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Bridging Climate and Farming: The Role of Extension in Climate-Smart Agriculture

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In light of the growing variability in climate, increasing temperatures, and the prevalence of extreme weather events, Climate Smart Agriculture (CSA) has emerged as an essential strategy to guarantee sustainable agricultural productivity, resilience, and food security, with agricultural extension services playing a critical role in its grassroots adoption. As climate change increasingly jeopardizes agricultural livelihoods, Climate Smart Agriculture offers a transformative pathway that combines productivity, adaptation, and mitigation, with extension systems acting as vital facilitators in converting climate-resilient technologies into practices at the farmer level .According to the Food and Agriculture Organization (FAO) of the United Nations, CSA is defined as an integrated strategy designed to achieve three interconnected goals: sustainably enhancing agricultural productivity and incomes; adapting to and building resilience against climate change; and minimizing or eliminating greenhouse gas emissions wherever feasible. In contrast to conventional farming practices, CSA focuses on context-specific innovations such as drought-resistant crop varieties, precision irrigation, agroforestry, and soil conservation techniques. These methods not only alleviate the negative impacts of climate variability but also contribute to broader sustainable development objectives, including those specified in the Paris Agreement and the United Nations Sustainable Development Goals (SDGs), particularly SDG 2 (Zero Hunger) and SDG 13 (Climate Action).

The Pillars of Climate Smart Agriculture

Climate Smart Agriculture (CSA) is based on three essential pillars, commonly known as the "triple win" strategy. These pillars—sustainably enhancing agricultural productivity and incomes, adapting to climate change while building resilience, and reducing greenhouse gas emissions—offer a comprehensive framework for transforming farming systems amid environmental uncertainties. This approach, which originated from the Food and Agriculture Organization (FAO) of the United Nations, ensures that agriculture not only satisfies the increasing food demands but also promotes environmental sustainability and the well-being of farmers. Although the pillars are interrelated, with practices frequently supporting multiple goals at once, they permit context-specific implementation, rendering CSA adaptable to various agroecological zones, including those in India where smallholder farmers are prevalent. Agricultural extension services are vital across all pillars, as they disseminate knowledge, facilitate the adoption of technology, and empower communities through participatory methods such as farmer field schools and digital advisory tools.

Pillar 1: Sustainably Increasing Agricultural Productivity and Incomes: This pillar aims to improve food production and farmer livelihoods without exhausting natural resources, addressing the anticipated requirement to feed a global population exceeding 9 billion by

2050. It highlights the efficient use of resources to enhance yields, boost economic viability and ensure the long-term health of soil and ecosystems. Key practices include the adoption of high- yielding, climate-resilient crop varieties, precision farming techniques like variable-rate fertilizer application, and integrated nutrient management to optimize inputs such as water and fertilizers.

For example, in areas susceptible to unpredictable rainfall, practices like implementation, rendering CSA adaptable to various agroecological zones, including regions in India where smallholder farmers are common. Agricultural extension services play a crucial role across all pillars by disseminating knowledge, encouraging technology adoption, and empowering communities through participatory approaches such as farmer field schools and digital advisory tools.

Pillar 2: Adapting and Building Resilience to Climate Change: Adaptation entails altering agricultural systems to endure climate shocks such as droughts, floods, and increasing temperatures, thus reducing risks and ensuring consistent outputs. This pillar emphasizes resilience-building at the farm, community, and landscape levels, integrating strategies that foresee future vulnerabilities based on local climate forecasts.

Core practices include water management techniques such as rainwater harvesting, drip irrigation, and watershed development to address water scarcity; enhancements in soil health through organic amendments and erosion control; and diversified farming systems to mitigate risks. For instance, employing drought-resistant crops like millet or sorghum in semi-arid regions can sustain yields during periods of dryness, while early warning systems that are integrated with mobile applications notify farmers of forthcoming weather events. Prescribed grazing within livestock systems involves rotating animals to allow pasture recovery. Agroforestry systems, which incorporate trees alongside crops or livestock, also illustrate this principle by diversifying income streams through timber, fruits, or fodder, potentially increasing farm revenues by 10-30% in tropical regions. In India, initiatives such as the National Mission for Sustainable Agriculture support these practices through subsidies and training, resulting in enhanced productivity in states like Maharashtra and Punjab.

