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Agricultural Extension and Advisory Services in Support of Climate Change Adaptation and Mitigation: An Evidence Review

Enabling Farmers for Agricultural Transformation (EFAT)

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Acronyms

ACRON	Agroforestry Carbon Removal Units for the Organic Restoration of Nature
CBI	Community Based Intermediaries
CCAFS	CGIAR Research Program on Climate Change, Agriculture and Food Security
CGIAR	Consultative Group on International Agricultural Research
CCIMMYT	International Maize and Wheat Improvement Center
CO_2	Carbon Dioxide
DGM	Dedicated Grant Mechanism
EAS	Extension and Advisory Services
FMNR	Farmer Managed Natural Regeneration
GHG	Greenhouse Gas
IITA	International Institute of Tropical Agriculture
IRRI	International Rice Research Institute
KACP	Kenya Agricultural Carbon Project
LTAC	Local Technical Agro-climatic Committees
NGOs	Non-Governmental Organizations
PES	Payment for Ecosystem Services
SALM	Sustainable Agricultural Land Management
SCF	Seasonal Climate Forecast
SMS	Short Message Service
SRI	System of Rice Intensification
USAID	United States Agency for International Development
WISER	Weather and Climate Information Services for Africa

Executive Summary

The effects of climate change on agriculture and food production are evident in regions around the world. Effective climate change adaptation and mitigation in the agricultural sector calls for multiple context specific, and at times complex, strategies. Promoting these strategies effectively involves changing the behavior, strategies and agricultural practices of millions of producers. Studies point to the current role agricultural extension and advisory services (EAS) provided by public, private and civil society organizations play in promoting climate change adaptation and mitigation at scale and additional roles they could potentially play.

This evidence review aims to document the various roles and functions played by EAS in climate change adaptation and mitigation efforts. It also identifies challenges, as well as the capacities and support EAS need to effectively contribute to climate change adaptation and mitigation in agriculture. To do this, over 500 journal articles and other documents were reviewed and analyzed using the innovation management framework, which recognizes the wide range of roles and functions to be performed for innovation and impact at scale. The review identifies and describes eight roles played by EAS in climate change adaptation and mitigation:

- delivering climate advisory services,
- promoting seeds of stress-tolerant varieties of crops,
- promoting climate resilient value chains,
- supporting farmers to adopt alternative farming practices,
- promoting resource efficient technologies,
- supporting mitigation through market-based mechanisms,
- promoting agroforestry, and
- promoting social inclusion in climate action.

The review also identifies ten major functions played by EAS to promote climate change adaptation and mitigation. These include:

- creating awareness on adaptation and mitigation measures,
- demonstrating new technologies and practices,
- developing educational and training materials,
- organizing trainings and learning events,
- improving access to inputs,
- mobilizing communities for collective action,
- promoting digital decision support tools,
- supporting communities to secure community rights,
- stakeholder coordination, and
- policy advocacy.

However, low capacity means some of the roles and functions played by EAS are not performed effectively. While public sector EAS providers play an important role in areas that are primarily focused on adaptation, such as promoting stress tolerant varieties and alternative farming practices, EAS' contributions to promoting climate resilient value chains and other areas primarily focused on mitigation interventions such as agroforestry, improved technologies, and market-based mitigation mechanisms, is more limited. This is due to the generally low level of funding for EAS, the lack of relevant mechanisms to ensure multistakeholder coordination, the limited

technical and functional capacities to promote adaptation and mitigation efforts among EAS staff and a lack of explicit recognition of the contributions of EAS to enhancing climate resilience. This review recommends the following measures to enhance the contribution of EAS to climate change adaptation and mitigation:

- *Include a climate focus in the goals of EAS*: Explicit climate objectives are needed to draw attention to climate change adaptation and mitigation at both organizational- and individual-levels of EAS and to ensure that EAS providers and systems are fully accountable to achieving specific climate adaptation and mitigation targets.

- *Build the evidence on the contributions of EAS to climate actions:* To support an increased climate focus, there is a need to generate a more robust evidence-base on the contributions of EAS to climate change adaptation and mitigation, including agricultural practices that enhance climate resilience.

- *Explore new roles and functions for EAS*: To be able to effectively address the climate crisis, EAS in most countries need to undergo reforms to shift away from a technology transfer paradigm to a more demand-led approach that emphasizes co-creation with producers, use of effective communication and dissemination tools as well as effective mechanisms to coordinate multiple actors.

- *Strengthen technical and functional capacities of EAS*: EAS providers from public, private and civil society organizations need upgraded technical and functional capacities in different approaches to managing climate change (e.g. climate smart agriculture, agro-ecology, regenerative agriculture), in facilitating farmer experimentation and responding to the needs of women, youth, and other marginalized farmers, as well as in soft skills such as facilitation, multistakeholder coordination and brokerage.
- *Increase sustainable funding for EAS:* Both public and private EAS providers need finances to hire more local-level staff and to cover the operational expenses associated with organizing farmer training and demonstrations, adopting new innovative, including digital, approaches, and providing tools and training for their staff.
- *Create extension policies that emphasize the role of EAS for climate action*: Extension policies should explicitly outline the role of EAS in a country's development strategy broadly and their role in national climate adaptation and mitigation plans.
- *Recognize the contribution of EAS in national climate strategies and plans*: Explicit recognition of the contribution of EAS in achieving climate resilience and positioning these services as important actors that can support upscaling climate adaptation and mitigation technologies and strategies is critical for ensuring that EAS receive policy and financial support.
- *Direct climate funds to agriculture and EAS*: Climate initiatives in agriculture should explicitly fund public and private EAS to strengthen their abilities to contribute to adaptation and mitigation.

1. Introduction

1.1 CLIMATE CHANGE, AGRICULTURE AND RURAL LIVELIHOODS

Current food systems generate as much as 34% of the current total greenhouse gas (GHG) emissions contributing to climate change (Crippa et al. 2021). The impacts of climate change – such as rising temperatures, longer droughts, more severe storms, warming oceans, and recurring floods and landslides - are decreasing agricultural productivity around the world and threatening global food security (IPCC 2022). The 2022 report from the Intergovernmental Panel on Climate Change on "Climate Impacts, Adaptation and Vulnerability" details how global warming has resulted in a 30% drop in productivity on the African continent alone since 1961 (IPCC 2022). Low-income countries that are the most impacted by climate change have low adaptive capacities, which is contributing to food insecurity caused by reduced food production and food price increases (Georgieva et al. 2022). As climate change affects the frequency, intensity, and duration of extreme weather events, it alters precipitation patterns, disrupts ecological systems, and causes temperatures and sea levels to rise (IPCC 2021). These changes are devastating for smallholder farmers in low-income countries, particularly those who are reliant on rainfed farming and dependent on forests for their livelihoods. The fewer assets that a person or family has – human, financial, natural, social, political, physical, etc. – the more challenging it is to cope with the changes necessary to adapt to climate change and longer it takes for them to recover from even modest shocks (Simpson et al. 2014). Climate change and its associated stressors negatively impact human development by disrupting livelihood systems, particularly those that mostly involve low-income women and youth, people with a high dependence on natural resources, who have weak social and financial safety nets and lack basic infrastructures (Duru et al. 2022; Government of Zimbabwe and UNDP 2017). The direct risks of climate change and the indirect impacts of climate-induced changes on natural resource systems are increasing the vulnerability of the rural poor, making it more likely that they will slide into an intractable cycle of poverty (Barbier and Hochard 2018).

While vulnerable to climate change, agriculture is also a major source of GHG emissions, both directly, through emissions from agricultural production, and indirectly, through land use changes resulting from agricultural expansion (OECD 2022). Accounting for roughly 30% of the world's total end-use energy consumption and 34% of global GHG emissions, agricultural activities largely remain dependent on diesel and grid electricity for core activities, such as irrigating fields and operating machinery (Crippa et al. 2021). Synthetic fertilizers derived from fossil fuels also contribute to emissions, through the production processes and from inappropriate application (Drugmand et al. 2022). Post-production activities, such as food storage, cooling, processing, and distribution, are also energy intensive. To strengthen the climate resilience of agriculture, a two-pronged approach that supports adaptation - adjusting to actual and expected future climate challenges – as well as promotes mitigation - reducing greenhouse gases and enhancing carbon sequestering - is needed. Sequestering carbon[1] will have mutual benefits for climate change

[1] Atmospheric carbon is sequestered in three ways: biologically, geologically, and technologically. Biological carbon sequestration includes soil, forests, and grasslands that can act as major carbon sinks. A carbon sink is a natural environment viewed in terms of its ability to absorb carbon dioxide from the atmosphere (CLEAR Center 2019).

adaptation and mitigation, food security, and as well as give the agricultural sector access to carbon markets.

Several approaches to fostering climate-smart[2] food systems are currently being promoted around the world including nature-based solutions, conservation agriculture, natural farming, and regenerative agriculture. Some of these approaches promote climate-adaptive agricultural technologies, agroforestry, more sustainable regenerative agroecological practices that conserve soil, water, biodiversity and the of use renewable resources. (Campbell 2022; Alvar-Beltrán et al. 2021). Many of these approaches also support mitigation by sequestering carbon and reducing emissions. Most countries have also invested in providing agro-meteorological advisories to farmers, including early warning systems to support adaptation. However, the adoption of these practices by small farmers varies considerably and several factors — socio-economic, biophysical, and institutional, including access to agricultural extension and advisory services (EAS) - influence adoption decisions (Diro, Tesfaye and Erko 2022; Musafiri et al. 2021).

Agricultural extension and advisory services (EAS) is an umbrella term that refers to organizations, individuals and activities that supply information and services required by farmers and other agricultural actors to develop their own technical, organizational, and managerial capacities for livelihoods and well-being improvement (Christoplos 2010). Public and private sector EAS are on the frontline in supporting smallholder farmers to adapt to the changing climate as they engage in field level activities and work closely with farmers to provide new technologies, technical information, knowledge, and skills, as well as linking them to other rural actors. EAS also work with policy makers and development program implementers to disseminate information about and put into practice new agricultural interventions, programs, and policies.

This evidence review examines existing literature to understand the roles and functions EAS play in supporting climate change adaptation and mitigation. The specific objectives of the evidence review are:

1. Identify, through a review of literature, the current state of support by EAS in helping smallholder farmers in low-income countries adapt to and mitigate climate change and promising advisory approaches used.
2. Document the preparedness of EAS organizations and individual providers to address climate change challenges.
3. Identify gaps that need to be addressed to develop climate-responsive EAS.
4. Identify policy issues that need to be addressed to facilitate EAS support for climate change adaptation and mitigation.

This review also examines selected cases in detail to draw operational lessons on how EAS is promoting climate change adaptation and mitigation. In this process, the review identifies gaps and proposes roles EAS could play in climate adaptation and mitigation, and what changes in policies and capacities are needed to support EAS to become more climate responsive. Earlier reviews on EAS and climate change focus on specialized areas, such as climate smart agriculture (Sulaiman, Chuluunbaatar and Vishnu 2018; David 2016) and climate adaptation (Simpson and

[2] Climate smart is an approach to making choices that promotes sustainability, resilience, and positive outcomes in the face of climate change-related challenges.

