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Building Climate-Resilient Agriculture: Strategies for a Sustainable Future

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Climate change poses a significant threat to Indian agriculture, impacting crop yields, soil health, water availability, and farmer livelihoods. With 65% of the population dependent on agriculture, erratic weather patterns, rising temperatures, and extreme climatic events like droughts and floods exacerbate vulnerabilities. The challenge is intensified by over-reliance on groundwater, low crop diversification, and inadequate climate adaptation measures. To combat these challenges, Climate-Resilient Agriculture (CRA) emerges as a sustainable solution, integrating adaptation, mitigation, and resource-efficient farming practices. Strategies such as agroforestry, soil and water conservation, crop diversification, organic farming, and climate-smart irrigation can enhance productivity while minimizing environmental impact. Government initiatives like NICRA, NMSA, and PMFBY aim to bolster resilience, but their success depends on strong policy frameworks, farmer awareness, and grassroots implementation. The way forward demands greater public investment in climate-resilient crops, expansion of sustainable irrigation techniques, and active involvement of local governance. Empowering farmers with scientific innovations, financial security, and climate-smart policies will be crucial to ensuring long-term agricultural sustainability. A holistic, technology-driven, and community-centric approach will pave the way for a future-proof, productive, and resilient Indian agriculture sector amidst the growing climate crisis.

Keywords: CRA, Climate risk mitigation, farmer livelihood resilience, local governance, SDGs, smart agriculture

Introduction

Climate change and its variability pose significant challenges to Indian agriculture by altering weather patterns, leading to extreme temperatures, erratic rainfall, and rising sea levels that threaten freshwater reserves and increase flood risks. Agriculture is particularly vulnerable, as higher temperatures reduce crop yields and promote the spread of pests and weeds. While some regions may see minor benefits, the overall impact is negative, with irrigated crops suffering due to heat stress and water scarcity, while rainfed agriculture is affected by unpredictable rainfall and fewer rainy days (Venkateswarlu and Shanker, 2012). Additionally, climate change may increase the prices of agricultural commodities, feed, and livestock products like milk and meat.

Indian agriculture faces the immense challenge of feeding 17.5% of the global population with just 2.4% of the world's land and 4% of its water resources. Depleting natural resources, coupled with climate change and extreme weather events, make traditional farming methods inadequate to ensure food, nutrition, and environmental security. The solution lies in

producing more with lower carbon and water footprints. Transitioning to climate-smart agriculture requires supportive policies, strong institutions, robust infrastructure, and an informed, well-equipped farming community.

Climate Resilient Agriculture (CRA) involves integrating adaptation, mitigation, and sustainable practices to enhance the agricultural system's ability to withstand and recover from climate-related disturbances. These disturbances include droughts, floods, extreme temperatures, erratic rainfall, prolonged dry spells, and pest outbreaks. Essentially, CRA enables the system to "bounce back" by recognizing threats and responding effectively. It focuses on the efficient management of natural resources like land, water, soil, and genetic diversity through the adoption of best practices (Sarma *et al.*, 2024). According to the Food and Agriculture Organization (FAO), climate resilient agriculture is defined as "the ability of an agricultural system to anticipate and prepare for, as well as adapt to, absorb and recover from the impacts of changes in climate and extreme weather". The National Innovations on Climate Resilient Agriculture (NICRA), a network project by ICAR, assesses climate change impacts on agriculture and farmers. Studies suggest that without adaptation, climate change could reduce irrigated rice yields by 3%, rainfed rice by 7-28%, wheat by 3.2-5.3%, and maize by 9-10%, while soybean yields may increase by 2.5-5.5% between 2020 and 2039. Extreme events like drought worsen food security, increase poverty, drive migration, raise indebtedness, and weaken farmers' ability to adapt.