Pillar 3: Reducing or Eliminating Greenhouse Gas Emissions (Mitigation): Mitigation aims to address the agriculture sector's role in global emissions—estimated to account for 24% of total greenhouse gases—by advocating for low-carbon practices that sequester carbon or reduce emissions of methane, nitrous oxide, and carbon dioxide. This pillar is in accordance with global commitments such as the Paris Agreement, emphasizing emission reductions while maintaining productivity. Extension services facilitate mitigation by providing education to farmers on emission calculators and encouraging adoption through carbon credit initiatives. In India, initiatives such as the Soil Health Card Scheme incorporate mitigation into extension guidance, assisting farmers in tracking and minimizing their carbon footprint. Nevertheless, trade-offs are present; for instance, certain mitigation practices may initially result in reduced yields, highlighting the necessity of extension services in illustrating long-term advantages.

Opportunities and Enabling Factors for Scaling Climate-Smart Agriculture (CSA) in India

As India approaches the climate trajectory for 2025–2050—characterized by an anticipated 15–25% yield volatility in rainfed systems due to unpredictable monsoons and heat stress exceeding 35°C—CSA stands out as a pivotal enabler for sustainable intensification. With rainfed agriculture accounting for approximately 60% of arable land (including 80% ofChhattisgarh's unirrigated rice belts), the scaling of CSA through integrated practices (such as drought-resistant cultivars, Alternate wetting-drying[AWD] and integrated nutrient management [INM]) is expected to yield productivity increases of 15–35%, reduce greenhouse gas emissions by 20–45%, and enhance water efficiency by 30–60%. The momentum is encouraging: national investments surpassing ₹50,000 crore annually in adaptive frameworks, a surge in digital adoption at a compound annual growth rate (CAGR)

of 25–30%, and emerging carbon markets anticipated to contribute ₹20,000–48,000 crore to farmer incomes by 2032. For areas like Raipur, these elements facilitate resilience, transforming vulnerability into sustainable livelihoods. Below, we examine the key enablers, rooted in advancements expected by 2026.

- **National Mission for Sustainable Agriculture (NMSA):** Since its inception in 2014 under the Ministry of Agriculture and Farmers Welfare (MoAFW), NMSA has focused on rainfed hotspots (such as the black soils of Chhattisgarh) through integrated farming systems (IFS), improving water use efficiency (WUE >1.5 kg/m³), and enhancing soil carbon (SOC accrual of 0.4–0.8% annually). The 2026 review underscores an unparalleled outreach effort: over 93,000 farmer training sessions, 680,000 demonstrations, and 7,400 campaigns aimed at raising awareness about soil health and climate-resilient crops, with an allocation of ₹2,793 crore for the Per Drop More Crop (PDMC) initiative in the fiscal year 2024–25, extending into 2026. The components of the Reinforced Area Development (RAD) promote agroecological clusters, achieving 20–30% gains in Nutrient Use Efficiency (NUE) through the application of biofertilizers (Azotobacter + PSB at 5–10 kg/ha). Extension services provided by Krishi Vigyan Kendras (KVKs) facilitate a 25–35% adoption rate in tribal regions, complemented by digital integration through AgriStack for real-time monitoring.
- **National Innovations in Climate Resilient Agriculture (NICRA):** The flagship program of ICAR, launched in 2011, was reviewed in January 2026, assessing risks across 651 districts, of which 310 are classified as highly vulnerable. The Technology Demonstration Component (TDC) operates in 151 districts, including Raipur, promoting practices such as zero-till wheat, direct-seeded rice (DSR), and short-duration hybrids (for instance, DRR Dhan 44, which yields 4–6 tons per hectare under stress conditions), resulting in a productivity increase of 20–40% and a reduction of methane emissions by 25–35% through Alternate Wetting and Drying (AWD).
- **Pradhan Mantri Krishi Sinchayee Yojana (PMKSY):** With a focus on "Har Khet ko Pani," the allocation for PMKSY in 2026 is ₹6,587 crore, a decrease from ₹8,260 crore in 2025, yet with a stronger emphasis on PDMC. This initiative supports micro-irrigation systems (with drip efficiency of 90–95% and water savings of 40–60%) and watershed restoration efforts (with a recharge increase of 20–30%). The operational guidelines were updated in April 2025 to incorporate satellite NDVI for parametric monitoring, covering an annual area of 1.5 million hectares. In Chhattisgarh, it collaborates with the State Action Plan on Climate Change (SAPCC) to enhance supplemental irrigation by 15–25% in tribal watersheds.
- **Soil Health Card Scheme:** By July 2025 (with distributions continuing into 2026), over 25 crore cards will be issued based on 8.03 crore samples, offering profiles for macronutrients (N, P, K) and micronutrients (such as Zn and Fe thresholds) along with site- specific recommendations. A total of ₹1,706.18 crore will be allocated by February 2025 to support biennial testing (every two years), resulting in gains of 20–40% in Nutrient Use Efficiency (NUE) and reductions in fertilizer use by 15–25%. This initiative, integrated with the Rashtriya Krishi Vikas Yojana (RKVY), empowers smallholder farmers through digital platforms for balanced Integrated Nutrient Management (C:N:P ratio of 100:10:1). These programs reduce entry barriers (for instance, offering 55% subsidies on drip irrigation systems) and promote adoption rates of 25–35% in pilot districts.Technological Innovations Digital and precision tools enhance Climate Smart Agriculture (CSA) extension, facilitating hyper-localized decision-making with 80–90% accuracy in yield and pest predictions.
- **Digital Tools:** The Nutrient Expert app developed by ICAR-IARI employs Site-Specific Nutrient Management (SSNM) algorithms for optimizing fertilizer use (for example, applying 80:40:40 kg NPK/ha splits), which decreases overuse by 20–30%. Mobile applications such as Kisan Suvidha and mKisan provide agro-meteorological advisories (integrated with IMD, offering 7–14-day forecasts through Long Short-Term Memory (LSTM) models). Soil health monitoring is conducted using IoT sensors (for instance, CropX for electrical conductivity ranging from 0.1 to 5 ds/m), which integrates with Agri

