Adaptation for Smallholder Agriculture Programme
ASAP

IFAD
Investing in rural people

CLIMATE INFORMATION SERVICES

ASAP TECHNICAL SERIES

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TABLE OF CONTENTS

Tables

List of figures

Boxes

ACRONYMS

ASAP	Adaptation for Smallholder Agriculture Programme
ASAP+	Enhanced Adaptation for Smallholder Agriculture Programme
AWS	automated weather stations
CIS	climate information services
EWS	early warning systems
FAO	Food and Agriculture Organization of the United Nations
GFCS	Global Framework for Climate Services
GIS	geographic information system
GMet	Ghana Meteorological Services
ICT	information and communications technology
LDCs	least developed countries
LMICs	low- and middle-income countries
NDC	nationally determined contribution
NMHS	national meteorological and hydrological service
PICSA	Participatory Integrated Climate Services for Agriculture
PPCR	Pilot Programme for Climate Resilience (of the Climate Investment Fund)
PxD	Precision Development
REAS	rural extension and advisory systems
SIDS	Small Island Developing States
SMS	short messaging service
WMO	World Meteorological Organization

EXECUTIVE SUMMARY

Smallholder production systems are particularly vulnerable to hydrometeorological and climate change impacts, which affect the farming environment, yields, productivity and assets. Farmers have limited adaptive capacity and lack access to reliable information on weather forecasts, and the recommended actions to take in response to or in anticipation of climate risks.

Timely and reliable climate information services (CIS) are critical to farmers, communities, and agrifood value chain actors in planning and implementing climate adaptation strategies, and in improving productivity, food and nutrition security, and livelihood resilience in rural economies.

Rural extension and advisory systems (REAS) are well-positioned to deliver CIS to farmers and other actors in the value chain in an accessible, credible and timely manner. Because REAS offers evidence-based advice and support on new technologies and good agricultural practices to farmers, farmer groups, and their communities, CIS can complement and reinforce REAS products and services.

The Adaptation for Smallholder Agriculture Programme (ASAP), launched in 2012, aimed to mainstream climate change adaptation across IFAD operations. ASAP Phase 1 allocated US$316 million in 44 project grants across 41 countries, between 2012 and 2022, and benefited approximately 6.8 million farmers. ASAP-funded projects placed strong emphasis on enhancing CIS as a means of strengthening the adaptive practices of smallholder farmers.

This technical paper summarizes experiences and lessons learned on CIS, including from IFAD's ASAP portfolio. The findings and lessons presented reiterate that CIS investments positively influence smallholder and rural community resilience and adaptation through multiple pathways. Early warning systems enable farmers and communities to better anticipate and prepare for slow-onset and extreme weather events. CIS promotes and complements the uptake of on-farm climate-smart or climate-resilient agricultural technologies and practices by reducing downside risks. Finally, community-level natural resource management and adaptation planning is often underpinned by CIS integrated with traditional knowledge.

At the same time, despite an array of investments across low- and middle- income countries over the last few decades by IFAD, other multilateral institutions and national governments, the physical network of weather and climate data collection and monitoring stations is inadequate and requires upgrades. The technical capacities to process the primary data, identify and combine complementary secondary datasets, refine models, and develop CIS also require strengthening. Based on the global stock take and ASAP experience, some of the critical factors for successful design and implementation of CIS include:

- effectively engage with and coordinate between a wide range of stakeholders to ensure improved decision-making and clarity on roles and responsibilities, data collection and timely sharing of data, and the improved production, tailoring and delivery of advisories;
- involve farmers and communities in the design and production of climate information products and services to fully reflect end-user needs;
- design investments in CIS as an integral part of improvements to REAS; and,
- provide for adequate investment in capacity building of national meteorological and hydrological services (NMHSs), and intermediary users and end-users of CIS.

The key recommendations of this technical paper are as follows:

Increase investments to enhance agrometeorology services: Agrometeorology itself is a specialized field and requires investments to, for example, pilot and refine agrometeorological models to improve forecast accuracy and better represent farming environments.

Broaden sectoral coverage and deepen outreach along the agricultural value chain: Within the agricultural sector, the target of CIS is predominantly the crop subsector. In addition to farmers and farmer groups, CIS interventions should also encompass and respond to the needs of all the other actors along the agricultural value chain.

Develop a fuller understanding of whether or not CIS are "fit for purpose": The credibility of CIS is a function of location-specificity, timeliness, accuracy of data, and the variables and models used. Its relevance and effectiveness are, however, determined by socio-economic and cultural factors such as end-users' access to CIS, their capacity to understand or interpret the information, who communicates the information, the approaches and means utilized, what information is conveyed and how often, how it fits with traditional knowledge, etc.

The development of CIS should be considered an iterative process with intermediary users' (such as extension system officials) and end-users' feedback incorporated into the design and refinements. More attention needs to be given to the needs and preferences of the socio-economically marginalized, such as women and Indigenous Peoples (including basic and digital literacy skills and access to ICT tools). Active efforts to integrate traditional environmental knowledge should also be made because it can offer insights at a much finer spatial scale, and can improve the communicability of and trust in the more formal CIS. The ASAP experience also suggests that a multiplicity of dissemination channels should be deployed, commensurate with the local context.

Better document farmer decision-making processes and socio-economic benefits: A greater effort is needed to document the farmer decision-making/iterative learning processes involved and the economic benefits of CIS in a manner that can make a strong case for taking a long-term view and a "public goods" or "rights-based" approach to CIS investments. Developing such an understanding is even more important when one considers that decision-making in agricultural contexts is often non-linear. Focusing on farmer cognition and decision-making could also inform how intermediary CIS users should convey the uncertainty inherent in the forecasts and models.

Communicate uncertainty in an understandable and helpful manner: Closely related to the above, it is important to understand how best to communicate uncertainties associated with CIS and mitigate the risks of maladaptation.

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INTRODUCTION

Weather and climate information[1] has been identified as critical to resilient development planning and decision-making, and essential to the implementation of the Paris Agreement, as stated by more than 40 developing countries in their nationally determined contributions (NDCs) (Allis et al., 2019). The increased frequency and intensity of extreme weather events necessitate the widespread deployment of climate information services (CIS) (see BOX 1) to anticipate weather-related events, reduce losses, proactively adapt and recover faster.

The target users/recipients of CIS can range from policymakers and planners[2] to agribusinesses, service providers,[3] and local communities, farmers and farmer groups. Given the increasing frequency and intensity of extreme weather events, humanitarian international NGOs and other public and private organizations are also leveraging climate information to build community capacities to engage in anticipatory actions and response and recovery strategies.[4] Early warning systems (EWS) have received a renewed impetus in 2022 with the UN Secretary-General's call for all persons[5] to be covered by EWS within the next five years. Climate information is also critical for climate risk screenings and assessments, which underpin the rationale for climate finance proposals and inform mid- to long-term adaptation and mitigation planning.

Smallholder production systems are particularly vulnerable to hydrometeorological and climate-related events. Between 2008 and 2018 alone, over 34 per cent (US$37 billion) of crop and livestock production loss in least developed countries (LDCs) and LMICs – lower-middle-income countries was attributed to droughts (FAO, 2021). Farmers have limited adaptive capacity and often lack access to reliable information on weather forecasts, related climate risks, and the recommended actions to take in response to or in anticipation of such risks.

Timely and reliable CIS can inform farmers and community adaptation strategies, whether incrementally or transformatively; positively affect productivity and livelihood resilience; contribute to food and nutrition security and support the identification of appropriate emission reduction measures.

Rural communities and Indigenous Peoples have long relied on traditional environmental knowledge, typically gained through generational experience and transmitted orally to understand the natural resource environment, and the weather and its interaction with agricultural practices (Balehegn et al., 2019; Garay-Barayazarra and Puri, 2011; Masinde, 2015). However, the accelerating rate of climate change and other factors (e.g. ecosystem degradation,

1/ The World Meteorological Organization (WMO) defines "weather" as short-term natural events in a specific place and time, and "climate" as average weather conditions for a particular location and over a long period of time. For the purpose of this publication, climate information services (CIS) comprise both weather and climate information.
2/ Policymakers and planners, for example, need such information to take actions on potential food crises in the short term. Medium- and long-range CIS may inform land-use planning, strategies on cropping patterns or natural resource management, investment priorities for agricultural research, etc.
3/ Credible agrometeorological databases underpin the design and implementation of agricultural insurance products, whether offered to governments, institutions or individuals.
4/ Early warning and anticipatory action interventions have typically involved cash transfers (forecast-based finance) that allow communities to engage in actions to protect lives and productive assets (e.g. purchasing water drums and grain storage bags) as well as capacity development (e.g. training on actions to take between 1-7 days of alerts such as the transfer and storage of seeds, and moving of livestock to pre-identified shelters) and infrastructure investments (e.g. construction of storm shelters). Increasing attention is being paid to ex ante risk reduction and management strategies for food security and livelihoods (e.g. home gardens to reduce food insecurity).
5/ The WMO found that one in three people in a Small Island Developing State (SIDS) or least developed country (LDC) and 6 out of 10 people in Africa do not have access to EWS (https://public.wmo.int/en/media/news/climate-risk-and-early-warning-systems-initiative-brings-message-of-hope).

biodiversity loss and socio-economic conditions) are already challenging and stress-testing the relevance and utility of these knowledge systems. For instance, Mogotsi et al. (2011) document how Kalahari agropastoralists' use of and preference for traditional knowledge have evolved over time and across generations owing to such influences.

Rural extension and advisory systems (REAS) – when adequately resourced and capacitated – are well positioned to deliver CIS in an accessible, credible and timely manner, and in a way that aligns with larger goals for a sustainable agrifood sector and NDCs. In coordination with the scientists of national agricultural research systems, REAS – particularly government extension officials – have typically delivered research-based information on new technologies and management practices by building relationships with farmers and farmer groups, and through contextual expertise. CIS can complement and reinforce the products and services delivered by REAS, and the design and delivery of CIS can benefit from REAS inputs.

A key objective of this technical paper is to use lessons learned from IFAD projects and recent global publications to enhance the performance of the Adaptation for Smallholder Agriculture Programme (ASAP) portfolio and future IFAD programming vis-à-vis the enhanced ASAP (ASAP+) and other climate finance projects. Section 2 provides an overview of how CIS interventions are deployed and integrated into agricultural extension systems, including a summary of best practices. An analysis of ASAP projects follows in sections 3 and 4, informed by project supervision and completion reports, and an online survey (conducted in September 2022) of Project Management Unit and IFAD Country Office staff. Section 5 presents recommendations for IFAD and other stakeholders to enhance support to and implementation of CIS interventions in the future.

