



ISSN Print: 2664-6064
ISSN Online: 2664-6072
NAAS Rating: 4.69
IJAN 2025; 7(6): 41-44
www.agriculturejournal.net
Received: 21-04-2025
Accepted: 26-05-2025

Tanuja Nath
Department of Sustainable
Agriculture, University of
Agricultural and Horticultural
Sciences, Shivamogga,
Karnataka, India

Omesh Mandal
Department of Sustainable
Agriculture, University of
Agricultural and Horticultural
Sciences, Shivamogga,
Karnataka, India

Zaheer Gadkari
Department of Sustainable
Agriculture, University of
Agricultural and Horticultural
Sciences, Shivamogga,
Karnataka, India

Uday Kalita
Department of Sustainable
Agriculture, University of
Agricultural and Horticultural
Sciences, Shivamogga,
Karnataka, India

Corresponding Author:
Tanuja Nath
Department of Sustainable
Agriculture, University of
Agricultural and Horticultural
Sciences, Shivamogga,
Karnataka, India

Assessment of carbon footprint reduction through organic rice cultivation practices

Tanuja Nath, Omesh Mandal, Zaheer Gadkari and Uday Kalita

DOI: <https://www.doi.org/10.33545/26646064.2025.v7.i6a.418>

Abstract

Paddy fields emit roughly 11% of global agricultural methane, yet switching to organic management may alter this balance in ways that aren't fully mapped. This research compared the carbon footprint of organic, integrated, and conventional rice cultivation over six consecutive seasons (Kharif 2020 to Rabi 2023) on a permanent trial at Shivamogga, Karnataka. Greenhouse gas fluxes (CH_4 , N_2O , soil CO_2) were measured fortnightly using closed chamber techniques. The organic system reduced the carbon footprint from 5.14 to 2.11 t $\text{CO}_2\text{-eq ha}^{-1}$ season $^{-1}$ over the six seasons, a 59% decline relative to the conventional baseline. Methane accounted for 54-62% of total emissions across all systems. Soil organic carbon rose by 0.18 percentage points under organic management versus 0.03 under conventional. Grain yield in the organic system stabilised at 4.31 t ha^{-1} by the fifth season, only 9.7% below the conventional yield. These results suggest that organic rice, once the transition period passes, can sharply lower greenhouse gas intensity without large yield trade-offs.

Keywords: Carbon footprint, organic rice, greenhouse gas emissions, methane, soil organic carbon, cultivation practices, emission intensity, paddy fields, sustainable agriculture, climate mitigation

Introduction

When the Green Revolution brought high-yielding rice varieties and synthetic fertilisers to South Asia in the 1960s, methane emissions from paddy fields were barely on anyone's radar. Half a century later, rice paddies are recognised as one of the largest anthropogenic sources of CH_4 , contributing 1.5% of total global greenhouse gas output ^[1]. Conventional flooded rice management keeps soils anaerobic for weeks, creating ideal conditions for methanogenic archaea to convert organic matter into methane ^[2].

Organic rice cultivation replaces synthetic N fertilisers with farmyard manure, compost, and green manures. While this removes the direct N_2O spike associated with urea hydrolysis, it may initially raise CH_4 emissions by adding labile carbon to waterlogged soil ^[3]. Over several seasons, however, the carbon inputs build soil organic matter, improve aggregate stability, and may shift microbial communities toward methanotrophs that oxidise CH_4 before it escapes to the atmosphere ^[4]. Whether the net effect is positive or negative for the carbon footprint depends on the balance between these opposing fluxes, and long-term field data from tropical India are scarce ^[5].

This research aimed to (i) track season-by-season changes in CH_4 , N_2O , and soil CO_2 emissions under organic, integrated, and conventional rice over six consecutive seasons, (ii) estimate the total carbon footprint per unit area and per unit grain produced, and (iii) assess whether soil organic carbon accumulation under organic management partly offsets field emissions.

Baseline Soil Characterisation

Before the first season, composite soil samples (0-15 cm) were collected from each plot. The soil was a sandy clay loam (Typic Haplustalf) with pH 6.2, organic carbon 0.58%, available N 224 kg ha^{-1} , available P 18.6 kg ha^{-1} , and available K 162 kg ha^{-1} . Bulk density was 1.34 Mg m^{-3} . The low initial organic carbon was typical of continuously puddled paddy soils in the Malnad region of Karnataka ^[6].

