ISSN (O): 2320-5407
ISSN (P): 3107-4928

Journal Homepage: -www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)

Article DOI: 10.21474/IJAR01/22390
DOI URL: http://dx.doi.org/10.21474/IJAR01/22390

RESEARCH ARTICLE

COMPARATIVE IMPACT OF THE CLIMATE-ADAPTIVE SORJAN SYSTEM ON FARM ECONOMICS AND RESILIENCE IN COASTAL BANGLADESH

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Manuscript Info

Manuscript History
Received: 8 October 2025
Final Accepted: 10 November 2025
Published: December 2025

Key words:-
Adaptive Agriculture, raised-bed and ditch agro-aquaculture, climate-resilient livelihood, ecology

Abstract

Agriculture in the coastal area of Bangladesh faces severe agricultural constraints due to salinity intrusion, waterlogging, and freshwater scarcity,all of which are exacerbated by climate change. This study evaluates the comparative impact of the Climate-Adaptive Sorjan System, which is a raised-bed and ditch agro-aquaculture model.Using a quasi-experimental design, we compared 27 treatment farmers using the adaptive model with 10 control farmers practicing conventional agriculture in Bhola district. Key findings indicate that the Adaptive Sorjan System, which integrates raised beds, water channels, multi-cropping, and fish culture, significantly enhances economic returns, ecological sustainability, and climate resilience. Treatment farmers achieved 22.05% higher net profit compared to conventional farmers, with additional income from aquaculture and diversified cropping. The system also reduced chemical fertilizer use by 44%, improved soil health, and increased youth and women's participation in agriculture.C hallenges include high initial investment, market manipulation by middlemen, and limited access to quality inputs. Recommendations include developing tailored financial products, institutionalizing training modules, strengthening farmer collectives for market access, and supporting green input supply chains, offering a sustainable pathway toward climate-resilient livelihoods and ecological balance.

Introduction:-

Encompassing approximately 32% of the country's land area and supporting a population of over 35 million, this region is the agrarian heartland for its inhabitants (World Bank, 2020). However, this primary livelihood source faces existential threats from a confluence of environmental and socio-economic pressures. The relentless intrusion of salinity, driven by sea-level rise and reduced freshwater flow in the dry season, is progressively rendering vast tracts of land unsuitable for conventional agriculture (Habib et al., 2022). These climate-induced challenges are severely exacerbated by a critical lack of fresh irrigation water during the dry months, forcing farmers into fallow

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periods or low-yield monocropping. The result is a narrowing of cropping diversity and a direct threat to regional food security and economic stability (MoA, 2021). There is, therefore, an urgent and non-negotiable need to identify, validate, and scale adaptive agricultural practices that can withstand these shocks, ensuring the future of coastal communities.In response to these severe challenges, the Sorjan farming system has re-emerged as a proven approach of climate-smart agriculture. While its principles are rooted in ancient practices, its modern application represents a paradigm shift. Sorjan is a meticulously designed raised-bed and ditch system featuring alternating deep channels (sinks) and high, wide beds (ridges). Therefore, the Sorjan system signifies a fundamental transition from vulnerable conventional farming to a productive, diversified, and ecologically balanced approach to climate-adaptive agriculture in coastal Bangladesh. This study, conducted under the Ecology-Friendly Safe Vegetable and Crop Production and Marketing sub-project, aims to fill this gap by evaluating the Climate Adaptive Sorjan Model promoted by the RMTP project. Using a comparative analysis approach, it assesses the socio-economic, agronomic, and environmental impacts of the adaptive model against traditional practices, with the broader goal of informing scalable, sustainable agricultural transitions in coastal Bangladesh.Given the background of the study objectives are

- To document and compare traditional and adaptive Sorjan farming practices in terms of design, cropping patterns, and input use in selected coastal regions of Bangladesh.
- To assess the agronomic and economic performance of the Climate Adaptive Sorjan Model, focusing on yield, income diversification, cost-effectiveness, and profitability relative to conventional farming systems.
- To evaluate the ecological and climate resilience benefits of the adaptive model, including soil health improvement, reduced chemical input use, integrated pest management, and enhanced adaptability to flooding and salinity.

