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IMPACT OF RICE-RAJMAH / TORIA BASED DOUBLE CROPPING PRACTICES FOR CLIMATIC ACCESSIBILITY AND ENHANCING AGRICULTURAL INTERVENTION IN SRIBHUMI, ASSAM, INDIA

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ABSTRACT

Agricultural productivity in Assam faces significant challenges due to seasonal weather patterns and traditional farming practices that often limit farmers to a single crop per year. This study evaluates the efficacy of rice-based double cropping systems as a sustainable strategy in the Sribhumi district of Assam, India. The study examined two systems (i) Rice followed by Rajmah and (ii) Rice followed by Toria across a 20-hectare (ha) participatory demonstration area. Following flood-induced damage to the medium-duration rice (135-140 days) variety Numali, the short-duration (105-110 days) variety Disang was introduced as a contingency, highlighting adaptive farm management. The program was conducted with 16 farmers across 15 ha of rice–rajmah (rice varieties Numali/Disang with rajmah varieties Kota Rajmah and Tripura Selection) and 5 ha of rice–toria (Toria variety TS-38). Results showed that the rice–rajmah system achieved a Rice Equivalent Yield (REY) of 123.05 q/ha and a Production Efficiency (PE) of 51.27 kg/ha/day, significantly outperforming the rice–toria system (REY: 62.16 q/ha, PE: 25.90 kg/ha/day). Economic analysis revealed gross returns of Rs. 2,83,004/ha for rice–rajmah and Rs. 1,42,959/ha for rice–toria, compared to Rs. 1,00,004/ha from rice monocropping, representing a 367%- and 55%-income increase, respectively. Both double cropping systems achieved 200% cropping intensity, demonstrating enhanced land use efficiency, economic resilience, and income diversification. The successful use of short-duration varieties as a flood contingency highlights a scalable and climate-resilient strategy for similar agro-ecologies across South Asia.

***Keywords*: Double cropping, Rice Equivalent Yield, Production Efficiency, Cropping Intensity, Contingency planning.**

Introduction

Rice (*Oryza sativa* L.) is the dominant staple crop in Assam, cultivated by majority of the farming population and contributing significantly to food security and rural livelihoods. As per the final estimates for 2020–21, paddy was cultivated across 23.60 lakh hectares of land in the state (Government of Assam, 2022). In the flood-prone Barak Valley region, particularly in districts like Sribhumi, rice is primarily grown as a monocrop during the kharif season, leaving vast areas fallow post-harvest due to waterlogging, late harvesting, or lack of irrigation facilities (Dhar and Nandargi, 2000; Dhar and Nandargi, 2003). This hydrological pattern has historically confined farmers to a single rice crop annually, leaving agricultural land fallow for 4-5 months. This single-cropping pattern results in low cropping intensity and underutilization of land resources, directly impacting the annual income and resilience of smallholder farmers (Srivastava *et al.,* 2022; Kumar *et al.,* 2024).

In double cropping system cultivating two crops sequentially on the same land within a single agricultural year which offers potential to transform this underutilization of arable land (Waha *et al.,* 2020). With climate variability increasing the unpredictability of monsoon floods, there is a growing need to diversify and intensify rice-based cropping systems. Short- and medium-duration rice varieties such as Disang (100-110 days) and Numali (135-140 days) allow for early harvest and provide a suitable window for cultivating second-season crops like rajmah (*Phaseolus vulgaris* L.) and toria (*Brassica campestris* L. var. toria). These high-value legumes and oilseeds not only enhance land-use efficiency and rice equivalent yield (REY) but also improve soil health through nitrogen fixation and nutrient recycling (Kumar *et al.,* 2018; Peramaiyan & Singh, 2022).

