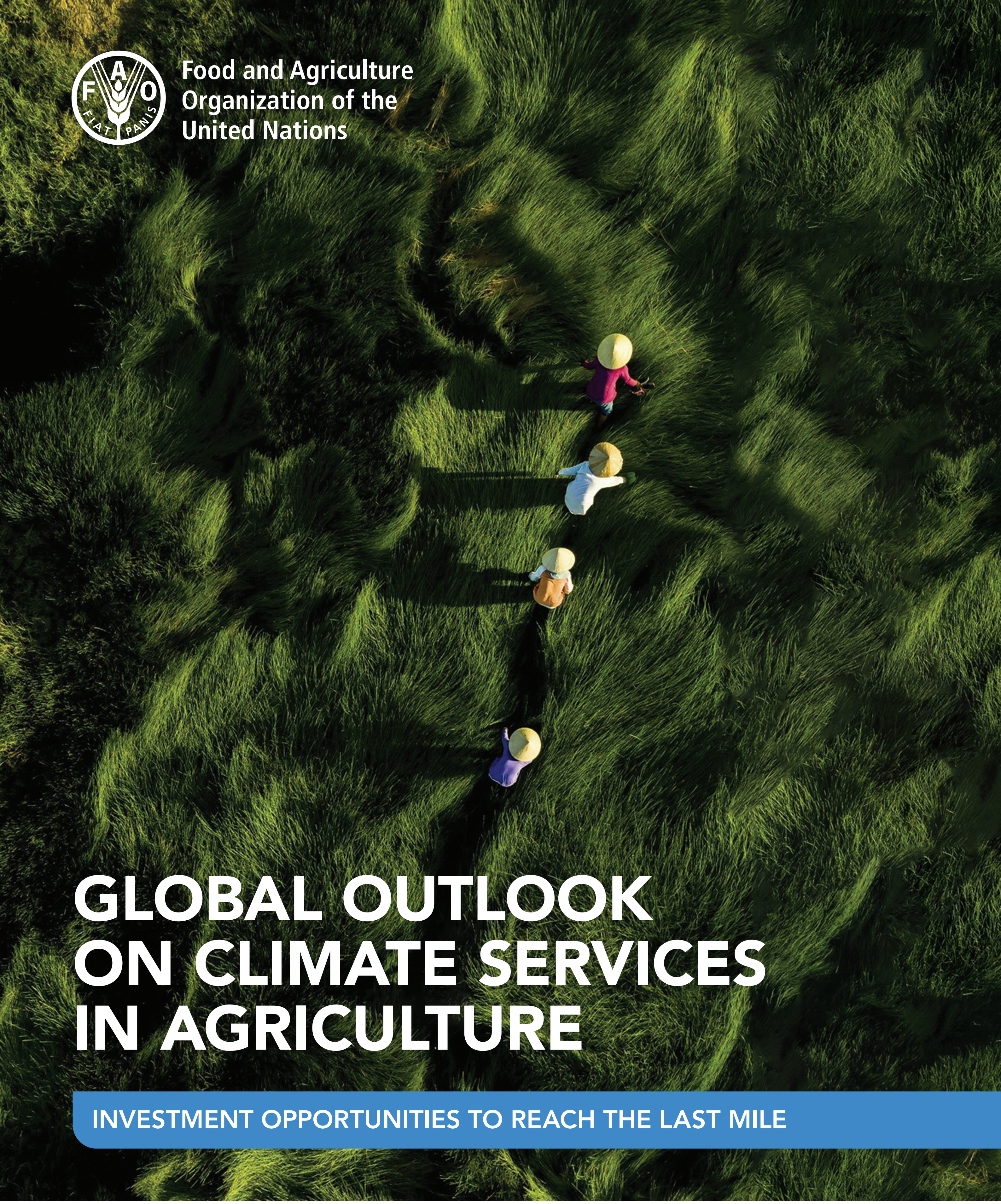
Food and Agriculture
Organization of the
United Nations



GLOBAL OUTLOOK ON CLIMATE SERVICES IN AGRICULTURE

INVESTMENT OPPORTUNITIES TO REACH THE LAST MILE

WMO

GFCS
GLOBAL FRAMEWORK
CLIMATE SERVICES

GLOBAL OUTLOOK ON CLIMATE SERVICES IN AGRICULTURE

INVESTMENT OPPORTUNITIES TO REACH THE LAST MILE

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 2021

Required citation:

FAO. 2021. *Global outlook on climate services in agriculture – Investment opportunities to reach the last mile*. Rome. https://doi.org/10.4060/cb6941en

ISBN 978-92-5-135011-9

Cover photograph ©Pixabay/Tri Le

Contents

Foreword

This first edition of the Global Outlook on Climate Services in Agriculture: Investment opportunities to bridge the last mile gap comes at a pivotal time as the world faces unprecedented climate and environmental challenges compounded by the impacts of the COVID-19 pandemic. Smallholder farmers and small-scale producers are the backbone of global food security and stewards of our natural resources, but they are among those most vulnerable to the impacts of climate change. Agri-food systems and food security face mounting threats – from weather shocks, biodiversity loss, economic slowdowns, conflict and protracted crises, to transboundary animal and plant diseases and the COVID-19 pandemic. Shifting from disaster response toward preventive and early action is fundamental to address these increasing challenges facing small-scale agricultural producers and food value chains.