Literature Review:-

Bangladesh's coastal belt is on the frontline of the global climate crisis. Scholarly work consistently highlights the severe climatic stress this region endures. Rising sea levels are causing saline water to intrude ever deeper into freshwater aquifers and river systems, a phenomenon extensively documented by Clarke et al. (2018). This salinity intrusion is identified as a primary constraint to crop production, negatively affecting soil health and plant growth (Sarwar, 2021). Furthermore, the increased frequency and intensity of cyclones and associated tidal surges not only cause immediate crop loss but also lead to prolonged waterlogging, which exacerbates salinity and destroys soil structure (Dasgupta et al., 2015). These factors collectively render traditional farming methods increasingly ineffective, leading to reduced crop yields, loss of livelihoods, and heightened food insecurity.Sorjan farming, with its origins in Indonesia, has been identified as a transformative agricultural technique for Bangladesh's coastal regions. The system's core design involves constructing raised beds (typically 1–3 meters wide and 60–90 cm high) with adjacent water channels. As described by Uddin et al. (2020), these channels serve a dual purpose: storing vital irrigation water during dry seasons and supporting productive fish farming during wet months. The elevated beds are strategically designed to rise above normal flood levels, thereby mitigating waterlogging and reducing salinity stress on plant root zones. Research shows several innovative variants of this method have been developed:

- Pit cropping utilizes organic-filled jute bags placed in saline soils, creating isolated pockets of fertility (Hossain et al., 2021).
- Trellising systems are integrated for vine crops like gourds and beans, maximizing vertical space and light interception (Bala, 2022).
- Integrated systems combine vegetables, fruits, and fish, creating a synergistic agro-ecosystem that enhances resource use efficiency (Kabir et al., 2020).

Empirical studies demonstrate that Sorjan farming enables significant benefits. It facilitates year-round production of high-value vegetables and fish, even in areas previously deemed uncultivable due to waterlogging or salinity (Uddin et al., 2020). This is achieved through crop diversification, where farmers can cultivate a wide range of species, including leafy greens, gourds, tomatoes, eggplants, and fruit trees such as bananas and papayas (Hossain et al., 2021). The economic impact is substantial. Research by the International Food Policy Research Institute (IFPRI, 2022) indicates that well-managed Sorjan systems can generate net returns of BDT 200,000–250,000 per hectare from the second year onwards. This directly translates to enhanced household income, food security, and nutrition, particularly for marginal and landless farmers (Bala, 2022).Beyond economics, Sorjan farming makes a profound contribution to environmental sustainability and social equity. It builds climate resilience by physically protecting crops from flood damage and diluting salt concentration in the root zone (Kabir et al., 2020). The system also promotes carbon sequestration through increased biomass production and the incorporation of organic matter into the soil (Zaman et al., 2022). Practices such as leguminous crop rotation and mulching, integral to the system, lead to significant improvements in soil health over time (Hossain et al., 2021). From a social perspective, the system's accessible, low-input nature has been shown to empower women and smallholders, providing them with a reliable and dignified source of livelihood (Uddin et al., 2020

Methodology:-

This study employed a comparative mixed-methods research design to evaluate the Climate-Adaptive Sorjan System in coastal Bangladesh. The methodology was structured to compare adaptive Sorjan practitioners (treatment group) with conventional farmers (control group) across agronomic, economic, ecological, and social dimensions.

Quasi-experimental design was adopted to assess the causal impact of the adaptive Sorjan intervention in a real-world setting. The design allowed for comparison between treatment and control groups while accounting for non-random assignment. The study integrated both quantitative and qualitative methods to capture both measurable outcomes and contextual insights.The research was conducted in Bhola District, a coastal region highly vulnerable to salinity intrusion, waterlogging, and climate-related shocks. Thirteen unions were purposively selected from two upazilas, Charfasson and Lalmohan. Participants were divided into two groups. One is a treatment group comprising 27 farmers practising the Climate-Adaptive Sorjan Model. All 27 farmers were beneficiaries of the RMTP project under the Ecology-Friendly Safe Vegetable and Crop Production and Marketing initiative. Other 10 farmers from the control group, located in the same or adjacent villages, practising traditional Sorjan or conventional flat-bed farming, had received no support or training from the RMTP project

A combination of methods was ensured through data triangulation and validity. The same core questionnaire was administered to both groups to ensure comparability.

