Agri Articles
(e-Magazine for Agricultural Articles)
Volume: 06, Issue: 02 (MAR-APR, 2026)
Available online at http://www.agriarticles.com
©Agri Articles, ISSN: 2582-9882

Role of Agricultural Extension in Climate Change Adaptation

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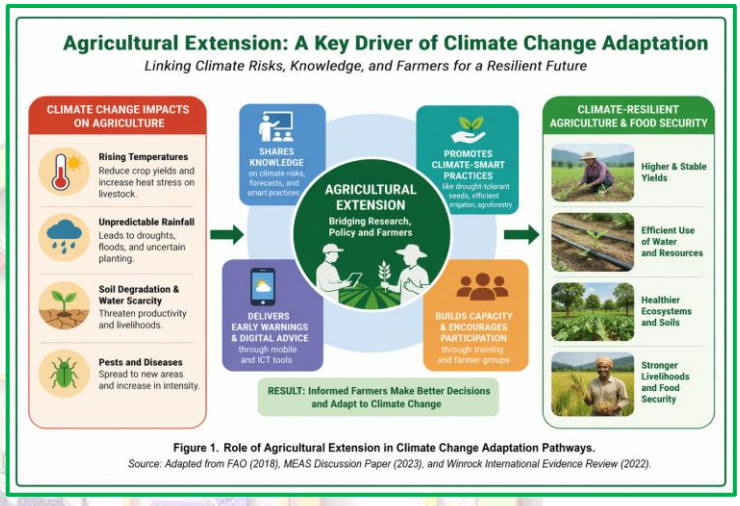

Figure 1. Role of Agricultural Extension in Climate Change Adaptation Pathways.
Source: Adapted from FAO (2018), MEAS Discussion Paper (2023), and Winrock International Evidence Review (2022).

In addition to altering global weather patterns, climate change is upsetting agricultural systems that provide livelihoods and food security. Yields, soil health, and water availability are under risk due to rising temperatures, unpredictable rainfall, and a rise in the frequency of severe events. Because they often lack access to the resources, technology, and knowledge necessary to adapt, smallholder farmers—who produce the majority of the food in many developing nations—are especially susceptible. A vital link between research, policy, and farmers is provided by agricultural extension and advisory services (EAS). They link farmers with markets, loans, and input suppliers, spread information, and encourage the adoption of climate-smart methods. Extension services must be reoriented to support resilience and adaptation measures while supporting mitigation efforts in light of the increasing urgency of climate change. This study examines how extension systems are changing to accommodate climate change by synthesizing data from reputable publications and peer-reviewed research papers. It evaluates gender-responsive and digital innovations, highlights policy changes and capacity shortages, and explores the functions, methods, and effects of extension in climate adaptation. More than thirty excellent papers from Africa, Asia, the Americas, and international reviews published between 2011 and 2026 are cited in the study. The importance of agricultural extension, the effects of climate change on agriculture, the roles and functions of extension in adaptation, digital and information innovations, gender and equity considerations, capacity building and policy reforms, case studies, opportunities and challenges, and conclusions are all covered. The objective is to provide a current, thorough knowledge of how extension services enhance smallholders' ability to adapt and what changes are required to make these services successful in the face of climate change.

The Importance of Agricultural Extension

Evolution of extension and advisory services

Historically, agricultural extension has concentrated on disseminating Green Revolution technology and boosting output. Innovations like better seeds, fertilizer, and insect control

were distributed top-down. Nonetheless, contemporary extension is changing to include farmers in problem-solving, co-learning, and promoting information exchanges between many players. Instead of focusing on one-way information sharing, the "Extension 3.0" paradigm emphasizes networked knowledge networks and communities of practice. In order to co-produce locally relevant solutions to complicated issues, such as climate change, trusted networks of extension agents, research institutions, non-governmental organizations (NGOs), and farmer organizations are being employed more and more.

Extension's contribution to climate resilience

Extension programs provide a vital role as a bridge between farmers and research. They provide information on early warning systems, climate smart technology, soil health, agricultural and livestock management, and weather predictions. Extension professionals facilitate prompt planting, irrigation, and risk management decisions by assisting farmers in interpreting climatic data. Access to extension services has a major impact on the adoption of climate smart agriculture (CSA) techniques, according to studies conducted in Ghana and other nations. Farmers that get timely alerts adopt better practices, retain greater yields and incomes, and are more aware of the hazards associated with climate change. When paired with digital platforms and participatory techniques, extension services may boost preparation for climate threats and boost production by 20–30%.