Science and technology can provide much-needed innovative and evidence-based solutions for risk reduction, effective resilience policies and adaptation planning. Climate services are increasingly seen as an integral part of the digital agricultural transformation and as a means to assist and improve climate change adaptation decision-making. They have the potential to bridge silos between adaptation and disaster risk management and resilience, and information gaps among rural and urban dwellers, particularly in Least Developed Countries and Small Island Developing States.

Climate services provide agricultural users – from farmers, pastoralists and fisherfolk to policy-makers – with tailor-made information to identify hazards and make timely, risk-informed decisions.

But despite increasing evidence of the benefits and importance of climate services for the agriculture sectors, reaching smallholders and those most marginalised with key information remains a significant challenge. Beyond limitations in dissemination, climate services are often not sufficiently aimed at specific contexts and are poorly communicated to farmers and other communities. Increasing the access to climate knowledge and ensuring the equitable use by farmers and technicians, including women and youth, is an important priority.

The Decade of Action to deliver the Sustainable Development Goals by 2030 has already started. We must act now, collectively, to prevent shocks and food crises and meet the imperatives set forth by the Paris Agreement and the Sendai Framework for Disaster Risk Reduction 2015–2030. Risk-informed policy decisions that reduce loss and allocate resources to prevent emerging risks call for better-articulated and strengthened national and local capacities.

This report provides latest data on climate services, with valuable case studies that highlight opportunities and lessons learned to ensure the equitable use and provision of climate services for farmers and other users in the agricultural sectors.

Reaching the "last mile" is integral to the work of the Food and Agriculture Organization of the United Nations and the implementation of FAO's Strategy on Climate Change and FAO's Strategic Framework 2022-2031 in support of the 2030 Agenda for Sustainable Development. Climate services are part of these ambitious frameworks towards the transformation to more efficient, inclusive, resilient and sustainable agri-food systems for better production, better nutrition, a better environment, and a better life, leaving no one behind.

Maria Helena Semedo
Deputy Director-General
Food and Agriculture Organization
of the United Nations

Elena Manaenkova
Deputy Secretary-General
World Meteorological Organization

Acknowledgements

The Global outlook on climate services in agriculture: Investment opportunities to reach the last mile was prepared by the Climate Risks team from FAO under the direction and overall guidance of Lev Neretin, Environment Workstream Leader of FAO's Office of Climate Change, Biodiversity and Environment (OCB). Significant technical inputs and advice were provided by various divisions, offices and regional offices within the Organization. Special recognition goes to WMO colleagues for connecting FAO with NMHS staff across the globe, and for the FAO country and regional offices' valuable support in gathering national-level outputs. The editorial review was carried out by Gordon Ramsay and the graphic design and publication layout was by Colin Foo.

FAO coordinating lead authors: Jorge Alvar-Beltrán, Ana Heureux, Lev Neretin, Candida Villa-Lobos.

Expert reviewers: Jim Hansen (IRI Columbia University), Filipe Lucio (WMO), Veronica Grasso (WMO), Jose Camacho (WMO) and Coleen Vogel (Wits University).

Individual contributors, Africa chapter: Direction des Ressources en Eau et de la Météorologie (DREM Chad), Agence Nationale de la Météorologie (Météo-Mali), Direction Nationale de la Météorologie du Niger, Agence Nationale de la Météorologie (ANAM Burkina Faso), Nigerian Meteorological Agency (NIMET), Direction de la Météorologie Nationale Côte D'Ivoire, Direction Générale de la Météorologie Nationale du Togo, Agence Nationale de l'Aviation Civile et de la Météorologie (ANACIM Senegal), Kenya Meteorological Department (KMD), Instituto Nacional de Meteorologia de Moçambique, Sebastian Grey (WMO), Simpson Junior Pedro (FAO Mozambique), Oliver Kipkogei (IGAD), Philippe Roudier (AFD), Vieri Tarchiani (IBIMET).

Individual contributors, Near East and North Africa chapter: Sudan Meteorological Authority (SMA), Palestine Meteorological Department (PMD), Civil Aviation and Meteorology Authority (CAMA Yemen), Service Météorologique Lebanon, Direction Générale de la Météorologie (Météo-Maroc), Directorate General of Meteorology (Oman), Office National de la Météorologie (OMN Mauritanie), Theresa Wong (FAO RNE), Mohamed Abdel Monem (FAO RNE), Marc Kaeraa (FAO Palestine).

Individual contributors, Asia and the Pacific chapter: Cambodia Department of Meteorology, Thai Meteorological Department (TMD Thailand), Indonesia Meteorological, Climatological and Geophysical Agency (BMKG), Samoa Meteorological Division (SAMET), Nepal Agricultural Research Council (NARC), Beau Damen (FAO RAP), Nora Guerten (FAO OER), Lina Jihadad (FAO RAP), Catherine Jones (FAO OER), Hideki Kanamaru (FAO RAP), Leo Kris Palao (CIAT), Kim Kuang Hyung (FAO Laos), Niccolò Lombardi (FAO OER), Krishna Pant (FAO Nepal), Monica Petri (FAO Laos), Giorgia Pergolini (WFP), Maria Quilla (FAO Philippines), Ria Sen (WFP).

