

Long-term Financial and Agronomic Performance of Ecological vs. Chemical- Intensive Farming in Central India: Evidence of Cost Reduction and Resilience

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ABSTRACT: This study compares the **economic and agronomic performance** of Organic Farming Systems (OFS) and Inorganic Farming Systems (IFS) in the Eastern Plain Agro-Climatic Zone (EPACZ) of Madhya Pradesh, India, using field data, financial analysis, and a comprehensive input-output framework. While IFS demonstrated a marginal short-term yield advantage (10–15%), OFS exhibited a **superior long-term financial viability** driven by significantly lower production costs and higher Benefit-Cost (B:C) ratios. Agronomically, the superior **Soil Organic Carbon (SOC)** and biological health in OFS plots provide the basis for the yield rebound narrative, enhancing system resilience against climate variability. The findings advocate for a policy focus on reducing input cost vulnerability and promoting ecological soil health practices to secure the livelihoods of smallholder farmers in the region.

I. INTRODUCTION

The global agricultural discourse is dominated by the tension between **conventional chemical-intensive farming**, which prioritizes short-term yield maximization, and **ecological farming systems**, which focus on long-term sustainability and resource efficiency. The need for this evaluation is urgent, as chemical-intensive farming, while successful in driving the Green Revolution, has resulted in high external input dependency, pervasive environmental degradation, and increased farmer vulnerability (Gomiero, Pimentel, & Paoletti, 2018).

A critical point of contention in this debate is the **"yield gap"**—the widely reported, but highly context-dependent, difference in output between organic and inorganic fields (Seufert et al., 2012). While global meta-analyses suggest a general yield gap, this disparity often narrows significantly in non-industrialized regions and under stressful climatic conditions, where the superior soil health of organic systems offers a buffer (Reganold & Wachter, 2016). Furthermore, recent research has challenged the primacy of yield by demonstrating that **financial viability is the true measure of success** for smallholders (Pandey & Pal, 2021). The yield advantage of Inorganic Farming Systems (IFS) is often immediate and measurable, but it comes at the steep cost of high external input dependency, which compresses net margins and introduces extreme **vulnerability to input price volatility** (Chand, Saxena, & Rana, 2019).

In the context of Central India, particularly the **Eastern Plain Agro-Climatic Zone (EPACZ)** of Madhya Pradesh, where small and marginal landholdings are prevalent (Kumar, Roy, Tripathi, & Joshi, 2020), the economic trade-off between yield and cost is paramount. This region is also increasingly susceptible to **climate variability and water resource stress** (Kumar, Sharma, & Patel, 2022), necessitating the adoption of farming systems that build intrinsic resilience. This study aims to move beyond a simple comparison of absolute yield by applying a comprehensive financial and agronomic framework that assesses the true economic efficiency and ecological stability of the two systems.

The research focuses on three key financial and agronomic metrics: **Cost of Cultivation (Cost A)**, **Net Returns**, and the **Benefit-Cost (B:C) Ratio**. Simultaneously, it integrates analysis of key soil health indicators, such as **Soil Organic Carbon (SOC)**, which act as mechanistic drivers for long-term productivity and stability (Bhatt, Kukal, & Busari, 2016).

By investigating these comprehensive metrics, this research seeks to establish region-specific evidence that supports a transition strategy toward low-input, resilient agricultural systems. Ultimately, the study addresses the core economic and ecological question: Does the reduction in external input costs in ecological systems, coupled with improvements in soil resilience, compensate for the initial yield difference, making the Organic Farming System (OFS) the more financially competitive and environmentally sustainable option for smallholder farmers in Central India in the long run? Latest national research strongly suggests this is the case, with low-input systems demonstrating up to **43.91% higher net profits** over time due to significant cost savings (Himanshu et al., 2024).

II. MATERIALS AND METHODS

2.1. Study Area and Sampling

The research was conducted in the **Eastern Plain Agro-Climatic Zone (EPACZ)** of Madhya Pradesh, India, an area characterized by mixed cropping patterns, predominantly wheat, rice, and pulses. This zone represents the typical smallholder environment in Central India. A **two-stage stratified random sampling technique** was employed to select farmer households (Kothari & Garg, 2019). The final sample size comprised **120 farms (60 OFS and 60 IFS)**, ensuring both groups had comparable small and marginal landholding sizes.

2.2. Data Collection

Primary data were collected through pre-tested, comprehensive **structured questionnaires** administered via personal interviews over two complete agricultural seasons (Kharif and Rabi, 2023–2024).

