



Climate-Smart Agriculture Needs Climate-Smart Extension: Turning Climate Knowledge into Action on the Farm

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A farmer wakes up to an uncertain season. The rains that once arrived like clockwork now come late, or too hard, or not at all. A sudden heat wave threatens the young crop in the field. A pest shows up weeks earlier than it used to. Water that was once dependable is now something to worry about every morning. How can farmers make the right decisions when the climate itself has become unpredictable? This is the question at the heart of climate-smart agriculture, or Climate-Smart Agriculture (CSA), an approach built around three goals: sustainably increasing agricultural productivity, building farmers' resilience to a changing climate, and reducing greenhouse gas emissions from farming systems (Thottadi & Singh, 2024; Raj & Garlapati, 2020). But knowing what CSA aims to do is only half the story. Getting it into farmers' hands and making sure it actually works on their land is the harder half. That is where agricultural extension professionals come in. Extension agents serve as the closest source of CSA information to farmers, demonstrating and disseminating technologies while linking farmers to researchers and policymakers. This article is about them: the people standing between climate science and the everyday decisions farmers must make.

What Exactly Is Climate-Smart Agriculture?

It helps to be clear about what CSA is not. It is not one invention, one seed, or one machine that farmers can simply buy and apply everywhere. It is better understood as an approach a basket of options that can include improved crop varieties, conservation agriculture, minimum tillage, cover crops, soil moisture conservation techniques, climate information services, and better resource management, among other locally appropriate practices. What counts as "climate-smart" for one farmer may not be the right fit for another. A practice that works for a rice farmer in a flood-prone delta may be irrelevant to a maize farmer coping with drought further inland. The crop, the soil, the local climate risk, and the farmer's own resources all shape what "smart" looks like on any given farm.

Why Farmers Need Climate-Smart Advice

The pressures are becoming familiar to anyone who has spent time in rural communities. Rainfall patterns are shifting. Water is harder to plan around. Soils are degrading. Pests and diseases are appearing in new places and at new times. And on top of all of that sits basic uncertainty about what a season will bring. Developing new climate-smart technologies and practices in research stations is necessary but it is not sufficient. A technology has to actually reach farmers. It has to be explained in terms they trust. And it has to be adapted to their specific plot of land, not just to a research trial down the road. This is precisely the gap that extension professionals are positioned to close.

The Extension Professional: The Bridge Between Science and the Farm

Picture a simple chain: researchers generate knowledge, extension professionals carry that knowledge to farmers, farmers put it into practice, and their experience what worked, what didn't, what got in the way flows back to researchers and policymakers. Extension professionals sit in the middle of that chain, and their job is not passive. They disseminate technologies, explain scientific findings in plain language, run demonstrations, build farmers' skills, facilitate learning between farmers, connect them to useful institutions, and carry farmers' problems back up to the people designing policy and research agendas. This intermediary role is not a minor detail in the CSA story. It is central to it. Across the evidence base on CSA extension, diffusion of innovations and multi-stakeholder collaboration emerged as the foremost role of extension services, reported in more than two-thirds of reviewed studies, followed closely by capacity building and human resource development. In other words, when researchers looked at what extension professionals actually do for CSA, connecting people to new practices and to each other came out on top.

Four Key Roles of Extension Professionals in CSA

- **Technology Disseminator.** This is the most visible role. Extension professionals promote practices such as cover cropping, minimum tillage, improved crop varieties, and conservation agriculture, helping farmers understand not just what a practice is, but how and why to use it on their own land.
- **Capacity Builder.** Beyond handing out information, extension professionals train farmers directly in soil moisture conservation techniques, through field demonstrations, and through ongoing monitoring and evaluation of how practices are performing.
- **Climate Information Provider.** Farmers increasingly need more than general advice; they need timely, localized information. Extension professionals share weather forecasts, seasonal advisories, and broader climate education, helping farmers interpret what the data actually means for their next planting decision.
- **Policy Advocate and Linkage Agent.** Extension professionals also work upward and outward, connecting farmers to government programmes, research institutions, farmer organizations, NGOs, and private-sector actors and in some cases, negotiating and advocating for policies that better support CSA on the ground.

