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Climate Resilient Rice Farming in India: An Overview

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Rice is a foundational crop for billions globally, yet it is increasingly vulnerable to climate change: rising temperatures, erratic rainfall, flooding, droughts and salinity all threaten yield stability and food security. Climate-resilient rice farming aims to enable rice-based systems to anticipate, adapt to, absorb and recover from these stresses.

Key strategies include deploying rice varieties bred for tolerance to heat, drought, flooding or salinity, and reshaping farming practices from direct-seeding rather than traditional transplanting, to water-saving techniques like alternating wet and dry field cycles. Resource-efficient water and soil management, residue use, crop diversification, and agro-ecosystem enhancements further strengthen resilience.

For farmers, these changes can mean more stable production, reduced risk from climate shocks, lower input costs (especially water and labour), and potentially higher returns. For wider society, resilient rice systems contribute to food security, sustainable resource use and reduced environmental impact. Still, realizing these benefits requires seed access, mechanisation, extension support, infrastructure and enabling policies. In short, making rice farming climate-resilient is imperative not just for surviving climate change, but for adapting and thriving in its face.

Definition

Climate-Resilient Rice Farming (CRRF) is the strategic adoption of genetic, agronomic, and institutional innovations that allow the rice production system to effectively adapt to the negative effects of climate change (such as extreme heat, drought, and floods) while simultaneously mitigating its contribution to climate change by reducing resource use and greenhouse gas (GHG) emissions. The CRRF concept operates on three fundamental principles of Climate-Resilient Agriculture (CRA):

Adaptation: Implementing technologies (e.g., flood-tolerant varieties) that help farmers cope with immediate climate shocks.

Mitigation: Adopting practices (e.g., Alternate Wetting and Drying) that reduce the agricultural sector's GHG footprint.

Productivity/Sustainability: Ensuring that the resilient practices do not compromise, but rather enhance, the overall productivity and profitability of the farming system.

Scope

The scope is vast and multidisciplinary:

- **Genetic Resilience:** Developing and deploying rice varieties that can tolerate multiple abiotic stresses simultaneously (e.g., flood + salinity + heat).
- **Resource Use Efficiency:** Revolutionizing how water, nitrogen, and energy are managed in rice fields to minimize waste and environmental impact.
- **Mechanization:** Promoting farm machinery (like DSR seeders and laser land levelers) to overcome labor scarcity and enable timely, climate-smart operations.

- **Information Dissemination:** Utilizing ICT and digital tools to deliver customized weather advisories and management plans.

Objectives

- **Enhance Adaptive Capacity:** Increase the ability of farmers and the rice system to absorb and recover from climate shocks.
- **Conserve Natural Resources:** Achieve significant reduction in water use and improve soil health (e.g., retaining soil organic carbon).
- **Stabilize/Increase Yields:** Maintain or boost rice productivity even under climatic stress conditions.
- **Improve Farm Income:** Lower the cost of cultivation (especially labor and water) and reduce crop loss risk to ensure economic viability.

Strategies Involved in Climate-Resilient Rice Farming

The strategies span three main categories: Genetic, Agronomic, and Institutional.

A. Genetic Strategies: Stress-Tolerant Varieties

This involves breeding new rice varieties using conventional and modern molecular breeding techniques to tackle specific stresses.

Strategy	Climate Stress Addressed	Example Variety (India)	Key Mechanism/Feature
Submergence Tolerance	Flash floods, prolonged waterlogging.	Swarna Sub-1	Carries the Sub1A gene, which induces a state of near-dormancy under water, conserving carbohydrates for up to 14-17 days of complete submergence, allowing for rapid recovery when the water recedes. (Source 1.2, 1.4, 1.6)
Drought Tolerance	Delayed monsoon, terminal drought.	Sahbhagi Dhan, DRR Dhan 44	Possesses deep, strong root systems and higher Water Use Efficiency (WUE), enabling survival and yield under moisture deficit conditions.
Salinity Tolerance	Sea-level rise, coastal floods, brackish water irrigation.	Luna Suvarna (CR Dhan 403)	Tolerant to high salt concentrations, making them suitable for coastal lowlands (Source 1.9).

B. Agronomic Strategies: Resource-Efficient Practices

These focus on changing *how* rice is grown to save resources and improve soil condition.

Strategy	Description	Climate/Resource Benefit
Direct-Seeded Rice (DSR)	Sowing rice seeds directly into the field using machines (like DSR drill or Happy Seeder) rather than transplanting seedlings.	**Water Saving:** Eliminates puddling and saves 30-35% of irrigation water (Source 2.5). **Labor Saving:** Reduces dependence on labor for transplanting. **Methane Mitigation:** Avoids the continuous anaerobic conditions that promote CH4 release.
Alternate Wetting and Drying (AWD)	Intermittent irrigation where the field is allowed to dry to a specific depth (monitored by a field water tube) before re-irrigation, rather than maintaining continuous flooding.	**Water Saving:** Reduces irrigation water by 15-30%. **Methane Mitigation:** Introducing oxygen to the soil intermittently reduces the activity of CH4producing bacteria.