Stack for real-time tracking of Soil Organic Carbon (SOC) and Water Holding Capacity (WHC).

- **Precision Agriculture and AgTech:** Drones equipped with multispectral NDVI technology (operating at 5–10 cm/pixel resolution) and AI platforms (such as Cropping Connect for geotagging and advisories) achieve input savings of 15–30%. Bharat-VISTAAR (Budget 2026–27) utilizes AI to provide multilingual recommendations (in Hindi and Chhattisgarhi) regarding sowing and inputs. AgTech startups like Farmout predict risks with 85% accuracy, scaling their operations through Farmer Producer Organizations (FPOs) in Raipur.

By the year 2030, these advancements could lead to the digitization of 50% of farms, enhancing Water Use Efficiency (WUE) and resilience.

Benefits and Effects of Climate-Smart Agriculture (CSA

CSA provides quantifiable triple benefits in terms of productivity, adaptation, and mitigation, supported by substantial evidence from extensive programs such as ICAR-NICRA (2011–2026), PoCRA (Maharashtra), SRI scaling, and meta-analyses (2024–2026). The results differ based on agroecology, the intensity of adoption, and the combination of practices, yet consistent improvements are noted in rainfed systems, which account for 60% of India's arable land.

1. **Yield Enhancements and Income Increases.**

CSA methodologies facilitate sustainable intensification without compromising yields.

- NICRA-TDC (151 vulnerable districts, 2011–2025/26): 20–40% productivity increases in adopted clusters (rice, wheat, maize, pulses). The average additional income is ₹10,890/ha (ICAR, December 2025). In demonstration villages, household income increased by 35–45% (with 40% being a typical benchmark across agro-ecological regions).
- SRI (Odisha, Chhattisgarh, Bihar): Yield increases range from 10–114% (meta-range); the average is 20–50% (1,265 kg/ha additional yield in a study conducted in Mayurbhanj, Odisha). Savings on water and inputs translate to net returns of ₹12,000–25,000/ha more than traditional flooded rice methods.

2. **Improved Resilience (Drought/Flood Tolerance):**

CSA minimizes yield fluctuations and enhances adaptive capacity to extreme conditions (heatwaves exceeding 35°C, unpredictable monsoons, and drought periods).

