Market System Adaptation to Climate-Smart Agriculture: A Case of the Sorjan-Induced Bio-Economy in Coastal Bangladesh

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Abstract— *This study evaluates the transformative impact of the Climate Adaptive Sorjan Model on the agricultural market system in the coastal regions of Bangladesh, particularly in Charfasson and Lalmohan, Bhola. The research highlights how the adoption of this raised-bed and ditch farming system has catalyzed significant shifts in both backward and forward market linkages, fostering a sustainable and resilient agribusiness ecosystem. Key findings reveal a substantial expansion in the backward market for eco-friendly agricultural inputs, with bio-pesticide sales increasing by nearly 20% within a year and the number of input suppliers more than doubling in the region. This growth reflects a systemic shift toward ecological farming practices driven by farmer adoption of integrated pest management and organic fertilization. In the forward market, Sorjan-produced vegetables have achieved extensive penetration into national wholesale hubs, with over 80% of produce traded beyond local markets. The model's diversified, year-round production has attracted trader investment, ensured price premiums, and stimulated the development of a more resilient value chain. However, challenges such as post-harvest infrastructure gaps and price manipulation by middlemen persist. The study concludes that the Adaptive Sorjan Model not only enhances on-farm resilience and productivity but also actively reshapes local and regional market systems, creating a self-reinforcing cycle of demand for green inputs and premium produce. Strategic interventions in finance, market access, and supply chain development are recommended to sustain and scale this market-led climate adaptation pathway.*

Keywords— Sorjan, Climate Adaptive Agriculture, backwards and forward market, agribusiness, bio-pesticides, ecological farming.

I. INTRODUCTION

The coastal region of Bangladesh, a dynamic and fertile landscape, is paradoxically recognised as the nation's most climate-vulnerable territory. 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). This slow-onset disaster is compounded by acute shocks—frequent and intense cyclones, tidal surges, and seasonal flooding—that lead to catastrophic waterlogging, destroying standing crops and eroding precious topsoil (IPCC, 2022).

These climate-induced challenges are severely exacerbated by a critical lack of fresh irrigation water during the dry months, forcing farmers into periods of fallow land 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 need to identify, validate, and scale adaptive agricultural practices that can withstand these shocks, ensuring the future of coastal communities.

In response to these challenges, the Sorjan farming system has re-emerged as a beacon 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). This design fosters a dynamic and resilient micro-ecosystem that provides multifaceted benefits, including proactive salinity management, improved drainage, integrated water reservoirs, and opportunities for crop and fish diversification (BARI, 2019). As such, the Sorjan system signifies a transition from conventional farming that is vulnerable to environmental challenges toward a more productive, diversified, and ecologically balanced approach.

While much of the existing research has focused on the agronomic and environmental benefits of Sorjan farming, a significant gap remains in understanding how its adoption influences and transforms local and regional agricultural market systems. The success of climate-adaptive technologies depends not only on on-farm adoption but also on the responsiveness of input supply chains, output market linkages, and value chain actors. Therefore, this study shifts the analytical lens from a purely comparative farm-level assessment to a systemic examination of market adaptation spurred by the Climate Adaptive Sorjan Model. the research aims to:

- Assess the influence of the Climate Adaptive Sorjan Model on the transformation of the agricultural input market, specifically examining the growth and diversification of eco-friendly input supply chains in coastal Bangladesh.
- Evaluate the changes in forward market linkages resulting from Sorjan-based production, including market penetration, price dynamics, and trader engagement in the value chain.
- Identify the key drivers and barriers in the adoption of market-supporting mechanisms that enable scaling of climate-resilient farming systems in vulnerable coastal regions.
- Propose strategic recommendations for strengthening market systems that support the widespread replication and scalability of climate-adaptive agricultural models beyond project-based interventions.