Individual contributors, Latin America and the Caribbean chapter: Instituto de Hidrología, Meteorología y Estudios Ambientales (IDEAM Colombia), Instituto de Meteorología e Hidrología (INAMHI Ecuador), Trinidad and Tobago Meteorological Service, Dirección Meteorológica de Chile (DMC), Civil Aviation and Barbados Meteorological Service, Dirección de Meteorología e Hidrología (DINAC Paraguay), National Meteorological Service of Belize, Cayman Islands National Weather Service (CINWS), Servicio Nacional de Meteorología e Hidrología del Perú (SENAMHI), Dirección General de Meteorología Nicaragua (INETER), Andrea Castellanos (CGIAR-CCAFS), Carlos Eduardo (CGIAR-CCAFS), Deissy Martínez (CGIAR-CCAFS), Tanja Lieuw (FAO RLC), Marion Khamis (FAO RLC).

Individual contributors, Europe and Central Asia chapter: National Meteorological Administration (NMA Romania), Hydrometeorological Authority of North Macedonia (HMS), Agency for Hydrometeorology Tajikistan (AoH), Centre of Hydrometeorological Service (Uzhydromet Uzbekistan), Jovidon Aliev (FAO Tajikistan), Fadi Karam (international consultant), Olga Buto (FAO).

Abbreviations and acronyms

African Centre for Meteorological Application and Development **(ACMAD)**

Association of Southeast Asian Nations **(ASEAN)**

Arab Centre for the Studies of Arid Zones and Dry Lands **(ACSAD)**

Bangladesh Meteorological Department **(BMD)**

Caribbean Agrometeorological Initiative **(CAMI)**

Caribbean Institute for Meteorology and Hydrology **(CIMH)**

CGIAR Research Program on Climate Change, Agriculture and Food Security **(CCAFS)**

Climate Adaptation and Mitigation Program for Aral Sea Basin project **(CAMP4ASB)**

Climate Prediction and Applications Center **(ICPAC)**

Common Agricultural Policy **(CAP)**

Consultative Group on International Agricultural Research **(CGIAR)**

Copernicus Climate Change Service **(C3S)**

Crop weather index insurance **(CWII)**

Department of Agriculture Extension **(DAE)**

Egyptian Meteorological Agency **(EMA)**

European Union **(EU)**

Farm Weather Services Section **(FWSS)**

Food and Agriculture Organization of the United Nations **(FAO)**

Global Framework for Climate Services **(GFCS)**

Global Information System Centres **(GISCs)**

International Center for Agricultural Research in the Dry Areas **(ICARDA)**

Information Communication Technologies **(ICTs)**

International Research Centre on El Niño **(CIIFEN)**

Japan Meteorological Agency **(JMA)**

Joint Research Centre **(JRC)**

Laos Climate Service for Agriculture **(LaCSA)**

Less developed countries **(LDCs)**

Local Technical Agro-Climatic Committees **(LTACs)**

Meteorological Service of Jamaica **(MSJ)**

Monitoring Agriculture ResourceS **(MARS)**

National Institute for Agronomic Research **(INRA)**

National Meteorological Hydrological Services **(NMHS)**

Nepal Agricultural Research Council **(NARC)**

Non-governmental organization **(NGO)**

Normalized difference vegetation index **(NDVI)**

Organisation for Economic Co-operation and Development **(OECD)**

Pacific Island Climate Services **(PICS)**

Pacific Meteorological Council **(PMC)**

Participatory Integrated Climate Services for Agriculture **(PICSA)**

Regional Climate Centres **(RCC)**

Regional Center on Hydrology **(RCH)**

Regional Specialized Meteorological Center **(RSMC)**

Small Islands Developing States **(SIDS)**

United Nations Framework Convention on Climate Change **(UNFCCC)**

World Food Programme **(WFP)**

World Meteorological Organization **(WMO)**

World AgroMeteorological Information Service **(WAMIS)**


©FAO/Arete/Isak Amin

Executive summary

Since 2014, conflict, economic slowdowns and extreme weather events have led to an increase in the number of undernourished and food insecure people worldwide. The COVID-19 pandemic has created new challenges for food security and resulted in wide-ranging and compounding impacts on agriculture and food systems. In 2020, the magnitude and severity of food crises worsened, and the primary drivers of acute food insecurity were protracted conflict, economic shocks, including those resulting from COVID-19, and extreme weather events. Climate change poses major risks at every step of the food value chain, from production to trade and markets.

As the world emerges from the COVID-19 pandemic and deals with other drivers of food security, poverty and inequality, the international community is calling for a climate-resilient and sustainable recovery. Underpinned by robust science and information, climate services and digital advisories provide actionable decision-making support and facilitate adaptation in the agriculture sector. Risk advisories and early warning systems – which fall under climate services – are increasingly recognized as key to prevent crises and build resilience to climate impacts that threaten present and future food systems.

However, there remain major challenges to developing effective climate services in the agriculture sector. One key challenge is bringing tailored and actionable climate information to the 'last mile' – the small-scale agricultural producers and actors in the food value chain. Scaling up efforts to build effective climate services that reach those most vulnerable is essential to safeguard millions of livelihoods and global food security.