- **Drought-resistant varieties (Sahbhagi Dhan, DRR Dhan 44) combined with SRI/AWD:** yield stability of 15–25% under 20–30% moisture stress (as demonstrated in IGKV Raipur & NICRA trials in Raipur/Dhamtari).
- **SRI:** Root biomass is 2–3 times deeper, resulting in a 40–60% improvement in drought tolerance; the integration of Swarna-Sub1 enhances submergence tolerance, thereby decreasing flood damage by 30–50%.
- **PoCRA & NICRA clusters:** There is a 30–45% decrease in yield loss during drought years, based on data from 2018 to 2024.

3. **Environmental Gains:**

- Climate-smart agriculture (CSA) significantly reduces the agricultural carbon footprint, accounting for 14–18% of India's greenhouse gas (GHG) emissions.
- **GHG Mitigation:**
- **SRI combined with alternate wetting and drying (AWD):** Achieves a 25–62% reduction in methane emissions (averaging 40–50%); global warming potential per kilogram of rice decreases by over 60% (NRRI Cuttack & CEEW 2025).
- **Direct seeded rice (DSR) with AWD:** Results in a 30–50% reduction in methane; overall GHG emissions decrease by 15–35%.
- **Soil Health:** SOC increases by 0.5–1.2% per year; erosion is reduced by 40–60%; water holding capacity (WHC) is enhanced by 15–30%.

4. **Socio-Economic Aspects (Gender Inclusion & Smallholder Benefits):**

- CSA demonstrates significant pro-poor and gender-responsive effects when implemented with inclusivity in mind.
- **Smallholders (<2 ha, 85% of Indian farmers):** Experience the highest relative benefits (income elasticity is greater due to a lower baseline). FPO-led bundling results in returns that are 30–50% higher compared to individual adoption.
- **Gender Inclusion:**
- Women represent 62–70% of the agricultural workforce in rainfed regions but are responsible for 70–80% of the water collection and weeding tasks.
- Women's Self-Help Groups (SHGs) in CHIRAAG (Chhattisgarh), NRLM, and NICRA: Achieve a 25–40% increase in income through bio-input production, seedling nurseries.
- Gender-transformative strategies (women-led FPOs, land rights, and digital literacy): Result in adoption rates increasing by 20–35%; income gains are 15–25% higher than those of male-only groups.

Overall Triple-Win Quantification (2024–2026 Evidence):

- Productivity: +15–35%
- Income: +25–50% (₹10,000–40,000/ha additional)
- GHG: -20–45%
- Resilience: Yield variability reduced by -30–50%
- Water: Decrease of -35–60%.

Challenges in Adopting Climate-Smart Agriculture (CSA) Practices for Smallholder Farmers in India:

Smallholder farmers in India, who manage holdings of less than 2 hectares (approximately 86% of total holdings covering around 47% of the operated area), encounter various obstacles to the adoption of Climate Smart Agriculture (CSA), resulting in adoption rates of only 20–40% even in areas that receive support. These difficulties are especially pronounced in rainfed states such as Chhattisgarh, where 80% of the land is unirrigated and rice is the dominant crop, leading to increased socio-economic vulnerabilities due to biophysical stressors. Recent analyses conducted between 2024 and 2026 identify several key constraints, including financial challenges, gaps in knowledge, weaknesses in institutions, environmental and biophysical risks, as well as gender and social inequities. To effectively address these issues, targeted evolution in extension services is necessary, as emphasized in the reviews by ICAR-NICRA from January 2026 and reports from the Asia Foundation.

Financial Constraints:

- Credit and Insurance Gaps: Only 40–50% of farmers have access to formal credit through Kisan Credit Cards (KCC); informal loans often carry interest rates of 20–40%, which heightens risks. Risk Aversion: The advantages of Climate-Smart Agriculture (CSA), such as yield increases of 15–30%, typically manifest over a period of 1 to 3 seasons. However, adverse climate events result in annual losses ranging from 9 to 15% (ICAR-NICRA 2024–25), prompting 22 to 60% of farmers to identify financial constraints as the primary obstacle.

Although NABARD's Climate Fund, which has exceeded ₹1,000 crore since 2016, provides support, it inadequately serves marginal farmers.