II. 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

While the existing body of research robustly establishes the agronomic viability, economic benefit, and ecological promise of the Sorjan system, significant gaps remain regarding its systemic market impacts. Most studies focus on farm-level productivity, income comparisons, or environmental outcomes (e.g., Uddin et al., 2020; IFPRI, 2022), with limited investigation into how the adoption of such climate-smart practices reshapes local and regional agricultural market structures.

This study addresses these gaps by shifting the analytical focus from a purely comparative farm-level assessment to a holistic examination of market system adaptation. It investigates how the Climate Adaptive Sorjan Model catalyzes change in both backward linkages (input supply chains for eco-friendly products) and forward linkages (output markets and trade networks). By doing so, it contributes to the broader discourse on scaling climate-resilient agriculture, emphasizing that technological adoption must be supported by responsive and resilient market ecosystems to achieve sustainable transformation.

III. MATERIAL AND METHODS

This study employed a **mixed-methods case study design** to investigate the adaptation of agricultural market systems in response to the widespread adoption of the Climate Adaptive Sorjan Model in coastal Bangladesh. The research was conducted as a holistic, single-case study of the Bhola district, a region characterized by high climate vulnerability and significant promotion of the Sorjan system. This design was chosen to enable an in-depth, contextual exploration of the complex interactions between a climate-resilient farming practice and its surrounding economic ecosystem, focusing on both backward (input) and forward (output) market linkages. The mixed-methods approach allowed for the triangulation of qualitative insights on market processes and actor behaviours with quantitative data on market trends, providing a comprehensive understanding of systemic change.

3.1 Study Area:

The study was conducted in Bhola district, specifically in the coastal upazilas of **Charfasson and Lalmohan**. This site was selected due to its representative vulnerability to salinity, waterlogging, and cyclonic events, and because it has been a focal area for promoting the Climate Adaptive Sorjan Model under the Rural Microenterprise Transformation Project (RMTP). The concentration of adopters in this region provided a unique opportunity to observe emerging market dynamics around a specific agricultural innovation. Data were collected in October 2025 from four primary sources to ensure methodological triangulation and data validity.

3.2 Data Collection Procedures:

3.2.1 In-Depth Interviews (IDIs):

Semi-structured interviews were conducted with 37 farmers to understand on-farm decision-making, input sourcing, and market engagement practices. The sample included farmers practicing the Adaptive Sorjan Model to capture the producer perspective driving market demand. The interview guide was designed to explore changes in input procurement (e.g., shift to bio-pesticides), selling strategies, relationships with traders, and perceptions of market access and fairness.

3.2.2 Key Informant Interviews (KIIs):

A total of 12 KIIs were conducted with actors across the agricultural value chain to capture systemic perspectives. Participants were purposively selected and included 5 representatives from major companies (e.g., Ispahani) and local agro-inputs retailers

to discuss changes in product demand, sales trends, and supply chain expansion. 4 local buyers (*Baparis)* and regional wholesalers involved in procuring and distributing Sorjan produce to understand changes in sourcing, pricing, quality demands, and their evolving role in the value chain and 3 Institutional Actors from the Department of Agricultural Extension (DAE) and project implementing staff (FDA/PKSF) to gather insights on programmatic support and observed market shifts.

3.2.3 Focus Group Discussions (FGDs):

Three separate FGDs were held, each with 8-10 participants, to explore shared community experiences and collective challenges related to the market system. Two FGDs were with Sorjan-adopting farmers, and one was with a mixed group of conventional and transitioning farmers. Discussions focused on themes of collective bargaining, price transparency, access to finance, and perceived power dynamics with middlemen.

3.2.4 Secondary and Quantitative Market Data:

To objectively measure market growth and trends, secondary sales data for the period 2022–2025 were obtained from a leading national agri-input company (Ispahani) operating in Bhola. This dataset included from the annual and quarterly sales revenue for bio-pesticides, chemical pesticides, and seeds, volume sales data for specific bio-inputs (e.g., pheromone traps) and records of distributor network expansion within the district. These data provided a reliable, third-party validation of market transformations described qualitatively by participants.

