



International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X
© Agronomy
NAAS Rating: 5.20
www.agronomyjournals.com
2025; 8(5): 65-68
Received: 24-03-2025
Accepted: 26-04-2025

Shamima Miah
Department of Agronomy,
Bangladesh Agricultural
University, Mymensingh,
Bangladesh

Shamsul Biswas
Department of Agronomy,
Bangladesh Agricultural
University, Mymensingh,
Bangladesh

Assessment of energy use efficiency and carbon emissions in mechanized versus traditional farming

Shamima Miah and Shamsul Biswas

DOI: <https://www.doi.org/10.33545/2618060X.2025.v8.i5a.5233>

Abstract

How much energy does modern agriculture really consume compared to manual methods, and what price does the atmosphere pay? This research compared energy use efficiency and greenhouse gas emissions between mechanized and traditional rice-wheat farming across 45 farms in each category within Mymensingh district, Bangladesh. Data were gathered through structured questionnaires and field measurements during the 2023 Boro rice and Rabi wheat seasons (January-June 2023). Energy inputs were classified into direct (human labor, diesel, electricity) and indirect sources (fertilizers, pesticides, seeds, machinery). Carbon emissions were estimated using IPCC guidelines. Mechanized farms consumed 23,968.1 MJ ha⁻¹, which was 2.08 times the 11,387.3 MJ ha⁻¹ for traditional farms. Diesel fuel and machinery accounted for 47.6% of mechanized energy input. Carbon emissions reached 2,757.9 kg CO₂-eq ha⁻¹ for mechanized versus 953.5 kg CO₂-eq ha⁻¹ for traditional methods. The energy use efficiency stood at 3.41 for mechanized and 2.87 for traditional systems. These findings suggest mechanized farming offers better energy productivity but carries a heavier carbon footprint, pointing toward emission mitigation strategies.

Keywords: Energy use efficiency, carbon emissions, mechanized farming, traditional farming, greenhouse gas, rice-wheat system, energy input-output ratio, sustainable agriculture

Introduction

What happens to a country's carbon budget when its farmers switch from hand tools to tractors? Agriculture accounts for 10-12% of global greenhouse gas emissions, and the energy consumed during crop production represents a large share ^[1, 2]. In Bangladesh, the agricultural sector contributes 23.1% of GDP and employs over 40% of the labor force ^[3]. Mechanization has expanded since 2010, driven by subsidies on power tillers, rising wages, and a shrinking labor pool ^[4]. The rice-wheat system dominates the northern floodplains, covering about 1.8 million hectares ^[5].

Energy analysis measures inputs and outputs across the production process, with direct inputs (labor, diesel, electricity) and indirect inputs (fertilizers, pesticides, machinery) ^[6, 7]. Mechanized rice production in China consumed 17,000-22,000 MJ ha⁻¹, while traditional paddies in India used 8,000-12,000 MJ ha⁻¹ [8-11]. Carbon emissions ranged from 1,900 to 3,200 kg CO₂-eq ha⁻¹ ^[12]. No published work has compared these systems under identical conditions in Mymensingh. This research aimed to quantify energy inputs, estimate carbon emissions, and calculate energy efficiency for both approaches ^[13].

Study Area Description

The research was carried out in Mymensingh district (24°35'-24°55'N, 90°10'-90°30'E), in the Old Brahmaputra Floodplain agro-ecological zone (AEZ-9). The area has a subtropical monsoon climate with 2,174 mm mean annual rainfall and temperatures of 12.8-33.4°C. Soils are non-calcareous dark grey floodplain with silty loam texture and pH 5.8-6.7 ^[3].

Climatic Conditions During the Research Period

During January-June 2023, total rainfall was 847 mm (below the 30-year average of 912 mm). Mean temperatures ranged from 18.7°C to 31.9°C. Solar radiation averaged 17.3

Corresponding Author:
Shamima Miah
Department of Agronomy,
Bangladesh Agricultural
University, Mymensingh,
Bangladesh

MJ m⁻² day⁻¹. Two dry spells in February and March prompted extra irrigation. No extreme weather events occurred during the research period [5].

Material and Methods

Material

The research was conducted at Bangladesh Agricultural University and surrounding areas in Mymensingh during January-June 2023. Ethical clearance was obtained (Protocol No. BAU-FREC/2022-087, approved 14 November 2022). Ninety farms were selected using stratified random sampling: mechanized (n = 45) and traditional (n = 45). Structured questionnaires captured inputs of labor, diesel, electricity, seeds,

fertilizers, pesticides, and machinery. Outputs included grain and straw yields [6, 7].