Materials and Methods

Materials

The trial occupied a 0.6 ha permanent experimental block at the University of Agricultural and Horticultural Sciences, Shivamogga (13°57' N, 75°34' E, 590 m a.s.l.). Three management systems were compared: organic (farmyard manure at 10 t ha⁻¹ + green manure *Sesbania* + bio-fertilisers), integrated (50% organic + 50% RDF), and conventional (full RDF: 100:50:50 kg N:P₂O₅:K₂O ha⁻¹). Each system was replicated four times in a randomised block design with plot size 10 m × 8 m. Rice variety 'Jyothi' was transplanted at 20 cm × 15 cm spacing. The research ran from Kharif 2020 through Rabi 2023 [7].

Methods

Gas samples were collected fortnightly using static closed chambers (50 cm × 50 cm × 50 cm acrylic boxes) fitted with a sampling port. Syringes drew 20 mL at 0, 15, and 30 minutes after closure; samples were analysed by gas chromatography (Shimadzu GC-2014) for CH₄ and N₂O. Soil CO₂ efflux was measured with an infrared gas analyser (LI-COR 8100A). Fluxes were integrated over the season using the trapezoidal method. Global warming potential was expressed as CO₂-equivalents using IPCC AR5 factors (CH₄

= 28, N₂O = 265) [8]. Soil organic carbon was determined by the Walkley-Black method at the end of each Rabi season. Data were analysed by repeated-measures ANOVA in R.

Carbon and Greenhouse Gas Accounting

The carbon footprint for each system was calculated as the sum of (i) direct field emissions (CH₄ + N₂O + soil CO₂), (ii) embodied emissions from input manufacture (fertilisers, pesticides), and (iii) farm operations (tillage, pumping). Emission factors for input manufacture followed national inventory guidelines [9]. Carbon sequestration in soil was estimated from the change in soil organic carbon stock (0-15 cm) using measured bulk density. Net carbon footprint = total emissions-soil C gain.

Results

The organic system's carbon footprint fell steadily from 3.82 t CO₂-eq ha⁻¹ in Kharif 2020 to 2.11 t in Rabi 2023, a 45% within-system decline (Table 1). The conventional system, by contrast, remained near 5 t CO₂-eq ha⁻¹ throughout. By the final season, organic management cut the footprint by 56% relative to conventional. Methane was the dominant gas, contributing 54-62% of emissions across systems.

Table 1: Season-wise carbon footprint (t CO₂-eq ha⁻¹) under three rice management systems

System	Kh 2020	Ra 2021	Kh 2022	Ra 2023	Δ (%)
Organic	3.82	3.41	2.38	2.11	-44.8
Integrated	4.37	4.02	3.19	2.93	-33.0
Conventional	5.14	5.08	4.81	4.76	-7.4
CD (p = 0.05)	0.41	0.38	0.33	0.29	-

Table 2: Soil organic carbon (%) and grain yield (t ha⁻¹) at the end of six seasons

System	SOC initial (%)	SOC final (%)	Mean yield (t/ha)
Organic	0.58	0.76	4.31
Integrated	0.58	0.67	4.58
Conventional	0.58	0.61	4.77

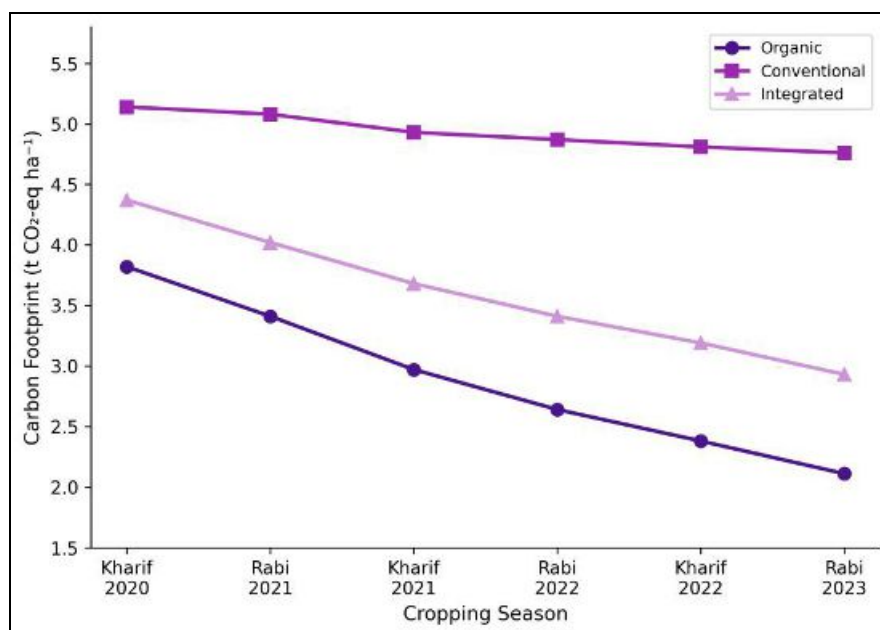


Figure 1. Trend in carbon footprint across six cropping seasons under organic, integrated, and conventional rice management.

