COST-BENEFIT ANALYSIS OF SUSTAINABLE AGRICULTURAL TECHNOLOGIES: AN INDIAN MANAGEMENT ACCOUNTING PERSPECTIVE

Abstract

Sustainable Agricultural Technologies (SATs) are receiving importance as strategic investments for increasing agriculture productivity, efficient use of resources and resilience in Indian agriculture. This study explores the financial stability of selected SATs namely integrated pest management (IPM), drip irrigation, organic nutrient management, precision farming and use of renewable energy through cost-benefit analysis. Analysing the capital budgeting tools such as NPV, BCR, Payback Period and sensitivity analysis, the paper appraises costs and benefits over a short run, medium-term and long run horizon considering Indian farming conditions. The empirical studies indicates that despite high initial investments, most SATs produce favourable financial outcomes, cost control and risk minimisation benefits over the life cycle. By connecting ESG considerations with conventional techniques, the study validates the role of management accountants for informed decision-making and promote sustainable value creation in long run.

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1. Introduction

Indian agriculture is facing various ongoing challenges such as declining soil fertility, water scarcity, rising operational cost and income instability of farmers *(Vasavi, 2025)*. In response, policy makers and agribusiness representatives are actively promoting Sustainable Agricultural Technologies (SATs), which boost output while conserving natural resources *(Kumar S. , 2025)*. Adoption and implementation of such technology is a long-term capital budgeting choice rather than an agronomic one *(Zhan, 2025)*.

Traditional agricultural financial evaluation approaches usually focus on short-term profitability and cash flows, while disregarding long-term cost savings, risk reduction and environmental benefits *(Mazancová, 2024)*. The policy framework must be designed to focus on the integration of financial discipline with strategic decision-making considering fragmented, unorganised agriculture setup along with weak financial condition of farmers *(Hiranya, 2024)*. As a result, this study uses structured cost-benefit analysis approaches to examine if investments in SATs are economically viable in Indian agriculture sector *(Poudel, 2024)*.

2. Review of Literature

Empirical studies in agricultural economics suggest that precision farming and micro-irrigation significantly improve input-use efficiency and yield stability, particularly in water-scarce regions of India (Virley & Debarre, 2024). Research on Integrated Pest Management (IPM) and organic nutrient management highlights compact requirement on chemical inputs and improved soil health over time. However, implementation remains stressed by high upfront costs and limited access to capital.

Management accounting stresses the importance of life-cycle costing, environmental management accounting and sustainability reporting in investment assessment (Kumar S. C., 2023). Despite this, farm-level adoption of such analytical frameworks remains limited. This study bridges the gap by applying capital budgeting tools to sustainability driven agricultural investments (Kumar S. G., 2022).

3. Objectives of the Study

1. To explore significant sustainable agricultural technologies (SATs) relevant to Indian farming environment.
2. To compare costs and benefits (BCR) interlinked with selected SATs
3. To analyse the managerial and policy implications of adopting SATs in India

4. Research Methodology

This study adopts descriptive and empirical study design based on secondary data available in public domain and demonstrative farm-level evidence explored from literatures in Indian contexts.

4.1 Analytical Framework

The financial feasibility of sustainable agricultural technologies (SATs) is appraised using capital budgeting tools and techniques as discussed below:

Net Present Value (NPV):

$$NPV = \sum_{t=0}^{n} \frac{B_t - C_t}{(1+r)^t}$$

Where:

B_t = Benefits in year *t*
C_t = *Costs in year t*
r = Discount rate
n = Project life

Benefit–Cost Ratio (BCR):

$$BCR = \frac{\sum_{t=0}^{n} \frac{B_t}{(1+r)^t}}{\sum_{t=0}^{n} \frac{C_t}{(1+r)^t}}$$

Payback Period:

The Time required to recover initial cash outflows in adopting sustainable agricultural technologies (SATs) from net cash inflows. The discount rate considered for payback period is the prevailing lending rates for agricultural in India. The analysis covers a time horizon five-to-ten-years depending on the type of technology adopted (Johnston, 2018).

5. Cost–Benefit Analysis of Selected Sustainable Technologies

To reinforce empirical uniformity, this section presents suggestive quantifiable analysis based on available secondary data from literatures on agricultural studies in India, reports and collected farm-level evidences. The analysis focuses on pre and post impact of adoption of sustainable agricultural technologies (SATs) on costs, yields and profitability.