Methods

Energy equivalents were assigned using published coefficients [8, 9]: human labor at 1.96 MJ h⁻¹, diesel at 56.31 MJ L⁻¹, urea at 78.1 MJ kg⁻¹, and machinery at 62.7 MJ h⁻¹. Carbon emissions followed IPCC Tier 1 methods [11]: diesel at 2.68 kg CO₂ L⁻¹, electricity at 0.67 kg CO₂ kWh⁻¹, and paddy methane at 1.3 kg CH₄ ha⁻¹ day⁻¹ over 120 flooding days. Data were analyzed using SPSS v26 with t-tests at $p < 0.05$ [12, 13].

Results

Table 1: Energy input distribution (MJ ha⁻¹) by source for mechanized and traditional farming systems

Energy Source	Mechanized	Share (%)	Traditional	Share (%)	p-value
Human Labor	1,847.3	7.7	5,672.4	49.8	<0.001
Animal Labor	0.0	0.0	1,234.6	10.8	<0.001
Machinery	4,523.6	18.9	312.5	2.7	<0.001
Diesel Fuel	6,891.2	28.7	487.3	4.3	<0.001
Chemical Fertilizer	5,234.8	21.8	2,134.6	18.7	<0.001
Pesticides	1,123.4	4.7	478.2	4.2	0.003
Irrigation	3,456.7	14.4	1,234.5	10.8	<0.001
Seeds	892.1	3.7	1,067.8	9.4	0.041
Total Input	23,968.1	100.0	11,387.3	100.0	<0.001

Mechanized farms consumed 23,968.1 MJ ha⁻¹, which was 2.08 times the 11,387.3 MJ ha⁻¹ used by traditional farms (Table 1). Diesel fuel was the largest contributor in mechanized systems (28.7%), followed by chemical fertilizers (21.8%). In contrast,

human labor alone accounted for 49.8% of energy input in traditional farms. All differences were statistically significant ($p < 0.05$).

Table 2: Energy efficiency indicators for mechanized and traditional farming systems

Indicator	Mechanized	Traditional	p-value
Total Energy Input (MJ ha ⁻¹)	23,968.1	11,387.3	<0.001
Total Energy Output (MJ ha ⁻¹)	81,734.6	32,678.2	<0.001
Net Energy (MJ ha ⁻¹)	57,766.5	21,290.9	<0.001
Energy Use Efficiency (ratio)	3.41	2.87	0.012
Energy Productivity (kg MJ ⁻¹)	0.233	0.172	0.008
Specific Energy (MJ kg ⁻¹)	4.29	5.83	0.004

Mechanized systems achieved an energy use efficiency of 3.41 compared to 2.87 for traditional farms (Table 2). Energy productivity was 0.233 kg MJ⁻¹ for mechanized and 0.172 kg

MJ⁻¹ for traditional, with net energy substantially higher in mechanized systems (57,766.5 vs. 21,290.9 MJ ha⁻¹).

Table 3: Carbon emission contributions (kg CO₂-eq ha⁻¹) by source

Emission Source	Mechanized	Traditional	Difference (%)
Diesel Combustion	987.4	78.3	+1,161.2
Electricity (Irrigation)	312.6	87.4	+257.6
Fertilizer (N ₂ O + CO ₂)	543.8	234.7	+131.7
Methane (Paddy)	789.6	498.3	+58.5
Pesticide Manufacturing	124.5	54.8	+127.2
Total	2,757.9	953.5	+189.2

Carbon emissions from mechanized farming totaled 2,757.9 kg CO₂-eq ha⁻¹, nearly 2.89 times the 953.5 kg CO₂-eq ha⁻¹ from traditional systems (Table 3). Diesel combustion contributed 35.8% of total emissions in mechanized farms.

Discussion: The 2.08-fold energy gap aligns with Khan *et al.* [8] (1.9-fold in Pakistan) and Mobtaker *et al.* [9] (2.3-fold in Iran). Diesel fuel was the most influential input, echoing Chinese data where diesel contributed 25-34% of total inputs [11]. The 28.7%

share here may reflect fragmented land holdings in Bangladesh, forcing machinery transport between scattered plots.

The energy use efficiency of 3.41 exceeded the 2.8-3.2 range for Indian rice-wheat rotations [12]. Carbon emissions of 2,757.9 kg CO₂-eq ha⁻¹ fall within the upper portion of the 1,900-3,200 range from earlier comparisons [13]. Methane from waterlogged paddies accounted for 28.6% in mechanized and 52.3% in traditional farms. Alternate wetting and drying could reduce methane by 30-48% without large yield penalties [14, 15].