Burpee 2014). This review attempts to understand climate change adaptation and mitigation in greater detail and the roles and functions played by EAS in promoting both.

1.2 ORGANIZATION OF THE REPORT

This evidence review is organized into six sections. The following section provides a discussion on the methodology adopted for this study; section 3 reviews the current status and performance of EAS in promoting climate change adaptation and mitigation and discusses eight specific roles played by EAS in promoting climate change adaptation and mitigation. Section 4 presents four cases that illustrate various functions performed by EAS in promoting climate change adaptation and mitigation. Section 5 discusses how to strengthen the contributions of EAS in supporting adaptation and mitigation by drawing lessons from the different examples and cases discussed in the previous section. The report ends with conclusions and a broad set of recommendations in section 6.

2. Methodology

In order to produce this evidence review, over 500 documents, mainly peer- reviewed journal articles and grey literature, were examined between May and August 2023. Web search engines - Google search, Google scholar, Web of Science, etc. - were utilized to collect the reviewed materials using keywords including agricultural extension, advisory services, rural advisory services and climate change adaptation, climate change mitigation, climate smart agriculture, rural advisory services approaches and climate change and carbon farming.

This evidence review has several limitations, including:

- Limited attention to climate change adaptation and mitigation in the livestock, fisheries, and forestry sectors due to the paucity of documents found on these topics.
- Due to the lack of evidence, limited documentation of the contribution of EAS to climate change adaptation and mitigation.
- A greater focus on climate finance directed towards climate change mitigation as opposed to adaptation.

2.1 CONCEPTUAL FRAMEWORK

This evidence review used the Innovation Management Framework (Sulaiman et al. 2010) to examine the role of EAS in promoting climate change adaptation and mitigation. This framework argues that innovation involves a wide range of functions, activities, and tools that are delivered by several agencies operating through platforms, alliances, or partnerships, and whose work can be collectively referred to as “innovation management.” While facilitating access to new knowledge, it is important to equally promote innovation, innovation being the process of generating, adapting, diffusing, and using new knowledge at scale to achieve wider developmental impact. This is because the true value of knowledge is only achievable when it is combined with other elements of the innovation management process, such as building networks, organizing producers, communicating research needs, conflict mediation, facilitating access to credit, inputs and output services, convening innovation platforms, advocacy for policy change, and negotiations and agreements leading to other changes in practice and action (Figure 1).

Figure 1: Innovation Management (Source: Sulaiman et al. 2010)

Several studies that have looked at the innovation process (Klerkx, van Mierlo and Leeuwis 2012; Glover et al. 2019; World Bank 2012), including scaling of new knowledge (Schut, Leeuwis and Thiele 2020; Hall and Dijkman 2019; Glover, Venot and Maat 2017), recognize the role of different agents and their interactions in promoting technological change. EAS are an important intermediary in the innovation process; they promote interactions and knowledge flows among many of these actors in the agricultural innovation system, as well as help in achieving the scaling of new knowledge (Blum, Cofini and Sulaiman 2020; Sulaiman, Chuluunbaatar and Vishnu 2018; Sulaiman and Davis 2012). However, this means EAS must perform a broad range of functions in partnership with other actors in the agricultural innovation system to bring about technical, institutional, and policy-level changes to create an enabling environment for innovation.

The Innovation Management Framework recognizes the importance of collaboration among multiple actors as well as the need for a broad range of functions and the deployment of appropriate tools to upscale new knowledge. The adoption of practices that support climate change adaptation and mitigation are more complex and often go beyond the adoption of a single practice or technology by individual farmers. Moreover, addressing climate change challenges necessitates engaging with multiple stakeholders to reconcile climate, conservation, and development objectives (Reed et al. 2019) and calls for new and different forms of interactions,

partnerships and collaborations between multiple actors. In conclusion, this review used the Innovation Management Framework to explore the role of EAS in supporting climate resilience and identifying the functions it is performing to play these roles.

3. Current Status and Performance of EAS In Promoting Climate Change Adaptation and Mitigation

3.1 THE CURRENT STATUS OF EAS

EAS consists of organizations and individuals from the public and private sectors and civil society. At field level, EAS providers include extension agents, agronomists, advisors, knowledge intermediaries, agro-dealers, and community-based or farmer extensionists. These providers deliver a range of services and technical, organizational, entrepreneurial, and managerial support to producers, other agricultural value chain actors and rural communities. Although EAS have become increasingly pluralistic, in most countries, public- and donor-supported EAS initiatives remain the primary sources of advice for smallholder farmers and farmers outside of organized supply chains (ISF Advisors 2020). A 2022 study found functional public EAS systems in 55 out of the 80 countries examined, providing essential public EAS services to 450 million farmers (Yang and Ou 2022).

However, public EAS are generally under-funded (Yang and Ou 2022) and face significant challenges, including limited capacity to respond to new challenges and low reach. While public sector EAS are typically present across the landscape of a country, most private and civil society EAS providers, including NGOs, concentrate in target locations and reach only the farmers in those regions or those that meet specific criteria. In some cases, agri-businesses work only with producers that supply their produce or those using the inputs they sell, and they often target larger producers who can provide a consistent supply of high value crops. There is an increasing interest among donors to invest in pluralistic EAS (Nyathi and Even 2022; Blum, Cofini and Sulaiman 2020; Zhou and Babu 2015), but for pluralistic EAS to work, an improved overall frame-work in which multiple actors can operate and coordinate their activities is needed (Davis, Babu and Ragasa 2020). The pluralistic extension systems currently found in most countries are often characterized by providers (particularly from the public sector) that have inadequate financial resources and lack personnel with the necessary knowledge and skills to address changing demands, are implemented through short-term projects and lack coordination between providers (David 2016). In addition, there is overwhelming evidence that shows women, young farmers, the poorest producers, and those living in remote areas have disproportionately less access to and benefit less from EAS (FAO 2022; Katz 2018; Petrics et al. 2015).

3.2 EAS IN PROMOTING CLIMATE CHANGE ADAPTATION AND MITIGATION

Effective climate change adaptation and mitigation for global agriculture calls for multiple strategies that are context specific and, at times, complex (Autio et al. 2021; Malhi, Kaur and Kaushik 2021). These strategies encompass various approaches, ranging from promoting the adoption of knowledge intensive technologies or practices to the delivery of climate information services (Aryal, Sapkota, et al. 2018) (Figure 2, Table 1).

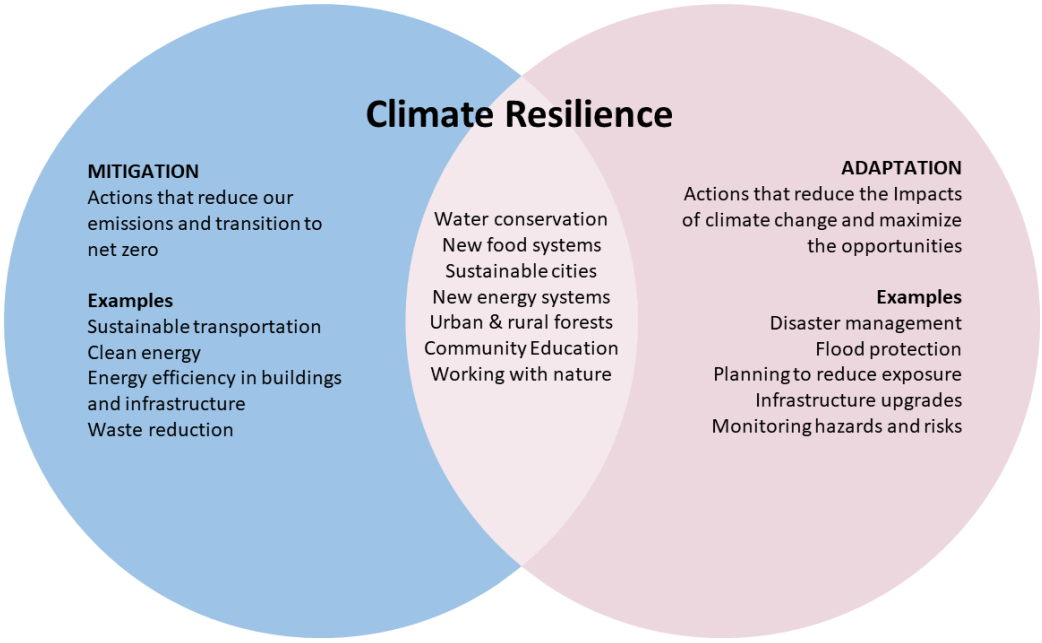

Figure 2: Actions contributing to climate change mitigation and adaptation
Adapted from Khan, Rashid and Koç (2023).

Over time, new and improved strategies continue to emerge, but smallholder farmers often lack the resources, knowledge, and capacity to understand and then implement these strategies effectively (Ndhlovu and Mhlanga 2023; Kuhl 2020; Antwi-Agyei, Dougill and Stringer 2014). Consequently, they bear a substantial burden when it comes to coping with the challenges posed by climate change (Mizik 2021; Nyiwul 2021). In this context, the roles EAS play to support farmers is crucial for promoting climate change adaptation and mitigation strategies at scale and impacting the behaviors, strategies, and practices of millions of agricultural producers (Table 2).

Table 1: Climate change adaptation and mitigation approaches/methods and their role in addressing climate change.

Approach/ Method	Focus	Role in Climate Change
Climate Smart Agriculture	Climate change	An exclusive approach designed to combat climate change (both adaptation and mitigation)
Climate Resilient Agriculture	Climate change	An exclusive approach designed to combat climate change (both adaptation and mitigation)
Natural Farming	Environment	Reduces or eliminates use of chemical fertilizers, thereby reducing emissions from agriculture. Use of mulching and organic manures to maintain soil fertility.
Regenerative Agriculture	Environment, biodiversity, and climate change	By adopting minimum or no tillage, this approach promotes carbon sequestration
Organic Agriculture	Environment and health	Relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Minimizes energy consumption and use of chemicals
Conservation Agriculture	Soil	Conservation Agriculture mitigates climate change by reducing greenhouse gas emissions and sequestering carbon through its practices.
Biodynamics	Environment and spirituality	It is a form of organic farming with a feeling of spirituality and cosmos. Climate change mitigation and adaptation is as similar as in organic agriculture.
Agroforestry	Land-use and multi-purpose	Climate mitigation by sequestering carbon in biomass and soils, reducing greenhouse gas emissions, and avoiding emissions through reduced fossil fuel and energy use on farms. Climate adaptation through windbreaks, conserving soil and reducing crop transpiration rates.
Permaculture	Environmental stability	Aims to maintain agriculturally productive ecosystems which have the diversity, stability, and resilience of natural ecosystems.
Precision Agriculture	Energy and resource efficiency	Targeted application of inputs leading to reduction in their use and (together with GHG emissions) helping mitigation.
Agroecology	Environment and equity	An integrated approach that simultaneously applies ecological and social concepts and principles to the design and management of sustainable agriculture and food systems. Promotes low use of external inputs, as well as biodiversity and organic recycling.