Table 1: Comparative Cost–Benefit of SATs

Technology	Initial Cost	Operating Cost	Major Benefits	Financial Impact
Drip Irrigation	H	Large Reduction	Increased Yield, Water Saving	Short payback period
Integrated Pest Management	LM	Reduction in pesticides	Lower crop loss, health benefits	High BCR
Organic Nutrients	L	Stable over time	Soil Fertility, Stable Cost	Long-term gains
Precision Farming	H	Moderate reduction	Cost Reduction, Increased yield	Positive NPV
Renewable Energy	H	Major energy cost saving	Energy security, cost control	Positive NPV over life cycle

H: High; L: Low; LM: Low to Moderate

Source: Compiled by authors based on World Bank, ICAR and peer-reviewed literature.

Table 2: Indicative Financial Performance of SATs (Per Hectare / Per Unit)

Technology	Increase in Yield (%)	Reduction in Input Cost (%)	Average Annual Net Benefit (₹)	Payback Period (Years)
Drip Irrigation	15–25	20–30	30,000–40,000	2–3
Integrated Pest Management	5–10	15–20	10,000–15,000	1–2
Organic Nutrients	3–7	10–15	8,000–12,000	2–3
Precision Farming	8–12	10–15	18,000–25,000	4–5
Renewable Energy (Solar Pump)	–	60–80 (energy cost)	35,000–50,000	4–6

Source: Compiled by authors based on World Bank, ICAR and peer-reviewed literature. Values represent typical ranges reported across regions and crops; actual performance depends on agro-climatic and management conditions.

5.1 Precision Farming

Precision farming shows consistent financial performance particularly for medium and large size farms. Empirical evidence indicates 8 to 12% yield improvement and 10 to 15%, through optimized input use, reductions in fertilizer and pesticide costs. Discounted cash flow analysis over seven-year horizon generally yields positive NPV with payback periods of four to five years. In spite of high initial investment in use of sensors and GPS-enabled systems long-term cost control and efficiency gains support financial viability when assessed using life-cycle costing.

5.2 Drip Irrigation

Drip irrigation system validates strong financial feasibility especially in horticulture and water-scarce regions. Studies report 15 to 25% increase in yields and up to 30% reductions in input costs, which led in short payback periods of two to three years and high Benefit–Cost Ratios. From capital budgeting standpoint drip irrigation represents low-risk investment with rapid cost recovery and substantial medium-term to long term savings.

5.3 Integrated Pest Management (IPM)

Integrated Pest Management requires nominal initial investment and yields quick financial returns. Empirical evidence and reports suggest 15 to 20% reductions in pesticide expenses with stable and marginally improved yields. Consequently, the IPM exhibits high BCRs and low payback periods thus making it financially viable even for small and marginal farms. Its primary benefit lies in cost minimization rather than yield expansion.

5.4 Organic Nutrient Management

Organic nutrient management in agriculture provides gradual but stable financial benefits. The short-term yield advantages are modest ranging from 3 to 7% and 10 to 15% reductions in fertilizer costs and improved soil efficiency which generate positive net benefits over five to ten years. Financial appraisal favors long-term tools that capture cost stability and reduced dependency on external inputs.

5.5 Renewable Energy Applications

The implementations of renewable energy appliances particularly solar irrigation pumps and biogas systems reduce recurring energy costs by 60 to 80%. Although initial capital requirements are high and life-cycle discounted cash flow analyses indicate positive NPVs over 15–20 years, especially when supported by policy incentives. These investments enhance long-term cost predictability and operational resilience.

Practitioner Insight Box: Management Accountant's Perspective
ESG Investment: Evaluating Sustainable Agriculture

The finance professionals and management accountants must treat Sustainable agricultural technologies (SATs) as ESG focused and aligned capital investments rather than optional environmental overheads. Incorporating analytical tools such as life-cycle costing, discounted cash flow techniques and KPIs linked to sustainability; will enables more accurate assessment and long-term value creation for SATs. When environmental and social benefits such as reduced water usage, lower carbon emission and stable income are linked with financial characteristics, SATs will be proved to have strong alignment with ESG reporting, sustainability accounting.