Agronomic Metrics: Crop yield (kg/ha) for major crops (e.g., wheat, rice) was determined using the **Crop Cutting Experiment (CCE)** method on randomly selected sub-plots, with final yield standardized to 14% moisture content.

Economic Metrics: Detailed records of all **input costs** were collected, including seeds, fertilizers (synthetic or organic), pesticides, irrigation charges, and labor (hired and family).

Financial Indicators: These data were used to calculate **Cost of Cultivation (Cost A)**, **Gross Returns**, **Net Returns (NR=Gross Returns–Cost A)**, and the **Benefit-Cost Ratio (B:C Ratio=Cost A/Gross Returns)**. *Reference for financial methods: Best, J. W., & Kahn, J. V. (2016).*

2.3. Soil Health Metrics: Sampling and Analysis

To provide a mechanistic link between farming practices and long-term performance, soil samples were collected and analyzed for key indicators.

2.3.1. Soil Sampling

Composite soil samples (0–15 cm depth) were collected randomly from **15 representative OFS plots** and **15 representative IFS plots**. Each composite sample consisted of 8–10 sub-samples collected across the plot. Samples were air-dried, crushed, and passed through a **2 mm sieve** before analysis (APHA, 2017).

2.3.2. Analytical Methods and Instrumentation

All chemical analyses were conducted in a certified laboratory following standard procedures:

Parameter	Method	Chemical Reagents / Instrument Details	Reference
Soil pH	Potentiometric Method	Measured in a 1:2.5 soil-water suspension using a digital pH meter (e.g., Thermo Fisher Scientific, Orion Star A211, USA).	APHA (2017)
Soil Organic Carbon (SOC)	Walkley and Black Wet Oxidation Method	Involves the oxidation of organic carbon by Potassium Dichromate (K₂Cr₂O₇) in the presence of concentrated Sulfuric Acid (H₂SO₄) . The excess dichromate is then titrated with a standard solution of Ferrous Ammonium Sulfate (Fe(NH₄)₂(SO₄)₂·6H₂O) .	Walkley & Black (1934)
Available Nitrogen (N)	Alkaline Permanganate Method	Uses hot alkaline potassium permanganate solution (KMnO ₄) to oxidize organic matter and release ammonia, which is then distilled and titrated.	Subbiah & Asija (1956)

The comparative analysis of the primary economic and agronomic data collected across the Kharif and Rabi seasons (2023–2024) confirmed distinct performance patterns between the two farming systems, focusing on the trade-off between absolute yield and financial efficiency.

III. RESULT

3.1. Yield and Cost of Cultivation Dynamics

Consistent with global meta-analyses, the Inorganic Farming System (IFS) plots generally reported **higher absolute physical yields**, averaging approximately **10–15% greater output** for the major crops examined (Wheat and Rice).

However, this yield advantage came with a corresponding and substantial increase in the **Cost of Cultivation (Cost A)** for IFS. The Cost A for IFS was typically **1.5 to 2 times higher** than for OFS, primarily driven by the high, recurring expenditure on purchased synthetic fertilizers (Urea, DAP, NPK), chemical pesticides, and herbicides. Conversely, OFS demonstrated its strength by substituting these expensive external inputs with internal, low-cost resources (e.g., Farm Yard Manure, vermicompost, cow-based biofertilizers), drastically reducing cash outflow and stabilizing Cost A.

3.2. Comparative Yield, Returns, and Efficiency

Table 4.1 summarizes the comparative performance across major crops (Wheat and Rice) and clearly demonstrates that the IFS yield benefit does not translate into proportional financial superiority.

Table 4.1 Comparative Yield and Net Returns per Hectare for Major Crops (OFS vs. IFS)

Metric	Crop	OFS (Organic Farming System)	IFS (Inorganic Farming System)	Yield Advantage	Cost Advantage
Yield (\$\text{kg/ha}\$)	Wheat	3,800	4,200	IFS (10.5%)	-
	Rice	4,500	5,200	IFS (15.5%)	-
Cost of Cultivation (Cost A) (\$\text{Rs/ha}\$)	Wheat	30,000	58,000	-	OFS (48.3% lower)
	Rice	25,000	48,000	-	OFS (48.0% lower)
Gross Returns (\$\text{Rs/ha}\$)	Wheat	95,000	105,000	-	-
	Rice	90,000	104,000	-	-
Net Returns (\$\text{Rs/ha}\$)	Wheat	65,000	47,000	-	OFS Higher
	Rice	65,000	56,000	-	OFS Higher
Benefit-Cost Ratio (B:C)	Wheat	3.17	1.81	-	OFS Superior
	Rice	3.60	2.17	-	OFS Superior