Bridging gaps

While the benefits of overcoming the last mile barrier are clear, this global assessment points to a significant gap in investment in climate services for the last mile. Bridging this gap and scaling climate services is essential if actionable information is to be communicated in an equitable and effective manner to users, making sure no one is left behind. It has been estimated that an investment of US$7 billion is required by public and private actors to build the resilience of an additional 300 million small-scale producers through climate services by 2030 (Ferdinand *et al.*, 2021).

Digital technologies offer new opportunities to ensure that small-scale agricultural producers and value chain actors have access to information that supports informed decision-making. Information and Communication Technologies (ICTs) and platforms are invaluable to increasing the capacity to translate and interpret complex agro-meteorological information into context-specific and actionable content tailored to user needs.

The report highlights the importance of science-based action and user-driven climate services to increase resilience of vulnerable agricultural communities. It points to the significant potential of climate services in bridging the gap between climate science and policy through inclusive planning and transdisciplinary co-design and co-production processes. The role of national agricultural extension services and their mandate to provide information and advisories to the last mile play an important role in maintaining feedback mechanisms and enhancing capacity building to support the uptake of information.

The report presents the latest data on the state of climate services for agricultural users with surveys from 36 countries across all FAO regions. The report's findings have major implications for institutional frameworks to effectively target investments in resilience, preparedness and recovery.

Case studies highlight additional challenges, opportunities and lessons learned from specific interventions across the climate services provision framework. Despite many challenges, climate services have demonstrable benefits to agriculture and food security by navigating agricultural producers around unpredictable and changing weather patterns.

Major challenges to reaching the last mile

In Africa, a major constraint in the development of climate services is the limited availability of high-quality data and accessibility by agricultural users.

In Asia and Latin America, major challenges remain in tailoring the information to agricultural practices and ensuring users are providing continuous feedback to improve the production and dissemination of climate services.

In Central Asia and the Near East and North Africa, data sharing, co-production of sector-specific services and the effective communication of information to users are significant obstacles.

In Europe, more data is available and there is greater access to information, but users in the agriculture sector highlight that services are often not specific to their farming contexts or available in user-friendly formats.

Blueprint and investment roadmap

The report presents a blueprint for targeted investments to ensure that finance is effectively allocated not only to enhance the production of climate services, but also their provision, engagement and application by agricultural communities. Recommendations are made based on the identified barriers and challenges in reaching the last mile. It is fundamental that funds allocated upstream in the climate services provision framework (e.g., investments in monitoring networks, capacity development and service production) are not made in isolation and support the entire framework to the last mile.

The report concludes with an investment roadmap for funding entities, international agencies and project developers to bridge the last mile gap. Climate finance advisors should consider regional differences as well as finer scale contextual, cultural and socio-economic factors when targeting investments to reach the last mile.

Selected priority investment opportunities for project developers

- Finance sensitization activities for relevant institutions on the importance of collaboration, developing institutional arrangements and formalized agreements between NMHSs, Ministries of Agriculture, Livestock and Environment, and other stakeholders (e.g., research institutions, private institutions and NGOs).
- Invest in forecasts and early warnings with longer lead times to ensure that users have sufficient time to act before disasters occur.
- Support and finance engagement of users and different stakeholders in the development of climate services.
- Invest in tailoring products into languages, figures, animations, cartoons and other media that are easily understood and actionable by farming communities.
- Establish participatory approaches such as the Participatory Integrated Climate Services for Agriculture (PICSA) approach and Farmer Field Schools to ensure that farmers can offer feedback on the effectiveness of climate services.
- Invest in increasing the number of recipients and users of climate services by increasing outreach, private sector and investing in cooperation with mobile phone and internet operators.
- Support lowering the costs associated with service delivery and improving network coverage.

©FAO/Ismail Taxta/Arete

1 | Introduction

Problem statement

Agriculture underpins the livelihoods of over 2.5 billion people worldwide. In many LDCs, agriculture accounts for more than 25 percent of the gross domestic product (FAO, 2012). After decades of decline, the number of undernourished and food insecure people has risen since 2014 as a result of conflict, economic slowdowns and extreme weather events (FAO *et al*., 2020). The COVID-19 pandemic has introduced new vulnerabilities for food security and food systems around the world. The effect of concurrent weather shocks and major economic slowdowns and other transboundary threats, such as conflict, public health emergencies and agricultural pest and disease outbreaks, has amplified the risks to agriculture and food systems, and threatened food availability and access. According to FAO and the World Food Programme (WFP), in the first half of 2021 there were 20 hunger hotspots, and climate-related risks were important drivers for 12 of them: nine in Africa, two in Latin America and the Caribbean, and one in Asia and Pacific (FAO and WFP, 2021).

Climate change is altering the frequency, intensity and duration of extreme weather events, and is in itself a global threat to food security (Mbow *et al*., 2019; UNFCCC, 2020). The past two decades have witnessed not only the highest global temperatures on record, but also the greatest number of natural disasters (FAO, 2021). The impacts of climate change, including slow onset shifts and extreme weather events, cause significant damage and losses in climate-sensitive economic sectors and the communities that rely on them. Slow onset climatic events evolve from sustained and incremental shifts in the climate system, whose rate of impact is gradual and appears less destructive than that of extreme weather events. Examples of these gradual shifts are changes in rainfall and temperature, desertification, sea level rise and ocean acidification. Extreme weather events (e.g., heavy rains, heat waves, storms and pest and disease outbreaks, among others), on the other hand, have a rapid onset.