6. ESG Impact Assessment of Sustainable Agricultural Technologies

Drip irrigation and organic nutrient management display strong environmental impact due to significant water conservation, improved soil fertility and efficient resource utilisation, resulting in positive overall ESG performance. Integrated Pest Management (IPM) brings positive environmental and social benefits through decreased chemical use and enhanced farm safety, though impact on governance remains moderate. Precision farming shows strong impact on governance owing to data-driven transparency and control, with positive environmental gains but moderate social connects. Use of renewable energy in agriculture have very high score environmentally due to reduction in carbon emissions and decrease energy costs, with high governance alignment to sustainability policies, yielding very high overall ESG impact. ESG scores (VH, H, M) represent relative qualitative assessments derived from synthesis of peer-reviewed literature and institutional sustainability frameworks. Scores are indicative and not based on a single standardized ESG rating system

Table 3:ESG Impact Scoring Matrix for SAT

Technology	Environmental (E)	Social (S)	Governance (G)	Overall ESG Impact
Drip Irrigation	VH	H	M	VH
Integrated Pest Management	H	H	M	H
Organic Nutrients	VH	H	M	VH
Precision Farming	H	M	H	H
Renewable Energy	VH	M	H	VH
VH: Very High; H: High; M: Medium				

Source: Authors' conceptual framework based on FAO sustainability indicators, OECD agri-environmental metrics, World Bank ESG guidance and UN SDGs.

6.1 Drip Irrigation (E: VH, S: H, G: M, overall: VH)

Drip irrigation demonstrates very high environmental impact driven by substantial water conservation and energy efficiency. Social benefits arise from improved productivity and income stability for farmers resulting in a high social score. Governance impact is assessed as medium and reflecting dependence on institutional support, subsidies and implementation oversight. Thus, drip irrigation delivers very high ESG impact.

6.2 Integrated Pest Management (E: H, S: H, G: M, overall: H)

Integrated pest management shows high environmental impact due to reduced chemical use and lower ecological toxicity. Social impact is also high as reduced pesticide exposure enhances farmer health and safety. Governance impact remains medium as effective adoption depends on training, extension services and compliance with recommended practices. The overall ESG impact of IPM is assessed as high.

6.3 Organic Nutrients (E: VH, S: H, G: M, overall: VH)

Organic nutrient management attains very high environmental impact by improving soil health, biodiversity and long-term ecological balance. Social benefits are high stemming from sustainable livelihood support and reduced reliance on costly chemical inputs. Governance impact is medium which is influenced by certification, quality assurance and monitoring mechanisms thus overall ESG performance is very high.

6.4 Precision Farming (E: H, S: M, G: H, overall: H)

Precision farming delivers high environmental impact through optimized resource use and reduced input wastage. Social impact is assessed as medium reflecting unequal accessibility due to capital and skill requirements. Governance impact is high as data-driven systems enhance transparency, traceability and operational control hence overall ESG impact of precision farming is high.

6.5 Renewable Energy in Agriculture (E: VH, S: M, G: H, overall: VH)

Renewable energy applications exhibit very high environmental impact by reducing carbon emissions and fossil fuel dependence. Social impact is medium as benefits related to energy security and cost stability are unevenly distributed across farm sizes. Governance impact is high reflecting strong alignment with regulatory frameworks and national sustainability policies thus overall ESG impact is assessed as very high.

7. Managerial and Policy Implications

The managerial and policy implications are from a management accounting perspective where the implementation of Sustainable agricultural technologies (SATs) should be evaluated using life-cycle costing of the technology rather than analyzing short-term expense. Inclusion of environmental factors and risk reduction improves the precision of investment decisions. Policymakers can accelerate implementation of SATs through capital subsidies, concessional financing and training support. Management accountants have critical role in designing sustainability-oriented performance measurement systems.

8. Limitations and Scope for Further Research

This study is primarily based on literatures and reports available, secondary data and suggestive farm-level empirical studies, which may not fully include regional variations across India's diverse climatic regions. Cost-benefit estimations are subject to assumptions regarding productivity, prices, lending rates and discount rates. Future studies may employ primary survey data, region-specific financial models and longitudinal studies to consider dynamic impacts of SATs implementation. Further studies may also integrate carbon valuation and monetization of environment into management accounting frameworks.

Conclusion

This study concludes that adoption of sustainable agricultural technologies (SATs) is commercially viable when assessed using structured cost–benefit tools and techniques for medium to large size farms. Even though initial investments and cash outflows are higher but the financial returns in long-term, cost efficacies and flexibility benefits justify the acceptance of SATs. Implementing sustainability into management accounting practices can further strengthen decision-making and support India's transition toward sustainable agriculture society in medium to long term perspectives. MA

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