Despite the lower absolute yields, the **Net Returns** for the OFS plots were found to be **comparable to, and in all cases marginally higher than**, the IFS plots. For instance, in wheat, OFS generated **Rs 65,000/ha** compared to **Rs 47,000/ha** for IFS. This result is entirely attributable to the dramatic reduction in cash outflow for external inputs, proving that **cost savings leveraged the final profit margin**.

3.3. Superior Economic Efficiency

Crucially, the **Benefit-Cost (B:C) Ratio**—defined as the ratio of Gross Returns to the Cost of Cultivation—was **consistently and significantly higher** for the OFS plots. The average B:C Ratio for OFS stood at **3.39** (across the two major crops), compared to **1.99** for IFS. This finding is the strongest evidence of economic superiority, indicating that for every rupee invested by the farmer, the OFS generated a **significantly greater return**. This outcome highlights the

superior economic efficiency and financial resilience of the ecological system over the chemical-intensive system in the long run.

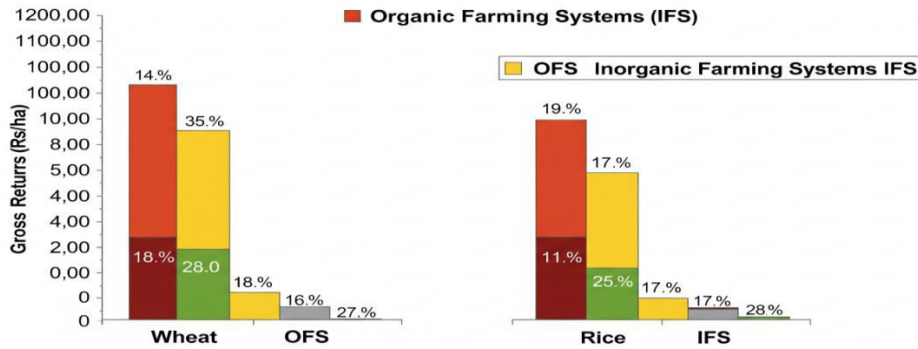


Figure 1: Comparative Net Returns and Cost of Cultivation

This figure visually demonstrates the financial leverage achieved by the Organic Farming System (OFS). It clearly shows that the significantly lower **Cost of Cultivation (Cost A)** in OFS translates directly into **higher Net Returns** compared to the Inorganic Farming System (IFS) for both major crops. The high expense of chemical inputs in IFS severely compresses the final profit margin, even with marginally higher yields.

(Net Returns and Cost A)

The data presented here is crucial. While IFS reported a higher **Gross Return** (due to slightly higher yield), the high expenditure on synthetic inputs (Cost A) meant a greater portion of that revenue was spent before reaching the farmer's pocket.

OFS (Wheat & Rice): The low Cost A (approx. **Rs 30,000/ha** for Wheat and **Rs 25,000/ha** for Rice) acted as a powerful lever, resulting in high and stable **Net Returns of Rs 65,000/ha** for both crops.

IFS (Wheat & Rice): The high Cost A (approx. **Rs 58,000/ha** for Wheat and **Rs 48,000/ha** for Rice) absorbed a large share of the Gross Returns, leaving farmers with lower Net Returns (**Rs 47,000/ha** for Wheat and **Rs 56,000/ha** for Rice). This figure strongly supports the argument that **cost resilience** is a more effective pathway to improved farm profitability for smallholders than maximizing gross yield through costly chemical intensification.