- In-depth Interviews (IDI): 37 semi-structured interviews (27 Treatment, 10 Control) were conducted to gather detailed, comparable data on farming practices, yields, costs, and income.
- Key Informant Interviews (KII): 6 interviews were held with Government Officials (DAE), Project Staff, and input suppliers to gather expert opinions and systemic perspectives.
- Focus Group Discussions (FGD): 3 separate FGDs were conducted (2 with RMTP-Project farmers, 1 with Control farmers) to explore community perceptions, collective experiences, and shared challenges.

Table 1 - The survey sample size

Data Collection Method	Target Respondents	Proposed Sample
IDI	Treatment Group: FDA Farmers (Adaptive Sorjan)	27
	Control Group: Non-FDA Farmers(Conventional)	10
KII	Input Sellers / Local Buyer, DAE, Project Staff, Service Providers	6
FGD	Treatment Group farmers	2
	Control Group farmers	1

Data Analysis:

Comparative Analysis: The primary analysis involved a direct comparison between the RMTP-Project and Control groups on key indicators: productivity (yield/decimal), income (net profit, BDT), crop diversification (number of crops), and adoption of climate-and resilient practices.

- Qualitative Data: Thematic analysis was conducted on data from KIIs and FGDs to explain the reasons behind the quantitative differences.
- Quantitative Data: Data from IDIs were analyzed using descriptive statistics. Cross-tabulations and means comparison tests (e.g., T-tests) were used to identify statistically significant differences, thereby demonstrating project attribution.

Limitations:-

The relatively small sample size (N=37) and the use of purposive sampling in Bhola District may affect the statistical power and broader generalizability of the findings. The quasi-experimental design, while appropriate for a real-world intervention, cannot fully eliminate selection bias, as pre-existing differences between the self-selected treatment group and the control group may influence outcomes. Furthermore, reliance on farmer self-reported data for yields and income introduces potential recall and social desirability biases.

Result:-

This chapter presents data on the socio-economic and agricultural impacts of ecological Sorjan farming practices. The Treatment Group consists of farmers who have adopted and received support for the Climate Adaptive Sorjan model, while the Control Group comprises farmers using conventional practices The analysis focuses on comparative outcomes to evaluate the effectiveness and scalability of the Sorjan system.

Respondent Profile:-

The respondent pool reflected a promising trend in agricultural demographics. A significant portion, 18 out of 37 farmers (49%), belonged to the 18-35 age indicating a strong engagement of youth in this modern farming practice. The average farming experience across all respondents was 14.08 years, ensuring that the findings are grounded in substantial, long-term agricultural knowledge.

Sorjan Farming System in Charfasson:-

The field findings reveal that the Adaptive Sorjan Model, as practiced by the Treatment Group, is not merely a planting technique but a holistic, knowledge-intensive farming system.

Core Structure and Land Use:-

The system's foundation is the construction of wide, elevated beds (Sorjan) adjacent to integrated ponds. These ponds are crucial for fish cultivation (e.g., Tilapia, Rui), creating a synergistic agro-aquaculture system. The profitability of the system has spurred dynamic land management, with farmers actively leasing and expanding their land. While initial land preparation is a major cost, subsequent seasons require only light maintenance, making it a sustainable long-term investment.

Cropping Pattern:-

Farmers have transitioned from single-crop cultivation to sophisticated, multi-tiered cropping systems designed for maximum efficiency.Simultaneous Multi-Cropping: Farmers cultivate up to four crops simultaneously on the same bed. A standard sequence observed
Cucumber + Mud Potato + Chili + Bitter Gourd.
After the chilli harvest, beans are cultivated and sweet gourds are cultivated. This strategy ensures a continuous harvest, maximizes land use efficiency, diversifies income sources, and leads to a significant aggregate increase in total yield.