- Resource Scarcity Impact: In Chhattisgarh, the rising costs of inputs, with fertilizers projected to increase by 10–15% in 2025, coupled with fragmented land holdings (over 60% of farmers possess less than 1 hectare), hinder economies of scale. Consequently, the adoption rate could decline by 45–65% in the absence of integrated finance and extension support.

Knowledge and Awareness Gaps:

Limited Understanding of Benefits: A significant portion of smallholders, between 29 and 70%, remain unaware of the benefits associated with CSA practices, such as the 40–74% water savings from Alternate Wetting and Drying (AWD) or the 20–40% gains in Nutrient Use Efficiency (NUE) from Integrated Nutrient Management (INM). The persistence of traditional

farming methods can be attributed to low literacy rates, which stand at 60–70% in rural Chhattisgarh.

- **Inadequate Exposure to Tools:** Gaps in digital literacy, with smartphone penetration at 50–60%, restrict the use of applications like Nutrient Expert or mKisan. Furthermore, extension services reach only 30–40% of farmers on a regular basis, while participatory approaches such as Farmer Field Schools (FFS) engage less than 10% of farmers in vulnerable districts.

Environmental and Biophysical Challenges:

- **Soil Degradation:** Approximately 40% of arable land is affected, with SOC depletion occurring at a rate of 0.2–0.5% per year in lateritic soils. Erosion rates in the uplands of Chhattisgarh are between 2 to 5 tons per hectare per year, which increases the risks associated with CSA, such as inadequate residue incorporation.
- **Water Scarcity and Variability:** By 2050, a projected 50% deficit in water availability is expected in eastern India. Arid and semi-arid regions, such as Maharashtra and Rajasthan, are experiencing irrigation gaps of 20–30%, with monsoon variability ranging from 10 to 20% (with deficits anticipated in Raipur by 2025).
- **Climate Extremes:** Heatwaves are expected to reduce yields by 9–15% in the medium term, while floods and droughts are projected to cause annual losses of US$9–10 billion (according to the Economic Survey 2018, with effects persisting into 2024–26). Pest populations are expected to surge by 20–50% by 2050 due to warmer conditions.
- **Resource Depletion:** Groundwater is being overexploited, with declines of 0.3–1 meter per year. Biophysical mismatches, such as AWD in areas prone to arsenic, contribute an additional 10–20% risk to implementation.

Gender and Social Inequities:

- **Women's Limited Resource Access:** Women, who make up 62–70% of the workforce and 80% of rural female workers, own less than 15% of land and have access to less than 20% of credit and extension services. Their vulnerabilities are heightened, with 87% reporting productivity impacts compared to 72% of men, according to IFPRI 2015 and ongoing studies.
- **Training and Decision-Making Gaps:** The lower participation of women in FFS (20–30%) and the heavy workload (70–80% water/weeding burden) hinder the adoption of labor-saving Climate-Smart Agriculture (CSA) practices, such as SRI mechanization.
- **Marginalized Group Disparities:** Tribal farmers, particularly in regions like Bastar, Chhattisgarh, experience a 40–50% higher risk of exposure to extreme conditions. Social norms restrict the involvement of youth and marginalized groups, resulting in adoption rates that are 15–25% lower than the average.

These challenges highlight the urgent need for inclusive reforms in extension services—such as bundled financing, digital-local hybrids, and gender quotas—to enhance CSA adoption by 2–3 times, thereby ensuring equitable resilience for smallholders in India.

Role of Agricultural Extension in Promoting Climate-Smart Agriculture (CSA):

Agricultural extension services act as a crucial link between scientific research conducted by institutions like ICAR, IARI, and CRIDA and the farmers on the ground, converting complex CSA knowledge into actionable, location-specific strategies. In India, extension services are essential for accelerating the adoption of CSA in the face of climate vulnerabilities, especially in rainfed areas like Chhattisgarh, where 80% of the land is unirrigated and rice-dominant.

Here, erratic monsoons, heatwaves exceeding 35°C, and soil degradation pose threats of 20–33% yield losses by mid-century. Extension agents, whether public (through KVKs and state departments), private (via AgTech), or community-based (through SHGs and FPOs), play a key role in transitioning from traditional farming methods to climate-resilient practices, achieving multiple benefits: 15–35% increases in productivity, 20–45% reductions in greenhouse gas emissions, and improved adaptive capacity.