Box 1. Definitions of CIS[6]

The World Meteorological Organization defines "climate services" as a "decision aide derived from climate information that assists individuals and organizations in society to make improved ex ante decision-making." CIS produce a "timely advisory." provided in a seamless manner and responsive to user requirements, "that end-users can comprehend and which can aid their decision-making and enable early action and preparedness." The timescales range from long to short, and end-users are a heterogenous mix of stakeholders from the national, subnational and community levels. Some of the national users may partner with national meteorological and hydrological services and use climate information (trend projections and forecasts) to produce sector-specific climate services. Tall (2013) notes that "for example, agricultural experts employed by departments of agriculture may receive 10-day rainfall forecast bulletins (climate information) to which they overlay information based on their knowledge of the growing season for farmers in a given region of the country, such as stage of planting, plant phenology, etc. (sector-specific knowledge), in order to produce tailored rural advisories."

The World Bank's CIS definition (Braimoh et al., 2015) is contextualized within the agricultural sector as including "immediate and short term weather forecasts and advisories as well as longer term info about new seeds, technologies and market information." It views CIS as "helping farmers to manage risks in what is already an exceptionally risky sector," and "reducing uncertainty that so often constrains decision making" such as "what to grow, when to plant and harvest, how to allocate their labor, and where to sell their produce."

The Climate Investment Fund's Pilot Programme for Climate Resilience (Vincent et al., 2022) defines climate services as "delivering useful and useable climate information to decision-makers to reduce climate risks." This entails "(i) quality data collection and management, (ii) development of relevant and useful information, products, and services, (iii) dissemination of these products in a timely and accessible manner, and (iv) application to inform decision-making and ultimately support climate-resilient development outcomes."

6/ Definitions of CIS: The mention of CIS and Climate services described in the box 1 are considered as equivalent terms and used interchangeably for the purpose of this publication.

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2

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DELIVERING CLIMATE INFORMATION SERVICES

Within agricultural development projects, the primary function of CIS is to serve as a planning and decision-support tool for farmers to identify adaptation strategies or engage in actions[7] to anticipate and manage risks (concerning weather, price, market, etc.) to livelihoods, and to enhance productivity and income (BOX 2). Typically, CIS provide information on input and output market prices, historical weather and climate trends including records of extreme events, and future climatic and agro-ecological model projections. Such services and information may be bundled or layered to tailor the advisories offered to farmers through the rural extension and advisory systems

Box 2. Applications of CIS as a planning and decision-support tool

Communities

- Undertake climate risk assessments and identify adaptation measures
- Land-use planning and natural resource management

Farmers

Short-term farm management (daily or weekly weather forecasts, seasonal forecasts, downscaled climate models, EWS, etc.):

- Choice of crops/crop varieties, livestock breeds or fish species
- Choice of inputs (seeds, fertilizers, livestock or aquaculture feed, and vaccines)
- Choice of management strategies (watering and irrigation, pesticide/insecticide spraying, shift of pastures, aquaculture pond preparation and fingerling stocking)
- Choice of planting and harvesting dates
- Harvest storage- and transportation-related decisions

Medium-/long-term farm management (e.g. seasonal forecasts, downscaled climate models and crop suitability maps):

- Shifts in cropping systems
- Significant (agriculture-related) capital investments
- Livelihood diversification

Micro agribusiness enterprises, small agribusiness enterprises and medium-sized agribusiness enterprises

- Stock management (e.g. seed varieties, fertilizers and insecticides) based on seasonal forecasts
- Storage and processing decisions for agricultural outputs

7/ These actions can be related inter alia to integrated crop management, climate-smart/regenerative agriculture, good agricultural practices, integrated pest and disease management, loss and damage reduction measures.

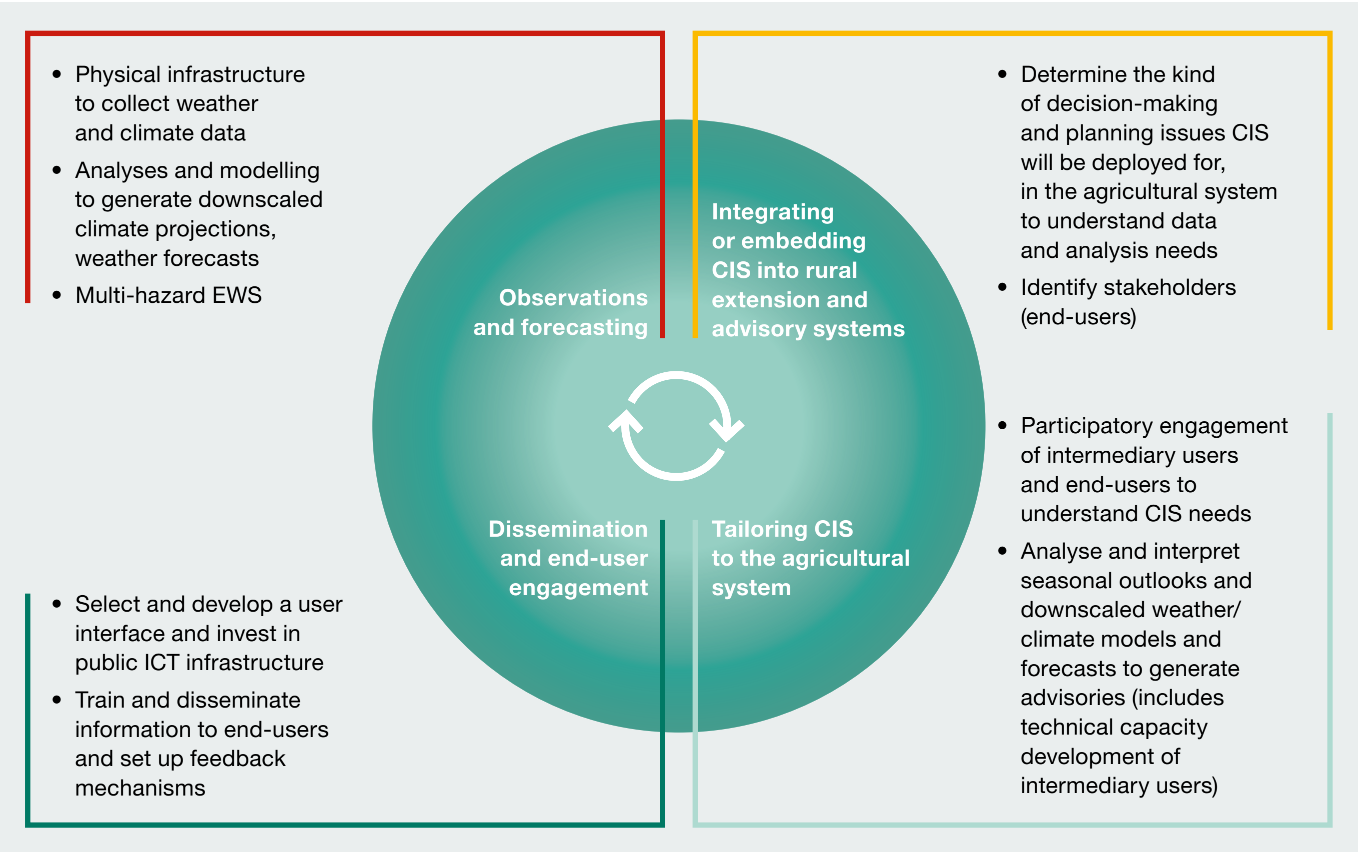
(REAS), provided primarily, but not solely, by governments.[8]

Increasingly, the provision of CIS is integrated into agricultural development investment projects – in many instances through REAS. The integration of CIS in REAS can support different aims, for example: community-led land-use planning and natural resource management; participatory identification and selection of agricultural/livelihood adaptation measures; formulation of tailored anticipatory action or disaster risk insurance mechanisms; and other climate-resilience-related investments.

Each climate investment project may deploy CIS differently. Some may encourage transformative shifts in farming (e.g. new or diversified production systems) with a focus on medium-term or decadal trends, yield impact and crop suitability based on climate scenarios. Other projects may focus on risk reduction and productivity enhancement (e.g. planting and harvesting dates, varieties and input management) in the immediate and near-term agricultural seasons using short-term forecasts and high-frequency weather data. Others still may focus on landscape-scale adaptation measures using a combination of climate risk assessments and resource maps.

The integration of CIS into REAS requires the following key components, as outlined in FIGURE 1.

FIGURE 1. **How Climate Information Services fit into Rural Extension and Advisory Systems**



8/ Rural extension and advisory services, also called extension services, are all the "different activities that provide the information and services needed and demanded by farmers and other actors in rural settings to assist them in developing their own technical, organizational, management skills and practices so as to improve their livelihoods and wellbeing" (Christoplos, 2010).

2.1 Public sector CIS and REAS: state of play and summary of lessons learned

The state of play: public sector

There have been several significant initiatives and investments to strengthen CIS by international development organizations and multilateral development banks (see BOX 3). Notwithstanding these investments, important infrastructural, technical, policy, institutional, and communication gaps remain to be addressed.

Regarding **physical infrastructure**, in many countries, for example, observational networks might be sparse and not provide sufficient spatial resolution[9] owing to limited deployment of automated weather stations (AWS), climatological and hydromet stations, automated or manual rainfall stations, automated water level recorders, sea surface temperature and upper air stations, lightning detection networks and weather radars. Even where the physical architecture is in place, the **equipment might be outdated** or the **communications network needed for real-time transmission of data might be inadequate** and require an upgrade.

Furthermore, **technical capacity to capture, verify, process and recast large volumes of data** might be weak and require strengthening. Simultaneously, the specialized **expertise of intermediary users** is also often insufficient to assess stakeholder needs, engage in participatory development with end-users, and interpret and tailor weather and climate information to advisories. When CIS target the agriculture sector, the strength of REAS is an important factor. This includes the **technical capacity of subnational extension officials, their geographical presence**, and **the alignment or integration of CIS with agricultural and rural development programmes.** Because of the regional and global aspects of CIS, **harmonization of databases and cross-country and regional cooperation** to ensure timely and accurate exchange of data are also critical.

Box 3. Significant cross-sectoral investments in CIS[10]

Given the growing interest in high-quality CIS, investments in the CIS value chain have increased over time (WMO, 2019).[11]

The World Bank has invested US$1.1 billion, primarily in hydromet infrastructure and across South Asia and Africa, and intends to invest US$10 billion per year in climate change adaptation, which will include EWS and CIS in 30 countries.

The Global Environment Facility reports US$415 million of investments in climate services and EWS through its Least Developed Countries Fund and Special Climate Change Fund.

The Adaptation Fund reports that, of the US$303.8 million allocated to 37 projects that have CIS embedded, US$34 million is specifically intended for concrete CIS and EWS components in various sectors.

The Green Climate Fund reports an investment of US$649 million (with an additional US$899 million leveraged as cofinance), with 25 per cent of this going towards modernizing hydrometerological services and 75 per cent to cross-sectoral approaches.

9/ https://wdqms.wmo.int; World Bank, 2021.

10/ These numbers do not reflect investments made at other multilateral and regional development banks. For example, the ClimDev-Africa Special Fund of the African Development Bank has allocated EUR 35.9 million (EUR 19.2 million disbursed between 2016 and 2020) to generate and disseminate CIS, and enhance policymakers' and policy support institutions' capacity to integrate CIS into development programmes across the African Union.

