

Mahara Irrigation in Eastern India's Rainfed Agroecology

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Article Info

E-ISSN: 3107-7145
Volume: 02
Issue: 04
Received: 12-08-2026
Accepted: 10-09-2026
Published: 08-10-2026
Page No: 16-19

Abstract
Darjani village in Bhuban Block, Dhenkanal, Odisha, traditionally relied on rainfed, mono-cropped paddy, resulting in low productivity and income. Under the HDFC-FRDP Project, Mahashakti Foundation revitalized the community-based Mahara Irrigation System across 32 acres by renovating traditional channels and constructing a check dam with 10.8 lakh litres of storage capacity. A Water User Group (WUG) was formed to ensure equitable water distribution and collective management.
A solar pump was installed for irrigation, while pilot solar fencing protected vegetable crops from wild animals. A Bio-Pesticide Resource Centre promoted vermicompost, Azolla, Jeevamrut and botanical pesticides, reducing dependence on external chemical inputs and supporting sustainable agriculture.
Crop diversification included a 20-acre Jhain Moong cluster and 12 acres of organic vegetables, supported by Farmer Field Schools. Improved irrigation and diversified cropping increased cropping intensity from 100% to approximately 200–250%, generating an estimated annual net cluster income of ₹17.4 lakh.
Economic analysis using mean, standard deviation (SD), coefficient of variation (CV), benefit–cost ratio (BCR), return on investment (ROI) and break-even analysis demonstrated strong economic viability. Jhain Moong achieved a BCR of 2.14 and ROI of 114%, while vegetables recorded a BCR of 2.4 and ROI of 140%. The Darjani model offers a replicable pathway for transforming rainfed farming into diversified, productive and climate-resilient agriculture.

DOI: https://doi.org/10.54660/IJANFR.2026.2.4.16-19

Keywords: Climate-resilient agriculture, Crop diversification, Economic viability, Mahara irrigation, Natural farming

Introduction

Rainfed agriculture in Odisha is highly vulnerable to monsoon variability, resulting in low productivity, limited irrigation, low farm income and inadequate crop diversification. Darjani village in Bhuban Block, Dhenkanal, exemplifies these challenges, including seasonal unemployment, youth migration and underutilization of agricultural land.
Previous studies have emphasized water productivity (Rockström *et al.*, 2003, 2010) [1, 5], agroecology (Pretty, 2008; Altieri, 2018) [2, 3], climate-smart agriculture (FAO, 2013), community-managed irrigation (Sharma & Amarasinghe, 2009; Pal & Verma, 2017) [4, 9] and sustainable inputs (Reddy & Reddy, 2010) [6]. However, limited field-level evidence evaluates these interventions as an integrated model combining traditional irrigation, solar energy, natural farming and economic viability (Singh & Kumar, 2014) [8].
To address this gap, the present study assessed an integrated agricultural model implemented by Mahashakti Foundation under the HDFC Bank Parivartan–FRDP (Chirantan Project) in Darjani village. The intervention revitalized the traditional Mahara irrigation system linked to the Chirugunia stream through water-harvesting structure renovation, channel restoration and check dam construction. A Water User Group (WUG) was established for equitable water distribution and collective management.

Complementary interventions included solar-powered irrigation, Jhain Moong and vegetable cultivation, natural farming practices and a Bio-Pesticide Resource Centre (BRC). The study evaluates the model's effectiveness and economic viability in improving cropping intensity, farm income, resource-use efficiency and climate resilience in rainfed farming systems.

Interventions Included

Renovation of water harvesting structure (10.8 lakh litre capacity), community lift irrigation, solar pump installation, 20-acre organic local (Jhain) Moong cluster, 12-acre diversified vegetable cluster, bio-input production units and mulching practices.