Despite established theoretical benefits, practical implementation of double cropping in flood-prone regions of Northeast India remains limited due to knowledge gaps regarding suitable crop combinations, variety selection, and contingency planning approaches. Previous studies have focused primarily on stable agro-ecological zones, while flood-prone regions present unique challenges requiring specialized strategies (Mandal *et al.,* 2015 and Mandal *et al.,* 2018). Additionally, the socio-economic viability of such systems in smallholder contexts demands quantification through robust field demonstrations rather than controlled experimental trials alone. Recent studies suggest that climate-adaptive agricultural intensification could increase smallholder incomes by 25-45% while enhancing food security in vulnerable regions, yet specific pathways remain underexplored (Lipper *et al.,* 2014). To address the limitations of traditional monocropping in flood-affected areas, Krishi Vigyan Kendra (KVK), Sribhumi, initiated participatory on-farm demonstrations to evaluate the productivity, production efficiency, and economic viability of two rice-based double cropping systems: rice–rajmah and rice–toria. The study involved 16 farmers using region-specific varieties and assessed performance using standardized metrics such as Rice Equivalent Yield (REY), Production Efficiency (PE), cropping intensity and benefit cost ratio etc. By integrating contingency planning with short-duration rice varieties, the study aimed to identify sustainable and climate-resilient alternatives to monoculture, generating location-specific recommendations and practical insights for extension services and smallholder farmers in similar agro-ecological zones.

Materials and Methods

Study Location and Environmental Conditions

The study was conducted during the session of 2024-25 cropping cycle across six villages in Sribhumi district, Assam, India (24°52'N latitude and 92°20'E longitude). The region experiences a subtropical humid climate with annual rainfall averaging 2200-2500 mm, predominantly distributed between May and September. Soil analysis indicated sandy loam to clay loam texture with medium nitrogen (285-315 kg/ha), medium phosphorus (18-22 kg/ha), and medium potassium (240-275 kg/ha) content, with soil pH ranging from 5.8-6.2.

Design and Participatory Approach

The study was carried out under the 2024 programme *"Promotion of Double Cropping System in Sribhumi District"* by Assam Agricultural University through KVK Sribhumi. A participatory approach was adopted, involving 16 smallholder farmers (0.4–1.2 ha holdings), each allocating at least 0.5-1 ha for demonstrations -15 ha under rice–rajmah and 5 ha under rice–toria systems. Instead of a formal experimental design, the study followed participatory action research principles (Chambers, 1994; Sharma, 2017), engaging farmers in planning, implementation, and data collection. While statistical replication was not employed, uniform agronomic practices were maintained across all plots, with technical guidance and monitoring provided by KVK scientists.

Cropping Systems and Contingency Planning

Table 1: Cropping Systems and Contingency Measures

System No.	Kharif Crop	Variety & Duration	Contingency Measure	Rabi Crop	Variety & Duration	Area (ha)
(i)	Rice	Numali (140 days)	Disang (110 days) (introduced after flooding)	Rajmah	Kota Rajmah, Tripura Selection (100 days)	15
(ii)	Rice	Numali (140 days)	Disang (110 days) (introduced after flooding)	Toria	TS-38 (90 days)	5

Initially, the medium-duration rice variety 'Numali' (140 days) was planted during the kharif season (June-November). However, unexpected flooding during 1st week of August damaged these crops in 4 of the 16 demonstration fields. In response, the short-duration rice variety 'Disang' (110 days) was introduced as a contingency measure in these affected fields. The selection criteria for 'Disang' included for its short duration, photoperiod sensitivity, and established performance in similar regions. The shorter duration allowed timely harvest by last week of November, enabling the scheduled early December sowing of rabi crops. For rajmah, two varieties were selected: 'Kota Rajmah' and 'Tripura Selection', both chosen for their 100-110 day maturity period and market premium. For toria, variety 'TS-38' was selected for its 90-100 day maturity and oil quality. Both rabi crops were sown in the first week of December 2024 and harvested in March 2025 (Table 1).

Crop Management Practices

Standard Package of Practice (POP) from Assam Agricultural University were followed for both cropping systems (Table 2).

Table 2: Agronomic practices for component crops.

Practice	Rice (Numali/Disang)	Rajmah (Kota/Tripura Selection)	Toria (TS-38)
Seed rate (kg/ha)	40	75	10
Spacing (cm)	20 × 15	30 × 10	30 × 10
Fertilizer (N-P-K kg/ha)	60-20-40	60-45-40	40-35-15
Irrigation	Rainfed	2 critical irrigations	2 critical irrigations
Plant protection	Need-based IPM	Need-based IPM	Need-based IPM

Data Collection and Analysis

Crop yields were recorded at harvest from three randomly selected quadrats (5 m × 5 m) within each demonstration plot. Market prices were determined based on the average selling prices reported by farmers across local markets in March 2025, with rates of Rs 2300/quintal for paddy (Government of Assam MSP), Rs 150/Kg for rajmah, and Rs 55/Kg for toria. Farmers' perceptions were assessed through semi-structured interviews and focus group discussions conducted post-harvest.