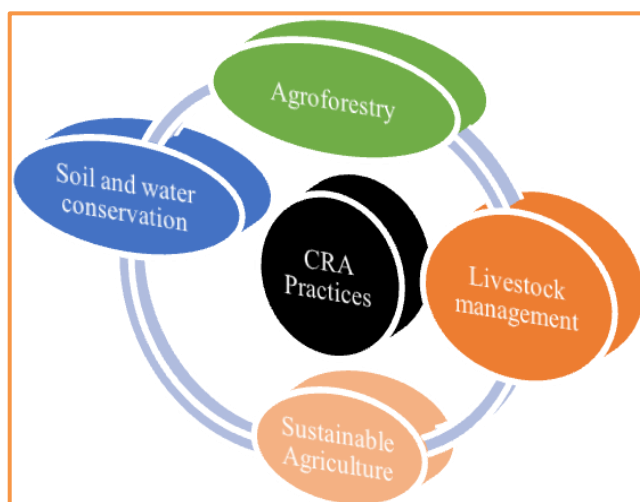
Climate Resilient Agriculture (CRA) Practices

Agroforestry: Growing trees alongside crops enhances soil health, prevents erosion, and promotes biodiversity. This approach also improves soil moisture retention and provides multiple benefits to farmers.

Soil and Water Conservation: Methods like contour bunding, farm ponds, and check dams aid in retaining soil moisture, reducing erosion, and replenishing groundwater. These techniques help farmers mitigate the effects of drought and water scarcity, which are worsening due to climate change.

Sustainable Agriculture: Strategies such as crop diversification, organic farming, and integrated pest management minimize chemical input use while improving soil fertility. These practices also lower greenhouse gas emissions, boost farmers' incomes, and strengthen food security.

Livestock Management: Techniques like stall-feeding and mixed cropping enhance livestock productivity and resilience. They also help conserve natural resources, especially grazing lands, which are increasingly under pressure due to climate change (Alvar-Beltrán *et al.*, 2021).



Government initiatives

- **National Action Plan on Climate Change (NAPCC):** The Indian government is actively addressing climate change challenges in agriculture through this initiative.
- **National Mission for Sustainable Agriculture (NMSA):** Focuses on improving soil health, conserving water, and enhancing the resilience of rainfed farming.
- **Supporting Programs:**
 - * **Soil Health Card (SHC):** Promotes soil testing and fertility management.
 - * **Paramparagat Krishi Vikas Yojana (PKVY):** Encourages organic farming.
 - * **Mission Organic Value Chain Development in the Northeast (MOVCDNER):** Supports organic farming and market linkages in the Northeast.

- * **Per Drop More Crop:** Promotes efficient water use in agriculture.
- **NICRA (National Innovations in Climate Resilient Agriculture):**
 - * Launched by ICAR in 2011 to support farmers in adapting to climate extremes.
 - * Focuses on research, training, and practical solutions for climate resilience.
 - * Developed **1,888 climate-resilient crop varieties** and formulated **District Agriculture Contingency Plans (DACPs) for 650 districts** to provide timely support during climate crises.
- **Agricultural Risk Management Schemes:**
 - * **Pradhan Mantri Fasal Bima Yojana (PMFBY):** Provides financial protection against crop losses due to extreme weather conditions.
 - * **Restructured Weather-Based Crop Insurance Scheme (RWBCIS):** Offers weather-indexed insurance to safeguard farmers from climate variability.
 - * These schemes help stabilize farmers' incomes, ensuring the long-term sustainability of Indian agriculture (Chary *et al.*, 2022).