Effective pluralistic EAS also requires organizational changes among public and private service provider agencies to create an enabling environment for facilitating climate change adaptation and mitigation for farmers. Research shows that institutional policy changes made by pluralistic EAS providers constitute crucial elements in climate adaptation strategies (Mazhar et al. 2021; Raj and Garlapati 2020; Sardar, Kiani and Kuslu 2021). Several studies have found that EAS is an indispensable component in scaling up climate smart technologies (Tanti et al. 2022; Emmanuel et al. 2016), practices (Aryal et al. 2018; Sulaiman 2017), and strategies (Jha and Gupta 2021; Zikhali et al. 2021; Ranjbar et al. 2019; Mardy et al. 2018). Extension agents often also play a role in facilitating networking and bringing together multiple stakeholders, creating opportunities for

climate adaptation and mitigation strategies to be systematized (Gannon et al. 2021; Acosta et al. 2019; Partey et al. 2018).

Table 2: Summary of the roles EAS plays in climate change adaptation and mitigation.

Adaptation	Mitigation
▪ Organizing training, clinics, demonstrations, and field schools/days for farmers and promoting climate-smart technologies and practices, strengthen capacity, and provide guidance and climate information (Smith et al. 2022; Siregar and Crane 2011; Carr and Onzere 2018) ▪ Distributing new technologies and inputs as part of schemes that promote adaptation (Ozkan, Dube and Reed 2022; Dar et al. 2021; Haworth et al. 2018; Buah, Nyuor and Hashim 2017) ▪ Assessing the vulnerability of distinct types of farmers and developing adaptation plans (Kamruzzaman et al. 2020) ▪ Linking farmers to crop insurance (Akter et al. 2016)	▪ Promoting climate smart, resource efficient technologies and practices that reduce methane emissions, for example direct seeded rice and promoting solar pumps (Elahi, Khalid and Zhang 2022; Enriquez et al. 2021) ▪ Strengthening farmer groups and linking them to voluntary carbon markets (Martinez et al. 2022) ▪ Promoting payment for ecosystem services (Haile, Tirivayi and Tesfaye 2019) ▪ Promoting agroforestry (Baig, Burgess and Fike 2021)

Existing literature shows that EAS play a role in enhancing the capacity of farmers to address the effects of climate change (Maka, Ighodaro and Ngcobo-Ngotho 2019; Rickards et al. 2018). Trainings provided by extension agents have been found to have a significant impact on raising awareness (de Janvry, Macours and Sadoulet 2016) and increasing adoption of climate risk management strategies (Bairagi, Mishra and Durand-Morat 2020), and climate smart agricultural practices (Zakaria et al. 2020; Mulwa et al. 2017). EAS also play a crucial role in supporting women, youth, indigenous communities and other groups marginalized from accessing agricultural resources and opportunities to adapt to climate change (Dibon 2021; Bullock et al. 2020; Lawson et al. 2020; Mcleod et al. 2019; Pearl-Martinez 2017; Mapfumo, Mtambanengwe and Chikowo 2016)).

Access to climate information services has proven to be core to climate adaptation strategies among smallholder farmers (Koseo and Ahmed 2022). Several studies indicate a positive influence made by climate information services, including digital extension, on climate change adaptation and mitigation (Andati et al. 2022; Mahmood et al. 2021; Saifan et al. 2021; Partey et al. 2020; Diouf et al. 2019; Ouedraogo et al. 2018). EAS add value to the climate information they provide by helping farmers understanding how climate change can impact them and how to respond to these changes.

Challenges for EAS in Promoting Climate Adaptation and Mitigation

Even though governments and NGOs incorporate aspects of climate adaptation into their extension and advisory services, in most cases it is not a prioritized goal (ISF Advisors 2020). EAS have relatively limited involvement in climate change adaptation and mitigation efforts at a

formal, institutional level, and there are few national providers that have initiated specific climate change programming (Simpson and Burpee 2014). In most cases, EAS are focused on promoting technology packages and general recommendations, highlighting a need for improved capacity to facilitate farmer decision-making and problem-solving (David 2016). At the same time, EAS providers also need improved functional capacities and soft skills in communications, facilitation, co-learning, and innovation brokering in order to meaningfully assist farmers to adapt to climate change and contribute to mitigation (David 2016; Sulaiman V. and Davis 2012; Klerkx, Hall and Leeuwis 2009).

EAS personnel need to be well-informed about the climate change risks that farmers currently and will face in future and should have the skills and capacities to identify and promote appropriate interventions. Special attention must be paid by EAS providers to the unique challenges experienced by women and other marginalized groups who are disproportionately impacted by climate change (El-Fattal 2012).

Considering the ever-evolving impacts of climate change, EAS providers also need to develop a long-term vision for their approach to climate change adaptation in the agricultural sector and need expertise in evaluating alternative scenarios through participatory scenario development and visioning exercises (Palazzo et al. 2016) to prioritize investments, contribute to policy formulation, and learn from policy and program implementation (Lamboll, Nelson and Nathaniels 2011).

3.3 ROLE OF EAS IN SPECIFIC AREAS OF CLIMATE ACTION

An analysis of over 200 documents on experiences from Africa, Asia, and Latin America reveals that worldwide, EAS support climate change adaptation and mitigation in specific ways, as discussed below. However, it should be noted that the documents reviewed provide limited evidence on how EAS contribute directly to climate change adaptation and mitigation.

Promoting Stress-Tolerant Crop Varieties

In response to increased temperatures and changing rainfall patterns leading to droughts, flooding, and increased soil salinity, agricultural researchers have identified and developed crop varieties that can better tolerate current and future adverse climatic conditions. EAS' role in promoting the adoption of new crop varieties cannot be overstated.

One example is the role played by EAS in promoting drought tolerant maize in sub-Saharan Africa. Between 2007 and 2013, the Drought Tolerant Maize in Africa project released 160 drought-tolerant maize varieties (Fisher et al. 2015). The International Maize and Wheat Improvement Center (CIMMYT) and the International Institute of Tropical Agriculture (IITA) collaborated with public and private entities in several countries, including public sector extension agencies, NGOs, radio stations and innovation platforms, to address the challenges involved in technology development, assessment, and promotion. In Ghana, access to EAS was a key factor in farmers' adoption of drought tolerant maize in addition to access to seed, labor availability, and location of farm households (Martey, Etwire and Kuwornu 2020). In Malawi, government extension agents introduced the seeds of drought tolerant maize through farmer-managed demonstration plots (CIMMYT 2012; Kassie et al. 2012). By linking with the country's Agricultural Input Subsidy Program, the Innovation Learning Platform led by the Ministry of Agriculture and Food Security enabled more farmers to access a drought tolerant maize variety and grow it in six of the most

drought-prone districts of Malawi, contributing to improved food security for thousands of farming households.

Similarly, the International Rice Research Institute (IRRI), in partnership with national agricultural research systems, developed and promoted several stress-tolerant rice varieties that can better tolerate drought, submergence, and salinity. In Odisha, India, the International Rice Research Institute and the state's Department of Agriculture and Farmer Empowerment organized demonstrations and trials of stress-tolerant rice varieties under its 'evidence hubs' in farmer fields and facilitated farmers, EAS providers and other value chain actors to evaluate the performance of these varieties (Mittal et al. 2018). To ensure adequate availability of quality seeds of these varieties, trainings on seed production were organized and women seed producer groups mobilized to produce and market certified seed through farmer producer companies (Puskur, Variar and Saksena 2021). As a result of training-of-trainer activities for EAS providers in 2019, a total of 132 master trainers were trained, who further facilitated community-level seed production training programs for 4,007 farmers, 35% being women (Puskur, Variar and Saksena 2021).

Supporting Farmers to Adopt Alternative Farming Practices

There is growing evidence that promoting single technologies or encouraging change in only one practice at the farm-level is not sufficient for long-term climate change adaptation or mitigation. Approaches that have emerged in the last two decades, including regenerative agriculture, conservation agriculture, and nature-based solutions, promise more holistic, integrated, sustainable, and climate-resilient farming practices. EAS in many countries play a critical role in promoting and supporting farmers to adopt these approaches. For instance, in India, the National Institute of Agricultural Extension Management sensitized public decision makers on techniques and benefits of 'natural farming' as a way of involving more farmers and expanding reach (Government of India 2023). As a result, materials in 22 regional languages were prepared and 997 trainings were conducted on natural farming, creating 697 master trainers (Government of India 2023).

Systems of Rice Intensification (SRI), a rice cultivation package that reduces 64% of methane emissions associated with rice farming, is practiced by 15 million smallholder farmers in about 60 countries (Phu, Linh, and Tra 2021; Jain et al. 2013). In most cases, SRI increases rice production and improves farmer resilience against droughts, storms, and extreme weather. In Vietnam, EAS promoted SRI through farmer field schools, and workshops that encouraged farmers to test, evaluate, and adopt SRI (Asian Institute of Technology 2017). Evidence-based advocacy efforts to promote SRI also resulted in the government's recognition of SRI as a technical advancement in rice production, which led to an increase in public investment (Sulaiman V, Chuluunbaatar and Vishnu 2018).

Another alternative farming practice that is helping smallholder farmers to adapt to climate change is floating gardens in Bangladesh. While NGOs and civil society organizations first promoted floating gardens, focusing on strengthening the social capital of the farmers and providing micro-credit, the country's public extension services played a major role by promoting it through the National Adaptation Program for Action, a country-wide program that encompasses the immediate and urgent adaptation activities to address the current and anticipated adverse effects of climate change through technology transfer and capacity building (Sales 2019; Irfanullah et al. 2011).

Conservation agriculture promotes minimum soil disturbance and a permanent soil cover, thereby contributing to a reduction in greenhouse gas emissions. In Zambia, EAS have played several important roles in scaling up conservation agricultural. The Zambian Agricultural Research Institute worked closely with the Kasisi Agricultural Training Centre to conduct extensive trials and test various practices such as enhanced fallow systems, efficient tillage practices, and the utilization of mechanical and animal-powered, low-till equipment tailored to diverse agroclimatic and socio-economic conditions (Abdulai and Abdulai 2016). Multiple stakeholders utilized the farmer-to-farmer extension model for information dissemination and organized demonstrations, radio broadcasts, on-farm trials, field events, and training sessions to promote conservation agriculture (Chompolola and Kaonga 2016; Haggblade and Tembo 2003). A study in Malawi found that EAS played a key role in scaling up conservation agriculture and concluded that the farmer-to-farmer extension model complemented the activities of the country's formal extension system (Fisher et al. 2018).