Over the past decade, the economic loss associated with natural disasters (meteorological, climatological, hydrological, biological and geophysical combined) has averaged roughly USD 170 billion per year, with peaks in 2011 and 2017 (CRED, 2021). In addition, in 2019, which was the second hottest year since 1851, many regions were affected by natural disasters, with losses soaring to over USD 300 billion (CRED, 2021). In LDCs and lower-middle-income countries (LMICs) climate-related disasters are responsible for 26 percent of the damage and losses in agriculture, with drought accounting for 83 percent of this damage (FAO, 2021). Between 2008 and 2018, 94 out of 109 countries that registered disaster-related agriculture loss were LDCs and LMICs, and 389 disasters affected agricultural production with losses estimated at USD 108.5 billion (FAO, 2021). More intense and frequent extreme weather events are threatening the agricultural sectors in every region of the world. The capacity to recover from these events varies according to the level of preparedness and capacity to cope with its impacts.

The role of effective climate services for adaptation in the agriculture sector

The agriculture sector is the number one priority for climate change adaptation. 93 percent of the developing countries and 44 percent of the economies in transition mention in their intended nationally determined contributions (INDCs) adaptation areas and/or actions in the context of the agriculture sector (FAO, 2016). Eighty-five percent of the countries identified climate services as a critical element for planning and decision-making for agriculture and food security (WMO, 2019).

Smallholder farmers and small-scale producers are the backbone of global food security and important stewards of land and water resources. However, they are among those most vulnerable to the impacts of climate change. Climate information for enhanced decision-making, or climate services, can increase farmers' capacity to make strategic agricultural decisions, which strengthens their adaptive capacity and builds their resilience to weather shocks. Building resilience requires awareness of climate and environmental risks and the effective and timely management of these risks. Building resilience also involves developing the capacities of individuals and communities to reduce or absorb the impact of disruptive events and make a quick recovery. A shift toward a more proactive response to expected risks, including early action and co-engagement of small-scale agricultural producers, is essential for climate resilience and transformational adaptation.

FAO estimates that a minimum of USD 105 billion is needed each year for global adaptation to climate change, and a substantial portion of this must be channelled to agriculture and food security (FAO, 2017). The importance of developing effective climate services in support of climate risk management, disaster risk reduction and adaptation in the agriculture sector is gaining increased recognition. The Global Commission on Adaptation (GCA) estimates that improved weather, climate, water observations and forecasting could lead to an annual increase in up to USD 30 billion in global productivity, and an annual reduction of up to USD 2 billion in asset losses. The benefits to cost ratios of enhanced climate services for adaptation are estimated at 10 to 1 or higher (WMO, 2015; GCA, 2019).

Climate services involve the production, translation, transfer, and use of climate knowledge and information in climate-informed decision-making and climate-smart policy and planning (Climate Services Partnership, 2021). Recent assessments of the global state on climate services indicate that over the last two decades significant advances in the monitoring, collection and analysis of climate information and forecasts have been made, mostly due to advances in technology, infrastructure and capacity building in the field (WMO, 2019). However, some of the main barriers to the effective and equitable communication of climate services are the lack of interaction between producers of climate services and the intended users, the lack of national capacity for communication, lack of user-driven tailoring of services, insufficient translation of relevant services into actionable products, and the strong digital divide across and within countries. Climate services in the agriculture sector often do not reach the 'last mile', which is understood to be the small-scale agricultural producers often living in remote areas far from public services. Along with these barriers, co-design and co-production of climate services may add other difficulties, particularly with regard to the integration of climate information into planning processes and decision-making that support the whole set of strategic and tactical decisions made at the farm level.

Key attributes for effectively delivering climate services include timeliness, accessibility, dependability, usability, credibility, responsivity, equity and integration. Information and communication technologies (ICTs) have tremendous potential to facilitate the communication of climate information and agricultural advisories to farming communities in real time. Increasing the capacity of users to interpret and use climate services is critical for mitigating the impacts of climate-related shocks and reducing vulnerability to hazards. However, access to ICTs in LDCs is lagging, with poorer communities, rural women and youth being disproportionately left behind. Limited access to information in rural communities is due to high costs and a general lack of infrastructure, ranging from intermittent supply of electricity to limited availability of ICT facilities (Trendov *et al.*, 2019). The FAO e-agriculture strategy highlights the potential benefits of using digital technologies to improve agricultural production, input supply, agricultural research and national agricultural information systems, extension and advisory services, post-harvest processes, weather information gathering and dissemination, and agricultural disaster management (FAO and ITU, 2017).

Increasing the availability and access to climate services by the most vulnerable groups is a major challenge to ensuring equitable adaptation to climate change and enhanced resilience among small-scale producers. Consequently, overcoming this challenge can have important contributions towards the achievement of several Sustainable Development Goals (SDG), particularly SDG 1: no poverty, SDG 2: zero hunger and SDG 13: climate action.

As the world recovers from the impacts of the COVID-19 pandemic and contends with the compounding drivers of food insecurity, poverty and inequality, the international community has called for investment in climate resilience, early preparedness and prevention to strengthen economies against future crises. Integrating resilience into development plans and economic recovery packages ensures that people and ecosystems are given priority as economies rebuild. Despite increased recognition of climate services as an important element in the climate adaptation agenda, there remains a gap in ensuring that climate services are user-centred and scaling up investments beyond bridging the last mile barrier. Investments in climate services that focus on the last mile as part of a range of evidence-based interventions can contribute to building resilient and sustainable food systems.