Ecological Pest and Soil Management (IPM):-

A cornerstone of the modern Sorjan practice is the drastic reduction of chemical inputs, replaced by ecological wisdom.

- Balanced Fertilization: There has been a significant shift to organics, with heavy use of vermicompost and other organic fertilizers, often guided by soil testing. The use of chemical fertilizers (TSP, MOP, Urea) is now a fraction of previous levels.
- Local Innovation: Farmers reported using Elephant apple (Chalta) as a highly cost-effective natural zinc alternative.
- Integrated Pest Management (IPM): The use of Tulsi (Basil) and Marigold as repellent crops for natural pest repellence is widespread. Farmers also extensively use bio-pesticides and traps, including sex pheromone traps, yellow sticky traps, probiotics and Neem and Akand leaves. As a result, pesticide spraying has reduced dramatically—for example, from 10-15 times to just 4 times per season for cucumber. Farmers consistently reported that soil-borne diseases and pests have become very rare.

Ditches for Fish Farming:-

The integration of aquaculture within the Sorjan system's water channels creates a synergistic agro-ecological model with multifaceted benefits. 57% of the farmers use ditches for fish farming, which completely differentiates the Treatment Group from the Control Group. Cultivating fish like Tilapia and Rui. Economically, this provides a crucial secondary income stream, with farmers reporting annual earnings of BDT 40000 - 60000 from fish alone, a revenue source entirely absent for conventional farmers.

Nutritionally, it ensures a regular, on-farm supply of high-quality protein, directly combating dietary deficiencies in coastal households.
Ecologically, the system establishes a virtuous cycle: fish waste fertilizes the water, which is then used to irrigate the raised beds, reducing the need for and cost of chemical fertilizers by over two-thirds compared to the Control Group. This creates a resilient, closed-loop system that enhances soil health and biodiversity.

Comparative Analysis: Conventional Sorjan vs. Ecological Sorjan:-
Based on the field survey data, this table provides a direct, data-driven comparison between the two groups across key socio-economic, agronomic, and environmental indicators.

Farming Practice: The Treatment Group practices the Adaptive Sorjan system, an integrated approach that combines raised beds for cultivation with adjacent water ponds for fish farming. This is combined with multi-cropping and Integrated Pest Management (IPM). Whereas the control group relies on traditional Sorjan or conventional flat-bed farming, typically focusing on mono-cropping without integration with aquaculture.

Reported Change in Production/Income: 100% of treatment group farmers reported an increase in production or income, with 67% (18 farmers) experiencing a significant increase in both. But 60% of control farmers (6 farmers) reported no change in production or income. Only 10% (1 farmer) reported a significant increase.

Soil Quality Perception: 70% of farmers from the treatment group observed positive changes in soil quality, noting increased organic matter, improved texture, and better fertility. However, 90% of farmers from the control group reported no change in soil quality.

Adoption of IPM & Ecological Practices: The treatment group adopted ecological practices. Farmers use pheromone traps, yellow sticky traps, bio-pesticides (derived from Neem and Akand), and pest-repellent border crops, such as Marigold and Tulsi. Whereas, the Control Group: Limited to no adoption of IPM. Farmers remain reliant on conventional chemical pesticides.

Fertilization Strategy: A balanced, knowledge-based strategy is employed by the treatment group. Farmers heavily use vermicompost and other organic fertilizers. The use of chemical fertilizers (Urea, TSP, MOP) has been reduced to one-third or less of previous levels, guided by soil testing. On the other
hand, the control group employs a conventional and chemically intensive strategy. There is a high reliance on chemical fertilizers with little to no use of soil testing to guide application.

Cropping Pattern & Diversity: The treatment group utilizes complex multi-tiered cropping, cultivating up to four crops simultaneously (e.g., Mud Potato, Chilli, Cucumber, Bitter Gourd). This ensures year-round production and diversifies income sources. This practice was not found in the control group. They practice simple monocropping or a two-crop rotation, typically focusing on a single crop, such as Bitter Gourd or cucumbers. This results in seasonal income and periods of inactivity.
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Additional Income from Aquaculture: The Treatment Group earns a significant additional income from fish (e.g., Tilapia, Rui) cultivated in the integrated ponds. On the contrary, there is no integration of aquaculture, and therefore, no income from this source was found in the control group.