TABLE 1
DATA COLLECTION SUMMARY

Method	Target Respondents	Sample Size	Primary Purpose
In-Depth Interviews (IDIs)	Farmers (Sorjan adopters)	37	Understand producer-level market interactions, input use, and sales strategies.
Key Informant Interviews (KIIs)	Input Suppliers, Traders, DAE/Project Officials	12	Analyze systemic changes in supply chains, trade networks, and institutional roles.
Focus Group Discussions (FGDs)	Farmer groups	3 (8-10 each)	Explore community perceptions, collective challenges, and market dynamics.
Secondary Data Analysis	Company sales records, project reports	N/A	Quantify market growth trends and validate qualitative findings.

3.3 Data Analysis:

3.3.1 Qualitative Data Analysis:

All interviews and FGDs were audio-recorded, transcribed, and translated into English. The transcripts were analyzed using thematic analysis. An initial codebook was developed based on research objectives, focusing on themes such as "input market evolution," "trader-farmer relationships," "price mechanisms," "financial access," and "institutional support." Codes were applied iteratively, and emerging themes were refined to construct a coherent narrative of the market adaptation system.

3.3.2 Quantitative Market Data Analysis:

Secondary sales data were cleaned and analyzed using descriptive statistics. Trend analysis was performed to calculate year-on-year growth rates for bio-pesticide sales. Sales distribution across different dealer locations was mapped to identify geographic hubs of market activity linked to Sorjan adoption. This quantitative analysis provided empirical evidence of market scaling and product diversification.

3.4 Limitations:

While the chosen methodology provides valuable insights, several limitations should be acknowledged. The findings are context-specific to Bhola district. While they offer deep insight into market adaptation processes, direct extrapolation to other regions with differing agro-ecological, infrastructural, or market conditions should be made cautiously. Additionally, the study captures a snapshot of market dynamics at a particular point in the adoption curve. Longitudinal data would be required to fully understand the sustainability of observed market changes and long-term systemic shifts. Moreover, sales data from a major

input provider are indicative of broader trends, they do not capture the entire market, including sales from smaller local suppliers or informal input exchanges, potentially underrepresenting total market activity.

IV. RESULT AND DISCUSSION

The empirical findings of the study, structured to first establish the nature and scale of the transformative agricultural practice climate adaptive Sorjan model and then analyze the resultant systemic market adaptations. The data illustrate a clear causal pathway, i.e. a shift to a knowledge-intensive, ecological farming system creates new patterns of input demand and output supply, where local and regional markets are dynamically responding. Field data reveal that the promoted Sorjan system is not merely a water management technique but a sophisticated, integrated agro-enterprise. Its adoption signifies a fundamental departure from conventional coastal agriculture.

4.1 Core Structural and Management Shifts:

The system is based on constructing wide, elevated beds (Sorjan) adjacent to integrated water channels or ponds. This infrastructure enables synergistic agro-aquaculture, with 57% of adopting farmers cultivating fish like Tilapia and Rui in the ditches. This integration is pivotal, providing secondary income (BDT 40,000–60,000 annually per farmer), on-farm protein, and nutrient-rich irrigation water, reducing chemical fertilizer dependency by over two-thirds.

4.2 Knowledge-Intensive Cropping and Ecological Management:

The most significant departure from convention is the shift to complex, multi-tiered cropping. Farmers cultivate up to four crops simultaneously on the same bed (e.g., Cucumber, Mud Potato, Chilli, and Bitter Gourd), ensuring continuous harvest and income. This diversity is managed through ecological practices that form the core of the model's input profile:

- A shift to balanced, knowledge-based strategies. Farmers heavily use vermicompost and other organic fertilizers, guided by soil testing. Chemical fertilizer (Urea, TSP, MOP) use has been reduced to one-third or less of previous levels.
- Widespread adoption of Integrated Pest Management (IPM) has drastically altered input demand. Farmers now rely on Bio-pesticides (derived from Neem, Akand), Physical traps (pheromone traps, yellow sticky traps) and Repellent/companion crops (Marigold, Tulsi/Basil) planted as borders. As a result, pesticide spraying frequency has fallen from 10-15 to just 4 times per season for cucumber.
- Practices like using Elephant apple (Chalta) as a natural zinc supplement demonstrate farmer-led adaptation within the ecological framework.