11/ These investments have been made through global climate and environmental funds and multilateral development banks, not the private sector itself.

Although most NMHSs in Africa provide seasonal rainfall forecasts, monthly climate outlooks and agrometeorological bulletins (Vaughan et al., 2017), the ClimDev-Africa Initiative reported that 96 per cent of African NMHSs require upgrading of operational infrastructure, 92 per cent require training on the production of climate products and services, and 85 per cent report a lack of effective coordination with other agencies as negatively impacting operations (Intsiful (slide 9), 2016). These issues are likely to remain a priority area of investment in CIS projects, particularly in African countries, LDCs and SIDS where the gaps are largest – with, of course, significant regional variation within the African continent (Vaughan et al., 2017).

In this context, it is important to note that agricultural applications – such as the production of agrometeorological advisories – not only require a different spatial resolution and frequency of data collection, but also require collection of additional data (e.g. evapotranspiration, soil moisture and solar radiation). That is, a country's synoptic, hydrological and climatological stations will need to be supplemented by agrometeorological stations (WMO, 2012) that are representative of agroecological zones.[12] Such stations measure additional variables that are relevant and important for agricultural applications (i.e. crop modelling, pest and disease monitoring, water balance modelling, etc.). Agrometeorological stations should be installed and calibrated in the field or the agricultural area of interest, at a higher geographical resolution than synoptic stations (FAO, 2021).

Summary of lessons learned: public sector

This section describes some of the overarching lessons learned from recent key CIS investments in developing countries with the support of international climate funds, multilateral development banks and United Nations agencies. The interventions were delivered through the public rural extension and advisory system and typically coordinated with NMHSs.

Stakeholder co-design, engagement and training: A key lesson from the PICSA project (box 4) was the importance of the involvement of a range of actors (local government, NMHSs, agricultural extension staff and other stakeholders) to produce messages when a seasonal forecast was released, with regular assessment of progress to ensure relevance and appropriateness. A second lesson was the importance of investing in training recipients to translate and incorporate CIS into their decision-making. Whilst farmers have some intuitive understanding of short-term weather forecasts and how to apply the information to make decisions, as the timescale of the information provided increases (from weather to climate), the information becomes more challenging for farmers to use and involves uncertainties (e.g. what practices should they adopt based on seasonal probabilities?). Even in cases in which the design and mode of advisory delivery have been tailored to the local context, and the public REAS has a long history of providing effective decision support to farmers, it is likely that farmers will need training in interpreting the more quantitative or graphical representations of climate information. The initial training should also be the start of a two-way dialogue, and ensure that the farmers have a voice in the design, production and evaluation of CIS (Hansen et al., 2019; Hansen et al., 2019b; Selvaraju, 2013; Tall et al., 2014).

Gender and inclusion: Other projects (McOmber et al., 2013) have found that women and socially marginalized groups have differing CIS needs and should be targeted through communication channels that are relevant to them, and that CIS should be tailored to the different roles that they have in agricultural value chains. For example, Senegalese women tend to share information at borewells and petty sale points, and prefer receiving information by SMS on their or their children's phones. Women also require distinctly different information than men (Gumucio et al., 2018; Tall et al., 2014). The same study found that, among farmers, because women's planting season begins a month later than men's, knowing when rains would end (owing to early cessation of rains being a cultivation risk) is more important than rainfall onset to women farmers.

Physical infrastructure: The Climate Investment Fund's Pilot Programme for Climate Resilience (PPCR) focused on strengthening hydrometerological and climate services through

12/ https://gaez.fao.org.

Box 4. Farmers' use of and benefits from CIS: what did GFCS project's PICSA pilots tell us?

The World Meteorological Organization (WMO) established the Global Framework for Climate Services (GFCS) in response to the third World Climate Conference (2009) call. GFCS supports the development and incorporation of science-based climate information and prediction in planning, policy and practice on global, regional and national scales to enable the better management of the risks of climate variability and change (WMO, 2020).

Participatory Integrated Climate Services for Agriculture (PICSA) is an approach to integrating CIS into REAS that was first piloted under a GFCS project targeting the agricultural sector. It was implemented in Malawi and the United Republic of Tanzania by the World Food Programme; the CGIAR Research Programme on Climate Change, Agriculture and Food Security; the International Federation of Red Cross and Red Crescent Societies; and WMO. PICSA combined local climate information with participatory resource mapping and seasonal calendars to assist farmers in evaluating their farming and livelihood strategies. The project also delivered agroclimatic information through radio and SMS and used these same channels to collect feedback.

Information on how CIS change farmer behaviour and decision-making, and the resultant impact on food security and livelihoods, is often anecdotal or limited in nature. Because the pilots of the PICSA approach specifically targeted farmer decision-making, based on site-specific and accurate CIS for crops and livestock, it is useful to examine its outcomes and impacts.

In Malawi and the United Republic of Tanzania, the project found that, although 96 per cent of 193 Malawian farmers adapted their crop management as a result, only 47 per cent adapted their livestock management and only 22 per cent changed their livelihood enterprise.[13] This finding is mirrored in a review (Vaughan et al., 2017) of 66 studies, conducted across 23 African countries and over 40 years, that evaluated the outcomes and impact of CIS and found that a majority of farmers use the information to adjust management decisions, but also that farmers do not use CIS to make costly investments (e.g. in irrigation or agroforestry).

However, 80 per cent of farmers in Malawi (and 88 per cent in the United Republic of Tanzania) reported that PICSA improved their ability to cope with bad seasons caused by weather and 98 per cent of Malawian farmers (and 94 per cent of Tanzanian farmers) reported increased confidence in farm and livelihood decision-making. Along similar lines, Vaughan et al. (2017) also reported that the impact of CIS on yields and gross margins was generally positive, but there were differences based on farmer income quintiles and crop type.

Case studies of farmers illustrate exactly how PICSA enabled household resilience to climate change (Clarkson et al., 2022). In Malawi, a farmer who adopted early-maturing maize and conservation agriculture techniques was able to harvest maize when others were unable to – allowing her to pay her child's school fees, purchase seeds for the new agricultural season and maintain food consumption. A Tanzanian farmer, on the other hand, bought cattle breeds that were better suited to droughts, reduced their herd size and vaccinated their animals.

investments in upgraded/modernized hydromet infrastructure and the technical capacity of hydrometerological agencies, and is an example of one of the earliest climate finance investments in CIS across the most climate-vulnerable countries. Because PPCR projects were launched in contexts where climate services were less developed, a key focus was on data gaps. It targeted a range of sectors (e.g. water, health, transport and agriculture) and user needs (e.g. early warning for farmers during the Nepal monsoon, cyclone preparedness and response in Mozambique, and Jamaica's sectoral planning).

Data and analysis capacities, and cross-sectoral collaborations: PPCR projects used

13/ https://drive.google.com/file/d/1X_vGhYJf5f5IGlu4_GbkOB1UmnpKMyPY/view; the numbers were 33 per cent of 611 Tanzanian farmers for crops, 25 per cent for livestock and 8 per cent for livelihood.

a range of delivery channels and intermediaries, who translated technical concepts into more accessible terms and relayed feedback from users. However, a key finding was that capacity remains insufficient in terms of infrastructure and trained staff to process and analyse data from improved equipment. The end-user capacity to understand the value of CIS and provide feedback on the services received and refinements to the design is also limited. The PPCR identified sufficient budgetary allocation to cover the costs of generating information, products and services as key to long-term sustainability. Collaboration between various actors, within countries and regionally, is also recognized as critical to improved data production, management and sharing by reducing the duplication of efforts.

The efforts described above represent successes, and lessons pertaining to the first of two critical "last mile" information gaps, identified by the Food and Agriculture Organization of the United Nations, between what CIS farmers need and what is available (2019). That is, they improved the access that NMHSs have to local extension staff and farming communities, which enabled better integration of meteorological and local knowledge.

The second gap relates to the lack of local agrometeorological information that can realistically represent the farming environment, limiting CIS utility. For instance, are thresholds for decision-making clear and are CIS appropriately actionable for users? How accurate were the forecasts provided and were the associated uncertainties well communicated? In this context, a review of CIS for agriculture and food security (WMO, 2019) identified that Africa and SIDS face challenges regarding the density of observation networks and reporting frequency of observations essential for generating CIS-related products and services.

2.2 Private sector CIS and REAS: state of play and summary of lessons learned

The state of play: private sector

The growth of data science and private weather satellites, monitoring systems and weather services, has resulted in several public–private or private, ICT-based CIS initiatives.[14] Such services can be particularly important in countries where the public extension system has reduced capacity and the gap is expected to be filled by private actors. GEOPOTATO,[15] led by CGIAR and Wageningen University, is an example of a private initiative where data from AWS and satellite imagery are used to generate warnings three days in advance through SMS and voice messages to subscribed Bangladeshi farmers of the risk of late blight for potato crop to encourage preventive spraying.

Precision Development (PxD)[16] is another initiative[17] that provides a range of mobile-based advisory services to smallholders in multiple countries, and real-time weather-based advice is a part of the content "pushed" to farmers. With mPower (a social enterprise), PxD runs the platform "Agro360" wherein farmers select their crop and sowing dates to then receive advice on pre-sowing through to post-harvest management.

Summary of lessons learned: private sector

Financing private sector engagement: Private sector companies, which focus on specific value chains or financial services (e.g. credit, or crop or weather insurance), often have a financial incentive

14/ Some countries, such as Uganda, have regulatory restrictions meaning that only the NMHS can provide weather and climate information to the public.
15/ https://www.wur.nl/en/project/GEOPOTATO-Control-fungal-disease-in-potato-in-Bangladesh.htm.
16/ https://precisiondev.org/our-learnings/learning/.
17/ Other initiatives include Farmerline (Ghana), Manobi Africa (East and West Africa), aWhere (global), Ignitia (West Africa), MeteoGroup (Philippines) and FieldFocus by 6th Grain (Africa and the Middle East). The Digital Agri Hub project has mapped many others as part of its digital agricultural solutions project (https://digitalagrihub.org/en/web/guest/dashboardframe?tags=1).

to provide timely and actionable advisories to producers or organizations to increase the quality and output of their products. One such example involves tea producers in Kenya, where scientists from the Tea Research Foundation have a strong collaboration with the Kenyan Meteorological Department and use data available from local weather stations. The Tea Research Foundation have also developed drought-resistant tea varieties and yield prediction models that mitigate, to some extent, the potential impacts of climate change (Kadi et al., 2011).

Many other private sector interventions are subscription-based and deployed in contract farming contexts or through the agribusiness input supply chain as in the case of Bayer-funded GEOPOTATO. As a result, the advisories tend to fall into the broadest definition of CIS and farmers typically have the option to call and ask questions through toll-free lines.