Climate Change and Agricultural Systems

Rising temperatures, altered rainfall patterns, extended droughts, floods, and heightened pest and disease pressure are all signs of climate change. These effects jeopardize livelihoods and food security. For instance, many tropical countries are expected to see a drop in the yields of basic crops like rice and maize. Planting times are impacted by erratic rainfall, which also makes irrigation water supplies less dependable. Frequent heat waves and droughts cause cattle deaths and ruined rangelands in Asia and Africa. In order to adapt to this "new normal," agricultural extension agencies must help people adjust their behavior. According to the MEAS discussion paper, extension and advisory services are essential conduits for farmers to access new knowledge and resources, and they must encourage behavioral changes in order to adapt to climate shocks. To boost farmers' resilience, extension professionals must interact with meteorological services, include climate risk management into their mandates, and collaborate with other sectors.

Roles and Functions of Extension in Climate Adaptation

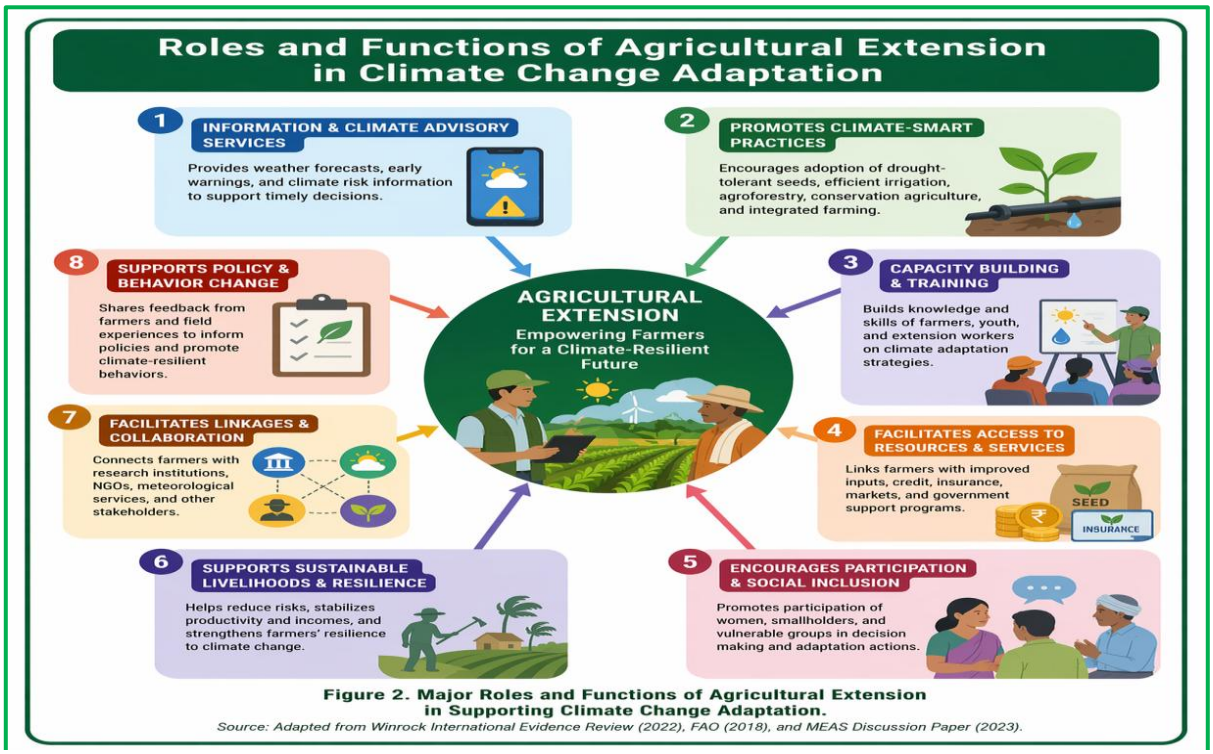

Figure 2. Major Roles and Functions of Agricultural Extension in Supporting Climate Change Adaptation.

Source: Adapted from Winrock International Evidence Review (2022), FAO (2018), and MEAS Discussion Paper (2023).