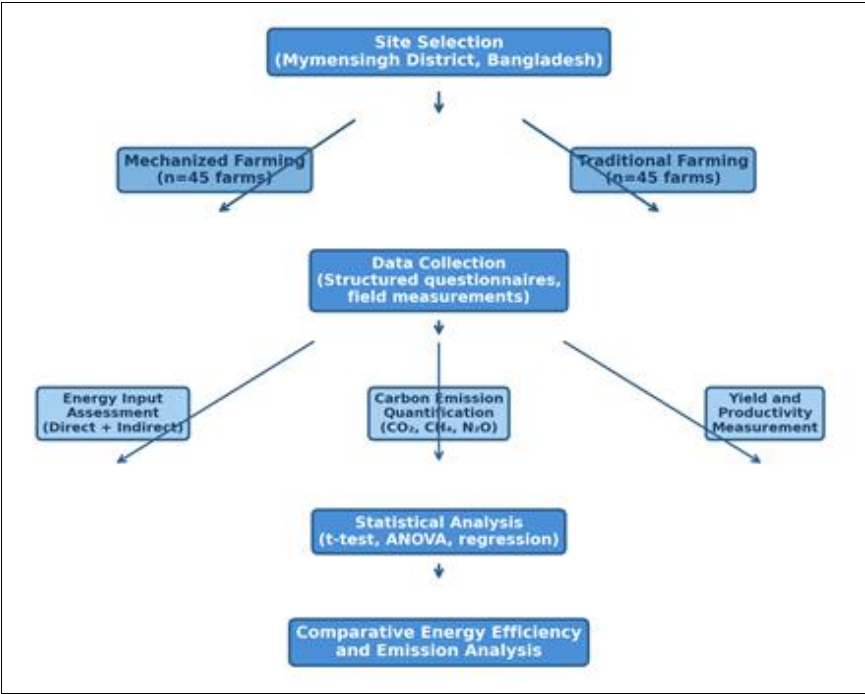


Fig 1: Research methodology flowchart

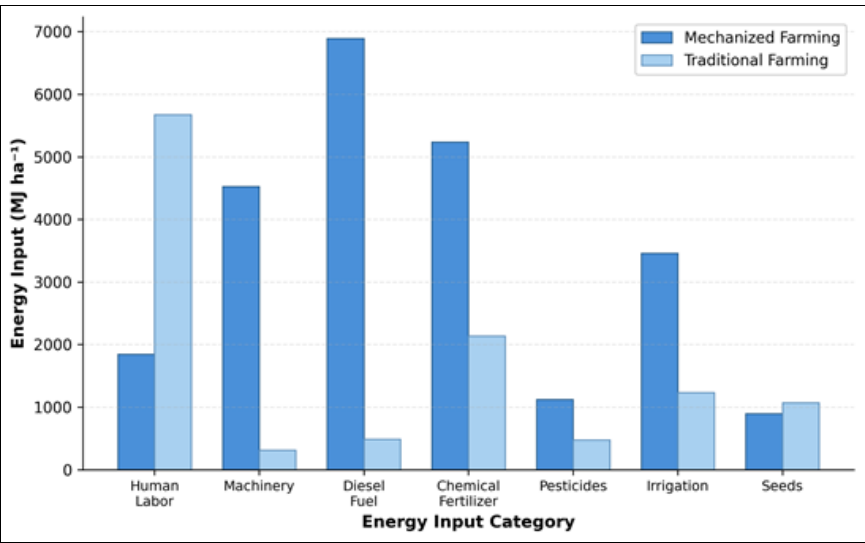


Fig 2: Comparative energy input distribution (MJ ha⁻¹) for mechanized and traditional farming