Farmer Managed Natural Regeneration (FMNR) has emerged as a progressive approach to combating desertification and promoting sustainable land management, contributing significantly to climate change adaptation and mitigation efforts. This innovative method entails the careful pruning and safeguarding of naturally occurring tree and shrub species, enabling them to regenerate and flourish (Kuyah et al. 2023). World Vision promoted FMNR in 27 countries worldwide by deploying several strategies involving EAS (Rinaudo, Muller, and Morris 2019). These include establishing national re-greening committees; organizing awareness workshops, exchange visits, demonstration plots and conferences, and disseminating information products such as written materials, video clips, and presentations (Birch et al. 2016).

Similarly, the success of FMNR In Ethiopia (Reij, Tappan and Smale 2009) and Ghana (Weston et al. 2015) is attributed to multiple extension and advisory strategies, including securing legally binding forest user rights from the government, organizing community members into cooperatives, allocating forest areas to cooperatives, training farmers on forest management, record keeping and leadership, and fostering community ownership of, and responsibility for, implementing the management plan and upholding agreed by-laws. In this way, EAS supported farmers to become experimenters and innovators to find context-specific solutions and promote a farmer-to-farmer extension model to disseminate the innovations to more farmers.

Promoting Climate-Resilient Value Chains

Value chain interventions are important for building sustainable food systems that meet increasing demands while remaining profitable in the face of climate change (World Economic Forum 2016). In many countries over the last few years, private sector agribusiness firms have started increasing their involvement in entire value chains, often motivated by the need to comply with sustainability commitments and certification, or demands from consumers, and they view EAS as a mechanism for managing climate impacts (ISF Advisors 2020).

In Uganda, the private sector played a significant role in value chain development of rice for climate change adaptation. A study on the project 'Private Sector Investment in a Changing Climate: Resilient Rice Value Chain Development' (PSI-Climate) found that financial services provided by the Uganda Commercial Bank, coupled with access to climate-resilient rice varieties, were key factors in climate risk management by actors involved in the Ugandan rice value chain

(Dekens and Daze 2016a). The company provided extension services by disseminating information and training farmers on agronomic practice (Dekens and Daze 2016b).

In Kenya and Ethiopia, TechnoServe and the Nespresso AAA Sustainable Quality program has built the capacity of hundreds of coffee wet mills and thousands of coffee farmers to improve quality, sustainability, and productivity since 2013 (Biswas-Tortajada and Biswas 2015). At farm-level, the program used different extension and advisory methods and approaches including on-farm training through the AAA Academy on agronomic practices such as composting and rejuvenation of coffee trees and key business skills. To improve wet mill operations, TechnoServe provided trainings to improve compliance with TASQ Core Criteria – a set of indices that assess adherence to specific social, environmental, quality, and economic standards, such as minimum wage and the disposal of waste products (Baptista and Jenkins 2017). TechnoServe also works to improve the sustainability of the cocoa value chain in Peru by disseminating information to smallholder farmers through small demonstration plots and training on the productivity-enhancing "Synchronized Fertilization and Pruning Technique" (TechnoServe 2015). Other approaches used to strengthen the program include using cooperatives and producer organizations as additional delivery networks for follow-up technical assistance, improving the trainer-to-smallholder ratio, and increasing the participation of female smallholders. TechnoServe also connected strengthened producer organizations with social lenders that can provide financing for direct export of their products.

Touton, a major cocoa buyer in Ghana, has been working with farmers in 10 districts of the country's High Forest Zone since 2014 (IDH 2018). Touton implements a seven-pillar service delivery model for farmers, providing a variety of support activities through Rural Service Centers that help farmers produce better quality cocoa in greater quantities. The services provided include access to agro-inputs and integrated agro-services, including training and individual coaching on cocoa rehabilitation, productivity, and intensification. The model also includes providing access to finance, livelihood diversification, food security, and landscape governance to fully achieve climate-smart outcomes (IITA, CCAFS, SFL, Root Capital 2018). While data are not available on the broader impact of the program, a study from Ghana reported that the uptake of shade tree planting[3] was more prevalent among farmers who received Touton's agricultural extension services (Maguire-Rajpaul, Khatun and Hirons 2020).

Ecom Ghana and Cargill in Côte d'Ivoire are two private sector actors that also utilize EAS to enhance climate change mitigation in the cocoa value chain. Through smallholder development centers, Ecom Ghana provides smallholder farmers with training on good agricultural practices, manages nurseries, and runs demonstration farms. Ecom Ghana sources its cocoa from the farmers receiving its services, thereby strengthening the traceability and sustainability of Ecom's supply chain. In addition, Ecom Ghana builds boreholes and village resource centers for educational services (Kroeger et al. 2017).

In Côte d'Ivoire, Cargill works with input suppliers to sell subsidized input packages to smallholder farmers and cooperative groups and trains government extension services. Cargill sets aside a portion of its cocoa sale proceeds to pay input suppliers in cases where a farmer client defaults on paying for inputs (Kroeger et al. 2017).

[3] Shade tree planting is a climate-smart agroforestry technique in which cocoa is grown under the shade of larger trees.

In 2011, Olam, a large, global agribusiness company, partnered with the Rainforest Alliance to start the "Climate Cocoa Partnership for Reducing Emissions from Deforestation and Forest Degradation in Developing Countries" project in Ghana. The focus of the project was to reduce deforestation and promote sustainable cocoa production in forested areas by increasing the resilience of forest lands in the face of climate change (Brasser 2013). Under this partnership, farmers were trained for certification by the Sustainable Agriculture Network standard, which helps farmers earn more from high quality cocoa and promotes intercropping and maintaining carbon stocks as a supplementary income source. In 2018, Olam started working with the UK funded Partnerships for Forests and Rainforest Alliance to restore the Sui River Forest Reserve in Ghana. By the end of 2021, ten thousand cocoa farmers were trained in climate-smart agricultural practices to help them improve their yields whilst lowering their environmental impact. To help farmers access seedlings, the project established four community cocoa nurseries, which, by 2021, had supplied over 176,000 seedlings (OFI 2021).

Delivering Climate Advisory Services

Smallholder farmers are concerned more about climate than other risks associated with farming (The Nudge Institute 2022). Farmers' climate change awareness, combined with an accurate perception of climate change, are a preliminary step to improving their ability to mitigate the effects on farming activities and increase their adaptive capacity (Akano et al. 2022; Sen et al. 2021). Public and private sector EAS providers in many countries deliver climate advisory services informed by climate-related information that assists individuals and organizations to make climate-responsive decisions.

There are two types of climate information users: intermediary users and end users. Intermediary users receive climate information from the source and tailor it for end users to utilize in their decision making. In the case of agriculture, researchers and extension personnel working in the public sector as well as private EAS providers are often the intermediary users, who convert climate information based on the context of a region and share it with EAS providers and farmers.

In India, public sector EAS providers are at the forefront of delivering climate advisory services to farmers. The India Meteorological Department delivers "Agromet Advisories" prepared by Agromet Field Units and District Agromet Units based on medium-range weather forecasts (Gopalakrishnan and Subramanian 2020). Agromet Advisories are disseminated to farmers twice a week through multiple channels, including print and electronic media, national TV, radio, internet, text messages, and a farmer's portal. Presently, around 43 million farmers are directly benefiting from climate advisory services through SMS in multiple languages. Farmers make use of these services for planning operations in the face of extreme weather, such as when to sow seeds, irrigate, apply fertilizer and pesticide, and harvest crops. Regular agrometeorological information is provided twice a day through the state-owned television system. In 2020, experimental block-level[4] advisory information was issued twice a week for about 2,200 blocks and communicated to farmers and other users through social media and the extension mechanism of the State Department of Agriculture (IMD 2020).

One of the key activities for scaling climate services involves working with and developing the capacity of extension officers, farmers, and the media to bridge the gap between experts and

[4] A block, also known as a Panchayat Samiti, is an intermediate level local government body in rural parts of India.

farming communities. In Mali, the National Meteorological Agency established and strengthened a group of 30 farmers through whom climate information is shared daily. Each farmer is required to then reach out to 30 other farmers, creating an effective network for spreading critical climate information (Dossou-Yovo et al. 2022). In South Africa, community members and local EAS providers contribute to a local early warning system through monitoring, providing local knowledge, and tailoring climate information to the local context (Andersson et al. 2020). In Colombia, Local Technical Agro-climatic Committees (LTACs) involve local stakeholders, farmers, the private sector, research organizations, and government institutions in discussions on how best to manage crops and farms in a specific location at a specific moment in time (Loboguerrero et al. 2018). The basic premise behind the LTAC approach is: if farmers and the local rural community at large can access and understand weather and climate forecasts and its effects on their crop production, processing, and marketing options under local conditions, then they can make better decisions on how to manage their farms and businesses. LTACs actively publicize their findings through bulletins, social networks, extension services, farmers organizations, radio, TV, and the press.

Challenges with downscaling, increasing the accuracy of weather forecasting, and ensuring timely delivery impact the effective use of climate services by EAS providers and farmers alike (Stigter 2011). Improving the farmer to extension provider ratio would facilitate a better flow of climate information to farmers, especially to those who cannot afford information technology devices (Owusu et al. 2021). Moreover, female farmers have disproportionately less access to climate services, resources, and information to manage risks and make livelihood changes due to gendered divisions of labor, resource control, and decision-making power (Gumucio et al. 2020a).

Supporting Mitigation Through Market-Based Mechanisms

Carbon markets are trading systems in which carbon credits are sold and bought. A large number of institutions are needed to support carbon sequestration efforts, including market mechanisms that support trade in emissions credits, groups that provide insurance against sequestration shortfalls, brokers who aggregate individual carbon contributions to facilitate trades and offer risk reducing sequestration portfolios, organizations and procedures to document and certify emissions reductions, and educational programs that provide training and facilitate adoption of more complicated strategies (Marland, McCarl and Schneider 2001). In general, carbon credit markets are still evolving, however, they have already proven to be a pragmatic approach to supporting community-based tree planting programs (Rodrigo and Munasinghe 2023; Lokuge and Anders 2022). Smallholder farmers typically prefer agroforestry systems that allow a net fixing of atmospheric carbon dioxide (CO_2), while also meeting their socio-economic needs. EAS providers could assist in bundling eligible lands for carbon trading (i.e. over 2,000 hectares), monitoring land lots, and identifying the changing needs of farmers that can be addressed through monetary gains from carbon credits. However, in general, capacity building is needed for EAS providers to play an effective role in educating farmers on carbon trading. At the same time, the policy environment in many low- and middle-income countries is not conducive to supporting small farmers to access carbon markets (Tamba et al. 2021).

Payments for ecosystem services (PES) schemes are another market-based mechanism that contributes to climate change mitigation. Relying on incentives to induce behavior change, PES schemes can be classified in three broad types: public payment schemes, private payment schemes, and public-private payment schemes (Smith et al. 2013). In general, apart from sellers,

who are land and resource owners, or managers, who can provide beneficial services, PES programs need a buyer who is willing to pay for these services, intermediaries who link buyers and sellers and support implementation, as well as knowledge providers who are experts on PES (Smith et al. 2013). EAS often plays the role of intermediaries, and in some cases knowledge providers. Government agencies, NGOs, international agencies, local organizations, and professional consulting firms can also serve as intermediaries, providing services and information and functioning as mediators, arbitrators, equalizers, representatives, watchdogs, developers of standards, and bridge builders (Pham et al. 2010). Concerns have been raised about the quality of the participatory work by intermediaries, the political influence on their activities, and the need to maintain a neutral status. There is also a general need for increased capacity by all actors (sellers, intermediaries and knowledge providers) to monitor environmental services and enforce contracts (Pham et al. 2010).