Together, extension agents perform intermediary functions and support learning processes that directly influence farmers' adoption of climate-smart practices, and they do this largely through farm visits, result demonstrations, and method demonstrations, delivering up-to-date CSA information and helping farmers interpret climate data to manage risk.

Does Extension Really Increase CSA Adoption?

It's a fair question. Does all this activity actually translate into farmers changing what they do? The evidence, drawn from specific studies in specific places, suggests it often does. In northern Ghana, farmers who participated in extension services adopted 1.27 more CSA practices, on average, than farmers who did not participate a modest but meaningful difference, showing that extension contact nudges farmers toward using a broader combination of climate-smart practices rather than relying on just one (Anang, 2022). In southern Malawi, the effect looked different in shape but pointed the same direction: interaction with farmer extension facilitators increased low, medium, and high resource-intensity CSA adoption by 42%, 87%, and 96%, respectively (Amadu, 2022). Interestingly, the boost was largest for the more resource-intensive practices. The kind of changes that typically require more confidence, more investment, and more support to attempt. In India, an extension-led CSA strategy achieved a 62% adoption rate within two years and a cost-benefit ratio of 1.8:1 (Heena et al., 2025), a signal that consistent training can also make economic sense, not just agronomic sense. None of these figures should be read as universal laws. They come from particular farming systems, particular crops, and particular extension arrangements in Ghana, Malawi, and India. What they consistently show is a pattern, not a

guarantee: where extension services are active and well-connected to farmers, CSA adoption tends to move in the right direction. Adding to that picture, farmer participation in extension-linked training is itself shaped by access to extension services and by membership in farmer-based organizations, which together help drive how intensively CSA practices are adopted (Zakaria et al., 2020).

Why Demonstration Matters

There is a real difference between telling a farmer what to do and letting a farmer see, test, and understand how a practice actually performs on real soil, in a real season. Farm visits, result demonstrations, and method demonstrations give farmers something a leaflet cannot: proof, under local conditions, that a new practice is worth the risk of trying. Farmer-to-farmer learning adds another layer of trust. A neighbour's field that has visibly benefited from a new tillage method or a cover crop often carries more persuasive weight than any outside expert's explanation. Extension work, at its best, creates the conditions for that kind of peer learning to happen organizing the visit, running the trial plot, and making sure the right people see the results.

When Extension Professionals Themselves Need Support

For all the responsibility placed on extension professionals, they are not always equipped to carry it. In South Africa, extension practitioners had theoretical understanding of climate change but little practical knowledge of how to apply CSA on the ground, with the majority having received no CSA training (Maka et al., 2021). Knowing that climate change is happening is not the same as knowing how to help a specific farmer adjust their planting calendar or manage soil moisture under new rainfall patterns. In Nigeria, the picture includes an attitude problem as well as a knowledge gap: over half of extension agents exhibited unfavourable attitudes toward CSA practices, and participation was particularly low for advanced tools such as index-based weather insurance, precision agriculture, and ICT-enabled advisory (Ojo et al., 2025). If the people responsible for promoting a practice are themselves sceptical of it, or unfamiliar with the newer digital tools meant to support it, that gap will show up downstream, in what farmers do or don't try.

The Extension Worker on the Ground: Practical Constraints

Even a well-trained, well-motivated extension professional can be defeated by simple logistics. High agent-to-farmer ratios, lack of transportation, and insufficient incentives rank among the top constraints impeding effective CSA dissemination (Ojo et al., 2024; Antwi-Agyei & Stringer, 2021). Poor coordination between organizations and geographical disparities in service coverage add to the problem, creating ambiguous roles and raising the risk of maladaptation, advice that is well-intentioned but poorly matched to local conditions (Billah et al., 2025; Katiyatiya & Ncanywa, 2026). Inadequate training on the fuller range of CSA practices also limits how well agents can support less common but potentially valuable interventions, such as soil amendments and agroforestry (Olorunfemi et al., 2020; Maka et al., 2021). None of these constraints sound dramatic on their own. But add them together, and the effect is real: if one extension professional is responsible for far too many farmers, with no reliable way to travel between them and little institutional backing, even a genuinely useful climate-smart technology can end up going nowhere.