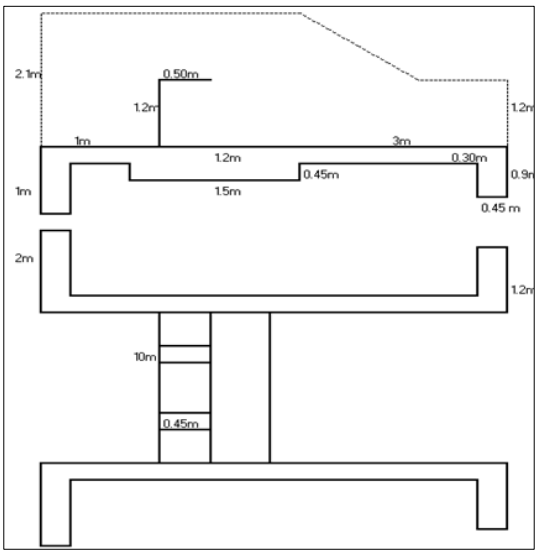


Fig 1: Lay out Design of the Mahara Irrigation System

Data Analysis

Mean, standard deviation, coefficient of variation, benefit–cost ratio, return on investment, break-even and sensitivity analysis were applied.

Methology

The study was conducted in Darjani village of Bhuban Block in Dhenkanal district, Odisha, where a community-based Mahara Irrigation System was implemented to improve rainfed agriculture (Rockström, J., Barron, J. and Fox, P, 2003; Pal S, Verma S., 2017) [1, 9]. The intervention covered approximately 28–32 acres of farmland involving 50 farmers, including about 40% women farmers. The project was implemented by Mahashakti Foundation with support from HDFC Bank Parivartan under the FRDP (Chirantan Project), aligning with national objectives for sustainable livelihoods in rainfed areas (https://nmsa.dac.gov.in 2020). A participatory and field-based approach was adopted, combining infrastructure development, capacity building, and climate-resilient agricultural practices (Pretty J.N., 2008; FAO, 2013) [2].

The major physical interventions included renovation of the existing Water Harvesting Structure (WHS), revival of traditional Mahara irrigation channels, and construction of a small check dam (9 m × 1.5 m) with a storage capacity of approximately 10.8 lakh litres (Sharma & Amarasinghe, 2009; Rockstrom J, *et al*, 2010) [4]. A community-managed lift irrigation system with pipelines was established to distribute water across the cluster area (Pal & Verma, 2017; MNRE, 2022) [9]. A Water User Group (WUG) consisting of 30 farmers was formed to manage irrigation scheduling, water distribution, and maintenance of the system (Pal & Verma, 2017) [9].

Agricultural interventions included cluster-based cultivation of 20 acres of organic Jhain Moong and 12 acres of diversified vegetables such as brinjal, tomato, chilli, okra, beans, and cucurbits (Singh & Kumar, 2014) [8]. Improved agronomic practices such as line sowing, mulching, intercropping, integrated nutrient management (INM), and integrated pest management (IPM) were promoted (Altieri, 2018; Rockstrom *et al*, 2010) [3]. Organic inputs including vermicompost, Azolla, Jeevamrut, Neemastra, and Dashparni Ark were produced locally through a bio-pesticide resource centre (Altieri, 2018) [3].

Primary data on cost of cultivation, yield and income were collected from participating farmers through field observations, farmer diaries, and group discussions. Descriptive statistics such as mean, standard deviation, and coefficient of variation were used to assess variability in production and income. Economic indicators including Benefit–Cost Ratio (BCR), Return on Investment (ROI), break-even analysis, and sensitivity analysis were applied to evaluate the economic viability and sustainability of the irrigation and cropping model (Singh & Kumar, 2014) [8].

Brief Explanation of Economic Indicators

Benefit–Cost Ratio (BCR)

The ratio of total discounted economic benefits to total discounted costs over the project lifecycle. A value greater than 1 indicates that the financial returns of the irrigation and cropping model outweigh the investment cost.

Return on Investment (ROI)

Measures the net profit generated relative to the initial capital invested, expressed as a percentage (ROI)= (Net_Income/Total Cost) * 100. It evaluates how efficiently the capital was utilized.