Legitimacy of data and end-user awareness and engagement: Farmers or farmer groups can be made aware of CIS through input suppliers, cooperatives or the agribusinesses that they contract with for crop or commodity sales. Enrolment of phone numbers or addition to social media groups (e.g. WhatsApp groups, Messenger/Facebook) might be automatic or a condition of the purchase of products or services. Some private sector actors (e.g. Ignitia) also have partnerships with local mobile service providers to help expand their subscriber base and disseminate information. However, it is not always evident how user consent is obtained, who bears the cost of such services[18] and, in cases in which farmers respond to questions, whether users are fully aware of who uses the data and for what purpose.[19]

A challenge with the private sector delivery model is the assessment of the **accuracy of underlying weather and climate data/models**, since these may not be in the public domain.[20]

Another challenge is that smallholders may have to pay for this service – the evidence on farmers' ability and willingness to pay is mixed (Camacho and Conover, 2019; Cole and Fernandes, 2021; Hidboro et al., 2020), and the agricultural input package **recommendations and advisories may not be generic but brand specific** – with implications for cost of production.[21] Such input recommendations may also not be congruent with, say, a country's NDCs or biodiversity-related targets for agriculture (e.g. if advisories are not designed to address the overuse of certain pesticides, insecticides or mineral fertilizers). Finally, there is a risk that such initiatives remain top-down, that farmers/end-users do not co-produce the CIS and that farmers targeted by the private sector might be large-scale farmers (further exacerbating exclusion issues).

The engagement of the private sector is often proposed as a solution to the **long-term sustainability of CIS**, i.e. after project completion. Evidence on the willingness and ability of farmers to pay for CIS delivered through the for-profit private sector is mixed. Furthermore, the private economic returns to smallholder farmers from the transition to climate-smart agriculture may also be limited by a range of contextual and systemic factors (Branca et al., 2021). Therefore, any assessment of the costs and benefits of CIS to justify delivery by the for-profit private sector should be based on real-world data, and not just agronomic trial assumptions on yields and economic returns.

The GEOPOTATO and PxD interventions also included socio-economic research to evaluate and improve the relevance of advisories to farmers (and document the resultant impact) and, therefore, lessons are context-specific.

18/ Of course, the cost of CIS might be embedded in the sale price of agricultural inputs or be donor funded at the pilot stage.
19/ For example, Reuters Market Light provided advisories to farmers on improving productivity specific to agroecological conditions, weather and commodity prices. At the same time, such companies can use data from farmers to improve yield predictions for critical commodities in global commodity markets.
20/ This is even more of a challenge in cases in which the company installs its own observation and monitoring equipment.
21/ There may also be cases in which farmers are uninformed of government programmes that may subsidize a particular input, in favour of private purchase.

The broader lessons pertain to (i) the content of advisories, i.e. they should be carefully designed, tested and tweaked, and (ii) the potential socio-economic benefits to farmers, i.e. CIS result in better comprehension and retention of farm management knowledge (e.g. optimizing the use of fungicide) and positive yield gains.

New developments leveraging digital expansion: Over the 2010s, there has also been a proliferation of websites and mobile applications (e.g. Accuweather, Windy and Meteologix) that collate weather forecast models (both regional and global) to produce near-term weather forecasts. Some companies such as Weather Underground rely on a network of private weather stations to deliver commercial services (O'Grady et al., 2021). Interpreting such information and understanding the uncertainties (e.g. the resolution of each forecast model) still requires specialized skills. Combined with an increase in the frequency and intensity of extreme weather events, which have necessitated community mobilization and crowdsourced information (e.g. on flooding within a city), this has resulted in "amateur weatherpersons" or "weather bloggers"[22] who interpret and report on major variables (e.g. precipitation and cyclone movement) for the subnational or local level through social media. While these amateur weatherpersons are not focused on agriculture per se and not all of them provide seasonal forecasts, farmers are able to interact with them and directly ask questions (typically on precipitation, heat waves and extreme events) that enable better seasonal and near-term planning.[23] This type of information sharing allows farmers to cross-reference forecasts and, over time, develop trust in and a better understanding of CIS. While NMHSs may have justifiable concerns about the potential for misuse or misrepresentation of information by these informal channels – and that this could increase yield or income loss for farmers should they make decisions based on unreliable data – they do hold important lessons on information dissemination and end-user engagement[24] that may be worthy of focused research.

In summary, there could be a case for creating CIS value chains with different actors (both public and private, for-profit and not-for-profit, and formal and informal) playing different roles across the CIS value chain, recognizing that no one institution or actor can develop and deliver all components.

22/ https://indianexpress.com/article/india/chennai-rains-twitterati-flocks-to-self-styled-tamilnadu-weatherman-to-get-updates-5791270/.
23/ Such individual providers of CIS, owing to their interest in meteorology and as part of building their reputation, also tend to explain how they arrived at their conclusions through lengthy write-ups or videos.
24/ https://www.firstpost.com/india/as-chennai-grapples-with-erratic-weather-amateur-weather-bloggers-help-the-city-stay-afloat-4248793.html; https://www.washingtonpost.com/world/asia_pacific/how-amateur-weathermen-are-tackling-climate-change-in-india/2017/12/20/97caaa76-e4d1-11e7-927a-e72eac1e73b6_story.html. In the specific instance of the State of Tamil Nadu, India, weatherpersons were able to influence state policy on hydromet infrastructure investments in the 2021 state budget (e.g. expansion of the radar network by comparing available data for the State of Tamil Nadu and its neighbouring states with a more expansive network).

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3

CIS IN THE ADAPTATION FOR SMALLHOLDER AGRICULTURE PROGRAMME (ASAP)

3.1 Introduction to ASAP and ASAP+

ASAP[25] was launched in 2012, channeling US$316 million as grant-based climate finance to be blended with IFAD's investment portfolio to mainstream climate change adaptation across IFAD operations. ASAP was established to accelerate the scaling up of successful innovative "multiple benefit approaches" to climate adaptation to increase agricultural system productivity and resilience to shocks, create carbon sequestration opportunities, and achieve gender equality and social inclusion. CIS were integrated into several ASAP financed projects to encourage and support the adaptive practices of smallholder farmers.

Building on the experience, lessons and success of ASAP, ASAP+[26] was launched in 2020 aiming to mobilize a further US$500 million to address climatic drivers of food insecurity and achieve the following two overarching goals:

- Increasing resilience of vulnerable communities to the uncertainty caused by climate change on food production and nutrition.
- Reducing greenhouse gases through win-win interventions that also yield significant food security benefits, particularly for vulnerable groups.

CIS remains a priority investment under ASAP+ with a view to further enhancing the use of climate information for decision-making and planning to increase resilience.

3.2 The nature of ASAP-supported CIS investments

CIS investments supported by ASAP fall under three broad areas:[27] CIS for climate change adaptation, CIS for land-use planning and natural resource management, and CIS for early warning systems. None of the ASAP-supported CIS investments included all eight components described in section 1 (FIGURE 1).

Out of the eight ASAP projects[28] (TABLE 1 and ANNEX I) for which survey responses are analysed herein, two were focused on **EWS** addressing significant weather or climatic risks. The project in Kyrgyzstan focused on providing 10-day forecasts to livestock herders (through their unions) on 11 different weather hazards

25/ https://www.ifad.org/en/asap.
26/ https://www.ifad.org/en/asap-enhanced.
27/ All analysis done in this paper is for ASAP Phase 1 running from 2012 to 2025.
28/ Refer to Annex I for the long list from where the 8 projects were selected on the basis of their relevance and pertinence with the scope of this publication.

to reduce livestock morality within the context of a livestock market development project. The Bangladesh project, in the flash floods and flood-prone Haor region, invested in communication infrastructure (roads), community infrastructure and resource management (village protection walls, market development and minor irrigation), and livelihoods (vocational training, marketing assistance). The flash flood EWS complemented these activities designed to build household resilience and protect assets.

In four of the eight projects (TABLE 1 and ANNEX I), i.e. those in Ghana, Morocco, Mozambique and Uganda, ASAP investments typically involved upgrading or introducing basic CIS infrastructure as well as investments to develop the technical capacity of NMHSs and REAS staff for analysing data, to disseminate information and to train end-users to use data, maps, forecasts etc. to plan immediate or medium- and long-term adaptation actions (section 2). In all four cases, the projects targeted the enhancement of farmers' and/or communities' knowledge of **CIS for climate change adaptation** and ASAP investments aimed to enable the demonstration, and later adoption (by farmers), of crops or tree species, crop varieties, input management practices and agroforestry techniques that are climate-smart or climate-resilient.

In two of the eight projects (TABLE 1 and ANNEX I), i.e. those in the Lao People's Democratic Republic and Bolivia, the aim of **CIS** was **land-use planning and natural resource management** at the community level. This was different from the four projects above, where it was primarily deployed as a planning and decision-support tool for agricultural and livelihood activities.

In the Lao People's Democratic Republic, the IFAD project that became effective in September 2013 aimed to encourage pro-poor agricultural diversification and market development by linking farmers to agribusinesses and buyers; the ASAP component was added in February 2016 to reduce the climate vulnerability of the target beneficiaries. The ASAP component intended for communities to become better informed on climate change adaptation (using demonstration sites established with support from technical service centres and agricultural research stations). It was also designed to enable communities to use geographic information system (GIS) maps of land-use and natural resources (showing soil types, forest classification, flooding areas, agricultural areas, etc.) along with weather/climate scenario forecast maps to develop and implement local adaptation investment plans (LAIP). While demonstration sites were established and the maps and tools were transferred to communities, the actions laid out in the local adaptation investment plans did not occur within the project time frame. In addition, although the ASAP component had aimed to provide mobile phones to farmers in remote areas so that they could receive regular weather updates, this was changed in favour of other investments owing to a lack of internet connectivity.

In Bolivia, the ACCESOS project targeted community-based natural resource management, and IFAD investments in technical assistance and financial inclusion were aimed at supporting sustainable livelihoods (i.e. agricultural and non-agricultural enterprises). The ASAP component, added in 2014, focused on climate vulnerable territories (15 of the 52 ACCESOS municipalities) to reduce climate-related losses through the integration of GIS/satellite data and traditional knowledge, which informed territorial planning and investments in microdams for water management. While CIS infrastructure and dissemination investments were also planned, these did not materialize, and the absence of a public extension system complicated CIS delivery.