Key challenges

- **High Vulnerability:** Developing countries rely heavily on agriculture but lack advanced technology to manage climate risks.
- **Dependence on Agriculture:** In India, **65% of the population** is engaged in farming and allied activities, making them highly susceptible to climate change.
- **Poverty Cycle:** Poor farmers remain trapped in **low income, high debt, and poverty** due to inadequate mitigation and adaptation measures.
- **MSP Limitations:** The **Minimum Support Price (MSP) regime** focuses on only a few crops, discouraging crop diversification.
- **Groundwater Overuse:** Excessive groundwater extraction, especially in **northern India**, threatens sustainability efforts.
- **Agriculture and Emissions:** The sector contributes **14% of India's greenhouse gas emissions**, with **synthetic nitrogen fertilizers** raising nitrous oxide levels.
- **Low Productivity:** India's **rice yield is 2.5 tons per hectare**, far below China's **6.5 tons per hectare**.
- **Weak Local Governance:** **Panchayats and local bodies** are unsuccessful to recognize climate risks, leading to poor policy implementation at the grassroots level (Srivastav *et al.*, 2021).

Future prospects

- **Integrated Approaches:** Advancements in **technology, meteorology, and data sciences** can help mitigate the adverse effects of climate change.
- **Expansion of NICRA:** The **National Innovations in Climate Resilient Agriculture (NICRA)** scheme should be implemented in all **high-risk villages** to safeguard farmers from climate-related challenges.
- **Crop Diversification:** Encouraging a **diverse range of crops** can help **agricultural ecosystems** adapt, improve **soil fertility, pest control**, and ensure **food security** with stable yields.
- **Drip Irrigation Expansion:** The use of **drip irrigation** should extend beyond **high-value horticultural crops** to a **wider variety of crops** for efficient water use.
- **Reevaluating Groundwater Policies:** The government should reconsider **electricity subsidies** for groundwater extraction, as they contribute to **declining water levels**. **Water-efficient irrigation** tools must be adopted.
- **Promotion of Organic Farming:** Organic farming should be actively promoted due to its potential to **reduce greenhouse gas emissions**. **Prohibiting synthetic nitrogen fertilizers** in organic farming helps lower **nitrous oxide emissions**.

- **Strengthening Krishi Vigyan Kendras (KVKs):** KVKs need **better infrastructure and technology**. Providing **24/7 information in regional languages** through digital tools will enhance their outreach.
- **Investment in Climate-Resilient Crops:** Increased **public investment** is necessary to develop and distribute **climate-resilient crop varieties** with better adaptability to **temperature and rainfall fluctuations** and **efficient water and nutrient use**.
- **Agricultural Policy Reform:** Policies should **prioritize productivity**, establish **safety nets for farmers**, and integrate **local governance** to tackle climate-induced risks effectively.
- **Empowering Local Governance:** Climate resilience efforts will be more effective when **Panchayats are actively involved** in policy formulation. Raising **awareness at the village level** can help them leverage funds from multiple government schemes.
- **Incentivizing Climate-Resilient Practices:** A **ranking system** at the **national or regional level** for villages adopting the best climate-friendly practices could **motivate broader adoption** and encourage sustainable agriculture.

Conclusion

Climate change presents a formidable challenge to Indian agriculture, threatening food security, farmer livelihoods, and environmental sustainability. The increasing frequency of extreme weather events, declining natural resources, and erratic climatic patterns necessitate a shift from conventional farming methods to climate-resilient agriculture (CRA). By integrating technological advancements, sustainable farming practices, and efficient resource management, CRA offers a comprehensive approach to mitigate climate risks and enhance agricultural productivity. Government initiatives such as NICRA, NMSA, and PMFBY have laid a strong foundation for climate adaptation, yet policy reforms, improved local governance, and increased public investment are essential for long-term resilience. Strengthening crop diversification, organic farming, water conservation, and climate-resilient crop development will not only ensure food security but also reduce agriculture's carbon footprint. To make Indian agriculture truly climate-resilient, farmers must be empowered with knowledge, resources, and institutional support. Encouraging grassroots participation, promoting sustainable practices, and leveraging modern technologies will be crucial in safeguarding the future of agriculture against climate uncertainties. By adopting a holistic and proactive approach, India can build a sustainable, productive, and climate-resilient agricultural system, securing livelihoods and ensuring food security for future generations.

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