Information and technology transfer

Disseminating knowledge and technology is one of extension's primary roles in climate adaptation. Eight roles of extension were identified by Winrock International and partners' evidence review: providing climate advisory services; encouraging stress-tolerant seeds and breeds; supporting climate resilient value chains; facilitating alternative farming practices; introducing resource-efficient technologies; promoting market mechanisms for climate smart agriculture; expanding agroforestry and ecosystem-based approaches; and guaranteeing social inclusion. Weather and seasonal predictions, integrated pest and disease control, water management, soil conservation, and climate-resilient crop types are among topics covered by extension agents. Additionally, extension services provide solutions that improve adaptability while lowering greenhouse gas emissions. Conservation agriculture, agroforestry, effective irrigation systems, better animal feeding techniques, and renewable energy technology are a few of them. Research highlights the need of context-specific suggestions due to regional variations in socioeconomic situations and climatic effects. Extension agents assist in adapting methods to the agro-ecological circumstances and farmers' capabilities in the area.

Capacity building and farmer training

Extension services enhance farmers' abilities via peer learning, training, and demonstrations in addition to information sharing. In order to improve their climate resilience, farmers in Gqumashe village asked for specialized training and frequent visits from extension agents, according to the South African Journal of Agricultural Extension. Adoption of drought-tolerant crops, water collection, conservation tillage, and sustainable storage were among the training subjects. The publication emphasized that extension staff must meet market and storage demands in addition to providing current knowledge and technology. Building capacity is important for extension workers as well as farmers. Many extension workers must manage many areas outside of their training, and many of them lack technical competence in climate change. According to a research conducted in northern Vietnam, the majority of extension workers were female, but they lacked both technical training and real-world experience in adapting to climate change. To improve technical and communication abilities, the research suggested gender-responsive methods, interactive training, and practical demonstrations.

Facilitation and participatory decision-making

Communities and farmers must be involved for adaptation to be effective. In order to co-produce solutions, extension workers lead community workshops, farmer field schools, and participatory planning. Building local institutions and community networks is crucial for disseminating climate knowledge and creating backup plans, according to the FAO climate risk management guidance. Farmers are encouraged to experiment with new methods, share indigenous knowledge, and manage resources as a group via participatory ways. Additionally, they contribute to the development of trust and social capital, both of which are essential for group activity.

Policy and governance roles

In addition to providing technical training, extension agents also influence policy and connect farmers with organizations. Extension agents may promote policy advocacy and make social safety programs, climate insurance, and credit more accessible, according to the Winrock evidence assessment. Advocating for budget allocations, supporting the execution of National Adaptation Plans (NAPs) and Nationally Determined Contributions (NDCs), and encouraging community involvement in policy discussions are examples of policy responsibilities. The IFPRI blog highlights the need of public extension services in supporting nature-based solutions, integrating emergency services and insurance, and connecting climate policy with smallholders' needs. However, the need for change is highlighted by the fact that extension systems often have little funding, poor technical capability, and coordination issues.

Digital Innovations and Climate Information Services

By facilitating quick information sharing, customized alerts, and feedback loops, digital technologies are revolutionizing extension delivery. New channels for climate information,

early warnings, and decision support are made possible by smartphones, mobile applications, text messaging, social media, radio, video, remote sensing, Internet of Things (IoT) devices, and artificial intelligence (AI).