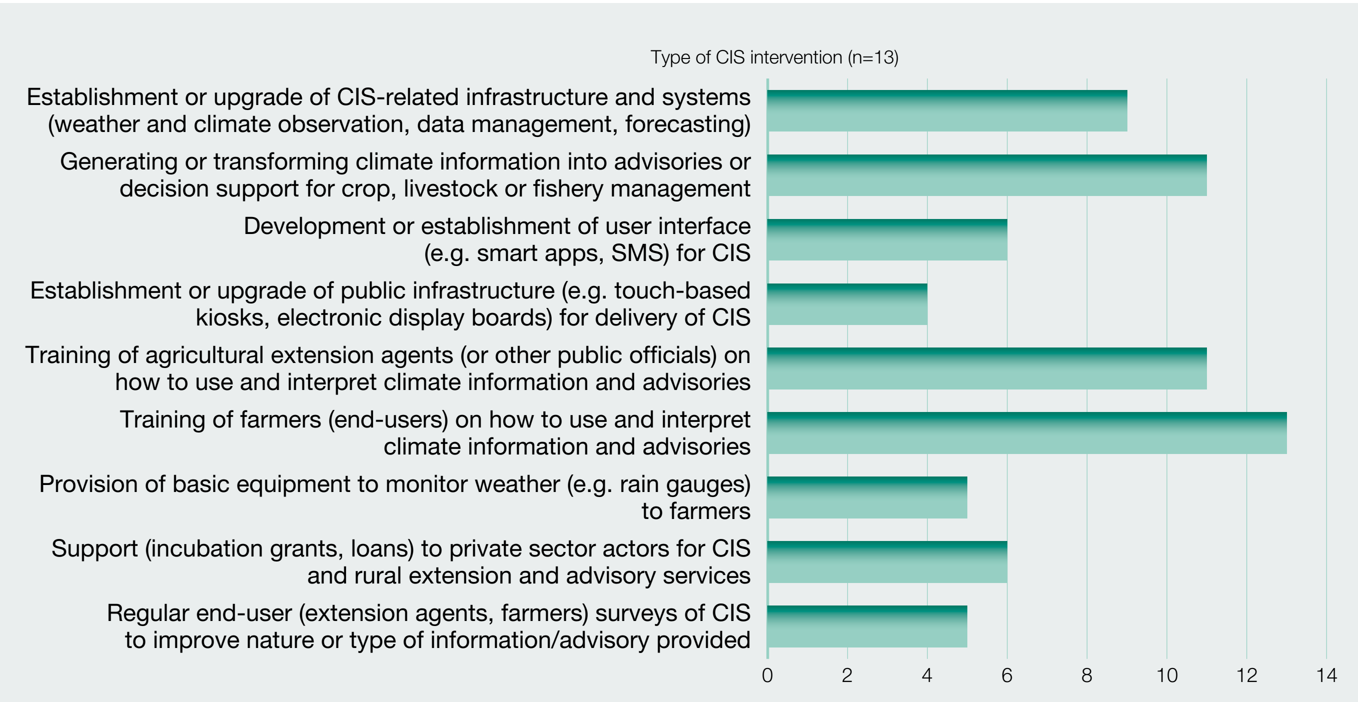
In addition to the eight ASAP projects (TABLE 1) for which survey responses were received, this paper draws on the experience and lessons learned from an additional six ASAP projects (ANNEX I) for which some information on **CIS for climate change adaptation** is available in IFAD reports. In all six cases (taking place in Egypt, Kenya, Lesotho, Malawi, Nigeria and Rwanda), ASAP investments supported the development of advisories, investments in the capacity development of REAS staff and the training of end-users (i.e. farmers and farmer groups) to use information to plan and implement recommended resilience and adaptation strategies as well as (to a limited extent) investments in new or upgraded hydromet/agromet infrastructure. The project in Rwanda contained an extensive CIS intervention integrated into REAS, combining the use of PICSA and production of climate risk assessments for 12 commodity value chains as well as the calibration and maintenance of 121 weather stations. Because the Lesotho CIS project, was layered onto a livestock project, it targeted rangeland farmers (the other five projects focused on crop agriculture).

TABLE 1. **Survey respondents: ASAP countries and projects**[29]

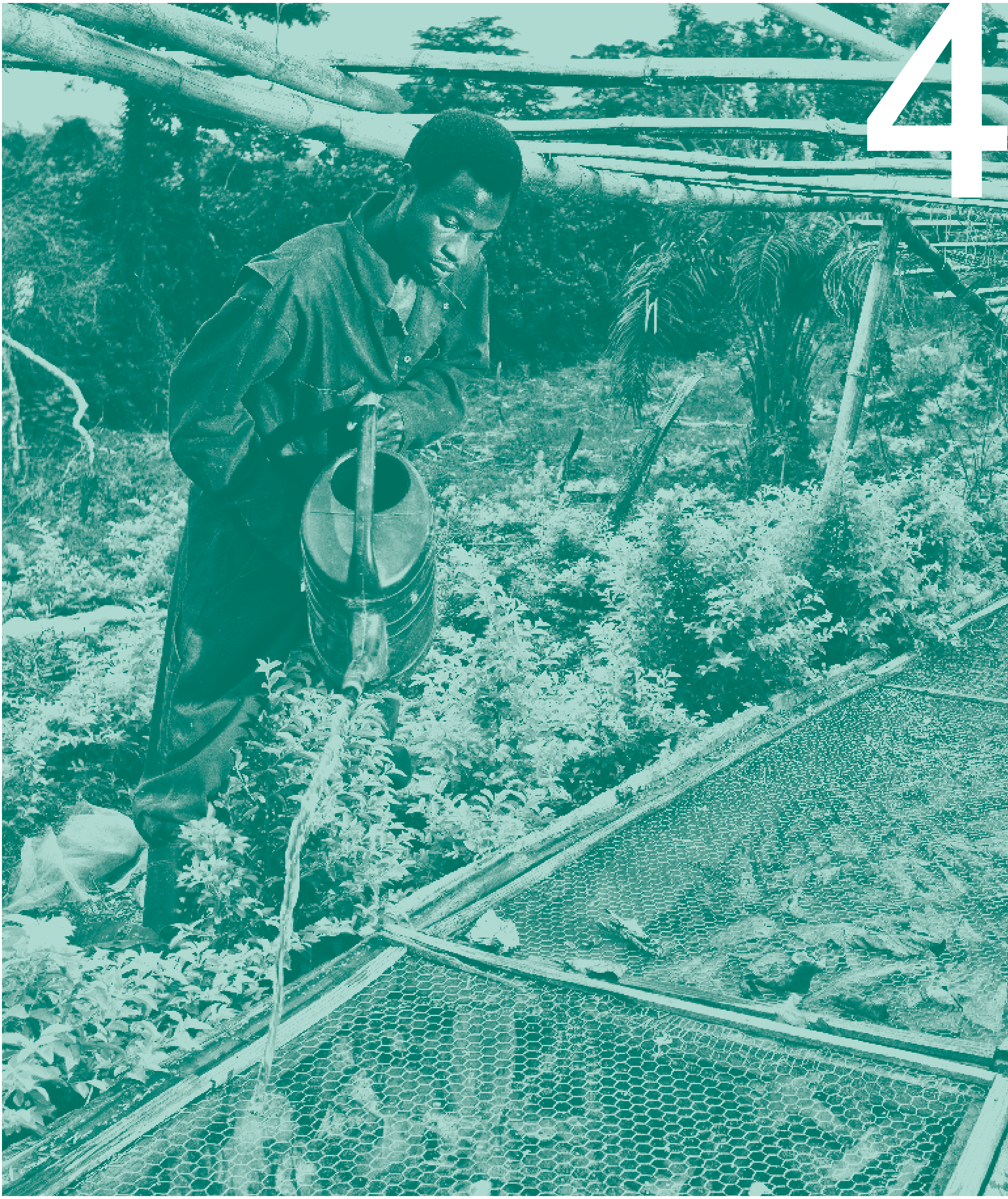
PROJECT NAME	COUNTRY
Haor Infrastructure and Livelihood Improvement Project – Climate Adaptation and Livelihood Protection (CALIP)	Bangladesh
Programa de Inclusión Económica para Familias y Comunidades Rurales en el Territorio del Estado Plurinacional de Bolivia (ACCESOS)	Bolivia
Ghana Agricultural Sector Investment Programme (GASIP)	Ghana
Livestock and Market Development Project – 2 (LMDP2)	Kyrgyzstan
Southern Laos Food and Nutrition Security and Market Linkages Programme (FNML)	Lao People's Democratic Republic
Rural Development Programme in the Mountain Zones – Phase I (PDRZM)	Morocco
Pro-poor Value Chain Development in the Maputo and Limpopo Corridors Project (PROSUL)	Mozambique
Project for Restoration of Livelihoods in the Northern Region (PRELNOR)	Uganda

FIGURE 2. **Survey responses for CIS interventions**

Type of CIS intervention (n = 13)



29/ Based on responses to a survey sent to ASAP projects with components of CIS integrated into REAS. Projects for which secondary data were the only source are described in Annex I.



4

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KEY FINDINGS AND LESSONS LEARNED FROM CIS IN ASAP

4.1 Physical infrastructure, complementary data and enabling environment

Across all ASAP-supported CIS projects, survey responses and supervision reports show that the current network of weather and climate data collection and monitoring stations is not extensive enough or requires upgrades/rehabilitation.

In Ghana, although 12 AWS have been installed within a 40 km radius, the Ghana Meteorological Services (GMet) estimated that a further 50 AWS will be required in the project area. To adequately cover the Northern Zone, for achieving acceptable coverage, a further 100 AWS will be needed together with the existing stations to ensure farmers receive location-specific information. An alternate proposal from GMet is to invest in agromet stations, which are less expensive than AWS, can complement AWS and provide additional farming-relevant data (section 2.1).

In other instances, it is not just the physical infrastructure for weather and climate data gathering and monitoring that might be inadequate; the non-weather-related information needed for a specific CIS application might be incomplete. In Bangladesh, the elevation (river bathymetry) and river discharge data needed to model flash flood forecasting were available only for parts of the Haor project area.

Even where a basic network is established, the enabling environment may not always support CIS dissemination and scale up to the most vulnerable communities: the project in the Lao People's Democratic Republic illustrates that other infrastructural issues (e.g. internet) can be a critical barrier to real-time or regular weather information delivery to farmers in remote areas. The project took the decision not to distribute mobile phones to farmers in the absence of a communication network; however, section 4.3 discusses how multiple dissemination channels (by design) might be needed in all settings.

The expansion of CIS-related observational and data collection infrastructure can also pose new challenges in terms of operational sustainability, and environmental and social impacts. The AWS equipment in Ghana was installed on individual farmer plots without clear guidelines on ownership, operation and maintenance. Thus, the project will need to clarify ex post with the farmers the acquisition and ownership of land where the AWS have been installed and identify additional funding to ensure continued AWS operations and the safety of equipment.[30]

30/ The Uganda supervision report identified that individuals would need to be employed by the Ugandan National Meteorological Authority to maintain the area around the rain gauge and ensure it is not covered by bush/grasses, reducing its utility. The Ghana project identified "theft of equipment" as an issue.

Similarly, where rain gauges have been distributed to farmers (i.e. in Ghana, the Lao People's Democratic Republic and Morocco), the projects collected data and transmitted them to agencies for analysis and processing. However, the availability of financing to continue such activities after project completion was uncertain across projects. The importance of project exit strategies and assessments of the feasibility of continued public investment are areas for attention highlighted by the Egypt project, which has procured five AWS and invested in SMS-based dissemination.

4.2 Technical capacity of and coordination between intermediary users

The ASAP-supported CIS experience strongly suggests that supporting the technical capacity of intermediate users is essential to producing timely and relevant forecasts, alerts, maps, and other decision-support and planning tools. As stated earlier (sections 2.1 and 2.2), this requires strong coordination between different government ministries, departments and agencies within and across countries.