Promoting Resource-Efficient Technologies

The use of energy-, water-, and fertilizer-saving technologies are helpful in climate change mitigation, and EAS play an important role in the promotion and scaling up of such technologies. In the Philippines, PhilRice and the National Irrigation Administration jointly initiated various research and dissemination activities to promote alternate wetting and drying practices, a water saving technology that aids farmers adapt to extreme weather conditions and mitigate GHG emissions. Activities implemented in collaboration with local partners in many parts of the country included farmer-participatory trials, demonstrations, and farmer field schools (Palis et al. 2017; Rejesus, Martin and Gypmantasiri 2014). In India, Jain Irrigation Systems Limited, a private company, has been implementing an integrated extension model that incorporates a research-development-demonstration approach to promote drip irrigation, a water saving technology (Soman 2020). The company's extension department conducts demonstrations, creates knowledge products, and organizes seminars, exhibitions, and campaigns. It also ensures direct outreach to farmers by deploying field agronomists who regularly visit individual farmers, providing crucial last mile support.

Promoting organic agriculture is also often a priority for EAS. In many countries, having access to EAS has a positive influence on farmers' willingness to use organic inputs and techniques (Qiao et al. 2022; Abebe and Debebe 2019). Organic farmers in Thailand obtained knowledge on organic agriculture techniques and skills primarily from NGOs, with approximately 81% of the farmers surveyed having attended more than ten training programs and 14% having participated in three to five training courses within the last three years. Those surveyed indicated that knowledge of organic farming obtained through observations, analysis of the field situation and problems, and the exchange of experiences was the major factor that convinced them to explore organic farming. The farmers then adapted this knowledge to their farms, a process that enhanced not only their self-reliance, but also the production of organic commodities (Pattanapant and Shivakoti 2009).

Promoting Agroforestry

On Java Island, Indonesia, 1.5 million smallholder farmers manage 444,000 hectares of teak agroforestry systems. Field demonstrations combined with farmer trainings and relevant extension materials helped these farmers gain an understanding of effective silvicultural management (Roshetko et al. 2013). Government extension providers implementing agroforestry farmer field school were employed to focus on five major commodities: clove, pepper, coffee,

cacao, and durian. To achieve scale, researcher-to-farmer and farmer-to-farmer learning approaches were used, as well as cross-learning visits and demonstration plots (Martini 2013).

Through its "Agroforestry Carbon Removal Units for the Organic Restoration of Nature" (ACORN) initiative, Rabobank focusses on supporting smallholder farmers around the world to transition to agroforestry practices and carbon sequestration activities. ACORN works with local partners that have direct relationships with farmers as well as the capacity to work with a large group of producers (Rabobank 2022). These include NGOs, farmer cooperatives, trading companies, and governments. Local partners involved in extension provision assist with project design, the selection of plant species, and the logistics of procuring seedlings and saplings as well as arranging funds to get farmers started with agroforestry. In 2023, 108,000 farmers around the world were transitioning to agroforestry systems and combating climate change through the ACORN initiative (Rabobank 202)

Promoting Social Inclusion in Climate Action

Women smallholder producers, Indigenous peoples, resource-poor farmers, and other marginalized groups are more vulnerable to the impacts of climate change. As original stewards of natural resources, many Indigenous communities rely heavily on natural products and processes that are changing and less available as a result of extreme weather conditions brought on by the climate crisis (Sardar and Bhaguri 2022). Unequal access to land, labor, and capital, a lack of agency to make household and economic decisions, gendered divisions of labor, and the feminization of agriculture in many low-income countries as a result of climate migration, makes women more vulnerable to climate change and less able to implement adaptation strategies (Katz 2018). Moreover, the impacts of the climate crisis on poverty levels and food insecurity exacerbates social inequalities, resulting in higher male migration, greater health risks for women and increased levels of gender-based violence (Awiti 2022; Katz 2018). However, it is also clear that groups most marginalized by climate change can serve as catalysts for change in both mitigation and adaptation efforts. Indigenous people play a key role in protecting and managing forests and are key agents in climate action (Schlingmann et al. 2021). Women's unique knowledge of agriculture and natural resource management is essential for ensuring the effectiveness and sustainability of climate change adaptation and risk reduction efforts.

The Female Extension Volunteer (FEVs) program implemented by ActionAid in Ghana uses farmer-led extension as a way of bridging the gender gap in extension (Binado 2018). The focus of the FEVs is to promote agroecology and support smallholder farmers' transition to climate-resilient sustainable agriculture through field demonstrations and farmer field schools. FEVs, female farmers trained in agroecology practices and basic extension delivery, function as EAS providers and work with public extension agents to connect women farmers to government support for agroecology through advocacy. Government agriculture extension agents and ActionAid provide support with simple tools and coordination to enhance their work.

Community seed banks are an effective strategy for climate resilience and adaptation (Porcuna Ferrer 2018; Gómez 2017). In tribal areas of Odisha, India, women are at the forefront of seed exchange of indigenous crop varieties, many of which can withstand adverse climatic conditions. Local civil society organizations, individual seed champions, and Indigenous farmer groups are playing a crucial role in promoting the conservation of heirloom varieties (Panda and Palita 2021). These seeds are freely shared, often facilitated by individual seed champions, seed conservationist

groups, and local civil society organizations. These civil society organizations have supported the documentation of the varieties, provided training to farmers on seed quality and storage, and supported the creation of seed fairs, where farmers can exchange and discuss seed varieties with other farmers. Extension officers of Odisha's Department of Agriculture have also collected these varieties from farmers and shared them with the state seed testing laboratory for validation and further distribution (Ciarli et al. 2022).

In response to women's limited access to seeds of stress-tolerant rice varieties in Bangladesh, the International Rice Research Institute, in collaboration with a local NGO and several agencies of the Government of Bangladesh, including the Seed Certification Agency, promoted the community-based rice seed entrepreneurship model (Nuruzzaman et al. 2023). Under this model, women took part in seed production groups, trainings, demonstrations, and exposure visits to help them understand quality seed production, seed processing, storage and preservation, seed marketing and certification, and opportunities in the seed business. Beyond technical training, the project placed emphasis on team building, communication skills, and decision-making abilities to strengthen the organizational capacity of producer groups.

Indigenous knowledge on adaptation to climate change is recognized as highly relevant and valuable for climate change adaptation (Berrang-Ford et al. 2021; Latulippe and Klenk 2020, Shaffril et al. 2020; Gyampoh et al. 2011). Strategies employed in low-income countries to bring indigenous knowledge and communities to the forefront of climate change action include community-based approaches to forest management, forest governance (FAO and FILAC 2021), forest enterprises (Humphries et al. 2012), mobilizing of forest and farm producer organizations (Covey et al. 2021), supporting land rights acquisition (Bray and Duran 2022; Mowat and Veit 2019), and conducting farmer field schools (Wulandari and Inoue 2018; Matsvange, Sagonda and Kaundikiza 2016). For instance, in the Peruvian Amazon, the Saweto Dedicated Grant Mechanism (DGM) under the Indigenous Peoples and Local Communities Project provided legal protection and recognition of native communities, land tenure security, financial support, and capacity building for increased income generation and food security in native communities through sustainable forest management. Sixteen women-led initiatives under DGM focused on formalizing indigenous women's cooperatives and associations, increasing productivity and promoting sustainable practices in community businesses by investing in improved facilities and equipment, training, and market access (Barletti, Begert and Loza 2021; World Bank 2021). Saweto DGM is implemented through the National Steering Committee, which brings together Amazonian Indigenous organizations. After five years of work, stakeholders celebrated the secured possession of more than 256,000 hectares of forest that belongs to 58 Indigenous communities and 10,000 families (WWF 2021).

Youth also serve as agricultural extension providers in many countries. The Philippine Rice Research Institute, in collaboration with the technical vocational unit of the Department of Education and the CGIAR Research Program on Climate Change Agriculture and Food Security (CCAFS), started a campaign for mobilizing high school students as "infomediaries", providing information to their parents and other farmers in their communities on climate-smart rice production techniques (CCAFS 2016). The campaign had a three-component strategy called "Read, Surf and Text." Students were given printed reading material on climate-smart rice production, then provided with electricity and internet access so that they could consult the Pinoy Rice Knowledge Bank, an online information portal on rice. Under the "Text" component, the

students were introduced to the PhilRice Text Centre, an SMS facility that responds to questions on rice production. The campaign worked with around 200 high schools and evidence suggests that technology adoption has grown through infomediaries (Philippine Rice Research Institute 2016; Manalo et al. 2016).

4. Functions Performed by EAS to Promote Climate Change Adaptation and Mitigation: Evidence from Diverse Cases

To further analyze the role of EAS and the diverse functions they perform to support climate change adaptation and mitigation, we selected four cases that provide specific details on the role of EAS in supporting adaptation and mitigation. These cases were selected based on:

- The availability of information to make a detailed analysis on functions performed by EAS to support climate change adaptation (Cases 1 and 2) and climate change mitigation (Cases 3 and 4);
- Geographic focus, to cover Asia (1 case), Africa (2 cases), and Latin America (1 case)

4.1 CASE 1: CLIMATE INFORMATION SERVICES IN RWANDA

Sources: CCAFS 2020; Gumucio et al. 2020a; Clarkson et al. 2020; Gumucio et al. 2020b

Context

Building climate information systems is a priority for Rwanda, as highlighted in the country's Nationally Determined Contributions. Two internationally funded projects supported the provision of climate information services to farmers in Rwanda: the first project was the four-year USAID-funded CGIAR/CCAFS initiative entitled Rwanda Climate Services for Agriculture, launched in 2016. The initiative was designed to empower Rwandan farmers to manage climate risks with the goal of increasing resilience to climate change by building the capacity of national systems in order to generate and provide climate services to farmers and extension staff across the country. The second project was the Weather and Climate Information Services for Africa (WISER) program, initiated in 2018 and funded by the UK's Department for International Development and managed by the UK's Met Office and Rwanda's national meteorological service. WISER aimed to enhance and scale up the co-production of climate services for improved climate risk management and to deliver an impact-based early warning system. The complementary efforts by these two initiatives built an effective climate information service in Rwanda. For instance, while the Rwanda Climate Services for Agriculture project delivered climate services to farmers, the WISER project developed mechanisms to bring farmers' feedback back to the service providers and promoted the use of climate services by local government for agricultural planning.

Interventions

- Working with *Twigire Muhinzi*, the government's agricultural extension service, farmers across the country's 30 districts were trained and supported to access, understand, and incorporate climate information into their production planning. Trainings were also conducted for local district agricultural officers.