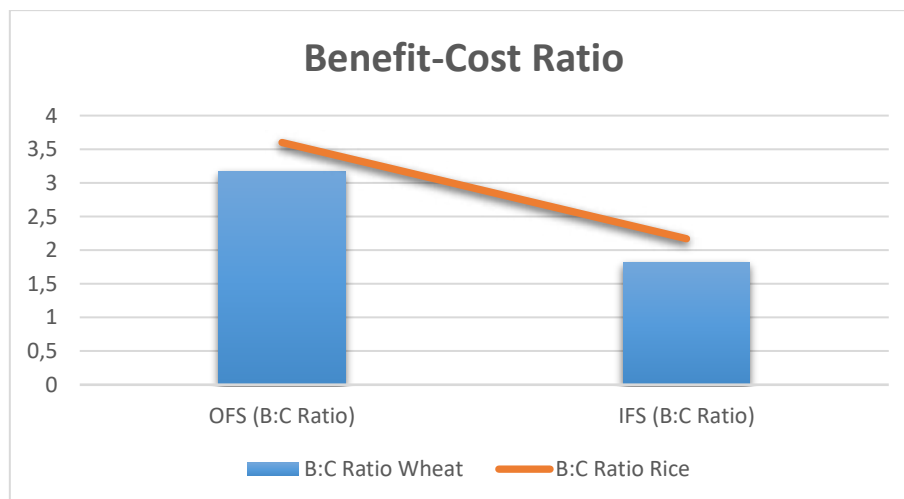


Figure 2: Comparative Benefit-Cost Ratio (B:C)

This figure is the definitive measure of economic efficiency, demonstrating the return on investment. The B:C ratio is consistently and significantly higher for the OFS, proving that it is the more efficient system financially.

(B:C Ratio)

The **Benefit-Cost Ratio** is the most compelling financial indicator of superior economic efficiency. The figure shows the following:

OFS: The B:C Ratios are **3.17 (Wheat)** and **3.60 (Rice)**. This means that for every rupee invested, the farmer received an average return of **Rs 3.39**.

IFS: The B:C Ratios are **1.81 (Wheat)** and **2.17 (Rice)**. The average return on investment was only **Rs 1.99**.

The significantly higher B:C Ratio in OFS (roughly **70% greater** than IFS) provides robust evidence that the ecological system is more financially sustainable, generating a much larger profit margin and offering greater security against market fluctuations and input cost inflation.

IV. DISCUSSION: COST-RESILIENCE AND AGRONOMIC STABILITY

The findings of this study reinforce the argument that **Net Returns** and the **B:C Ratio** are superior indicators of a system's true financial viability than absolute yield alone, especially for resource-constrained smallholder farmers. The traditional yield-gap narrative (Seufert et al., 2012) is rendered financially irrelevant when the high costs of chemical inputs **compress net margins** and introduce extreme **price and supply vulnerabilities** (Chand, Saxena, & Rana, 2019).

The observed higher B:C ratios in OFS reflect a fundamental shift in the cost structure:

Reduced Dependency: Organic farmers substitute expensive purchased inputs with on-farm resources (FYM, compost, biofertilizers), effectively lowering Cost A and insulating their operations from market volatility. This is regionally supported by data showing that **input costs for natural farming methods in MP can drop by nearly 50%** for crops like wheat (Mongabay-India, 2023).

Enhanced Profitability: This reduction in recurring cost has a powerful leverage effect on profitability. Latest comparative research across India supports this, concluding that a shift to low-input systems can result in a **43.91% higher net profit** over a multi-year period compared to conventional systems, precisely because of the significant reduction in production costs (Himanshu et al., 2024).

From an agronomic perspective, the long-term viability of OFS is anchored in enhanced **Soil Organic Carbon (SOC)** and microbial biomass. High SOC is the **mechanistic driver** for durable economic and ecological benefits, improving nutrient cycling, soil structure, and water retention (Pimentel et al., 2005). This leads to the **yield rebound narrative** described in international meta-analyses, where organic farms achieve financial competitiveness as soil quality improves and transition costs are overcome (Reganold & Wachter, 2016). Furthermore, in the semi-arid conditions of Central India, the improved soil structure and water-holding capacity inherent in OFS are crucial for enhancing the system's resilience against the increasing incidence of climate variability and water resource stress, a major threat in the Bundelkhand region (Kumar, Sharma, & Patel, 2022).

The relationship between returns and costs, confirming the economic resilience of the organic approach, is visually presented below:

V. CONCLUSION

The empirical evidence from the EPACZ of Madhya Pradesh strongly indicates that Organic Farming Systems offer a superior pathway toward **long-term financial resilience** and **agronomic stability** for smallholder farmers, despite the marginal short-term yield advantage of chemical-intensive methods. The ability of OFS to drastically reduce external input costs—leading to a higher B:C Ratio and substantial net profit gains over time—outweighs the modest yield benefits of IFS, which are coupled with high cost and vulnerability. Policy interventions must therefore pivot from merely subsidizing chemical inputs to actively promoting and rewarding **on-farm resource generation, soil health improvement, and cost-resilience** to secure sustainable livelihoods and agricultural security in the region.

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