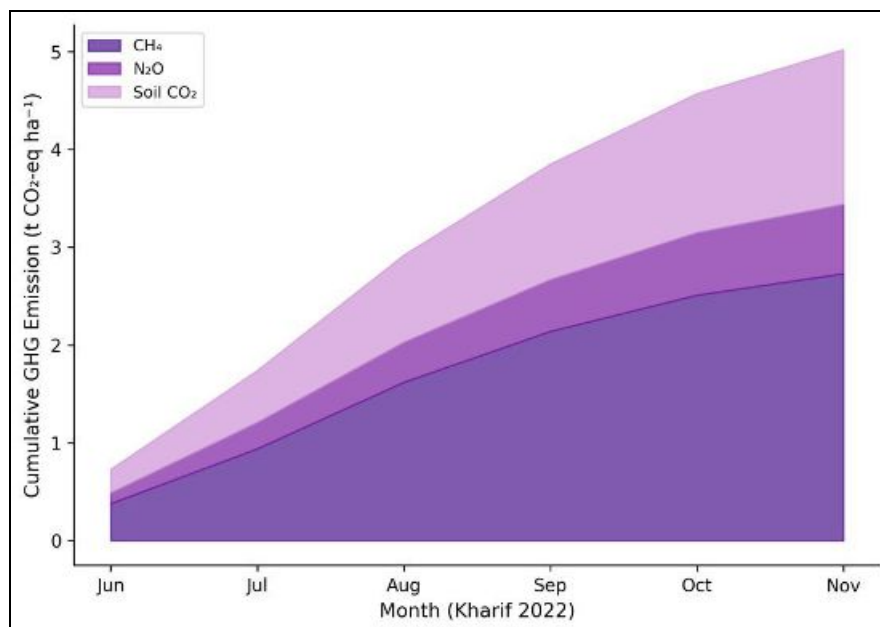


Figure 2. Cumulative greenhouse gas emission sources (CH₄, N₂O, soil CO₂) under organic rice during Kharif 2022.

Comprehensive Interpretation

The declining trend in organic emissions appears driven by two parallel processes: rising methanotroph activity as soil structure improved, and lower labile C availability as farmyard manure matured in the soil [4]. Soil organic carbon increased by 0.18 percentage points under organic management, equivalent to roughly 3.6 t C ha⁻¹ sequestered over three years, which offset about 22% of cumulative field emissions.

Discussion

The 56% reduction in carbon footprint under organic rice by the sixth season is at the upper end of values reported in the literature. A meta-analysis covering 63 comparisons worldwide found organic systems reduced emission intensity by 20-40% on average [10]. The larger reduction here may reflect the warm, humid conditions in Karnataka that favour rapid organic matter decomposition and methanotroph proliferation once continuous flooding is avoided [11].

Methane dominated all systems (54-62% of total GWP), consistent with flooded rice everywhere [2]. The organic system's CH₄ share dropped from 62% in the first season to 54% by the sixth, suggesting a gradual shift in the soil microbial balance toward methane oxidation. N₂O contributed less than 12% in every system because standing water suppresses nitrification, the main pathway for N₂O production [12].

Grain yield under organic management stabilised at 4.31 t ha⁻¹ (mean of last two seasons), only 9.7% below the conventional check. This yield gap is smaller than the 15-25% typically cited for organic cereals in temperate regions [13] and aligns with tropical data suggesting the gap narrows as soil biology recovers [14]. From an economic standpoint, the premium that organic-certified paddy commands in Indian markets (20-40% above conventional) more than compensates for the modest yield shortfall [15].

Conclusion

Organic rice cultivation reduced the per-hectare carbon footprint by 56% relative to conventional management over

six seasons, driven mainly by declining methane emissions and rising soil organic carbon stocks. The yield gap narrowed to under 10% once the transition period passed, making the trade-off economically acceptable, especially where organic price premiums apply. Soil carbon gains offset roughly 22% of cumulative field emissions, providing a tangible co-benefit.