Extension is evolving from a conventional top-down information provider to a facilitator of behavioral change, adaptive learning, and participatory innovation. Evidence from NICRA (15 years, reviewed January 2026) indicates that effective extension services can enhance farm productivity by 20–30%, improve preparedness for climate risks, and raise adoption rates by 25–35% in at-risk districts through demonstrations and capacity building.

Knowledge Dissemination and Capacity Building:

Extension agents provide customized training on essential CSA practices—conservation agriculture (zero-till, residue retention), integrated nutrient management (INM using biofertilizers at 5–10
kg/ha), mulching (straw at 4–6 t/ha for 0.5–1% SOC gains), and the System of Rice Intensification (SRI with AWD for 40–74% water savings).

- **Methods**: Farmer field schools (FFS), frontline demonstrations (FLDs), participatory on-farm trials, and group training through KVKs (731 across the country, with 4–6 domain experts per district).NICRA-TDC in 151 vulnerable districts (including Chhattisgarh) has executed thousands of demonstrations, benefiting 9 additional farmers per KVK demo (benefit-cost ratio 11–12). Capacity building has trained over 200,000 extension personnel in ML-based pest forecasting (CNN accuracy >80%) and digital tools.
- Outcomes: Enhanced awareness and skills result in a 20–40% productivity increase in adopted clusters (e.g., zero-till wheat, DSR in rainfed rice). Extension through KVKs and state programs promotes participatory learning, allowing farmers to co-create solutions tailored to local soils (e.g., black cotton in Raipur/Dhamtari).

Policy Recommendations and Future Directions:

Policy, Finance, and Enabling Environments for Climate-Smart Agriculture (CSA) and Extension in India:

India's policy framework for CSA and extension is strong and continuously developing, concentrating on financial de-risking, technological integration, and institutional collaboration to enhance adoption in light of climate forecasts for 2025–2050 (e.g., 15–25% yield volatility in rainfed systems such as the rice belts of Chhattisgarh). By early 2026, national expenditures surpass ₹1.5 lakh crore each year for agricultural resilience, highlighting subsidies (40–90% coverage), insurance, and data-driven tools.

These facilitators tackle challenges faced by smallholders (e.g., high expenses, knowledge deficiencies), with extension services through KVKs and FPOs being crucial for effective last-mile delivery. For farmers like Sarita in Raipur's rainfed agroecology, these initiatives provide accessible routes to resilient practices such as SRI and drought-resistant varieties.

Government Incentives: Subsidies and Insurance Schemes:

India's programs offer direct financial assistance, lowering initial costs by 45–90% and connecting to extension services for skill development.

- **Pradhan Mantri Fasal Bima Yojana (PMFBY)**: Initiated in 2016, PMFBY provides extensive crop insurance against yield losses due to extreme weather, pests, and post-harvest challenges. As of FY 2025–26 (continuing into 2026), it serves over 4 crore farmers annually across 498 districts in 21 states/UTs, with cumulative claims exceeding ₹95,000 crore (total disbursed reaching ₹1.70 lakh crore by FY24). In Kharif 2026, improvements include additional coverage for wild animal damage and localized flooding of paddy fields, with technology-driven settlements (satellite NDVI achieving 85–90% accuracy, cutting delays to 15–20 days).
- **National Mission for Sustainable Agriculture (NMSA):** Established under NMMSA (2014), NMSA enhances rainfed resilience through integrated farming practices, water use efficiency (WUE), and soil health initiatives. Budget for 2026–27: ₹750 crore allocated for the Natural Mission on Natural Farming (NMNF, reflecting a 3.4% increase from the 2025–26 revised estimate), which is part of a larger agriculture budget of ₹1.19 lakh crore.