This report aims to build an in-depth understanding on how to overcome the last mile barrier and, at the same time, how to ensure effective access and utilization of climate services in the food and agricultural sectors, which include crop, livestock, fishery and forestry systems. It looks at how to strategically identify future investments to bridge the key gaps that create the last mile barrier. The report also highlights the importance of the digital transformation of agriculture as the way to continue enhancing climate services and agricultural advisories to the last mile users while increasing their climate resilience. It addresses a key aspect in the digital agricultural transformation agenda and lays out an investment roadmap in which digital technologies and private sector engagement make significant contributions to the achievement of the 2030 Agenda for Sustainable Development.

2019 State of Climate Services for Agriculture and Food Security

In 2018, the 24th Conference of the Parties (COP24) to the United Nations Framework Convention on Climate Change (UNFCCC) requested the World Meteorological Organization (WMO) through its Global Framework on Climate Services (GFCS) to regularly report on the state of climate services with the objective of "facilitating the development and application of methodologies for assessing adaptation needs" (Decision 11/CMA.1). In 2019, the WMO, in collaboration with the GFCS, the Adaptation Fund, Consultative Group on International Agricultural Research (CGIAR), the Global Environmental Facility (GEF), Green Climate Fund (GCF), Global Framework for Disaster Risk Reduction (GFDRR), World Bank Group, FAO, and the World Food Programme (WFP) launched the inaugural State of Climate Services for Agriculture and Food Security report during COP25 of the UNFCCC.

The report noted that agriculture was one of the top sectors for adaptation priorities among the Parties to the UNFCCC. It highlighted large regional discrepancies between the ability to monitor and produce climate services and identified countries' priority needs by examining capacity gaps across six components of the climate services value chain including: governance, basic systems, user interface, capacity development, provision and application of climate services, and monitoring and evaluation. The report also made six strategic recommendations:

Recommendations

1) Climate services with proven demonstrated benefits for adaptation in the agricultural sector need to be operationalized, scaled up and supported by adequate financing.
2) Systematic observations are fundamental for the provision of climate services.
3) The urgency of action is required for SIDS and Africa.
4) The last mile barrier needs to be addressed.
5) Enhanced climate science is the basis for priority climate actions.
6) Systematic monitoring and evaluation of socio-economic benefits associated with climate services.

The report also identified four areas of action needed for enhancing climate services for effective agricultural adaptation:

(a) Africa and SIDS are facing the largest capacity gaps, mostly with regards to the density of the observational network and the frequency of reported observations that are essential for generating products and data needed by the agricultural sector.

(b) Monitoring and evaluation of societal outcomes and benefits of climate services is the weakest component in the process for the effective provision of climate services in agriculture.

(c) Even when relevant agrometeorological information is produced at the national level, the information may not reach the intended users, including small-scale agricultural producers.

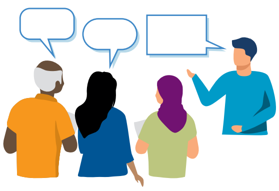
d) Increased and targeted investments are needed to ensure the provision of high-quality climate services for adaptation action in agriculture. Better investments must support the national, regional, global integrated hydrometeorological system on which all countries depend. The investments must be made in a more holistic, less piecemeal manner and targeted to overcoming the last mile barriers that impede the full use of climate information and services and consequently reduce the benefits they can deliver.

Climate services to the last mile: gaps and barriers

While interest and investment in climate services has increased considerably in recent years, the development of services tailored to user needs in the agriculture sector has lagged behind. Some of the main challenges to reach the last mile include:

Data collection and monitoring of weather and agronomic information

- Absence of real-time and accurate weather forecasts at a spatial scale relevant for agriculture.
- Lack of real-time information on crop growth and development monitoring information.



Co-production and co-design of tailored products

- Limited co-design and co-production processes in the development of information products and services, resulting often in unidirectional production chains and consequently insufficiently tailored products.
- Low engagement of agricultural producers in the co-production and use of services.
- Lack of institutional arrangements and cooperation for effective co-production of user-tailored climate services.

Communication of services to the last mile

- Insufficient infrastructure and technology for disseminating information to vulnerable agricultural users living in remote areas.
- Inequitable access to communication channels, including network coverage disparities between urban and rural areas.
- Gender gap, in which women take on equal or higher responsibilities, yet consistently have less access to productive resources, financial capital and advisory services compared to men.
- High costs associated with effectively communicating and delivering tailored agrometeorological services.
- Low affordability of ICTs and agrometeorological packages by most vulnerable agricultural users.

Participatory engagement of last mile

- Insufficient engagement and training on the use and value-added of tailored climate services through participatory approaches such as Farmer Field Schools where climate resilient practices are demonstrated, and its benefits highlighted.
- Lack of capacity of extensions services and outreach to establish trust and engagement front-end.
- Scant feedback mechanisms to enhance climate services and, therefore, increase information uptake.