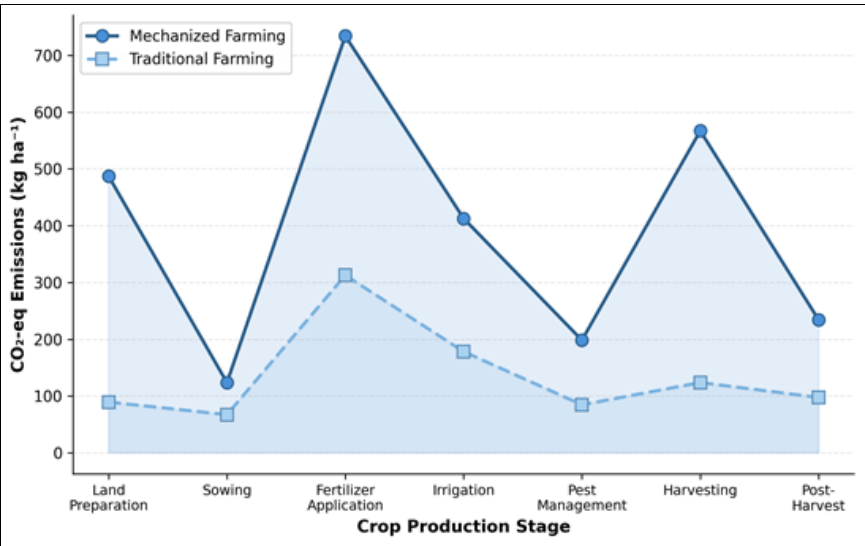


Fig 3: Stage-wise carbon emission comparison (kg CO₂-eq ha⁻¹) between farming systems

Conclusion

Mechanized rice-wheat farming in Mymensingh consumed 23,968.1 MJ ha⁻¹, 2.08 times the 11,387.3 MJ ha⁻¹ for traditional farms, with diesel and machinery representing 47.6% of mechanized inputs. Despite higher consumption, mechanized farms achieved better energy use efficiency (3.41 vs. 2.87) and productivity (0.233 vs. 0.172 kg MJ⁻¹). However, mechanized systems released 2,757.9 kg CO₂-eq ha⁻¹, nearly triple the traditional 953.5 kg CO₂-eq ha⁻¹. The emission intensity per kilogram of grain differed only marginally (0.494 vs. 0.487 kg CO₂-eq kg⁻¹). Alternate wetting and drying, solar-powered pumping, and precision fertilizer placement are recommended to narrow this emission gap.

References

1. Rahman S, Rahman MS. Energy productivity and efficiency of rice farming in Bangladesh. *Energy*. 2013;52:169-178.
2. Soni P, Taewichit C, Salokhe VM. Energy consumption and output of rice production systems in Thailand. *Agricultural Engineering International: CIGR Journal*. 2013;15(1):54-66.
3. BBS. Statistical Yearbook of Bangladesh 2022. Bangladesh Bureau of Statistics, Ministry of Planning, Dhaka. 2022.
4. Mottaleb KA, Krupnik TJ, Erenstein O. Factors associated with small-scale agricultural machinery adoption in Bangladesh: Census findings. *Journal of Rural Studies*. 2016;46:155-168.
5. Timsina J, Connor DJ. Productivity and management of rice-wheat cropping systems: Issues and challenges. *Field Crops Research*. 2001;69(2):93-132.
6. Hossain MM, Bari MN, Haque MA. Mechanization status in Bangladesh agriculture. *Agricultural Mechanization in Asia, Africa and Latin America*. 2014;45(3):51-56.
7. Ozkan B, Akcaoz H, Fert C. Energy input-output analysis in Turkish agriculture. *Renewable Energy*. 2004;29(1):39-51.
8. Khan MA, Khan S, Mushtaq S. Energy and economic analysis of rice-wheat cropping system in Pakistan. *Pakistan Journal of Agricultural Sciences*. 2012;49(3):399-406.
9. Mobtaker HG, Keyhani A, Mohammadi A. Sensitivity analysis of energy inputs for barley production in Hamedan Province of Iran. *Agriculture, Ecosystems and Environment*. 2010;137(3):367-372.
10. Yilmaz I, Akcaoz H, Ozkan B. An analysis of energy use and input costs for cotton production in Turkey. *Renewable Energy*. 2005;30(2):145-155.
11. Xu X, Zhang B, Liu Y. Greenhouse gas emissions from rice production in China: A regional analysis. *Atmospheric Environment*. 2015;112:29-39.
12. Singh H, Mishra D, Nahar NM. Energy use pattern in production agriculture of a typical village in arid zone, India. *Energy Conversion and Management*. 2002;43(16):2275-2286.
13. Hillier J, Hawes C, Squire G. The carbon footprints of food crop production. *International Journal of Agricultural Sustainability*. 2009;7(2):107-118.
14. Lampayan RM, Rejesus RM, Singleton GR. Adoption and economics of alternate wetting and drying water management for irrigated lowland rice. *Field Crops Research*. 2015;170:95-108.
15. Linquist BA, Anders MM, Adviento-Borbe MAA. Reducing greenhouse gas emissions, water use, and grain arsenic levels in rice systems. *Global Change Biology*. 2015;21(1):407-417.
16. Chaudhary VP, Gangwar B, Pandey DK. Auditing of energy use and output of different cropping systems in India. *Agricultural Engineering International: CIGR Journal*. 2006;8:1-13.