The following parameters were calculated to assess system performance:

1. Rice Equivalent Yield (REY):
   - REY (q/ha) = Rice yield (q/ha) + [Yield of second crop (q/ha) × Price of second crop (Rs/q)] / Price of rice (Rs/q)
2. Production Efficiency (PE):
   - PE (kg/ha/day) = [REY (q/ha) × 100] / Total duration (days)
3. Economic Analysis:
   - Gross returns: Yield × Market price
   - Additional economic indicators: Income gain over rice monocropping, percent increase in income
   - Benefit-Cost Ratio: Gross returns / Total cost of cultivation
   - Net returns: Gross returns - Total cost of cultivation
4. Cropping Intensity:
   - Cropping Intensity (%) = [Total cropped area in a year / Net cultivated area] × 100

Results and Discussion

Yield Performance and Impact of Contingency Planning

The yield performance of individual crops in both cropping systems is presented in Table 3. The average rice yield was standardized based on the participation of 16 farmers, where 12 (75%) of the farmers' areas cultivated the medium-duration variety 'Numali' and 4 (25%) of the farmers' areas cultivated the short-duration variety 'Disang'. This distribution resulted in a weighted average rice yield of 43.48 q/ha across all demonstration plots, calculated as: {(46.8 q/ha × 0.75) + (33.5 q/ha × 0.25) = 43.48 q/ha}. The substantial yield difference between Numali and Disang reflects the impact of timing and growing conditions following flood damage rather than inherent varietal potential.

The strategic decision to introduce Disang prioritized completing the cropping cycle within the shortened window to enable timely sowing of the subsequent rabi crops, thereby ensuring the overall success of the double cropping system rather than maximizing kharif rice yield (Fig.1).

The rajmah crop (both 'Kota Rajmah' and 'Tripura Selection' varieties) yielded an average of 12.2 q/ha, which exceeds the state average of 10.8 q/ha for Rajmah (Directorate of Economics and Statistics, 2020). This higher yield may be attributed to the residual moisture and fertility following rice cultivation, coupled with timely sowing enabled by the contingency planning. Toria 'TS-38' performed similarly well at 7.81 q/ha compared to the regional average of 6.5 q/ha for rapeseed varieties (Meena *et al.,* 2017).

Fig. 1: Demonstration and Field Performance of Double Cropping Technologies (Rice–Rajmah and Rice–Toria) in Sribhumi District, Assam.

Rice Equivalent Yield and Production Efficiency

Rice Equivalent Yield (REY) provides a standardized metric for comparing cropping systems with differing outputs and market values. Among the systems, the rice–rajmah combination demonstrated superior performance with an REY of 123.05 q/ha and PE of 51.27 kg/ha/day (Table 3, Fig. 2A). This can be attributed to the high price of rajmah (□15,000/q), which significantly enhanced economic returns despite a modest yield of 12.2 q/ha. This indicates that high-value legumes can successfully augment system productivity and profitability when integrated as a second crop. The rice–toria system yielded an REY of 62.16 q/ha and PE of 25.90 kg/ha/day, indicating moderate system performance. Although toria had a lower market price (Rs. 5,500/q) than rajmah, it still added value by efficiently utilizing the residual soil moisture after rice harvest. Its shorter growing period and adaptability to the post-kharif window make it a viable option for smallholders in flood-prone regions. In comparison, the rice-alone system recorded the lowest REY (43.48 q/ha) and PE (31.06 kg/ha/day) due to the absence of a secondary crop. Although this system had a shorter duration (140 days), it did not optimize land use or maximize returns per unit time. These observations are consistent with findings by Jat et al. (2019), who emphasized the benefits of legume-based double cropping systems in enhancing annual productivity due to their nitrogen-fixing ability and premium market prices.

Table 3: Rice Equivalent Yield (REY) and Production Efficiency (PE) of Different Cropping Systems in Sribhumi.