Climate-informed decisions

- Climate services are often not translated into local language and/or its uptake its reduced due to high illiteracy rates.
- Use of scientific language that is not easily understandable, sometimes too technical, not tailored to farmers' needs and often not presented in user friendly formats.
- Insufficient tailoring of the agrometeorological services to farmers' needs and preferences.

Typology of climate services for agriculture

To address the diverse needs of agricultural users, climate information and products need to be tailored and translated into actionable services that support decision-making. Services at multiple time scales (daily, dekadal, seasonal, interannual) are key to on-farm decision-making (e.g., the date from fertilizer application based on short-range weather forecasts, the date for land preparation, and the crop variety choice to match with seasonal forecasts). In the agriculture sector, improvements to crops (e.g., breeding drought- and flood-tolerant varieties) or in farm management activities and practices are considered incremental adaptation. Longer-term solutions or transformational adaptation take a variety of forms that include switching crop species, shifting locations for producing certain crops and livestock, and exploring alternative livelihood strategies (Kates *et al.*, 2012; Rippke *et al.*, 2016).

Climate services, climate products, agricultural advisories and agrometeorological services have many elements in common. However, they differ in their temporal and spatial scale and degree to which they must be tailored to meet different needs and preferences. The differences will depend on the intended users and communication channels used to deliver this information. There are many typologies of climate and agrometeorological services according to the sources of data used, the time horizon of interest, the spatial scale, the level of processing of the data, the purpose for their use, and the agricultural system of interest (Figures 1 to 4). Because everyone experiences weather on a daily basis, shorter time-scale weather phenomena are more commonly understood. Weather information is often used for decision-making throughout the agricultural calendar, and its short lead time must be communicated quickly. Didactic and frequent repetition of the information helps agricultural users to quickly understand weather forecasts, assess their accuracy and act appropriately. Climate information (e.g., seasonal forecasts and historical data analyses) is more challenging to understand because the information covers longer time scales and is inherently probabilistic. Because climate information is used at most a few times a year, decision makers must depend on statistical descriptions instead of personal experience to assess its accuracy and need to be trained to interpret and act appropriately on the information. Weather and climate information therefore need different communication strategies and means for provisioning the information.

Mobile phone and broadcast media channels are a good match for weather information, which is released frequently and is time sensitive. On the other hand, participatory processes are conducive for the learning and support that are needed to understand and act appropriately on the longer time horizons of climate information (Vaughan *et al.*, 2019; Marx *et al.*, 2007).

Definitions

Climate data

Historical and real-time climate observations along with direct model outputs covering historical and future periods. Information about how these observations and model outputs are generated (metadata) should accompany all climate data (GFCS, 2020).

Climate product

A derived synthesis of climate data that combines climate data with climate knowledge to add value (e.g., weather forecasts) (WMO, 2015).

Climate services

Services that provide decision makers in climate-sensitive sectors with better information to help society to adapt to climate variability and change. It requires appropriate engagement along with an effective access mechanism that responds to specific user needs and preferences (e.g., optimal sowing date based on weather forecasts) (GFCS, 2020).

Agrometeorological services

Uses knowledge on atmospheric sciences (weather and climate), soils (physical and chemical properties), the ocean (e.g., sea surface temperature), vegetation (normalized difference vegetation index – NDVI) and crops (e.g., historical yields) from recent decades and couples it with available weather and climate forecasts to offer guidance (e.g., the timing of agricultural management strategies during the growing season) (Stigter, 2011).

Agricultural advisory services

Involve the entire ensemble of organizations that enables farmers to co-produce farm-level solutions by establishing service relationships with advisers so as to produce knowledge and enhance skills (Labarthe *et al.*, 2013)

Figures 1 to 4 illustrate how climate products and agricultural advisories differ depending on the spatial and temporal scale of the data used, and how the information can be interpreted to produce strictly climate services as well as sector-specific advisories. The temporal and spatial scale of climate products and agricultural advisories is approximate.

