). Effect of organic farming on the restoration of soil quality, ecosystem services, and productivity in rice–wheat agro-ecosystems. *Frontiers in Environmental Science, 10*, Article 972394. https://doi.org/10.3389/fenvs.2022.972394

Reganold, J. P., & Wachter, J. M. (2016). Organic agriculture in the twenty-first century. *Nature Plants, 2*, Article 15221. https://doi.org/10.1038/nplants.2015.221

Sharma, S., Ghosh, T., Gupta, N., & Walia, S. S. (2026). Long-term effects of integrated organic and inorganic fertilization on soil properties, nutrient use efficiency, and crop yield in a rice–wheat system. *Frontiers in Soil Science, 6*, Article 1869636. https://doi.org/10.3389/fsoil.2026.1869636

Singh, N. K., Sachan, K., Ranjitha, G., Chandana, S., Manoj, B. P., Panotra, N., & Katiyar, D. (2024). Building soil health and fertility through organic amendments and practices: A review. *Asian Journal of Soil Science and Plant Nutrition, 10*(1), 175–197. https://doi.org/10.9734/ajsspn/2024/v10i1224

Singh, R., Babu, S., Avasthe, R. K., Das, A., Praharaj, C. S., Layek, J., Kumar, A., Rathore, S. S., Kancheti, M., Kumar, S., Yadav, S. K., & Pashte, V. (2021). Organic farming in North-East India: Status and strategies. *Indian Journal of Agronomy, 66*(5th IAC Special Issue), S163–S179.

Srivastava, R. K., Purohit, S., Alam, E., & Islam, M. K. (2024). Advancements in soil management: Optimizing crop production through interdisciplinary approaches. *Journal of Agriculture and Food Research, 18*, Article 101528. https://doi.org/10.1016/j.jafr.2024.101528

Watson, C. A., Atkinson, D., Gosling, P., Jackson, L. R., & Rayns, F. W. (2002). Managing soil fertility in organic farming systems. *Soil Use and Management, 18*(S1), 239–247. https://doi.org/10.1111/j.1475-2743.2002.tb00265.x

Yadav, D. S., & Kumar, A. (2009). Long-term effect of nutrient management on soil health and productivity of rice (*Oryza sativa*)–wheat (*Triticum aestivum*) system. *Indian Journal of Agronomy, 54*(1), 15–23.



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