Cropping System	Crop Components	Varieties Involved	Yield (q/ha)	Market Price (Rs/q)	Net Yield (q/ha)	REY (q/ha)	Total Duration (days)	PE (kg/ha /day)
Rice–Rajmah	Rice + Rajmah	Rice: Disang/ Numali	43.48	2300	55.68	123.05	240	51.27
		Kota Rajmah	12.2	15000				
Rice–Toria	Rice + Toria	Rice: Disang/ Numali	43.48	2300	51.29	62.16	240	25.90
		Toria (TS-38)	7.81	5500				
Rice (Monocrop)	Rice only	Rice: Disang/ Numali	43.48	2300	43.48	43.48	140	31.06

Note: Numali: 12 farmers and Disang: 4 farmers (total: 16).
Weighted average rice yield = (46.8 × 12/16) + (33.5 × 4/16) = 43.48 q/ha

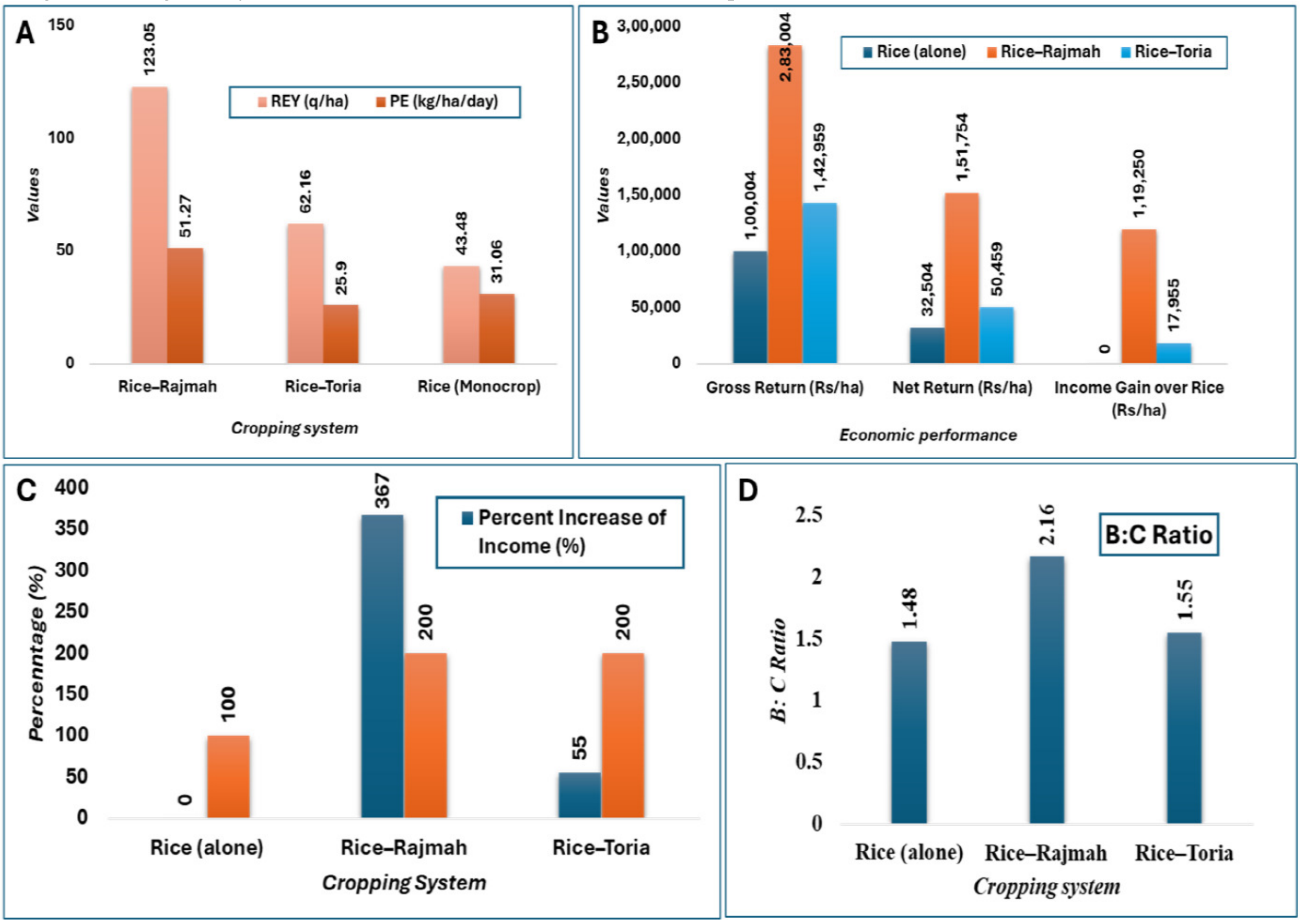

Fig. 2: Comparative Performance of Double Cropping Systems Based on Productivity, Profitability, and Income Enhancement in Sribhumi District.