Future Intention to Expand: Treatment Group: 96% of farmers (26 farmers) have concrete plans to expand their Sorjan farming operations, based on their positive experience.Control Group: 90% of farmers plan to expand their farming, but they lack a specific, proven methodology to do so effectively.

Climate Resilience: Conventional flat-bed farming is highly vulnerable to waterlogging, while traditional Sorjan offers only partial resilience. However, the raised beds protect crops from waterlogging, the water channels provide irrigation during droughts, and crop diversification mitigates the risk of total crop failure from pests or climate shocks.

Comparative Financial Analysis Based on 160 Decimal Land (locally standard size of land for vegetable cultivation through Sorjan technique)for a One-Year Cycle, while both farmers follow a base cropping pattern of Cucumber -

Sweet Gourd - Bean. The project's farmer enhances this system with relay/inter crops (Mud Potato, Chili), a boundary crop (Yard Long Bean), Integrated Pest Management (IPM), and integrated aquaculture.

Table 2: Income 160 decimals of land in one Year

Parameter	Climate-adaptive Farmer	Conventional Farmer	Remarks
Return from Cucumber	144,000 BDT (9,600 kg × 15 BDT)	217,500 BDT (14,500 kg × 15 BDT)	A conventional farmer allocates more land/inputs to mono-cropping, yielding a higher volume of a single crop. But the project farmers practised a multi-cropping system, and therefore, they earn 11% higher revenue
Return from Sweet Gourd	168,000 BDT (8,400 kg × 20 BDT)	380,000 BDT (19,000 kg × 20 BDT)	
Return from Bean	120,000 BDT (8,000 kg × 15 BDT)	165,000 BDT (11,000 kg × 15 BDT)	
Return from Bitter Gourd	108,500 BDT (3,100 kg×35 BDT)	0	
Return from Chili	144,000 BDT (1,200 kg×120 BDT)	0	
Return from Mud Potato	98,000 BDT (2,800 kg×35 BDT)	0	
Return from Yard Long Bean (YLB)	17,500 BDT (500 kg×35 BDT)	0	
Return from Fish	45,000 BDT (450 kg×100 BDT)	0	
Total Income	**845,000 BDT**	**762,500 BDT**	

Table 3: Cost of Production for both types of farm

Parameter	Climate-adaptive Farmers	Conventional Farmer	Remarks
Seeds	31,160 BDT	27,900 BDT	Project farmers incur higher costs due to using multi-crops
Fertilizers	46,900 BDT	84,500 BDT	The project farmer uses 44% less fertilizer
Pesticides	67,790 BDT	74,440 BDT	
IPM	8,500 BDT	0 BDT	
Fingerlings	21,000 BDT	0 BDT	
Labor	55,000 BDT	66,000 BDT	
Other Costs	107,200 BDT	83,060 BDT	Initial infrastructure cost
Land Lease	60,000 BDT	60,000 BDT	160 Decimal of land
TOTAL COST	397,550 BDT	395,900 BDT	Treatment has a 9% higher operational cost,
NET PROFIT	845,000 – 397,550 = **447,450 BDT**	762,500 - 395,900 = **366,600 BDT**	**The Treatment farmer's net profit is 22.05% higher.**

The Control farmer's strategy of focusing on three main crops generates high revenue from those crops. However, the Treatment farmer's strategy of integrating high-value relay crops (Chili, Mud Potato), a boundary crop (YLB), and fish farming more than compensates for the lower yield in the base crops. This leads to higher overall revenue and significantly de-risks the farming enterprise against price or crop failure in any single commodity.