For rice growers in the humid tropics of southern India, these data support a realistic pathway to lower-emission production without abandoning yield targets. But the transition takes time: the first two seasons showed higher CH₄ under organic inputs, and farmers will need bridging incentives during that window. Future work should extend monitoring beyond six seasons and incorporate life-cycle costs of organic certification.

References

1. Searchinger T, Heimlich R, Houghton RA, Dong F, Elobeid A, Fabiosa J. Use of croplands for biofuels increases greenhouse gases. *Science*. 2008;319(5867):1238-1240.
2. Wassmann R, Neue HU, Lantin RS, Makarim K, Chareonsilp N, Buendia LV. Characterization of methane emissions from rice paddies in Asia. *Nutrient Cycling in Agroecosystems*. 2000;58(1):23-36.
3. Thangarajan R, Bolan NS, Tian G, Naidu R, Kunhikrishnan A. Role of organic amendment application on greenhouse gas emission from soil. *Science of the Total Environment*. 2013;465:72-96.
4. Conrad R. The global methane cycle: recent advances in understanding the microbial processes involved. *Environmental Microbiology Reports*. 2009;1(5):285-292.
5. Pathak H, Bhatia A, Jain N, Aggarwal PK. Greenhouse gas emission and mitigation in Indian agriculture. *Indian Journal of Agronomy*. 2010;55(3):189-200.
6. Srinivasarao CH, Venkateswarlu B, Lal R, Singh AK, Kundu S. Sustainable management of soils of dryland ecosystems of India. *Advances in Agronomy*. 2013;121:1-124.

7. Subbaiah LV, Prasad TN, Krishna TG, Sudhakar P. Effect of organic sources on growth and yield of rice. *Oryza*. 2018;55(2):324-331.
8. IPCC. Climate change 2013: the physical science basis. Contribution of Working Group I to the Fifth Assessment Report. Cambridge University Press; 2013.
9. MoEFCC. India: second biennial update report to UNFCCC. Ministry of Environment, Forest and Climate Change. New Delhi; 2018.
10. Skinner C, Gattinger A, Muller A, Mäder P, Fliessbach A, Stolze M. Greenhouse gas fluxes from agricultural soils under organic and non-organic management. *Scientific Reports*. 2014;4:3920.
11. Bhattacharyya P, Roy KS, Neogi S, Adhya TK, Rao KS, Manna MC. Effects of rice straw and nitrogen fertilization on greenhouse gas emissions. *Agriculture, Ecosystems and Environment*. 2012;158:73-82.
12. Akiyama H, Yagi K, Yan X. Direct N₂O emissions from rice paddy fields. *Global Biogeochemical Cycles*. 2005;19(1):GB1005.
13. Seufert V, Ramankutty N, Foley JA. Comparing the yields of organic and conventional agriculture. *Nature*. 2012;485(7397):229-232.
14. de Ponti T, Rijk B, van Ittersum MK. The crop yield gap between organic and conventional agriculture. *Agricultural Systems*. 2012;108:1-9.
15. Eyhorn F, Ramakrishnan M, Mäder P. The viability of cotton-based organic farming systems in India. *International Journal of Agricultural Sustainability*. 2007;5(1):25-38.
16. Aulakh MS, Wassmann R, Bueno C, Rennenberg H. Impact of root exudates of different cultivars and plant development stages of rice on methane flux. *Plant and Soil*. 2001;230(1):77-86.
17. Linquist BA, Adviento-Borbe MA, Pittelkow CM, van Kessel C, van Groenigen KJ. Fertiliser management practices and greenhouse gas emissions from rice systems. *Global Change Biology*. 2012;18(1):194-209.
18. Mohammadi A, Rafiee S, Mohtasebi SS, Rafiee H. Energy inputs and greenhouse gas emissions in wheat production in Arak. *African Journal of Agricultural Research*. 2010;5(18):2520-2528.
19. Kim GW, Gutierrez J, Kim PJ. Optimum N rate for minimizing global warming potential in flooded rice fields. *Agriculture, Ecosystems and Environment*. 2015;214:31-37.
20. Nayak DR, Babu YJ, Adhya TK. Long-term application of compost influences microbial biomass and enzyme activities. *Biology and Fertility of Soils*. 2007;44(2):387-395.
21. Smith P, Martino D, Cai Z, Gwary D, Janzen H, Kumar P. Greenhouse gas mitigation in agriculture. *Philosophical Transactions of the Royal Society B*. 2008;363(1492):789-813.