Although the Bolivia project did not deliver CIS for agricultural decision-making and planning to farmers, it illustrated how strong the coordination between different agencies needs to be in order to produce climate risk assessments and the importance of combining CIS with traditional knowledge to inform territorial planning. The Kenyan project set up participatory scenario-planning workshops at the county level, which included local forecasters, to enhance subnational coordination between intermediary users and to develop advisories (on the selection of crops and agronomic practices) based on seasonal forecasts and likely impact on crops.

In Mozambique, the ASAP funding focused on improving climate resilience – through reducing crop and livestock losses during droughts, reducing soil degradation and promoting diversified commercial crops – of three specific value chains (horticulture, cassava, red meat). This necessitated coordination between multiple ministries and agencies; such engagement contributed to the effective dissemination of information to not just smallholder farmers but value chain actors and other stakeholders. The project also enhanced the capacities of intermediate users, as it explicitly references the strong efforts/investments in the capacity development of local meteorological technicians (and extension officials) to ensure they can disseminate information in a timely manner and accessible language, resulting in an increase in the number of farmers utilizing CIS for irrigation scheduling and other farm activities. By improving inter-agency collaboration and enhancing technical capacity of REAS, the project improved the design and outreach of CIS in a structured manner.

The Ghana project has been able to successfully leverage the lessons learned from the Ghana Agricultural Sector Investment Programme, including on coordination (to produce protocols for extension agents) between the Climate Change Division of the Crop Services Directorate of the Ministry of Food and Agriculture, the Centre for No-Till Agriculture and Gmet to design a new project.

The effectiveness of Bangladesh's EWS for pre-monsoon flash flood forecasting was hampered by inadequate data sharing by neighbouring (upstream) countries as well as technical challenges within Bangladesh in rainfall. Many meteorological phenomena and associated water/weather cycles are transboundary (such as monsoons, typhoons and cyclones), underlining the importance of cross-country coordination and cooperation in data collection, analysis, and exchange.

Sometimes, the technical skills needed to analyse, process and produce reports cannot be mobilized within a country owing to inadequate capacity or administrative/legal reasons. Hence, projects should anticipate and plan for internal capacity development and the associated investments in GIS equipment. In the Lao People's Democratic Republic, since GIS tools were critical to supporting climate vulnerability assessment and planning, after unsuccessful attempts at procuring GIS services, the focus shifted to mobilizing internal capacities at the Ministry of Agriculture and Forestry and the National Agriculture and Forestry Research Institute. In Nigeria, by contrast, even though global positioning system equipment was distributed to existing agromet stations to build a spatial database and function as a planning tool, the capacity to effectively utilize data was not developed during project implementation.

4.3 Tailoring advice, end-user training and feedback mechanisms

The nature and frequency of CIS required by end-users is bound to vary significantly by type of agricultural production and role in the value chain. This is illustrated by the Mozambique project: Mozambican cassava producers found seasonal forecasts the most helpful for determining planting dates, whereas horticulture farmers appreciated the daily weather forecast because it allowed them to make decisions on watering, spraying and harvesting. Horticulture farmers also identified a particular need for EWS for heavy rains/winds and heat waves. Similarly, Egyptian farmers requested that forecasts and associated advisories be expanded to include management recommendations for herbal and medicinal plants.

Therefore, upfront efforts to understand farmers' needs through discussions with farmers and extension agents is a critical part of CIS development and deployment, and the full range of intermediary users should be involved in these discussions. Multiple survey respondents also noted that translating climate information products and services into local languages is challenging, but is important to ensure that farmers understand the information.

Despite all 13 survey respondents, corresponding to eight ASAP projects, reporting "training of farmers on how to use and interpret climate information and advisory" (FIGURE 2) as one of the project activities, all projects identified this as an area for improvement. Similarly, all eight ASAP projects[31] confirmed that "training of agricultural extension agents or other public officials on how to use and interpret climate information and advisory" was a key project activity, but that it requires more effort. As stated elsewhere (section 2.1.b), training is necessitated by the complexity and inherent uncertainties of CIS (Hansen, 2019a), but also by the need to convey realistic expectations on what advisories can and cannot help with. Well-designed training often incorporates guidance on communication in addition to the technical aspects of CIS and their application.

Surprisingly, very few projects reported regular end-user surveys to solicit feedback and improve CIS, despite the "pilot" nature of these ASAP-supported CIS interventions (FIGURE 2). Some of this might be influenced by the channel used to disseminate CIS: for example, public radio and noticeboards at the subnational level enable a wider reach but are not always amenable to two-way communication. While the Kenya project engaged with local radio channels to disseminate advisories, it also gave farmers the opportunity to call in for clarification. However, it is unclear to what extent these interactions then systematically informed the design of CIS and the content of later advisories.

The type of communication channel requested by target users is another important aspect to understanding how best to disseminate CIS prior to investment in specific channels. Mobile apps, social media (e.g. WhatsApp and Facebook) and web platforms are not widely requested or are only an indirect communication channel with farmers (ANNEX I). SMS was the most common means of personalized communication to extension officials, farmer leaders and/or farmers – this could form the backbone of a simple feedback system in the future.

31/ In the case of the projects in Bolivia and Morocco, only one of the two survey respondents responded "yes" to this question in each country.

In Nigeria, the ASAP project benefited from a partnership with PxD (see section 2.3) that provided digital extension services in the local language through mobile phones in addition to the work of NMHSs. Such outreach was critical during the COVID-19 pandemic and in the context of insecurity (e.g. local conflicts), as well as a scaling down of the public extension system. However, CIS of the type delivered in the Lao People's Democratic Republic require in-person discussions between extension officials, agrometeorology/NMHS experts and communities. To summarize, ASAP projects deployed multiple dissemination channels targeting farmers, farmer groups, extension officials and (in a few cases) media personnel to expand CIS access, and inevitably commenced with end-user training (e.g. through farmer field schools).

4.4 Effect of CIS on farmer decision-making and associated benefits

Across IFAD projects, ASAP-supported CIS interventions were embedded in the wider context of enabling land-use planning and natural resource management, early warning to reduce losses and improve resilience, and/or climate-smart agriculture. The anecdotal evidence, from surveys and supervision reports, indicates that CIS have an important role to play in each of these applications.

CIS improve the capacity to cope with climate variability and complements extension services by encouraging the uptake of climate-resilient or climate-smart agriculture. CIS, in the context of EWS, does not just help avert losses but may also improve the bargaining power of farmers. The three-day flash flood forecasts helped Bangladeshi farmers harvest and secure crops in a timely manner, while the alternate "no-flash flood" forecast was equally helpful as it allowed for the unhurried mobilization of labour during harvest (and presumably reduced labour costs as farmers could manage their labour demand better). Even when CIS are not designed as EWS, the access to seasonal rainfall forecasts and subsequent ability to plan their crop calendar can allow farmers to avert huge losses from a looming dry spell, as was the case in Nigeria.

In the Lao People's Democratic Republic, rainfall projections enabled farmers to plan the cropping season and they were better prepared to handle climate hazards. More importantly, despite the lower than anticipated uptake of improved crop varieties and modern inputs that can reduce yield variance or improve yields and input use efficiency even under climatic stress, it is interesting to note that climate forecasts improved the popularity of crops and seeds that are climate-smart and enabled their selection by Laotian farmers. Rwandan farmers reported that knowing whether there would be long or short rains in the season allowed them to choose the appropriate variety of maize (as well as plan other inputs and management activities).

However, the benefit of CIS as an enabler for climate-smart or resilient agriculture is modulated by the cost of associated agricultural investments. In contrast to Laotian and Rwandan farmers, Mozambican farmers reported that the uptake of climate-smart horticulture technologies, including through the establishment of a local meteorological facility, was low because of the high cost of construction materials. The SAIL project in Egypt is considering hydroponic and aquaponic greenhouse pilots to complement CIS, but has concerns related to the high capital costs and long period required for capital return.

CIS support combined with improved natural resource management positively affects the resilience of smallholders and communities. In Nigeria, the sensitization of communities to climate risks and provision of seasonal rainfall forecasts improved the adoption of soil and water conservation and landscape rehabilitation techniques. When used for land-use planning and natural resource management investments, deploying CIS does not just reduce vulnerability; it can facilitate faster recovery. In Bolivia (Plurinational State of), combining traditional knowledge with GIS/satellite data and climate risk assessments to produce "talking maps" helped government agencies and communities to engage in territorial planning. For example, the maps determined the ideal locations for microdams (for water management) and other infrastructure to reduce physical vulnerability. This, in turn, reduced the cost of recovery and rebuilding after the occurrence of extreme events.

CIS that are designed as an integral part of REAS and in complementarity with IFAD investments have a higher potential for synergistic impacts. The distinct advantage of ASAP supported CIS inverventions interventions was that they were integrated with multiple complementary on- and off-farm activities. In Bangladesh, IFAD-supported roads and other infrastructure investments (e.g. a *killa*, or raised earth platform) complemented CIS – it is the combination of these interventions that had a synergistic effect on the reduction of livelihood and asset loss and facilitated recovery following flash floods. At the same time, environmental issues such as river siltation that were not addressed under this specific project increased the difficulty of both flash flood modelling and the associated risks. This merely highlights a larger point about climate change adaptation – because the nature of hazards, the sources of vulnerability and the degrees of sensitivity are so diverse, a standalone approach to a project is less likely to be effective than one that develops a more holistic approach that complements other project interventions in the same geographic or policy context.

5

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CONCLUSIONS

This stocktake of CIS provides lessons chiefly on (i) the importance of coordination between the full range of stakeholders in the design and deployment of CIS activities and investments, within countries and regions; (ii) the critical role that the training of intermediate users (i.e. the rural extension system) and end-users (i.e. farmers and farmer groups) on incorporating CIS into their decision-making plays in its effectiveness; and (iii) the importance of fully engaging with end-users, particularly socially marginalized groups and women, from the outset to ensure CIS are tailored to their needs (including, literacy). At the same time, it is clear that the physical infrastructure (both the type of equipment in use and the density of observation networks) and technical capacities in institutions responsible for CIS require strengthening.

The findings and lessons presented in this technical paper provide evidence that IFAD's ASAP investments positively influence smallholder and rural community resilience and adaptation through multiple pathways. Early warning systems enable farmers and communities to better anticipate and prepare for slow-onset and extreme weather events, and the effectiveness of such a service is mediated through synergistic investments at the farm, community or subnational level. CIS can also promote or complement the uptake of climate-smart or climate-resilient agricultural technologies and practices by functioning as a planning and decision-making tool. Community-level natural resource management and adaptation planning is often underpinned by CIS combined with traditional knowledge.

Key drivers of success identified based on ASAP experience and the global stocktake are as follows:

- effective engagement of and coordination between a wide range of stakeholders to ensure improved decision-making (e.g. in locating stations) and clarity on roles and responsibilities, data collection and timely sharing of data, and the improved production, tailoring and delivery of advisories, etc.;
- involvement of farmers and communities in the design and production of climate information products and services to fully reflect end-user needs;
- designing investment in CIS to be complementary and synergistic with other projects operating in the same geographic area; and,
- substantive investments in the capacity of NMHSs, and intermediary users and end-users of CIS.