- Radio listener clubs were piloted to increase climate service broadcasts and introduce interactive call-in programs that allowed farmers to talk about their plans to act on climate information.
- In addition to improved future climate analytics, Meteo Rwanda was supported to reconstruct about 15 years of lost climate data and generate historical records for every 4 km across Rwanda.
- An advanced online tool, Maprooms, was developed based on localized climate information data on a national scale. Maprooms has been adopted by the national meteorological services of Ethiopia, Senegal, Bangladesh, Colombia, and Guatemala as well as by the IGAD Climate Prediction and Applications Centre, the regional climate center for East Africa.
- The project supported the development of climate risk assessments and adaptation plans for six priority agricultural commodity value chains.
- An ICT-based five question (5Q) monitoring tool was introduced to efficiently and continuously capture feedback on the services farmers received. Around 100,000 farmers were trained to use the 5Q tool and provide regular feedback.
- MSc scholarships for seven Meteo Rwanda staff and three from the Rwanda Agricultural Board have improved the capacity of these national institutions.
- By August 2018, CCAFS partners had trained 1,612 public EAS personnel and volunteer promoters who provide training and support to farmers.

EAS Functions Performed

- Training farmers on using climate information in their planning.
- Training volunteer promoters, who in turn provide training and support to farmers on using climate information in their planning.
- Organizing radio listener clubs to enhance use of climate service broadcasts.

4.2 CASE 2: PROMOTING *IN SITU* CONSERVATION OF INDIGENOUS RICE VARIETIES THAT CAN WITHSTAND CLIMATE CHANGE IN INDIA

Sources: Ciarli et al. 2022; Sulaiman and Mittal 2021

Context

Many traditional seed varieties are climate-resilient, require fewer inputs, and are valuable sources of genetic diversity. Competing with high-yielding, modern varieties, these traditional varieties are under threat of extinction in many places. However, farmers in a few pockets across the globe continue to cultivate landraces adapted to local ecosystems characterized by environmental and climatic variations. In India, tribal communities in Koraput district have generated and conserved many indigenous cultivars of rice that are suitable for both dryland and wetland cultivation. Many tribal communities cultivate traditional varieties because of their food habits and taste preferences. Most of these farmers either do not prefer or do not have the capacity to buy modern crop varieties. The cultivation of landraces that are resilient to changing

climate in their natural habitat (*in-situ* conservation) allows the evolutionary process that shaped their genetic diversity and adaptability to continue and develop. In the current context of climate change, there is a wider recognition of the need for conserving biodiversity *in situ* and several NGOs are coming forward to promote conservation and cultivation of indigenous varieties and develop value chains. Moreover, landraces are grown without chemical inputs and irrigation, so their cultivation helps to reduce methane and nitrous oxide emissions that are produced during intensive, high-input rice farming.

Interventions

- Pragati, a local NGO, collected different rice landraces from farmers for multiplication through trials in farmers' fields. Pragati provided seeds to farmers and collected the seed after harvest for distribution to more farmers.
- Pragati facilitated community grain banks with the objective of conserving local seeds to improve resilience against extreme weather and facilitate easy and timely accessibility of seeds by farmers. Pragati provided storage bins and gunny bags to store seeds and encouraged the use of traditional conservation in bamboo baskets.
- Pragati supported seed banks managed by village committees and farmer producer groups formed by communities at broader community level.
- Pragati organized seed fairs and sent farmers it worked with to participate in seed fairs across the country. The seed fairs enabled the exchange of seeds between farmers from different locations and facilitated interactions between farmers, NGOs, officials from state seed corporations, public sector agencies, scientists and researchers, and other stakeholders. Seed exchanges help in building relationships between farmers from different communities and regions. It also serves as a platform for farmers to share their knowledge and experience with different seed varieties.
- Pragati identified and documented 456 traditional rice varieties, some that are resistant to pests and diseases and can withstand climatic stress.

EAS Functions Performed

- Collecting and documenting indigenous rice varieties.
- Distributing indigenous varieties among farmers for on-farm trial and then collecting the seeds for onward distribution.
- Organizing community grain banks and seed banks.
- Providing storage bins for storing seeds.
- Organizing seed fairs and funding travel of farmers to participate in fairs organized by other farmers.

4.3 CASE 3: CARBON SEQUESTRATION THROUGH SUSTAINABLE AGRICULTURE LAND MANAGEMENT IN KENYA

Sources: *Hughes et al. 2020; Nyberg et al. 2020; Butali and Wekesa 2018; Shames et al. 2016; Recha et al. 2014*

Context

The Kenya Agriculture Carbon Project (KACP) was initiated by the World Bank in 2008 to promote the adoption of Sustainable Agriculture Land Management (SALM) among 60,000 smallholders spread over 45,000 hectares in western Kenya. In 2009, Swedish NGO Vi Agroforestry took over as the main implementer of KACP and, in November 2010, KACP became the first project on the African continent to sell carbon credits generated, in part, from soil sequestration. The SALM methodology received approval from the Verified Carbon Standard[5] in December 2011, and in January 2014, the project issued its first carbon credits under the Verified Carbon Standard certification system for a reduction of 24,788 metric tons of carbon dioxide. Vi Agroforestry takes a comprehensive approach to project implementation, focusing not only on carbon, but also on improving farm productivity and livelihoods.

Interventions

- Vi Agroforestry staff performed most of the monitoring and management tasks for the carbon project, including collecting, analyzing, reporting carbon monitoring data, and liaising with carbon buyers. To reach a large number of farmers, the staff relied on community-based intermediaries (CBIs), who are predominantly farmers and leaders of local community-based organizations, to train and recruit other farmers into the project.
- To help enhance the role of CBIs in training and recruitment of farmers, Vi Agroforestry staff worked with We Effect, a development cooperation organization, to develop a training manual and a set of posters that focused on the implementation of SALM practices. These materials were then used by the Vi Agroforestry staff when they were training CBIs and then subsequently by the CBIs when they were training farmers.
- Vi Agroforestry established six field-based learning sites throughout the project area where the CBIs could hold training and demonstration activities and distributed the training materials to each of the learning sites for the CBIs to use.
- Vi Agroforestry worked through community-based organizations, primarily producer groups, women's groups, and self-help groups who undertook activities such as collecting the monitoring data from individual farmers, receiving, and managing the carbon bonus payments, and liaising with external organizations.
- To increase the participation and role of women, Vi Agroforestry staff instructed and supported the CBIs to identify, recruit, and train 1-2 women's groups, involved women in the planning of training sessions and recruited women as CBIs.
- To increase the role of the local government and other partners in the project, Vi Agroforestry organized a two-day training workshop on SALM practices, a two-day policy forum to discuss increasing policy support for these practices, and two county-wide field days to help link farmers to potential partners around the county. Following the training from Vi Agroforestry, the 30 CBIs went on to train 1492 male and 2686 female farmers.
- Vi Agroforestry held a high-level meeting with county policymakers and drafted a policy memo outlining how policymakers could support the scaling-up of SALM practices.

[5]The Verified Carbon Standard Program is the world's most widely used greenhouse gas (GHG) crediting program.

EAS Functions Performed

- Collecting, analyzing, reporting carbon monitoring data.
- Liaising with carbon buyers.
- Training CBIs, who in turn organize training and demonstrations.
- Developing a training manual and a set of posters.
- Identifying field-based learning sites.
- Distributing training materials.
- Organizing training workshops for local government actors.
- Organizing a policy forum to discuss increasing policy support for these practices.

4.4 CASE 4: PASTURE RESTORATION THROUGH ABC CERRADO PROGRAM IN BRAZIL

Sources: Souza et al. 2022; Brazilian Farmers 2018

Context

Brazil is one of the world's largest cattle producers. Restoration of pastures that are used intensively for beef and dairy production can alter greenhouse gas emissions by changing both the intensity and aggregate amount of direct emissions from production systems. Pasture degradation is primarily due to inadequate management practices – for example, elevated levels of soil compaction and disease – resulting in significant productivity loss. Pasture restoration entails a set of techniques for proper soil management and fodder plant cultivation, following specific criteria for each area. Adopting such practices reduces the need to clear new areas for pasture, thus reducing the pressure for deforestation while increasing cattle productivity.

With this objective in mind, a major government initiative was launched to reduce emissions in Brazilian agriculture, including ambitious targets for pasture restoration called the Low-Carbon Agriculture Plan (ABC Plan), developed for the 2011 to 2020 decade, and ABC+ Plan for the 2021 to 2030 decade. One of the projects implemented during this period was ABC Cerrado, a rural extension project implemented by the National Service of Rural Learning (Serviço Nacional de Aprendizagem Rural or SENAR). The project trained and provided technical assistance to rural producers on sustainable management techniques, focusing on the restoration of degraded pastures.

Interventions

- The ABC Cerrado program promoted the adoption of sustainable agricultural practices by rural producers through a combination of training and technical assistance. Since its creation, the ABC Cerrado program has trained 7,800 producers and offered technical assistance to 2,000 of these producers.
- The ABC Cerrado Project provided two types of extension programs: training and technical assistance. Producers only received field technical assistance after first participating in the training. The impact of combining training with technical assistance has been positive and significant. Producers who were targeted by the combined intervention restored more pasture areas, were more likely to adopt good rural management and environmental

conservation practices, invested more in inputs and machinery, and achieved greater productivity gains. Training consisted of 56 hours of courses taught by instructors trained by SENAR. The program's technical assistance component consisted of 24 visits (one visit per month) from field technicians to the farmers' property, where they received a customized action plan to implement new practices. SENAR also conducted seminars to increase awareness about pasture restoration.

EAS Functions Performed

- Training on sustainable pasture management for farmers.
- Training of field technicians.
- Field visits to provide customized technical assistance to farmers.
- Conducting seminars for awareness creation.

4.5. LESSONS

The four select cases discussed offer the following lessons on how EAS is supporting climate adaptation and mitigation:

- EAS providers perform a wide range of functions to help farmers apply new information and technologies that help them to deal with climate change. Beyond disseminating information, training farmers, and providing customized problem-solving advisory services at the field-level, they train a wide range of other knowledge intermediaries who work alongside farmers in applying the new knowledge.
- EAS providers mobilize farmers as groups to access inputs and services, for example community seed and grain banks, radio listener clubs.
- EAS providers are also engaged in the production and use of a wide range of information, communication, and educational tools to support farmers to adopt new practices.
- EAS providers organize platforms to engage with other actors, such as policy forums to garner policy support, community seed banks to store and exchange seeds of climate resilient seeds, and field-based learning sites.
- In all cases, EAS providers are part of a broader stakeholder network, are involved in regular exchange with other actors and are implementing their interventions in collaboration with others.
- The case studies and the broader EAS literature suggest that at present, public sector extension tends to be relatively more involved with adaptation activities, while private sector providers focus more on mitigation activities. This does not however mean that one type of provider is better suited to undertake certain climate actions. Limited involvement by government supported extension in climate change mitigation is largely due to their lack of capacity and resources, a situation that can be addressed through training and investment in the sector. Many agribusinesses have started investing in EAS and supporting climate change adaptation to climate-proof the value chains they are engaged with and to comply with sustainability commitments and green market pressures.