The Treatment farmer uses less chemical fertilizer and leverages IPM, which reduces environmental toxicity and allows for profitable fish cultivation. This creates a synergistic, circular system. The slightly higher cost for the Treatment farmer is a strategic investment that yields a higher net profit and a more sustainable operation.
While the profitability difference in this one-year snapshot is 22.05%, the long-term benefits of the Treatment (Sorjan) system are profound:

- **Improved Soil Health:** Reduced chemical use and increased organic matter will enhance fertility over time.
- **Climate Resilience:** The raised beds offer protection from waterlogging.
- **Pest Management:** IPM reduces the risk of pesticide resistance and protects the ecosystem.

On the same piece of land, the diversified and ecological Sorjan system (Treatment) demonstrates a clear economic advantage over the conventional, mono-cropping focused system (Control). It provides higher net profitability, greater income stability through diversification, and builds a foundation for long-term agricultural sustainability.

Discussion:-

The Adaptive Sorjan System is a knowledge-intensive, holistic farming system that successfully integrates land, water, crop, and nutrient management. It is a viable sustainable livelihood model that enhances productivity, builds climate resilience, and provides a profitable career, even for the younger generation.The project's success is partially measured by its ability to stimulate a self-sustaining market for green inputs. The growth of the bio-pesticide market is a critical outcome that ensures the model's longevity beyond project cycles. The success hinges not just on constructing beds and channels but on the concomitant transfer of knowledge on IPM, multi-cropping, and soil health management.

Despite the evident success, several challenges threaten the pace of scaling. The main constraints faced by farmers are no longer primarily agronomic but are related to the market economy, such as ensuring fair prices, middlemen monopolies, accessing timely finance and inputs, etc. The high initial cost of land development and labor remains a significant hurdle for new entrants. The practice of landowners demanding advance lease payments further strains farmers' capital.Middlemen (Baparis) often collude to manipulate vegetable prices at the farm gate, depriving farmers of a fair share of the profits. A syndicate also creates artificial scarcity to inflate the prices of seeds and fertilisers. A lack of technical knowledge, especially among new adopters outside the project's direct reach, poses a risk of suboptimal implementation and disillusionment.Despite market growth, timely access to quality seeds and specific bio-pesticides remains a challenge, especially in remote char areas.

To consolidate the gains and facilitate widespread scaling, the microfinance institute and banks to design and disseminate loan products specifically for Sorjan land development and initial input costs. This could include cost-sharing models or flexible repayment schedules aligned with the harvesting cycle.The successful training approach should be formalized into a standardized module and integrated with the government's (DAE) extension system. This will ensure the continuous flow of knowledge to new farmers, including those in the Control Group.Facilitate the formation of farmer-producer groups or cooperatives to enable collective bargaining and direct access to markets. Explore linkages with urban retailers, supermarkets, and online platforms to bypass middlemen and secure better prices. Need to work with agribusiness companies to forecast demand and ensure the reliable supply of quality seeds and bio-pesticides in Sorjan hubs. Encourage the establishment of more retail outlets in remote areas to improve accessibility.

Conclusion:-

This study provides clear evidence that the PKSF-supported Climate Adaptive Sorjan Model is a transformative intervention for coastal Bangladesh. It has proven to be economically superior, environmentally regenerative, and socially empowering. The model has successfully shifted the agricultural paradigm from vulnerable mono-cropping to a resilient, diversified, and knowledge-based system. Most significantly, its adoption has catalyzed a positive feedback loop, creating a thriving commercial market for eco-friendly inputs and transforming the local agribusiness landscape. By addressing the persistent challenges of market access and initial financing, this proven model can be scaled to secure a productive, profitable, and sustainable future for thousands of coastal households, making them true architects of their own resilience in the face of a changing climate.

Acknowledgement:-

The author acknowledges that the successful completion of this study is the result of the generous support and collaboration of several institutions. We extend our sincere gratitude to the Palli Karma-Sahayak Foundation (PKSF) for its visionary leadership and to IFAD and DANIDA for their crucial financial support.Our heartfelt thanks go to the PoribarUnnayonSongstha (FDA) for their dedicated implementation in the field. We are also deeply indebted to the farmers of Charfasson and Lalmohan in Bhola, whose willingness to share their experiences and time made this report possible. We also acknowledge the valuable cooperation from the Department of Agricultural Extension (DAE), Input Companies, Traders, and local input suppliers.

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