Moving forward, there are some important gaps and challenges to address, and many opportunities to improve the scope for impact – the recommendation section focuses on the role IFAD can play in this regard.

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RECOMMENDATIONS

The following section focuses on key recommendations of relevance to IFAD based primarily on experience from the ASAP programme and the global stocktake.

Increase investments to enhance agrometeorology services: The unique value proposition of IFAD is the technical understanding of agricultural systems. The weather and climate information generated by NMHSs is used by the agrometeorological and agricultural extension system to prepare impact outlooks, forecasts and advisories on management or adaptation response options. However, agrometeorology itself is a specialized field and requires investments to, for example, pilot and refine agrometeorological models to improve forecast accuracy and better represent farming environments.

WMO and multilateral development banks as well as specialized climate funds will continue to support the expansion of the observation-related infrastructure and technical capacity that underpins CIS. Therefore, an important area of focus should be the value addition of, and requirements to produce, agrometeorological services of relevance to IFAD's target group.

Stronger collaboration between IFAD and WMO through, for example, the Alliance for Hydrometeorological Development should be explored. In this context, IFAD could strengthen collaboration with WMO and other partners to coordinate with national governments and regional stakeholders to map priority applications, and identify potential synergies and trade-offs involved in various CIS-related investment plan options.[32] Such discussions should also consider options for long-term sustainability and exit strategies in a manner that ensures the inclusivity, reliability, robustness and continued enhancement of CIS and REAS.

KEY INVESTMENT/ACTION AREAS:

- invest in developing, piloting and refining agrometeorological models and services; and
- support countries to carefully consider and develop phased-in approaches to CIS investments, including through an understanding of the synergies and trade-offs involved.

Broaden sectoral coverage and deepen outreach along the agricultural value chain: Within the agricultural sector, the target of CIS is predominantly the crop subsector. While the livestock (particularly in agropastoral contexts) and marine fishery subsectors are a target of some projects, the aquaculture and forestry[33] subsectors appear neglected outside of projects that focus on land-use planning and natural resource management or that are led by research organizations (Hossain et al., 2021).

In addition to farmers and farmer groups, the entirety of the other actors along the agricultural value chain could benefit from CIS: for example, local input suppliers – which tend to be microenterprises or small enterprises[34] – could leverage CIS not only to safeguard product

32/ For example, some countries may want to focus on rapidly scaling up more expensive AWS that can be used for a variety of location-specific applications whereas others may decide to phase-in investments – an economy that is heavily dependent on crop exports may first focus on a comprehensive agrometeorological infrastructure whereas a country that is dependent on tourism will require aviation/shipping and EWS applications. An economy in which drought is the primary climate risk may opt to advance its satellite-based drought monitoring capacity and only later consider investments in expensive equipment such as Doppler weather radars.

33/ CIS for forestry typically involve information to manage fire hazards during heatwaves. CIS for the ocean/deep-sea fisheries typically involve generic cyclone and storm warnings, and weather forecasts on tides, sea surface temperatures, winds and visibility.

34/ The World Bank defines microenterprises as having fewer than 10 employees, and with assets and annual sales lower than US$100,000. Small enterprises are defined as having fewer than 50 employees, less than US$3 million in assets and less than US$3 million in sales. Medium-sized enterprises are defined as having fewer than 300 employees, less than US$15 million in assets and less than US$15 million in sales.

stocks but also to anticipate demand (e.g. through warnings for pest or disease outbreaks related to weather or climatic factors).

Such new directions in CIS investments require systemic efforts at mapping[35] and understanding the information needs of underserved subsectors and other potential CIS users.

KEY INVESTMENT/ACTION AREAS:

- map the CIS needs of value chain actors and their preferred communication channels; and
- invest in understanding the needs regarding CIS of other agrifood subsectors.

Develop a fuller understanding of whether or not CIS are "fit for purpose": The credibility of CIS is a function of location-specificity, timeliness, accuracy of data, and the variables and models used. Its relevance and effectiveness is, however, determined by socio-economic and cultural factors such as end-users' access to CIS, their capacity to understand or interpret the information, who communicates the information, the approaches and means utilized, what information is conveyed and how often, how it fits with traditional knowledge, etc. For example, while it is clear that seasonal forecasts or short-term weather forecasts are immediately relevant to and actionable by farmers (sections 4.3 and 4.4), it is not clear if these same farmers would be persuaded when presented with climate models that recommended significant shifts in livelihoods (section 2.2). Behavioural change, particularly when it requires farmers to incorporate new information and update their farm management approaches, could be unpredictable in other ways. For example, in case of youth in rural villages who receive CIS through social media or web platforms and relay this information to farmers to encourage shifts in cultivation patterns in response to predicted climate change (as suggested by projects that propose engaging youth to address CIS dissemination gaps), trust may be undermined by implicit biases associated with age, gender, occupation or other traits of information conveyors.

At the same time, where public extension services are being scaled down or are absent and farmers live in remote or conflict-prone areas, radio, mobile phone applications and digital extension services may become the only viable alternative for the regular transmission of information and advisories. Nevertheless, participatory approaches and in-person training remain extremely important in these contexts, especially at the initial stages of design and roll-out of CIS interventions. For example, some investments and in-person interaction will be needed to mobilize and build the capacities of local communities and smallholder farmers through farmer field schools or to engage them in the assessment or evaluation of CIS (e.g. at least once a year or at the end of the main agricultural season). The private sector, whether not-for-profit or for-profit, may become the primary provider of CIS and agronomic advisories. Understanding spillover effects and how information flows to non-target farmers or non-project geographies could also help optimize coverage. The ASAP experience suggests that a multiplicity of dissemination channels should be deployed, commensurate with the local context.

Therefore, the development of CIS should be considered an iterative process, such as that used by PICSA, with user feedback constantly incorporated into the initial design and refinements. Active efforts to integrate traditional environmental knowledge should also be made because it can offer insights at a much finer spatial scale, and can improve the communicability of and trust in the more formal CIS. For example, many communities observe changes in the phenology, behaviour and movement of animals, birds, insects and plants/trees to make predictions about the weather and season.

At the end of the process, one should be able to clearly map and describe what type and frequency of climate information is likely to influence or inform end-user's planning and decision-making processes – particularly when delivered through the rural extension system – and the information gaps that remain to be addressed (see Bernardi, 2011 for a discussion of the sub-Saharan African

35/ The Bill & Melinda Gates Foundation, for instance, over 2013–2015, contracted Brand Fusion to map the location (latitude and longitude) of agricultural institutions (agrodealers, markets, farmer organizations and cooperatives, warehouses, etc.) in priority countries across Asia and Africa using GIS tools. Such public datasets, hosted on Harvard Dataverse, could (i) be used to survey, analyse and categorize CIS needs; and (ii) be an input for location-specific CIS messaging and targeting.

context). In this regard, the ASAP-supported CIS interventions have laid some of the groundwork to build on (e.g. the typology of EWS, CIS for climate-smart agriculture at the farmer level, and CIS for land-use planning and natural resource management at the village or community level). The process should also inform the content of the training modules used to train extension system officials, communities and farmers.

None of the projects described here – by IFAD or others – delve deeply into gender dimensions of CIS. Given the feminization of agriculture and continued endowment- and access-related constraints (e.g. basic or digital literacy, access to mobile phones or internet) that women face, this needs to be a special area of focus. Similarly, social groups that are socio-economically marginalized, such as indigenous peoples, require more attention, from design through to dissemination.

KEY INVESTMENT/ACTION AREAS:

- strengthen end-user engagement to better map their CIS and related REAS needs, including those of socio-economically marginalized groups and youth, and ensure the mainstreaming of participatory approaches such as PICSA and farmer field schools in the process;
- develop bundled products that integrate weather forecasts, climate risk projections, etc. with agronomic advisories;
- investigate models of collaboration between the public and private sector that incorporate their respective strengths, and are equitable and inclusive; and
- map effective communication channels (e.g. television, radio, SMS, sirens, social media and mobile apps, interactive voice response systems and call centres) for CIS delivery that reflect the structure of REAS and future directions as well as synergistic communication infrastructure and service investments by the public and private sector.

Better document farmer decision-making processes and socio-economic benefits: Project logical frameworks often report the number of farmers who receive CIS and present survey data – through evaluative reports – on how farmers utilized this information and the anecdotal evidence of the impact on their livelihoods and household income or economic resilience. However, a greater effort is needed to document the farmer decision-making/iterative learning processes involved and the economic benefits of CIS in a manner that can make a strong case for taking a long-term view and a "public goods" or "rights-based" approach to CIS investments. That is, it is important to weigh the benefits of improved planning and decision-making by farmers and other value chain stakeholders, and the costs associated with CIS development and maintenance against the costs of inaction, as this will help strengthen the rationale for sustainability well beyond project time frames.

Because CIS interventions are often embedded in the context of climate change adaptation or agricultural development projects, it can be challenging to separate out the specific socio-economic contributions of CIS in impact assessments. Regardless, a more nuanced understanding is needed of how farmers use the climate information – given decision-making in agricultural contexts is often non-linear – and their perception of benefits from access to CIS. Focusing on farmer cognition and decision-making could also inform how intermediary CIS users should convey the uncertainty inherent in the forecasts and models.

KEY INVESTMENT/ACTION AREAS:

- invest in increasing outreach and farmer engagement to better understand the benefits and costs of integrating CIS into climate-resilience or climate-adaptation programmes;
- tailor products to address unique information needs of women, other socio-economically marginalized groups and youth; and
- evaluate if interventions are well targeted and ease access constraints (of smallholder farmers, women farmers, indigenous farmers, and so on) to extension and CIS.

Communicate uncertainty in an understandable and helpful manner: Closely related to the above, it is important to understand how best to communicate uncertainties associated with CIS and the risks of maladaptation. That is, any given CIS product or service will not apply to, for example, all crops or each crop–by-season combination. Furthermore, depending on the physical infrastructure and models used, there will be temporal and spatial (related to downscaling) uncertainties associated with any given forecast.

The risk of not communicating uncertainties is that failures in forecasting (and sunk costs of farmer actions emanating from an advisory) can erode trust in CIS. Therefore, communicating uncertainty is important, provided that farmers can intuitively understand what the decision thresholds and risks of action/inaction are.

KEY INVESTMENT/ACTION AREAS:

- ensure that CIS and REAS adequately address the inherent uncertainties and limitations of such systems and communicate decision thresholds clearly to mitigate the risk of maladaptation.