5. Discussion: Strengthening the Contribution of EAS to Climate Change Adaptation and Mitigation

EAS are critical to scaling climate change adaptation and mitigation interventions and supporting smallholder farmers to respond to changing conditions. While EAS currently play several functions in promoting climate resilience, there remains significant areas for improvement, particularly in most low- and middle-income countries where EAS from the public and private sector are not aligned with climate change needs in a planned or systematic manner. The following section discusses what can be done to strengthen EAS in support of climate change adaptation and mitigation and to align EAS more closely with broader climate change strategies and policies.

As discussed earlier, this evidence review utilized the Innovation Management Framework to understand and analyze how climate change adaptation and mitigation efforts are currently designed and implemented. This framework recognizes the importance of collaboration among multiple actors as well as the need to perform a broad range of functions to facilitate innovation. The examples and cases presented in Sections 3 and 4 clearly illustrate the important roles EAS play and the functions they perform in promoting climate change adaptation and mitigation (Figure 3, 4).

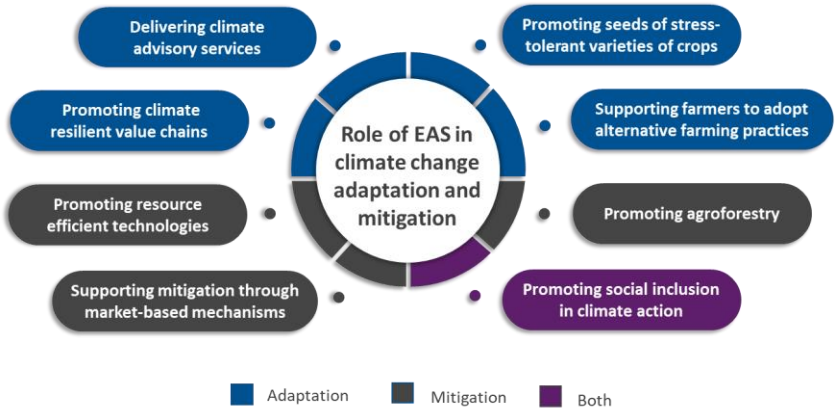

Figure 3: Roles played by EAS to promote climate change adaptation and mitigation.

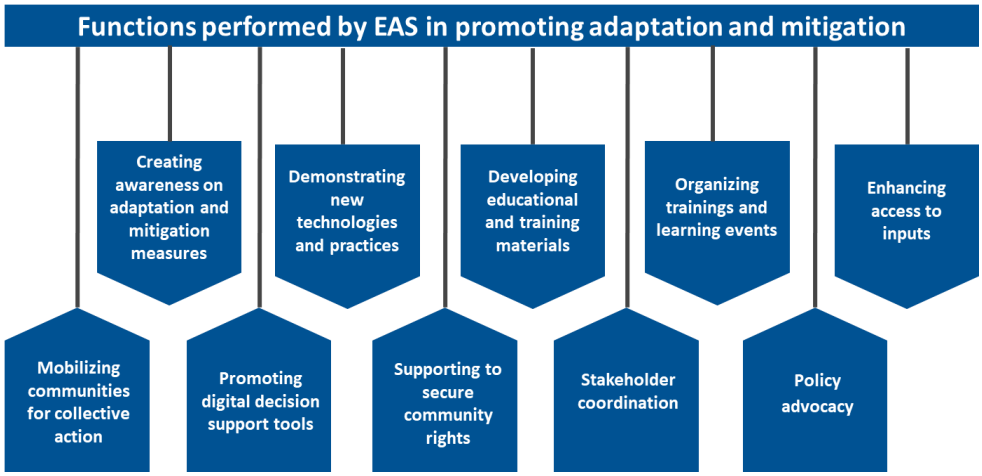

Figure 4: Functions performed by EAS to promote climate adaptation and mitigation.

EAS representing public sector agencies, private firms, international and local NGOs, and civil society organizations have all been a part of climate change adaptation and mitigation initiatives. While public sector EAS providers play a very important role in areas that are primarily focused on adaptation - promoting stress tolerant rice varieties and alternative farming practices, delivering climate advisory services, and promoting equitable and inclusive climate action - their contribution to promoting climate-resilient value chains and other areas focused on mitigation - promoting agroforestry, resource efficient technologies, and market-based mitigation mechanisms - are limited.

Private EAS providers and specialized NGOs are leading the promotion of climate-resilient value chain development, resource efficient technologies, and market-based mitigation mechanisms. While public EAS providers could play a very important role in this area, particularly in promoting these approaches within larger areas, their technical capacities are currently limited. Mobilization of rural producers as groups and collaborative action among pluralistic EAS providers and other agricultural innovation system actors are common in all the examples and cases presented in this evidence review. Agricultural research centers also play a role in providing extension and advisory services by, for example, developing and testing technologies on-farm and disseminating improved technologies and practices to farmers on a limited scale and training public sector extension staff on new innovations.

However, more action is required to enhance the current roles and functions EAS providers and their organizations play in promoting climate change adaptation and mitigation. These are discussed in detail below.

5.1 GREATER EMPHASIS ON MOBILIZING COMMUNITIES

While many recognize the importance of mobilizing farmers into groups for natural resource management, the cases examined reveal the importance of mobilizing farmers to promote behavior change that encourages uptake of even simple innovations such as stress tolerant rice varieties and solar irrigation. The same is the case if farmers are to benefit from climate-resilient value chains, carbon trading or other forms of payment-for-ecosystems-services. Beyond mobilization, farmers' capacity to manage collective action groups, engage with buyers, and support scheme implementation must also be enhanced.

Because public EAS providers often lack the capacity to effectively mobilize farmers, partnering with farmer groups, producer organizations and NGOs has been key. However, capacities for collective action have to be developed among public EAS, particularly because public providers have a wide coverage at country level, whereas NGOs and private sector providers tend to operate only in specific locations.

5.2 STRENGTHEN CAPACITIES FOR MULTISTAKEHOLDER COORDINATION

Coordinated action among multiple organizations within the agricultural sector, more broadly across the agricultural innovation system or from different sectors, facilitates adoption of climate change adaptation and mitigation strategies at scale. To promote new innovations and approaches and generally facilitate interactions between diverse actors, government line ministries, research organizations, private sector actors and civil society organizations are often involved in platforms such as stakeholder forums, committees or learning fora. State agencies often play a crucial role in providing legal protection and rights to communities in, for example,

forest management and seed certification, as well as adaptive research support and training for farmers and community resource persons. Partnerships between organizations with different expertise are critical for scaling up carbon farming and payment-for-ecosystem-services.

In some countries, EAS plays a role in coordinating multiple stakeholders to address climate challenges. However, this is an area where systems, institutional frameworks, and individual capacities need strengthening by enhancing coordination and collaboration among the pluralistic EAS providers at national and sub-national levels. Strengthening the linkages of EAS with other actors in the agricultural innovation system is another area that requires improvements. Having structures for coordinated functioning such as country-level EAS provider networks, policy working groups, or innovation platforms could encourage joint action for climate change adaptation and mitigation.

5.3 NEW ROLES, FUNCTIONS, AND IMPROVED TECHNICAL AND FUNCTIONAL CAPACITIES

In order to better contribute to addressing the complexities of climate change, EAS will have to take on additional roles and play different functions. These include involvement in disaster management and disaster prevention operations, searching for technological solutions from historical experiences and identifying lessons from other regions, tracking and verifying the effectiveness of climate action, and advocating for climate responsive interventions. These and other new roles and functions will require upgrading the technical and functional capacities of EAS providers.

EAS providers are currently asked to promote different climate-responsive approaches such as nature-based solutions, conservation agriculture, permaculture, biodynamic farming, regenerative agriculture, climate-smart agriculture, and natural farming without a deep understanding of their function or impacts. Similarly, many EAS personnel have an insufficient understanding of the mechanisms that incentivize carbon sequestration or how to promote resource efficient technologies. In addition to technical knowledge, EAS providers need improved capacities on identifying and addressing the needs of women, youth and other marginalized groups, determining what types of adaptive changes farmers need to make and when to make them, and ensuring that relevant technologies and modes of dissemination keep up with changing needs (Simpson and Burpee 2014). EAS providers also need training on disaster management and disaster prevention, and skills on how to find new technological solutions and training on introducing farmers to simple monitoring systems (Babu and Selvaraju 2023). In most countries, university-level and professional extension education curricula need to be upgraded to cover climate change as well as functional skills. Curricula reform could draw on existing technical manuals on climate change for EAS providers such as the modules developed by the Centre for Research on Innovation and Science Policy and International Rice Research Institute (IRRI and CRISP 2020) and a training manual by FAO on climate smart agriculture (FAO 2018). Digital tools and approaches for providing advisory services, including artificial intelligence, is an emerging area that requires investments by providers and developing staff competencies to use these innovations.

Beyond technical knowledge, EAS providers also need functional capacities to successfully deliver the technical knowledge to farmers and facilitate multi-stakeholder processes that are critical for promoting climate adaptation and mitigation. EAS providers should be able to build the decision-

making and problem-solving capacity of farmers and have the necessary “soft” skills to facilitate interactions between different stakeholders - communications, facilitation, co-learning, sensitivity to gender and diversity issues, managing power, and conflict dynamics.

5.4 STRENGTHENING THE ENABLING ENVIRONMENT

In order to successfully play current and future roles and functions related to climate change mitigation and adaption, EAS and systems need a supportive enabling environment that recognizes and strengthens EAS’ contributions for promoting climate resilience. In the context of EAS, the enabling environment includes policies, institutional arrangements, stakeholder involvement, infrastructure, and access to knowledge and support from a wide range of organizations that are critical for effective functioning. In other words, effective pluralistic extension and advisory systems require political financial, organizational, institutional, and infrastructural support to perform varied roles and functions in support of climate change adaptation and mitigation. This calls for countries to have clarity on the roles of EAS in their agricultural development strategy and for this role to be explicitly mentioned in national climate adaptation and mitigation plans. However, presently, many low and middle-income countries do not have an extension policy and EAS are scarcely mentioned in agricultural policy documents. This ultimately limits the involvement of EAS in climate action. For example, the Department of Agricultural Extension in Bangladesh only started promoting floating gardens after its inclusion in the 2009 National Adaptation Program for Action.

EAS also needs policy support from other sectors too. Promoting climate adaptation and mitigation measures over entire landscapes requires coordination with other agricultural sectors (natural resource management, forestry), as well as related sectors such as energy, water, finance, and insurance. For instance, policies related to data sharing and management associated with weather, crop status, production, farmer profiles, etc., are critical for EAS to develop climate adaptation and mitigation plans and respond better to natural disasters (Dominic, et al. 2022).