4.3 Socio-Economic Driver:

The system's appeal is underscored by strong socio-economic indicators. 49% (18 of 37) of engaged farmers are aged 18-35, indicating the success of attracting young people to agriculture. The economic rationale is clear. A comparative financial analysis for a local standard 160-decimal plot shows that while the ecological Sorjan system incurs a 9% higher operational cost (largely due to multi-crop seeds and initial IPM infrastructure), it generates a 22% higher net profit (BDT 447,450 vs. BDT 366,600) than a conventional mono-cropping system on the same area of land. This profitability, driven by diversified output (including fish and high-value relay crops like Chilli), is the primary engine for adoption and expansion, with 96% of adopters planning to scale their operations.

4.4 Transformation of the Backwards Market:

The adoption of the ecological Sorjan system has fundamentally reshaped demand and supply structures for agricultural inputs, catalyzing a shift from chemical-intensive to biology-intensive farming.

4.4.1 Market Growth for Eco-Friendly Inputs:

Sales data from a leading national agri-input company (Ispahani) provide certain evidence of a rapidly expanding market for bio-pesticides and Integrated.Pest Management (IPM) products in Bhola district. Revenue from bio-pesticides grew from BDT 61 lakh in 2023 to BDT 73 lakh in 2024, a nearly 20% year-on-year increase. The accelerated adoption is further underscored

by sales of BDT 26 lakh in just the first three months of 2025. High-volume sales of specific inputs, such as 35,000 pheromone trap pieces in 2024, indicate widespread, practical application. Assuming a standard recommendation of 2 traps per 6 decimals of land, these sales alone serviced a substantial cultivated area, directly linked to Sorjan adoption clusters.

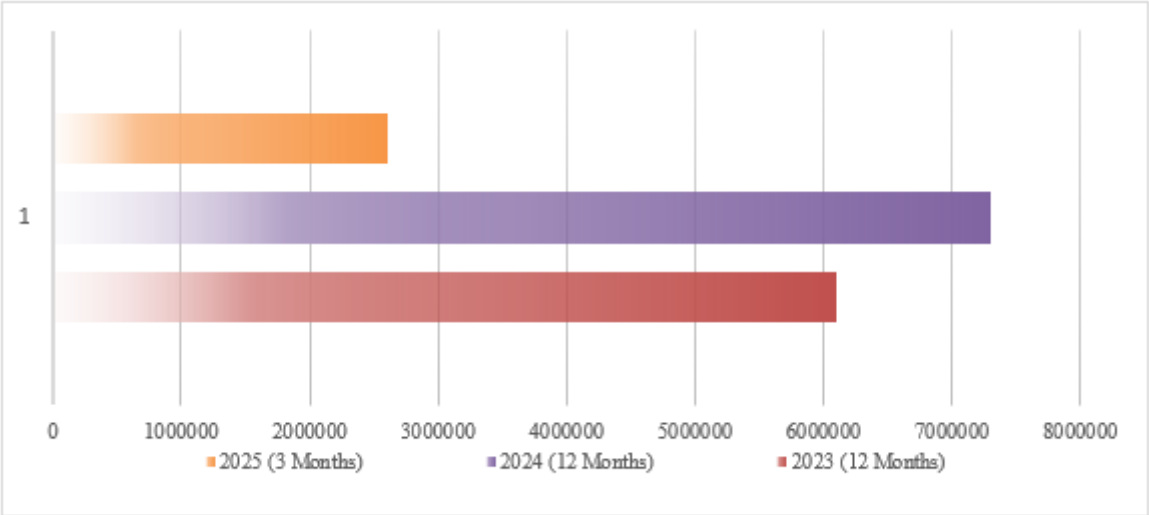

FIGURE 1: Annual Growth in Bio-pesticide Sales Revenue in Bhola District (2023-2025 Projection)