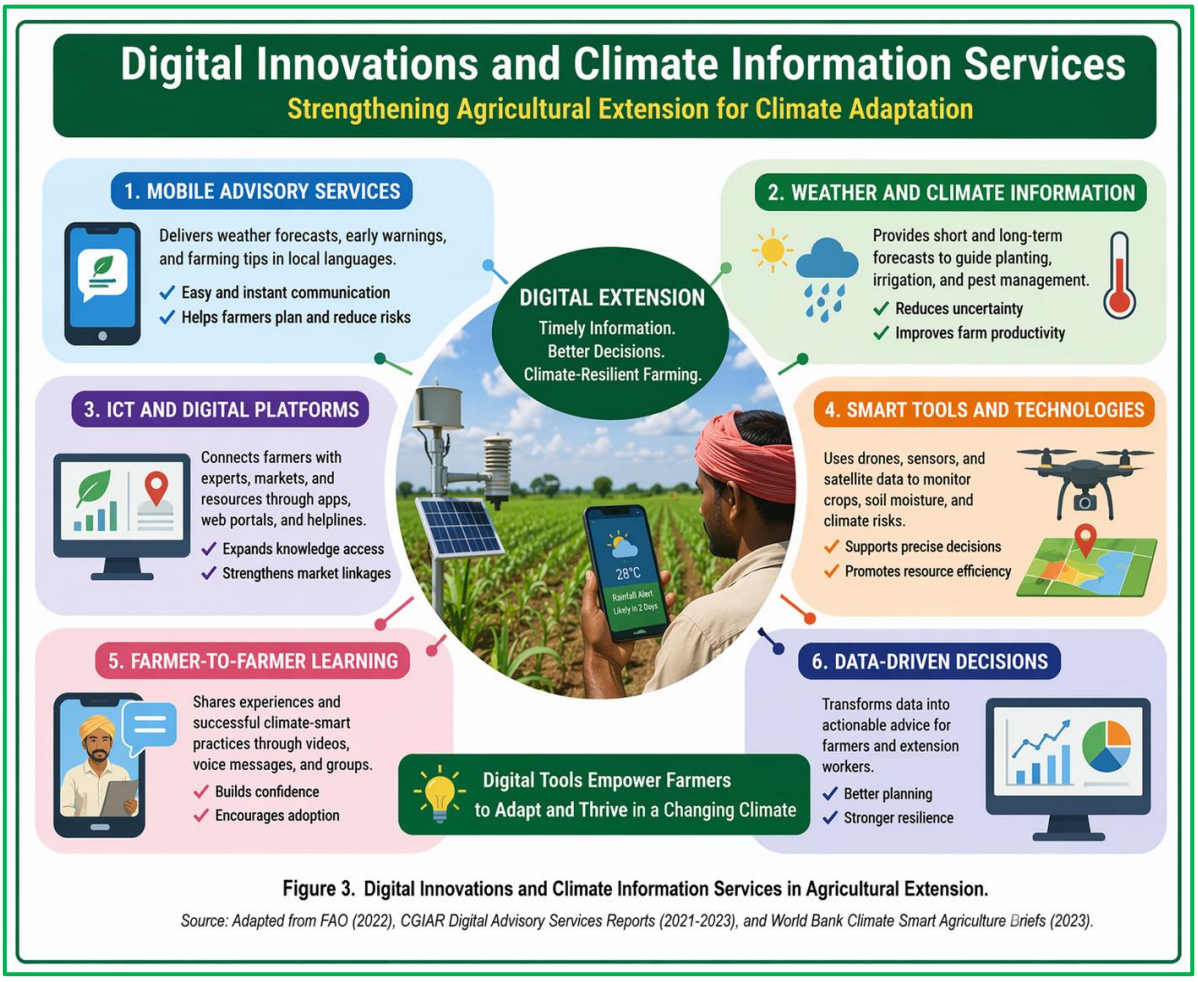

Figure 3. Digital Innovations and Climate Information Services in Agricultural Extension.

Source: Adapted from FAO (2022), CGIAR Digital Advisory Services Reports (2021-2023), and World Bank Climate Smart Agriculture Briefs (2023).

Impact of digital extension

Mobile phones, video advisories, remote sensing, IoT, and AI all increase water usage efficiency, provide early warnings, and encourage the adoption of better practices, according to a comprehensive evaluation of digital agricultural technology. Digital technologies empower farmers, reduce vulnerability, and encourage sustainable intensification, according to the research. But it also highlighted issues including gaps in internet literacy, poor infrastructure, financial obstacles, and gender inequality. To maximize the advantages of digital extension, several aspects need to be taken into consideration. A study of apple producers in Shaanxi province, China, showed that digital extension greatly encourages farmers to embrace climate adaption technology by lowering transaction and financing barriers and raising understanding of the economic and ecological advantages. Farmers with bigger farms and stronger digital abilities were more affected. In the West Bank of Palestine, another randomized controlled experiment (RCT) compared traditional and digital extension for grape growers. Due to political obstacles, traditional extension only reached 7.1% of farmers; however, digital channels, such as websites and WhatsApp groups, gave the possibility of overcoming logistical obstacles and disseminating climatic warnings. The research highlighted the potential of digital extension in conflict-prone regions by measuring productivity, cost efficiency, and adoption of climate adaptive techniques.

Climate information services and early warning systems

Adaptation requires quick access to climatic information. Weather and climate services (WCS) boost yields; according to a research by the International Growth Centre, offering WCS boosted wheat yields by 17% and maize yields by 27%, although only 18% of farmers had access. The report suggested mainstreaming WCS into extension systems and making

investments in climate forecasting. The South Asia Drought Monitoring System (SADMS), where extension workers get drought predictions and counsel farmers on solutions including planting drought-tolerant seeds, mulching, and effective irrigation, is described in the NetHope study on digital for climate adaptation. Farmers use WhatsApp groups to communicate with extension workers and get SMS alerts, demonstrating how integrated ICT systems improve early warning and action. It is crucial to adapt climate data to local circumstances. Existing one-size-fits-all climate information systems often fail because they are not contextualized and do not take social and regional variables into account, according to a research conducted in Papua New Guinea. Farmers' choices for information packages were modified by gender and geography, highlighting the need of customizing climate services and incorporating them into extension initiatives. In a similar vein, study on open government data (OGD) in Tanzania revealed little adoption of climate-related data despite moderate awareness because of infrastructural and digital literacy issues. In order to use OGD for climate resilient agriculture, the research suggested institutional adoption, better digital skills, and participatory policies.