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ANNEX I

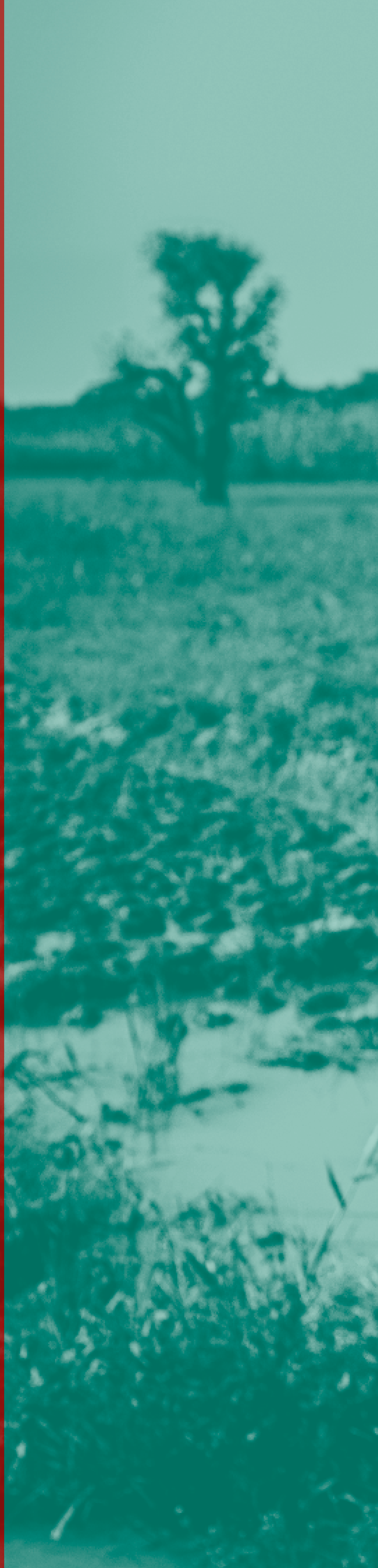
Description of ASAP projects supporting CIS interventions

ASAP COUNTRY	TARGET OF CIS INVESTMENTS	CIS STAKEHOLDERS/ USERS	ADDITIONAL INFORMATION/ LESSONS
Haor Infrastructure and Livelihood Improvement Project – Climate Adaptation and Livelihood Protection (CALIP)			
Bangladesh, completed project **EWS** *Source:* survey*, IFAD supervision report (May 2021 mission, June 2021 report)	• EWS: three-day lead time for pre-monsoon flash floods forecasting through model development and testing across 25 stations, and cross-agency collaboration • Mobile app for flash flood EWS	• Farmers – flash flood forecast allows timely harvest of rice and safe storage or prevents a rush in mobilizing labour when “no-flash flood” forecast issued	Disseminated through local administration but community-friendly system yet to be developed (disrupted by the COVID-19 pandemic)
Programa de Inclusión Económica para Familias y Comunidades Rurales en el Territorio del Estado Plurinacional de Bolivia (ACCESOS)			
Bolivia, completed project **CIS for climate-resilient land-use planning and natural resource management** *Source:* survey*, IFAD supervision report (February 2020 mission, June 2021 report)	• Climate risk maps • Territorial planning – combining traditional knowledge with GIS/climate risk maps	• Government agencies • Communities	CIS infrastructure investment planned but did not materialize
Ghana Agricultural Sector Investment Programme (GASIP)			
Ghana, ongoing project **CIS for climate-smart agriculture or livelihoods** *Source:* survey*, IFAD supervision report (December 2021 mission, March 2022 report)	• 12 AWS installed, on farmer plots, within a 40 km radius • 194 rain gauges for daily rainfall data collection • Weather updates were provided through: – Weekly text messages (survey states daily) – Social media platform	• 2,939 farmers (2,322 male; 617 female) • Extension agents/officers of district agricultural departments • Staff of agribusinesses • Media personnel	Since AWS installed on individual farmer plots but without clear guidelines on post-project ownership, operation and maintenance or documentation, follow-up actions needed to ensure future AWS operations and management
Livestock and Market Development Project – 2 (LMDP2)			
Kyrgyzstan, completed project **EWS** *Source:* survey*, IFAD supervision report (April 2021 mission, February 2022 report)	• EWS: weather/climate data collection and monitoring software and hardware upgraded for better forecasts of 11 different weather hazards • Weather/climate data disseminated through: – Web platform – Mobile app – E-mail	• 316 pasture user unions (number of individuals not captured by project) alerted to hazards. 10-day lead time to allow herders to relocate	

ASAP COUNTRY	TARGET OF CIS INVESTMENTS	CIS STAKEHOLDERS/ USERS	ADDITIONAL INFORMATION/ LESSONS
Southern Laos Food and Nutrition Security and Market Linkages Programme (FNML)			
Lao People's Democratic Republic, completed project **CIS for climate-resilient land-use planning and natural resource management** *Source:* survey*, IFAD supervision report (March 2021 mission, June 2021 report)	• Land-use planning and weather/climate scenario forecast maps to inform agricultural and forest planning in six watershed sub-catchments and 14 villages	• 14 villages received maps • Farmers and district authorities received information from the agricultural research station and technical service centers	Intended to provide mobile phones to farmers in remote areas to receive real-time weather/climate information, but this was not implemented
Rural Development Programme in the Mountain Zones – Phase I (PDRZM)			
Morocco, completed project **CIS for climate-smart agriculture or livelihoods** *Source:* survey*	• Five agrometeorological stations installed • SMS to disseminate weather/climate data (alerts, advice)	• Farmers	Public signages on climate disasters intended as a part of information and awareness-raising plan but not implemented Access to climate information remained limited and more efforts on training/dissemination needed
Pro-poor Value Chain Development in the Maputo and Limpopo Corridors Project (PROSUL)			
Mozambique, completed project **CIS for climate-smart agriculture or livelihoods** *Source:* survey*, IFAD supervision report (July 2020 mission, March 2021 report)	• Two AWS installed • Weather/climate data provided through: – WhatsApp – SMS – E-mail	• 60 agribusiness development agents • 35 extension officers • 1,050 farmers (daily SMS)	
Project for the Restoration of Livelihoods in the Northern Region (PRELNOR)			
Uganda, ongoing project **CIS for climate-smart agriculture or livelihoods** *Source:* survey*, IFAD supervision report (May 2022 mission, July 2022 report)	• 21 AWS installed • Uganda National Meteorological Authority shared AWS data with local FM radios and through SMS • SMS app – dial code to get information • Subnational noticeboards	• Farmers (local FM radio and SMS app; noticeboards at the subnational level that extension workers updated with SMS data) • Extension workers and farmer leaders (SMS)	
Wool and Mohair Promotion Project (WAMPP)			
Lesotho, ongoing project **CIS for climate-resilient land-use planning and natural resource management** *Source:* IFAD supervision report (March 2022 mission, May 2022 report)	• Five AWS installed • Rangelands mapped (20 sentinel sites – biophysical baseline) and disseminated through a website dashboard. Land degradation assessment framework training for government officials • PICSA training for farmers • Climate risk maps for vulnerability assessment	• Farmers (11,561) and community grazing associations • Government officials in the Department of Range Resources Management and the Lesotho Meteorological Services	
Programme for Rural Irrigation Development (PRIDE)			
Malawi, ongoing project **CIS for climate-smart agriculture or livelihoods** *Source:* IFAD supervision report (May 2022 mission, August 2022 report)	• Radio and SMS to disseminate climate information • Training on access to and utilization of climate services • Weather measurement equipment based on assessment • PICSA training for farmers	• Households (8,869) and lead farmers (720) • Government extension officials	Dissemination needs to improve as farmers receive climate information only through extension officials

ASAP COUNTRY	TARGET OF CIS INVESTMENTS	CIS STAKEHOLDERS/ USERS	ADDITIONAL INFORMATION/ LESSONS
Climate Change Adaptation and Agribusiness Support Programme in the Savannah Belt			
Nigeria, completed project **CIS for climate-smart agriculture or livelihoods** *Source:* IFAD supervision report (March 2022 mission, March 2022 report)	• 110 global positioning system units to agromet stations • Dissemination of seasonal rainfall predictions (i.e. start of rains, early warnings) and CIS to allow farmers to plan their crop calendar, provided through: – Mass media (radio and television) – Farmer field schools – private extension service agents – Digital – Nigerian Meteorological Agency application on mobile phones	• Farmers and community development associations (663) • The Nigerian Meteorological Agency produced downscaled information	Proof of concept – increased interest of states to collaborate with the Nigerian Meteorological Agency GIS data poorly utilized owing to lack of capacity Partnership with PxD for extension. Unclear whether or not digital extension through mobile phones and the Nigerian Meteorological Agency app were integrated
Climate-Resilient Post-Harvest and Agribusiness Support Project (PASP)			
Rwanda, completed project **CIS for climate-smart agriculture or livelihoods** *Source:* IFAD supervision report (November 2020 mission, May 2021 report)	• Calibration and maintenance of 121 weather stations in 12 districts • Climate risk assessment for selected commodity value chains • PICSA training for farmers (reading and interpreting climate data based on past trends and to interpret data on future weather and rainfall patterns. Information on crop water requirements, crop characteristics and historical climate graphs (onset, cessation, length of season, seasonal rainfall and dry spells) was provided • CIS (daily, weekly, monthly and seasonal forecasts), based on analysis of agrometeorological data, through: – Social media – SMS/toll-free numbers to Rwanda Meteorological Agency – Television and radio	• Farmers • Cooperatives • Project staff, agronomists and Rwanda Youth in Agriculture Forum members	Climate risk assessment of 12 commodity value chains undertaken but not made available (therefore not utilized) until the final project year
Sustainable Agriculture Investments and Livelihoods Project Supervision Report (SAIL)			
Egypt, ongoing project **CIS for climate-smart agriculture or livelihoods** *Source:* IFAD supervision report (May 2022 mission, June 2022 report)	• Five AWS installed and maintained by the Agricultural Research Center • SMS messages combined forecasts and advisories on irrigation and use of fertilizer and pesticides	• Lead farmers (876) and farmers (3,608)	Needs clear and feasible exit strategies to ensure the sustainability of these services. National budgets do not allow for such services, and poor smallholders cannot afford them; thus, innovative private sector engagement modalities are needed to ensure that the service does not stop immediately after the project ends
Kenya Cereal Enhancement Programme-Climate Resilient Agricultural Livelihoods (KCEP–CRAL)			
Kenya, ongoing project **CIS for climate-smart agriculture or livelihoods** *Source:* IFAD supervision report (August 2022 mission, September 2022 report)	• CIS units established to downscale forecasts (issued seasonally, monthly, weekly and daily) at the county level, with a focus on flash floods and droughts • Participatory scenario-planning workshops (47 held, 80 targeted), integrating local knowledge used to develop agromet advisories • Dissemination channels: – Radio (interactive call-in sessions) – SMS messages (weekly) – Social media, particularly WhatsApp (weekly, monthly and seasonal updates) – Churches and other social gatherings (in-person communication)	• County-level officials • All value chain actors, including farmers (crop selection and crop management). Group leaders and volunteers led some dissemination efforts	The adoption of an integrated approach for the dissemination of climate information is instrumental to smallholders' planning and decision-making. As described for this project, climate information was provided through seasonal weather forecasts associated with farming scenario planning and tailored communication outreach to last-mile users

*An online survey conducted in September 2022.



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