Break-even Analysis

Identifies the minimum yield or product price required to cover total production expenses. It marks the point where total revenue equals total cost, showing the risk threshold for farmers.

Sensitivity Analysis

Tests how changes in key variables (such as input cost increases, yield reductions, or price drops due to climate or market fluctuations) affect project profitability, demonstrating the economic resilience of the intervention. Bottom of Form

Results

Cropping intensity increased from 100% under the earlier mono-cropping system to approximately 200–250% following the introduction of diversified natural/organic farming practices, indicating increased use of available land across seasons. The economic outcomes were assessed for 32 acres, comprising 20 acres of organic local (Jhain) Moong and 12 acres of diversified organic vegetables.

Table 1: Economics of Organic Crop Production

Parameter	Local (Jhain) Moong (20 Acres)				Diversified Vegetables (12 Acres)			
	Mean per acre	SD (±)	CV (%)	Total (20 acres)	Mean per acre	SD (±)	CV (%)	Total (20 acres)
Cost of cultivation (₹)	21,000	1,500	7.14	4,20,000	75,000	5,000	6.67	9,00,000
Yield (quintals)	5.00	0.50	10.00	100 quintals	90.00	10.00	11.11	1,080 quintals
Selling price (₹/quintal)	9,000	500	5.56	—	2,000	300	15.00	—
Gross income (₹)	45,000	4,500	10.00	9,00,000	1,80,000	20,000	11.11	21,60,000
Net income (₹)	24,000	3,000	12.50	4,80,000	1,05,000	15,000	14.29	12,60,000
Gross margin (₹)*	24,000	—	—	4,80,000	1,05,000	—	—	12,60,000
Benefit–cost ratio (BCR)	2.14	—	—	—	2.40	—	—	—
Return on investment (ROI %)	114.29	—	—	—	140.00	—	—	—

Table 1 compares the economic performance of organic Jhain Moong cultivated over 20 acres and diversified vegetables over 12 acres. Jhain Moong generated a net income of ₹24,000 per acre, with a BCR of 2.14 and ROI of 114.29%, whereas vegetables generated ₹1,05,000 per acre, with a BCR of 2.40 and ROI of 140%. The relatively low CVs for cultivation cost and yield indicate limited variability in production expenditure and output. Overall, both enterprises were profitable, although vegetable cultivation generated higher returns per acre.

Table 2: Cluster Level Comparative Summary (32 Acres)

Indicator	Jhain Moong (20 acres)	Vegetables (12 acres)	Overall cluster
Total cultivated area (acres)	20	12	32
Total cultivation cost (₹ lakh)	4.20	9.00	13.20
Total gross income (₹ lakh)	9.00	21.60	30.60
Total net income (₹ lakh)	4.80	12.60	17.40
BCR (gross income/cost)	2.14	2.40	2.32
ROI (%)	114.29	140.00	131.82
Yield CV (%)	10.00	11.11	—

Table-2 presents the combined economic performance of the 32-acre cluster, comprising 20 acres of Jhain Moong and 12 acres of diversified vegetables. The enterprises involved a total investment of ₹13.20 lakh and generated gross income of ₹30.60 lakh and net income of ₹17.40 lakh. The overall BCR of 2.32 and ROI of 131.82% demonstrate the cluster's economic viability. Integrating the two enterprises also diversified income sources, combining the comparatively stable production of Jhain Moong with the higher returns from vegetables.

Table 3: MFC (Marginal Factor Cost), MVP (Marginal Value Product) and their ratio

Enterprise	Cultivation cost (₹/acre)	Gross income (₹/acre)	Gross income-to-cost ratio
Organic Jhain Moong	21,000	45,000	2.14
Organic diversified vegetables	75,000	1,80,000	2.40

Table-3 compares gross income with cultivation cost per acre to assess the economic efficiency of the two enterprises. Jhain Moong recorded a ratio of 2.14, while diversified vegetables achieved a higher ratio of 2.40, indicating greater gross returns relative to cultivation costs. Both enterprises generated gross income exceeding their cultivation expenditure, supporting their economic viability. For accuracy, the table should be titled Gross Income-to-Cultivation Cost Ratio, because the values represent average rather than marginal costs and returns.