5.5 INCREASED FINANCIAL AND HUMAN RESOURCES SUPPORT FOR EAS

Under-funding and an unwillingness to increase investments for public EAS systems remains a persistent constraint in most low-income countries, particularly in Africa and Central Asia, resulting in limited funds for expenses related to training, fuel for travel, technical materials, and other resources (Davis, Babu and Ragasa 2020, McNamara 2014). However, farmers need to be supported to experiment with and adapt climate-smart approaches to suit their specific farm conditions. This calls for increased investments and human resources within both public and private EAS organizations.

While donor funding attempts to fill the gap caused by poorly resourced public EAS, sustainability is an important challenge for externally funded projects. The private sector is increasingly active in integrated supply chains for export and high-value commodities but usually not for domestically consumed or low-value crops and commodities. Although agriculture was the most highly financed sector, accounting for 39% of the climate-related financial flows directed to agrifood systems in 2021 (Galbiati et al. 2023), smallholder farmers in low-income countries receive only 0.3% of total international climate finance (Climate Focus 2023). The proportion of climate funds invested in EAS is not currently known. Opportunities to increase investment and human resources as well as utilize climate finance to strengthen EAS need to be further explored.

6. Conclusion and Recommendations

Although EAS have become more pluralistic around the world, public provided EAS dominate provisioning for smallholder farmers in most countries. Public EAS are often primarily involved in the distribution of technologies and inputs as part of project implementation and generally have little operational funding to organize capacity development programs to enhance farmers' knowledge or the knowledge of their staff on climate change adaptation and mitigation. Partnerships with NGOs and specialized knowledge providers are limited except in the case of donor-funded projects and, that too, is limited to projects' duration. While a review of literature shows that EAS are contributing to climate change adaptation and mitigation, the evidence shows that EAS' roles and functions need to be urgently strengthened. Key recommendations emerging from this review include:

Include a climate focus in the goals of EAS: EAS often do not include climate change in their mission and often lack an explicit climate focus. Explicit climate objectives are needed to draw attention to climate change adaptation and mitigation at both organizational- and individual-levels and to ensure that EAS providers and systems are fully accountable to achieving specific climate adaptation and mitigation targets. Climate actions should be integrated in extension strategies, workplans, and budget.

Build the evidence on the contributions of EAS to climate actions: There is a dearth of data documenting and quantifying the specific contributions made by EAS to climate change adaptation and mitigation. To support an increased climate focus, there is a need to generate a more robust evidence-base on the contributions of EAS to climate change adaptation and mitigation, including agricultural practices that enhance climate resilience.

Explore new roles and functions for EAS: To be able to effectively address the climate crisis, EAS in most countries need to undergo reforms to shift away from a technology transfer paradigm to a more demand-led approach that emphasizes co-creation with producers, use of effective communications, and dissemination tools as well as develop effective mechanisms to coordinate multiple actors. continue to meet needs in a changing climate. Other new roles required to meet needs in a changing climate include: involvement in disaster management and disaster prevention operations, searching for technological solutions that can generate good agricultural practices from historical experiences and lessons from other regions that are already affected by adverse climatic conditions, tracking and verifying the effectiveness of climate action and advocating for climate responsive interventions.

Strengthen technical and functional capacities of EAS: EAS providers from public, private and civil society organizations need upgraded technical and functional capacities in different approaches to managing climate change (e.g. climate smart agriculture, agro-ecology, regenerative agriculture), in facilitating farmer experimentation and responding to the needs of women, youth, and other marginalized farmers, as well as in soft skills such as facilitation and brokerage. Additionally, EAS providers will need skills to improve coordination among stakeholders from multiple agencies and sectors related to climate, such as forestry, energy, water and biodiversity. To strengthen these capacities, extension education curricula at all levels need to be updated and climate-related issues included.

Increase sustainable funding for EAS: Promoting climate change adaptation and mitigation requires more direct engagements with farmers and their organizations, providing capacity building to address climate challenges and resources for investing in new advisory approaches. Both public and private EAS providers need finances to hire more local-level staff and to cover the operational expenses associated with organizing farmer training and demonstrations, adopting new innovative, including digital, approaches, and providing tools and training for their staff.

Create extension policies that emphasize the role of EAS for climate action: Extension policies should explicitly outline the role of EAS in a country's development strategy broadly and their role in national climate adaptation and mitigation plans. Many low- and middle-income countries do not have a national extension policy, and EAS is only briefly mentioned in agricultural policy documents. Extension policies are critical for defining the role of different EAS providers in a pluralistic EAS system, improving coordination among advisory services and streamlining service provision across related sectors such as environment, forestry and energy.

Recognize the contribution of EAS in national climate strategies and plans: In most countries, ministries of environment are in charge of the country's Nationally Determined Contributions and National Adaptation Plan implementation, while ministries of agriculture implement adaptation and mitigation strategies related to the agricultural sector. These strategies and plans generally do not mention the contributions of EAS in supporting climate change adaptation and mitigation and primarily focus on targets rather than on implementation. Explicit recognition of the contribution of EAS in achieving climate resilience and positioning these services as important actors that can support upscaling climate adaptation and mitigation technologies and strategies is critical for ensuring that EAS receive policy and financial support.

Direct climate funds to agriculture and EAS: To strengthen the resilience of the global agriculture sector to climate change, the sector needs more investments from multilateral and bilateral agencies, the private sector, and philanthropic organizations. Climate initiatives in agriculture should explicitly fund public and private EAS to strengthen their abilities to contribute to adaptation and mitigation. Policies that incentivize private investments in EAS and promote public-private partnerships among EAS are also likely to boost funding for the sector.

Glossary

Adaptation: actions that help reduce vulnerability to current or expected impacts of climate change, such as weather extremes and natural disasters, sea level rise, biodiversity loss, or food and water insecurity.

Agricultural Innovation: process whereby individuals or organizations bring new or existing products, processes, or ways of organization into use for the first time in a specific context in order to increase effectiveness, competitiveness, resilience to shocks or environmental sustainability, and thereby contribute to food security and nutrition, economic development, or sustainable natural resource management.

Agriculture Innovation System: a network of actors (individuals, organizations, and enterprises), together with supporting institutions and policies in the agricultural and related sectors, that bring existing or new products, processes, and forms of organization into social and economic use. Policies and institutions (formal and informal) shape how these actors interact and learn together, and how they generate, share, and use knowledge.

Agroecology: a holistic and integrated approach that simultaneously applies ecological and social concepts and principles to the design and management of sustainable agriculture and food systems. It seeks to optimize the interactions between plants, animals, humans, and the environment while also addressing the need for socially equitable food systems within which people can exercise choice over what they eat and how and where it is produced.

Agroforestry: a collective name for land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence.

Biodynamic Agriculture: in biodynamic agriculture, the farm is considered an autonomous and living organism that interacts with the environment to build healthy and living soil in order to produce healthy and nutritious foods.

Carbon Markets: trading schemes that create financial incentives for activities that reduce or remove greenhouse gas emissions. In these schemes, emissions are quantified into carbon credits that can be bought and sold. One tradable carbon credit equals one ton of carbon dioxide, or the equivalent amount of a different greenhouse gas that is reduced, sequestered or avoided.

Carbon Farming: a set of agricultural methods that aim to store carbon in the soil, crop roots, wood, and leaves.

Climate Resilient Agriculture: integrates adaptation, mitigation, and other practices in agriculture which increase the capacity of the system to respond to various climate-related disturbances by resisting damage and recovering quickly. In short, it is the ability of the system to bounce back. It essentially involves judicious and improved management of natural resources, i.e., land, water, soil, and genetic resources through the adoption of best-bet practices.

Climate Smart Agriculture: an approach to help people who manage agricultural systems to respond effectively to climate change. Pursues the triple objectives of sustainably increasing productivity and incomes, adapting to climate change, and reducing greenhouse gas emissions, where possible.

Climate Smart Agriculture and Food Systems: an integrative approach that helps guide actions to transform agriculture and food systems which explicitly aims for three objectives: (1) sustainably increasing agricultural productivity to support equitable increases in farm incomes,

food security, and development; (2) adapting and building resilience of agricultural and food systems to climate change at multiple levels; and (3) mitigating climate change by increasing carbon sequestration or reducing GHG emissions associated with agriculture (including crops, livestock, fisheries, and aquaculture), either in absolute terms or by reducing emission intensity in the context of low emission development. Broadening this approach to agriculture and food systems means expanding the lens past producers to examine these three objectives throughout the functions, capacities, and inputs of the agriculture and food systems. This includes the people, behavior, relationships, and resources involved in the production, storage, processing, and distribution of crops (e.g., food, feed, and fiber), livestock, forestry (e.g., timber and non-timber), and wild-caught fisheries and aquaculture.

Conservation Agriculture: a farming system that can prevent loss of arable land while regenerating degraded land. It promotes the maintenance of a permanent soil cover, minimum soil disturbance, and diversification of plant species. It enhances biodiversity and natural biological processes, both above and below the ground surface, which contribute to increased water and nutrient use efficiency, and to improved and sustained crop production.

Food Systems: the entire range of actors and their interlinked value-adding activities in the production, aggregation, processing, distribution, consumption, and disposal of food products that originate from agriculture, forestry, fisheries, and parts of the broader economic, societal and natural environments in which they are embedded.

Mitigation: any action taken by governments, businesses, or people to reduce or prevent greenhouse gas emissions, or to enhance carbon sinks that remove these gases from the atmosphere.

Natural Farming: a farming approach that emphasizes the importance of co-production of crops and animals so that synergistic effects of different parts of the system can be used, relying on easily available ingredients to produce crop treatments on-farm, and microbes or mycorrhizae to build soil fertility.

Nature-based solutions: actions taken to protect, conserve, restore, sustainably use and manage natural or modified terrestrial, freshwater, coastal and marine ecosystems to address social, economic and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services, resilience and biodiversity benefits.

Organic Agriculture: a production system that sustains the health of soils, ecosystems, and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions rather than the use of inputs with adverse effects. Organic agriculture combines tradition, innovation, and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved.

Payment for Ecosystem Services: policies that compensate individuals or communities for undertaking actions that increase the provision of ecosystem services such as water purification, flood mitigation, or carbon sequestration. It relies on incentives to induce behavior change and can thus be considered part of the broader class of incentive- or market-based mechanisms for environmental policy.

Permaculture: the conscious design and maintenance of agriculturally productive ecosystems which have the diversity, stability, and resilience of natural ecosystems. It is the harmonious integration of landscape and people, providing their food, energy, shelter, and other material and non-material needs in a sustainable way.

Precision Agriculture: the application of modern information technologies to provide, process, and analyze multi-source data of high spatial and temporal resolution for decision making and operations in the management of crop production.

Regenerative Agriculture: farming and grazing practices that, among other benefits, reverses climate change impact by rebuilding soil organic matter and restoring degraded soil's biodiversity, resulting in both carbon drawdown and improving the water cycle.

Resilience: the ability of people, households, communities, countries, and systems (social, economic, ecological) to mitigate, adapt to, and recover from shocks and stresses in a manner that reduces chronic vulnerability, and facilitates inclusive growth.

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