From Field Visits to Hybrid Extension

Traditional, face-to-face extension work is not being replaced so much as it is being reinforced. New tools are entering the picture: Farmer Field Schools, Participatory Rural Appraisal, chat-app microlearning, localized micro-videos, and SMS-based advisories. Emerging evidence suggests these digital additions can genuinely help. Hybrid extension systems that combine interpersonal trust with digital reinforcement chat-app microlearning, localized micro-videos, SMS advisories have been found to meaningfully improve farmer knowledge gain and adoption behavior. ICT-enabled extension and broader climate information services are helping bridge the knowledge gap at the grassroots level, though it is

worth noting that adoption of these same digital tools by extension agents themselves remains uneven (Raj & Garlapati, 2020; Thottadi & Singh, 2024; Ojo et al., 2025). The takeaway is not that digital tools will replace human extension agents, but that the two work best in combination, a human presence that farmers trust, reinforced by digital channels that extend reach and frequency of contact.

Farmers Should Not Just Receive CSA Technologies: They Should Help Shape Them

One of the more encouraging shifts in extension thinking is participatory. Approaches such as Farmer Field Schools and Participatory Rural Appraisal give farmers an active role in identifying their own local climate problems, testing technologies themselves, comparing alternatives side by side, and contributing their own local and indigenous knowledge to the process. This kind of participatory approach helps bridge the gap between generalized scientific recommendations and the specific realities of a given farming community (Prajapati et al., 2025). Climate-smart agriculture, in other words, has to be locally smart. A practice imposed from outside, without input from the people who will actually use it, is less likely to stick.

The Power of Partnerships

No single organization can deliver climate-smart agriculture on its own. Effective CSA extension depends on networks links between formal extension departments, research institutions, universities, farmer organizations, NGOs, private-sector actors, government agencies, and local communities. Networks that connect formal extension with NGOs, farmer groups, and private actors are described as essential for holistic CSA delivery (Thottadi & Singh, 2024; Prajapati et al., 2025). This is consistent with the broader finding noted earlier: multi-stakeholder collaboration is, alongside the diffusion of innovations, one of the most commonly reported roles of extension services in the CSA literature.

A New Generation of Extension Professionals

The skill set of an extension professional is expanding. Traditional strengths communication, training, running demonstrations, mobilizing communities remain essential. But newer skills are increasingly part of the job description: interpreting climate risk, digital literacy, delivering ICT-based advisory services, working with data, coordinating across multiple stakeholders, and applying participatory methods. The extension professional of the future looks likely to be both things at once: a trusted human advisor whom farmers know and rely on, and a navigator of climate information who can translate complex data into decisions a farmer can act on this season.

What Should Be Done to Strengthen Extension for CSA?

- **For extension organizations:** invest in regular CSA training, support digital upskilling, improve mobility and transportation for field staff, ensure adequate staffing levels, strengthen incentives, and build better climate information systems.
- **For policymakers:** invest in rural extension infrastructure, strengthen extension staffing more broadly, improve coordination across agencies, support the development of climate information services, and encourage multi-stakeholder partnerships rather than siloed programmes.
- **For researchers:** develop CSA technologies that are genuinely suited to local conditions, conduct participatory research alongside farmers rather than only about them, evaluate adoption and impact rigorously, and communicate findings in formats extension professionals and farmers can actually use.
- **For extension professionals themselves:** keep climate knowledge current, lean on demonstrations rather than instruction alone, blend digital tools with face-to-face contact, actively encourage farmer participation, and document farmer feedback so it can travel back up the chain to researchers and policymakers.

Conclusion: Climate-Smart Agriculture Needs Climate-Smart Extension

Climate-smart technologies cannot transform agriculture on their own. A better seed variety, a smarter irrigation method, or a more resilient cropping system means little if it never reaches the farmer who needs it or if it reaches them without the explanation, demonstration, and local adaptation that turns an idea into a working practice. Farmers need information. They need to see a practice work before they trust it. They need confidence, locally relevant solutions, and continued support long after the first demonstration plot is harvested. That is the work of extension professionals not a side activity to climate-smart agriculture, but one of its central mechanisms. The future of climate-smart agriculture will not be built only in laboratories and research stations. It will be built in fields, villages, and communities, with extension professionals helping farmers turn climate knowledge into climate action.

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