Table 4: Statistical Indicators (Optional Inclusion for Research)

Indicator	Jhain Moong	Vegetables
Cultivation cost (₹/acre)	21,000	75,000
Mean yield (quintals/acre)	5.00	90.00
Mean selling price (₹/quintal)	9,000	2,000
Break-even Yield (Qtl/Acre)	2.33	37.5
Break-even Price (₹/Qtl)	4,200	833
Sensitivity (−10% Price) Net Income Impact	−₹4,500/Acre	−₹18,000/Acre
Income Stability Rank	Moderate	High Risk–High Return

Table-4 assesses the minimum production or price required to cover cultivation costs and the potential impact of market fluctuations. Jhain Moong had a break-even yield of 2.33 quintals per acre and a break-even price of ₹4,200 per quintal, while vegetables required 37.5 quintals per acre and a break-even price of approximately ₹833 per quintal. A 10% reduction in selling price would reduce net income by approximately ₹4,500 per acre for Jhain Moong and ₹18,000 per acre for vegetables, assuming unchanged yields and costs. These results suggest that Jhain Moong offers comparatively greater income stability, whereas vegetables provide higher returns but greater exposure to price fluctuations.

Discussion

The study demonstrates that integrating the traditional Mahara water-harvesting system, solar-powered irrigation and diversified natural farming can improve cropping intensity, resource-use efficiency and livelihood resilience in

rainfed agriculture (Rockström *et al*., 2003, 2010; Pal & Verma, 2017) [1, 5]. Crop diversification through Jhain Moong and vegetables supports agroecological principles, including biological nitrogen fixation and more efficient soil and water management (Pretty, 2008; Altieri, 2018; Reddy & Reddy, 2010) [2, 3, 6]. The favourable economic performance indicates the potential of this integrated approach to strengthen smallholder livelihoods, although vegetable cultivation remains more exposed to market-price fluctuations (Singh & Kumar, 2014) [8]. Collective marketing, improved storage, responsible water governance and institutional support are therefore essential for sustaining benefits (Sharma & Amarasinghe, 2009; FAO, 2013) [4]. While the model offers a promising framework for climate-resilient agriculture in eastern India, its wider applicability requires multi-season validation of water availability, economic returns and institutional sustainability. The study contributes to sustainable agriculture by illustrating how indigenous knowledge, renewable energy and diversified natural farming can be combined within a locally managed water–energy–food system (FAO, 2013; MNRE, 2022) [7].

Conclusion

The Mahara Irrigation Model in Darjani village transformed rainfed monocropping into a diversified, climate-resilient farming system, increasing farm incomes by 2–3 times, reducing distress migration and strengthening participatory water governance. Its novelty lies in integrating traditional water harvesting, solar-powered irrigation, natural farming practices and farmer-led institutions. With a Benefit–Cost Ratio (BCR) of 2.31 and Return on Investment (ROI) of 132%, the model demonstrates economic viability and ecological sustainability. It contributes to scientific knowledge by presenting a scalable, community-driven approach to sustainable agriculture and integrated water–energy–food resource management in climate-vulnerable regions.

Acknowledgement

The author gratefully acknowledges the financial and technical support provided by Mahashakti Foundation and HDFC Bank Parivartan (FRDP–Chirantan Project) for the successful implementation of this initiative. Sincere appreciation is extended to the Water User Group members of Darjani village for their active participation, cooperation and valuable contributions throughout the study and field activities.

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How to Cite This Article

Pal A. Mahara irrigation in Eastern India's rainfed agroecology. Int J Agric Nat Farming Res. 2026;2(4):16-19. doi:10.54660/IJANFR.2026.2.4.16-19.

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