4.4.2 Supply Chain Expansion:

In response to this rising demand, the input supply chain has undergone a structural transformation. The number of Ispahani distributors in Bhola is now more than doubled, from 5 in 2022 to 11 at present. Notably, two dealers in Charfassion alone account for 40-45% of the district's total bio-input sales, confirming that Sorjan farming hubs have become epicenters of demand and are strategically shaping corporate distribution networks. The market has also matured beyond basic products, with a diversified portfolio now available, such as Bio-Chomok for fruit borers and K-mite for mites, indicating a sophisticated and responsive supply side aligned with the complex pest management needs of diversified Sorjan systems.

4.4.3 Farmer Motivations and Behavioural Shift:

Qualitative data from farmers interprets the drivers behind this market shift, as reducing the use of chemical pesticides and increasing the use of pheromone traps and bio-pesticides enables farmers to cultivate fish in the ditch. In FGDs, farmers reported reducing chemical pesticide sprays from 10-15 times per season to just 2-4 times for key crops, such as cucumber, primarily substituting them with bio alternatives.

4.5 Evolution of Forward Market Linkages:

The consistent, diversified, and quality-enhanced production from Sorjan systems has precipitated a significant reconfiguration of output market linkages. Sorjan produce has successfully breached local consumption boundaries. Over 80% of surveyed farmers' marketable surplus is now traded beyond the local Bhola markets. The produce has penetrated major national wholesale hubs, with Dhaka's Kawran Bazar and Shyam Bazar absorbing approximately 40% of the total trade, followed by Noakhali (24%) and Chattogram (16%). This geographic expansion demonstrates the model's scalability and the strong, consistent demand for its output in competitive urban markets.

4.5.1 Investment in the Value Chain:

Recognising the value of a reliable, high-quality supply of vegetables, traders have actively adapted their roles, such as advance payments to trusted Sorjan farmers for input purchases and securing their quality vegetable supply. Some traders offer support in the form of renting irrigation pumps or power tillers. Besides, superior shelf life, the appearance of Sorjan vegetables allows them to command a price premium of 2-5% over conventional produce.

This discussion synthesizes the key findings to extract broader lessons on market-led climate adaptation, identifies persistent challenges that threaten the sustainability and equity of the Sorjan model's expansion, and highlights actionable opportunities. The transformation observed in Bhola offers several critical insights for scaling climate-resilient agriculture are as follows:

- The success of the Sorjan system lies not only in its agronomic resilience but in its inherent compatibility with market demand. Its multi-cropping pattern produces a year-round mix of high-value vegetables that align with trader needs, while its ecological practices produce quality. This demonstrates that for an adaptive technology to scale, its output must be commercially viable and its input requirements must be sustainably supplied.
- The study provides a clear case of agricultural innovation driving parallel market innovation. Farmer adoption of IPM did not occur in a vacuum; it created a profitable demand for bio-inputs, which commercial suppliers rapidly met by expanding distribution networks and diversifying products. This virtuous cycle between adoption and market responsiveness is a crucial replicability factor.