Here, A: Comparison of cropping systems based on REY (Rice Equivalent Yield) and PE (Production Efficiency); B: Economic performance indicators such as Gross Return, Net Return, and Income Gain over rice monocropping; C: Percent increase in income compared to rice monocropping; D: Benefit-Cost (B:C) ratio of different cropping systems.

Economic Analysis

The economic performance of different cropping systems in Sribhumi was evaluated using key indicators including gross return, net return, income gain over monocropping, percent increase in income, cropping intensity, and benefit-cost (B:C) ratio (Table; Fig. 2B, C, D). Among the three cropping systems assessed, Rice–Rajmah recorded the highest gross return of Rs. 2,83,004/ha, followed by Rice–Toria (Rs. 1,42,959/ha), whereas Rice (alone) yielded the lowest gross return of Rs. 1,00,004/ha. The corresponding cost of cultivation was Rs. 1,31,250/ha for Rice–Rajmah, Rs. 92,500/ha for Rice–Toria, and Rs. 67,500/ha for Rice alone. The net return, calculated as gross return minus cost of cultivation, was significantly higher in the Rice–Rajmah system (Rs. 1,51,754/ha), followed by Rice–Toria (Rs. 50,459/ha), with Rice (alone) yielding only Rs. 32,504/ha. The income gain over rice monocropping was Rs. 1,19,250/ha for Rice–Rajmah and Rs. 17,955/ha for Rice–Toria, translating to a percent increase in income of 367% and 55%, respectively. These findings clearly indicate the economic advantage of double cropping systems over rice monocropping. In terms of cropping intensity, both Rice–Rajmah and Rice–Toria achieved 200%, effectively doubling the utilization of land area compared to rice alone (100%). This intensified cropping not only increased land productivity but also ensured better economic returns to farmers.

The Benefit-Cost Ratio (B:C) further corroborated these findings, with Rice–Rajmah achieving the highest B:C ratio of 2.16, followed by Rice–Toria (1.55), while Rice (alone) lagged behind at 1.48. B:C ratio greater than 2 in Rice–Rajmah signifies its superior economic efficiency and viability under the given agro-climatic conditions. Overall, the study suggests that integrating pulses like Rajmah or oilseeds like Toria in rice-based systems substantially improves farm income, cropping intensity, and resource use efficiency. Among the systems evaluated, Rice–Rajmah stands out as the most profitable and sustainable double cropping option, especially suitable for flood-prone yet resource-constrained regions like Sribhumi in Assam.

Table 4 : Economic performance of different cropping systems.

Cropping System	Gross Return (Rs/ha)	Net Return (Rs/ha)	Income Gain over Rice (Rs/ha)	Percent Increase (%)	Cropping Intensity (%)	B:C Ratio
Rice (alone)	1,00,004	32,504	0	0	100	1.48
Rice–Rajmah	2,83,004	1,51,754	1,19,250	367%	200	2.16
Rice–Toria	1,42,959	50,459	17,955	55%	200	1.55

These findings are consistent with Jat et al. (2016), who reported substantial income gains from diversified rice-maize cropping systems in South Asia. The exceptional performance of rice–rajmah in this study likely stems from the high market demand for quality beans in the region and neighboring states, resulting in premium pricing. This underscores the importance of market-oriented crop selection in double cropping systems, particularly for smallholder farmers with limited resources.