Gender-responsive digital extension

Women's access to digital extension is restricted by gender disparities. Women often experience a lack of knowledge, digital literacy, and customized material, according to an FAO/CRISP research on gender-responsive digital extension. It suggested creating regionally appropriate information, doing gender-responsive needs assessments, analyzing gender disparities, conducting pilot testing with female farmers, and supporting digital literacy initiatives. In the absence of focused measures, digital expansion might exacerbate already-existing inequalities. In addition to technologies, financing, and supporting networks, women farmers need secure learning environments.

Gender and Social Inclusion in Extension Services

Due to restricted decision-making authority, gender norms, and resource limitations, women and marginalized groups are disproportionately impacted by climate change. Equitable adaptation requires inclusive extension services. Evidence from The Gambia demonstrates that farmers encounter obstacles including a lack of resources, irrigation, and expertise, as well as low levels of education and insufficient extension services. Farmers' perspectives must be included into policy initiatives, and obstacles must be removed via funding, extension services, and infrastructural upgrades. Inequalities are made worse by a lack of gender-responsive extension; women often have less chances to participate in decision-making and get less information and training than males. Cultural norms, land rights, and intrahousehold labor dynamics must all be taken into account in gender-sensitive initiatives. Extension agents should use participatory techniques that empower women, interact with both men and women, plan meetings at suitable times, and provide childcare during trainings. Despite capacity issues, women predominate in the extension labor, according to the APN research from northern Vietnam. Training and mentoring female extension agents may improve their capacity to assist female farmers and provide advice that is gender-sensitive.

Capacity Building and Institutional Strengthening

Training extension personnel

Inadequate financing, poor coordination, and insufficient technical competence plague many extension programs. It is crucial to train extension staff on digital technologies, climate wise practices, and risk management. The AICCRA program in Ethiopia used a training of trainers (ToT) strategy, wherein subject matter experts and university employees received training on climate risk management before passing that information on to farmers and development agents. By using well-established extension networks, this strategy guarantees that farmers get climatic information. Traditional lecture-based techniques are less successful than participatory training methods that include field demonstrations, peer learning, and classroom teaching. In order to create backup plans, enhance data collection, and provide early warning systems, extension agencies and meteorological services must work together, according to the FAO climate risk management report. It suggests creating community information centers,

bolstering local networks, and planning seminars that include farmers. Extension staff should be kept up to speed on new technology, climatic scenarios, and adaptation tactics, and capacity building should be ongoing.

Institutional reforms and funding

The IFPRI blog highlights that structural issues such inadequate funding, inadequate technical capabilities, and unsupportive policies must be addressed in order to revitalize public extension. It suggests interdisciplinary methods, the integration of crop insurance and emergency services, enhanced policy procedures connecting expansion to NDCs and NAPs, and the encouragement of natural solutions. Consultations in India, Indonesia, and Nepal showed that collaborations between the public and commercial sectors, NGOs, farmer organizations, and research institutions are necessary for extension reform. These collaborations may guarantee that extension services satisfy a range of requirements, mobilize resources, and exchange knowledge.Financial methods are necessary to maintain extension services. The CABI policy brief on climate-responsive EAS promotes investments in human and technical resources, digital information distribution, and inclusive smallholder-reaching modes. It demands the joint development of locally driven adaptation initiatives, consistent capacity building, and long-term funding sources including cost-sharing and public-private partnerships. Extension organizations find it difficult to sustain outreach, employ qualified personnel, and use digital technologies without sufficient funds.