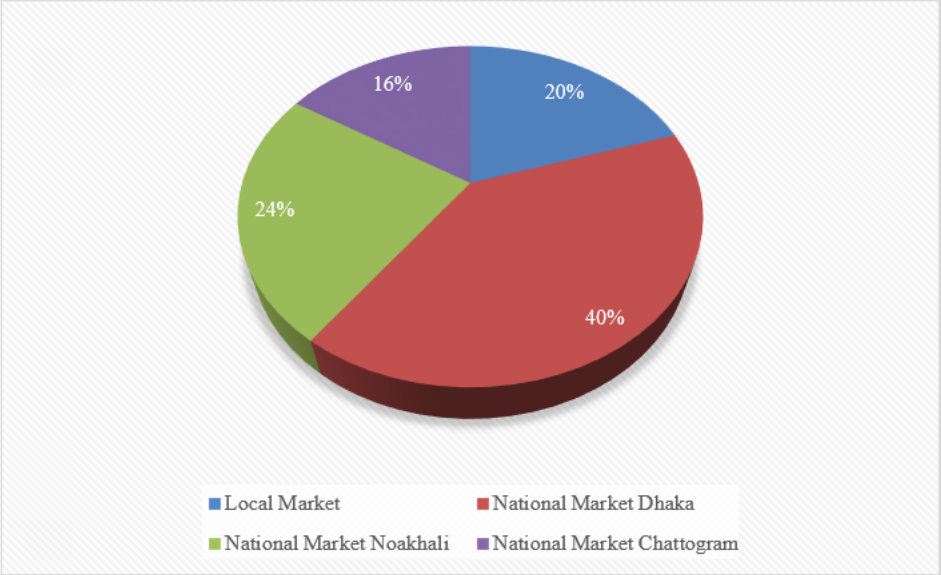

FIGURE 2. Market Destinations for Sorjan-Produced Vegetables

Despite the promising adaptation, the study uncovers deep-seated market failures that risk concentrating benefits and stifling inclusive growth. The most reported constraint was the collusion among middlemen (*Baparis*) to depress farm-gate prices, especially for perishable produce. Without mechanisms for price transparency or collective bargaining, the model's economic benefits are significantly diluted at the producer level. Moreover, the growth of the bio-input market is geographically uneven and concentrated under limited competitive pressure. While a major supplier like Ispahani has successfully expanded its network, its dominant market share in key Sorjan hubs raises concerns about long-term price competitiveness and farmer choice. Furthermore, production innovation has outpaced the development of market infrastructure. The drastic price collapse for overproduction, such as country bean seeds falling from BDT 120/kg to BDT 40/kg within weeks, is directly attributable to a lack of cold storage and processing facilities.

Addressing these challenges requires moving beyond promoting the farming technique alone to actively shaping an enabling market environment. Agribusiness companies can develop a last-mile distribution network for remote *chars*, potentially using mobile vendors. Public extension services could supplement this by validating and promoting low-cost, local bio-inputs (e.g., Neem extract preparation) to reduce dependency on commercial channels and mitigate the power of syndicates. In addition, developing tailored financial products with MFIs and banks for Sorjan establishment *and* post-harvest infrastructure. This could include loans for shared cold storage facilities or community-based processing units.

V. CONCLUSION

This study confirms that the Climate Adaptive Sorjan Model has catalyzed significant market system transformation in coastal Bangladesh. The shift to this ecological farming system has spurred rapid growth in the bio-input market and strengthened forward market linkages, integrating Sorjan produce into national supply chains. However, scaling remains constrained by persistent market imperfections, including price manipulation by middlemen, limited competitiveness in input markets, and a critical lack of post-harvest infrastructure. For the model to realize its full potential, strategic interventions must address these structural barriers by fostering more inclusive and competitive market institutions. Ultimately, the Sorjan experience demonstrates that sustainable climate adaptation requires not only technological adoption but also the development of equitable and resilient market ecosystems that enable farmers to thrive amid environmental change.

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CONFLICT OF INTEREST

The authors declare no direct conflict of interest regarding the publication of this study. The research was conducted independently by **GMark Consulting Ltd.** under the sponsorship of **Palli Karma-Sahayak Foundation (PKSF)** with funding from **IFAD** and **DANIDA**. The findings and conclusions presented in this report are based solely on empirical data and do not reflect the commercial interests of any supporting or implementing organization. The authors affirm that there are no financial or personal relationships that could be perceived as influencing the research outcomes or the reporting of results.

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