System of Rice Intensification (SRI)	Transplanting very young, single seedlings spaced wide apart, combined with cono-weeding and minimal, intermittent water application.	**Yield Increase:** Can increase yield by 20-50% in favorable areas. **Water Saving:** Uses 25-50% less water than traditional flooding.
Zero/Conservation Tillage	Sowing the next crop (e.g., wheat after rice) without disturbing the soil, often retaining crop residue.	**Soil Health:** Improves soil structure, increases soil organic carbon, and reduces soil erosion.

C. Institutional/Policy Strategies

- **NICRA:** The National Innovations in Climate Resilient Agriculture project by ICAR has established Technology Demonstration Components (TDC) in vulnerable districts to showcase and scale up these technologies.
- **Custom Hiring Centres (CHCs):** Establishing centres where farmers can rent specialized machinery like DSR drills and laser land levelers, overcoming the barrier of high capital cost.
- **Weather-Based Advisory:** Providing real-time, localized Agro-Meteorological Advisories to help farmers make informed decisions about planting, irrigation, and pest management.

Impacts and Challenges

Impacts

- **Enhanced Flood Resilience:** Swarna Sub-1 yields 1-2 tonnes/ha more than non-tolerant varieties in flood-affected conditions, translating to significant income protection (Rs. 5,000 to Rs. 25,000 extra per hectare) (Source 1.2, 1.3).
- **Water Footprint Reduction:** DSR and AWD significantly cut down on the vast water required for rice cultivation, easing pressure on groundwater resources, particularly in the Indo-Gangetic Plains.
- **Reduced Cultivation Cost:** DSR saves labor costs by eliminating transplanting, often making the production system more profitable and attractive to younger farmers.

Challenges and constraints in the Indian situation

While there is progress, substantial barriers remain:

- **Small landholdings and resource constraints**: Many rice-farmers are small/marginal, limited access to irrigation, credit, technology. Vulnerability is high.
- **Awareness & capacity gaps**: Farmers may not fully understand new practices, or have training/extension support to adopt them.
- **Infrastructure & investment**: Levelled fields, irrigation systems, adoption of line sowing/zero-till require investment.
- **Seed distribution, uptake of improved varieties**: Even if climate-resilient varieties exist, ensuring they reach farmers in large scale is tough. The “seed to farmer” chain needs strengthening.
- **Water rights and irrigation constraints**: Traditional paddy demands a lot of water; in water-scarce zones shifting practices is challenging.
- **Policy, institutional coordination**: Agriculture is a state subject; implementing climate-resilient programmes across states requires coordination.
- **Market & incentive alignment**: If farmers adopt improved practices but cannot access premium markets or get inputs timely, incentives may be weak.
- **Climate uncertainty**: Even with adaptation, there is residual risk: e.g., unexpected extreme events may still cause damage.

Recommendations / pathways for scaling in India

Based on the evidence, key recommendations for climate-resilient rice farming in India include:

- **Expand adoption of stress-tolerant varieties**: More outreach, seed supply chain strengthening, demonstrations of varieties tolerant to drought, heat, flood, salinity.
- **Promote alternative establishment methods**: Encourage direct seeded rice (DSR), line sowing, zero tillage, to reduce water use, labour, increase flexibility. (As the study from Bihar shows)
- **Improve water management**: Undertake field-level interventions such as land-levelling, alternate wetting and drying (AWD), aerobic rice in suitable zones, precision irrigation.
- **Diversify cropping systems**: In high-risk zones (e.g., areas with increasing salinity or low rainfall), rice may be replaced or supplemented with more resilient crops (millets, pulses) as part of a portfolio approach.
- **Build extension, capacity & farmer awareness**: Training of farmers on new practices, climate risk management, accessing climate advisories, weather data, and modern techniques.
- **Strengthen institutional & policy support**: Ensure state-level rollout of CRA programmes, incentives for farmers adopting resilient practices, integrate climate risk in agriculture planning.
- **Focus on value chains & market incentives**: If farmers adopt improved practices, there should be markets/rewards for the output; also cost savings from reduced inputs (water, fertiliser) should be captured.
- **Enhance research and monitoring**: Continue breeding efforts, monitor impacts of new practices, scale up demonstration sites, evaluate cost-benefit.

Climate mitigation co-benefits: Since rice cultivation is both a victim of and contributor to climate change (methane emissions etc), promoting low-emission rice systems (e.g., less flooding) is beneficial

Future Scope

- **Digital Agriculture:** Implementing Precision Rice Farming using Internet of Things (IoT) sensors for soil moisture monitoring (for AWD) and satellite imagery for pest/nutrient deficiency detection, allowing for highly targeted resource application.
- **Genomics and Gene Editing:** Developing next-generation rice varieties with **pyramided genes** for tolerance to multiple stresses (e.g., flood, drought, and Bacterial Blight resistance in a single variety) (Source 1.8).
- **Policy Reframing:** Shifting government incentives from input subsidies (water, power) to outcome-based payments for resource conservation and emission reduction (e.g., carbon credits for DSR adoption).

Conclusion

Climate-resilient rice farming is the foundational strategy for securing India's food future against the dual threats of climate change and resource depletion. The shift from water-guzzling, GHG-emitting traditional methods to resource-efficient, stress-tolerant systems like DSR, AWD, and rice varieties is irreversible. Achieving large-scale success requires a concerted effort to overcome adoption barriers through robust training, affordable access to technology, and supportive policy mechanisms.