Case Studies and Regional Experiences

Africa

- **South Africa:** Farmers in Gqumashe village acknowledged the effects of climate change and demonstrated a keen understanding of the need of adapting. They noted a variety of issues, including diminishing soil fertility, water shortages, and increasing pressure from pests and diseases. Farmers emphasized the need of frequent visits and timely information, and they asked extension agents to provide them with specialized training on climate resilient methods.
- **Nigeria:** According to a survey of extension responsibilities in Nigeria, 89.6% of studies found that farmers did not have access to extension services connected to climate change. Information transmission is the primary emphasis of extension services (98.2%), with little technical guidance and indigenous tactics. Information communication technology (ICT) and climate change technology skills are two areas that need training. In 95.7% of instances, extended contact had a favorable effect on adaption choices, demonstrating the potential benefits of high-quality extension.
- **The Gambia:** Lack of resources, irrigation, and education are obstacles to climate adaptation, according to research on farmers' opinions. Farmers highlighted the need for governmental interventions to enhance irrigation infrastructure, extension delivery, and training, citing insufficient financial assistance and extension services as the main barriers.
- **Tanzania:** Due to issues with digital literacy and infrastructure, a research on open government data found minimal adoption despite considerable awareness. To use open data for climate resilient agriculture, the authors suggested digital skills training and participatory policy. The research also demonstrated how geospatial information may provide early warning systems and localized predictions when paired with extension services.

Asia

- **India:** Climate-resilient crop varieties and technology are distributed via the National Innovations in Climate Resilient Agriculture (NICRA) initiative. According to research, access to inputs, educational attainment, and high-quality extension services are important factors that influence adoption. Extension professionals assist farms in implementing climate-smart soil management, water harvesting, and drought-tolerant crops. However, site-specific evaluations, training, and cooperative learning amongst farmers, researchers, and extension agents are necessary for adoption.

- **China:** By lowering transaction and credit limitations, digital extension for Shaanxi's apple producers greatly improved use of adaptive technology. Farmers with bigger businesses and higher levels of digital proficiency benefited more, underscoring the significance of digital literacy and scale in digital extension.
- **Palestine:** Due to logistical and political obstacles, conventional extension only reaches a tiny percentage of farmers in the West Bank, according to the RCT protocol for grape growers. To disseminate climate alerts and track uptake and productivity implications, a digital extension using websites and WhatsApp groups is being tried.
- **Vietnam:** The majority-female extension workers in northern Vietnam often worked across many technical disciplines without specialized assistance and without practical climate training. To increase capacity, the research suggested gender-responsive methods, interactive training, and practical demonstrations.
- **Latin America and the Caribbean:** Some experiences demonstrate the possibility for extension to promote climate adaptation in Latin America, despite the fact that there were fewer research available. For instance, digital platforms are being created to provide climate alerts to coffee producers who are under more strain from pests and diseases. Cooperatives and extension workers work together to incorporate climate projections into agricultural management choices. Digital literacy and inadequate infrastructure, however, continue to be obstacles.

Challenges

Limited resources and reach: The farmer-to-extension ratio is high in many extension programs. Just 7.1% of farmers in the West Bank got conventional extension assistance. Outreach is hampered by a lack of personnel, financial constraints, and practical difficulties.

Technical capacity gaps: Extension agents often lack current expertise in digital technologies, participatory methodologies, and climate science. Employees in Vietnam and Nigeria lacked ICT skills and practical climate training.

Digital divide: Digital literacy, connection, and device access are necessary for digital extension. The resources necessary to take use of digital services are often lacking for women and marginalized groups. Many rural communities lack digital skills and infrastructure, which results in limited utilization of digital advisories and open data.

Gender and socioeconomic inequality: Women farmers encounter obstacles with their access to extension, decision-making authority, and land rights. Women's schedules and needs may not be accommodated by extension programs. Support and training are often lacking for female extension agents.

Coordination and policy gaps: Extensions are delivered by a number of players (public, private, and NGOs), which causes confusion and overlapping messages. In order to create adaptation resources, the USDA Agricultural Research Service session description highlighted the need of coordinated messaging and co-production frameworks. Extension is often isolated from national adaption plans and climate policy.

Financial limitations: Extension services often get insufficient financing, which restricts their capacity to employ qualified staff, use digital technologies, or provide incentives to employees.

Conclusion

Services for agricultural extension are essential for assisting farmers in adjusting to climate change. By spreading climate smart technologies, developing skills, promoting supporting policies, and enabling participatory decision making, they close the gap between research and practice. Extension increases farmers' understanding, adoption of climate-smart practices, and production, according to the examined data. Opportunities to broaden reach and deliver customized advisories are presented by digital technologies and climate information services, but they must be paired with initiatives to close the digital gap and guarantee social and gender inclusiveness. Effective adaptation requires ongoing training, institutional changes,

and the development of extension staff capacity. Lastly, to scale up climate responsive extension, public and private actors must coordinate and provide sustainable funding.

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