Resilience through Contingency Planning

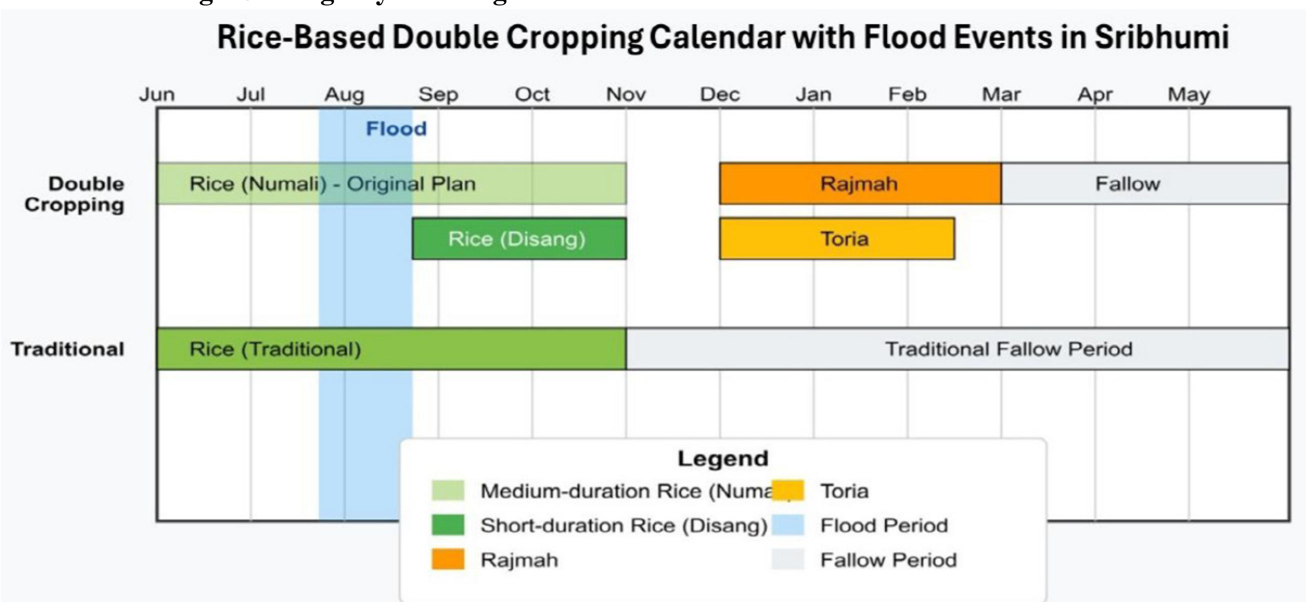

Fig. 3: Rice based double cropping calendar with flood events in Sribhumi

The study highlighted the effective implementation of contingency planning in response to flood-induced damage to the medium-duration rice variety *Numali*. Replacing it with the short-duration *Disang* variety (110 days) ensured timely rabi sowing, showcasing climate-resilient agriculture in action. This aligns with recommendations by Das *et al.* (2018) on the need for adaptive cropping strategies in climate-vulnerable regions. A structured approach rapid damage assessment, varietal selection, and swift replanting proved successful and could be strengthened further with digital forecasting tools. Among rabi crops, both rajmah varieties performed comparably, though *Tripura Selection* was preferred for its marketable traits, resembling the local *Rajmah* type. The toria variety *TS-38* adapted well to residual moisture conditions. These results confirm the suitability of rice–rajmah and rice–toria double cropping systems in Sribhumi's agroecology (Fig. 3). Farmer feedback was extremely positive, with perceived benefits including income diversification, improved soil health, and enhanced food security. A significant number of farmers intend to expand the system, while neighbouring farmers showed interest in adoption, reflecting strong potential for horizontal diffusion. However, challenges remain, including limited access to irrigation facility, quality seeds, storage issues, market infrastructure gaps, and insufficient agronomic knowledge. Scaling these systems to similar flood-prone areas in Barak Valley will require improvements in seed supply, market access, early warning systems, and tailored financial support. Policy backing through crop insurance and assured pulse procurement can further encourage adoption. Overall, coordinated institutional support is key to leveraging double cropping for climate-resilient, sustainable intensification.

Conclusion

The present baseline study highlights the potential of rice-based double cropping systems as effective alternatives to traditional monocropping in the flood-prone areas of Sribhumi district, Assam. Both rice–rajmah and rice–toria systems demonstrated improved productivity, economic viability, and resilience, particularly under climate-induced constraints. The adoption of short-duration rice varieties allowed farmers to maintain timely crop sequences despite flooding, reflecting strong adaptability. Additionally, these systems enhanced cropping intensity and contributed to soil health, particularly with the inclusion of leguminous crops. The findings emphasize the importance of promoting diversified, market-oriented cropping strategies that integrate local knowledge, contingency planning, and institutional support. Scaling up such systems can play a vital role in strengthening food security, improving farm incomes, and advancing sustainable agricultural practices across the Barak Valley and similar agro-ecological regions.

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