Advancing Sustainability in Rice Farming through Life Cycle Assessment and Climate-Smart Approaches

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Rice is a staple food for more than half of the world's population, and India is one of its largest producers. However, rice cultivation is also a major contributor to greenhouse gas emissions, high water use, and energy consumption, posing serious challenges to sustainable and climate-resilient agriculture (MoEFCC, 2023). Addressing these challenges requires scientifically grounded, field-based evidence on how different rice production systems perform from both environmental and socio-economic perspectives.

My research focuses on evaluating the sustainability of major rice cultivation systems in India using an integrated Life Cycle Assessment (LCA) and climate-smart agriculture framework. The study compares organic rice farming, conventional flooded rice systems, and Direct Wet Seeded Rice (DWSR) to identify pathways for reducing environmental impacts while maintaining productivity and farmer viability.

A key strength of this research is the use of primary, field-level data collected directly from farmers and institutions.

Fig 1: KVK Organic Agricultural Field

Detailed agronomic data for organic rice farming are collected from Krishi Vigyan Kendra (KVK), Medak, including information on seed rate, seed treatment methods, organic fertilizers (farmyard manure, vermicompost, green manure), biofertilizers, botanical and biological plant protection measures, irrigation practices, energy use, and labor inputs. This allows a realistic assessment of organic rice systems as practiced on the ground.

For conventional rice farming and DWSR, primary agronomic and management data are obtained from ICAR–Indian Institute of Rice Research (ICAR-IIRR), Hyderabad.

These datasets include chemical fertilizer application rates, pesticide and insecticide use, irrigation and electricity consumption, mechanization, and labor requirements, representing standard and improved rice production practices in India.

Using the Life Cycle Assessment methodology, all rice systems are evaluated from input production to on-farm operations and emissions. Primary field data are integrated with secondary data from internationally recognized databases such as ecoinvent and Agribalyse, and the analysis is conducted using openLCA software. This combined approach ensures scientific robustness while maintaining strong regional relevance.

KVK Organic Agricultural Field

Fig 2: ICAR-IIRR

The study compares environmental indicators such as greenhouse gas emissions, energy use, and resource intensityacross organic, conventional, and DWSR systems. A major focus is hotspot analysis, which identifies processes contributing the highest environmental impacts. Preliminary insights show that synthetic fertilizers and electricity-intensive irrigation are major hotspots in conventional rice systems, whereas organic systems generally exhibit lower environmental impacts due to reduced external inputs.

Beyond comparison, the research actively explores improvement scenarios—such as replacing high-impact fertilizers and plant protection products with lower-impact alternatives—while ensuring that crop productivity and farmer income are not compromised. This approach supports practical, implementable solutions rather than theoretical comparisons.

By integrating environmental LCA with socio-economic and Social Life Cycle Assessment (S-LCA) perspectives, the research also considers labor requirements, input costs, and farmer well-being, recognizing that sustainability must be environmentally sound, economically viable, and socially acceptable.

Overall, this research contributes to IIT Hyderabad's sustainability mission by providing evidence-based insights for low-emission, resource-efficient, and climate-resilient rice farming systems. The findings are expected to support policy formulation, institutional decision-making, and farmer-level adoption of sustainable rice cultivation practices aligned with national climate goals and global sustainability targets.

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