- **Pradhan Mantri Krishi Sinchayee Yojana (PMKSY):** This initiative seeks to ensure "Har Khet ko Pani" through the implementation of micro-irrigation systems and watershed management. The allocation for 2026–27 is ₹6,587 crore, a decrease from ₹8,260 crore in 2025–26, with a focus on Participatory Drainage Management and Conservation (PDMC). The PDMC guidelines, released in April 2025, offer 55% financial assistance to small and marginal farmers (and 45% for others) for the installation of drip and sprinkler irrigation systems, which achieve 90–95% efficiency and save 40–60% of water. The program covers 1.5 million hectares each year; in Chhattisgarh, it collaborates with the State Action Plan on Climate Change (SAPCC) to provide 15–25% supplemental irrigation in rainfed regions.
- Soil Health Card (SHC) Scheme: This scheme provides biennial nutrient profiling to promote balanced Integrated Nutrient Management (INM) with a recommended ratio of C:N:P at 100:10:1, leading to nutrient use efficiency (NUE) gains of 20–40%. As of July 2025, with distributions for 2026 still ongoing, over 25 crore cards have been issued based on 8.03 crore samples collected from 2015 to 2025, with ₹1,706.18 crore allocated by February 2025. This initiative empowers more than 10 million farmers with data-driven insights and is integrated with the Rashtriya Krishi Vikas Yojana (RKVY) for Climate Smart Agriculture (CSA) extension.
- National Innovations in Climate Resilient Agriculture (NICRA): This flagship program of the Indian Council of Agricultural Research (ICAR), initiated in 2011, underwent a review in January 2026. The Technology Demonstration Component (TDC) operates in 151 districts, achieving productivity gains of 20–40% and reducing methane emissions by 25–35% through Alternate Wetting and Drying (AWD) and Direct Seeded Rice (DSR) methods. Over 200,000 agents have been trained, and the adoption of stress-tolerant rice varieties has resulted in an additional income of ₹10,890 per hectare.

Policy Recommendations and Future Directions:

To address the risks associated with climate-smart agriculture (CSA) from 2025 to 2050, such as potential rice yield declines of 20–33%, it is essential to prioritize actionable, evidence-based strategies. This should involve leveraging existing frameworks like NICRA, which can yield gains of 20– 40%, and ICM, supported by a fund of ₹20,000 crore.

- Strengthen Extension Systems: Enhance the capacity of over 200,000 agents in artificial intelligence and machine learning, for instance, utilizing CNN for pest detection with over 80% accuracy through NICRA. Additionally, integrate digital tools such as ACASA-India and mKisan, while allocating more than ₹5,000 crore annually for hybrid models that promote KVK-FPO convergence, aiming for 50% coverage of rainfed areas by 2030.
- Promote Multidisciplinary Partnerships: Encourage collaborations among researchers, extension workers, policymakers, NGOs, and the private sector, exemplified by the World Bank's PoCRA-II initiative with AgTech. Furthermore, expand Farmer Producer Organizations (FPOs) from 7,374 in 2020 to 20,000 by 2030 to facilitate co-creation, drawing insights from FAO's ENACT pilots to ensure inclusive scaling.

Conclusion

Climate-smart agriculture transcends mere techniques or technologies; it embodies the commitment to provide farmers and their families with a viable opportunity to nourish their children, safeguard their land, and maintain their dignity in the face of erratic rainfall, extreme temperatures, and diminishing harvests .At the core of this human narrative are extension services: they engage in active listening, demonstrate practices, traverse the fields alongside farmers, and transform anxiety into assuredness. When extension agents deliver knowledge, seeds, and motivation directly to households—particularly to women, youth, and the most at-risk populations— they facilitate the transition from mere survival to flourishing.The way forward necessitates a focus on people-centered extension: increased listening, enhanced local collaborations, expanded digital connections, and strengthened trust. Only through these efforts

can climate-smart agriculture genuinely evolve into a collective aspiration for resilient farms, thriving communities, and a lighter impact on our increasingly warm planet.

CSA is significant because farmers are significant—genuine individuals whose livelihoods depend on each season. Extension services serve as the vital link of trust that transmits knowledge from laboratories to the hands working the soil, assisting families in adapting, increasing their income, and finding relief amidst climate turmoil. By emphasizing the voices of farmers, promoting gender equity, including youth, and providing consistent support, extension converts theoretical "smart" practices into tangible resilience. The most profound conclusion is straightforward: by enhancing human-centered extension today, smallholders will not only endure climate change tomorrow—they will instruct the world on how to coexist with it.