Figure 1

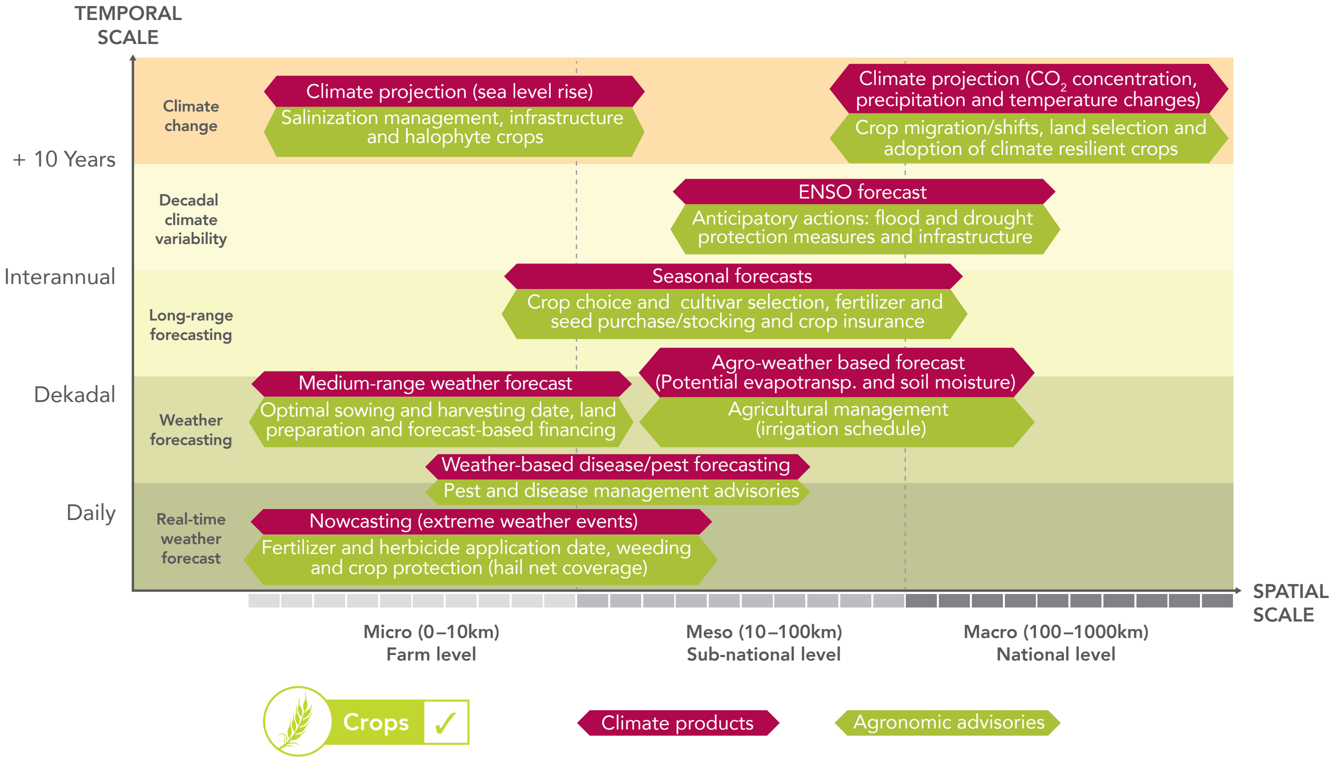


Figure 2

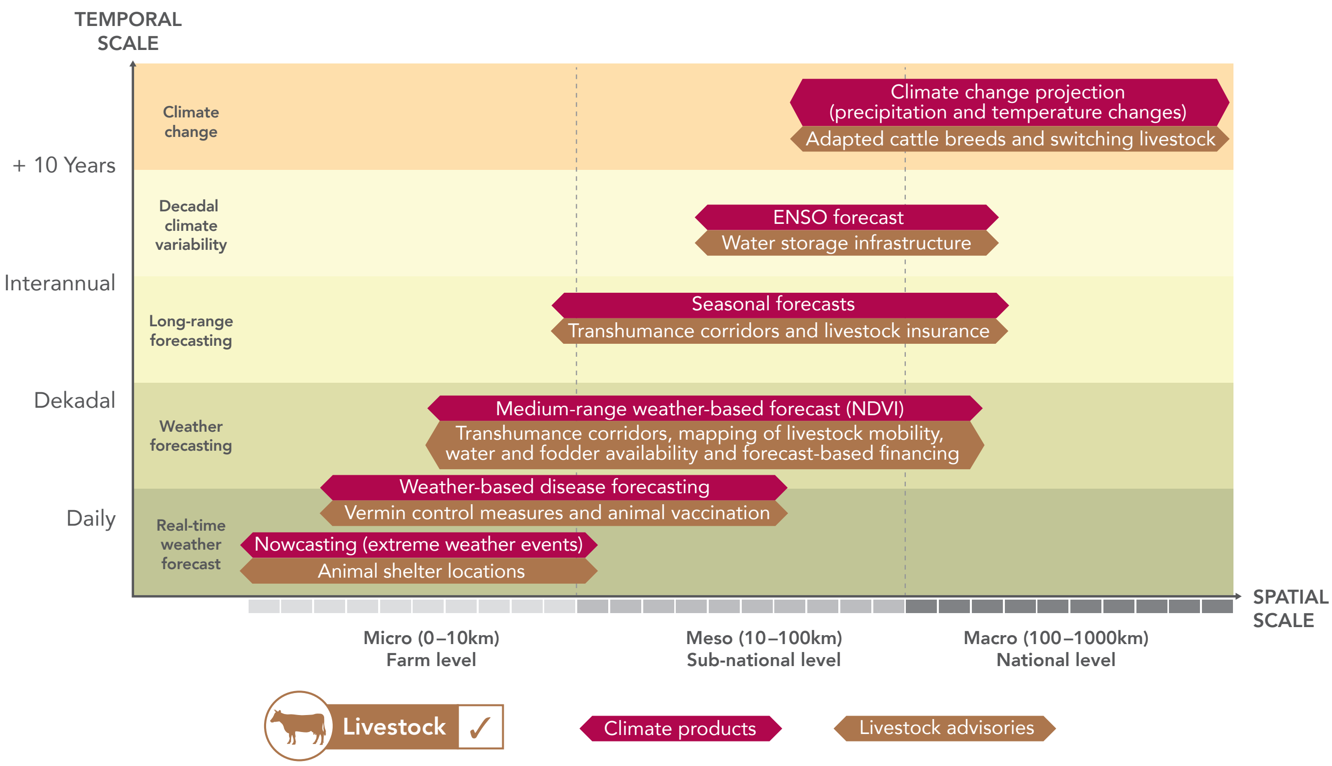


Figure 3

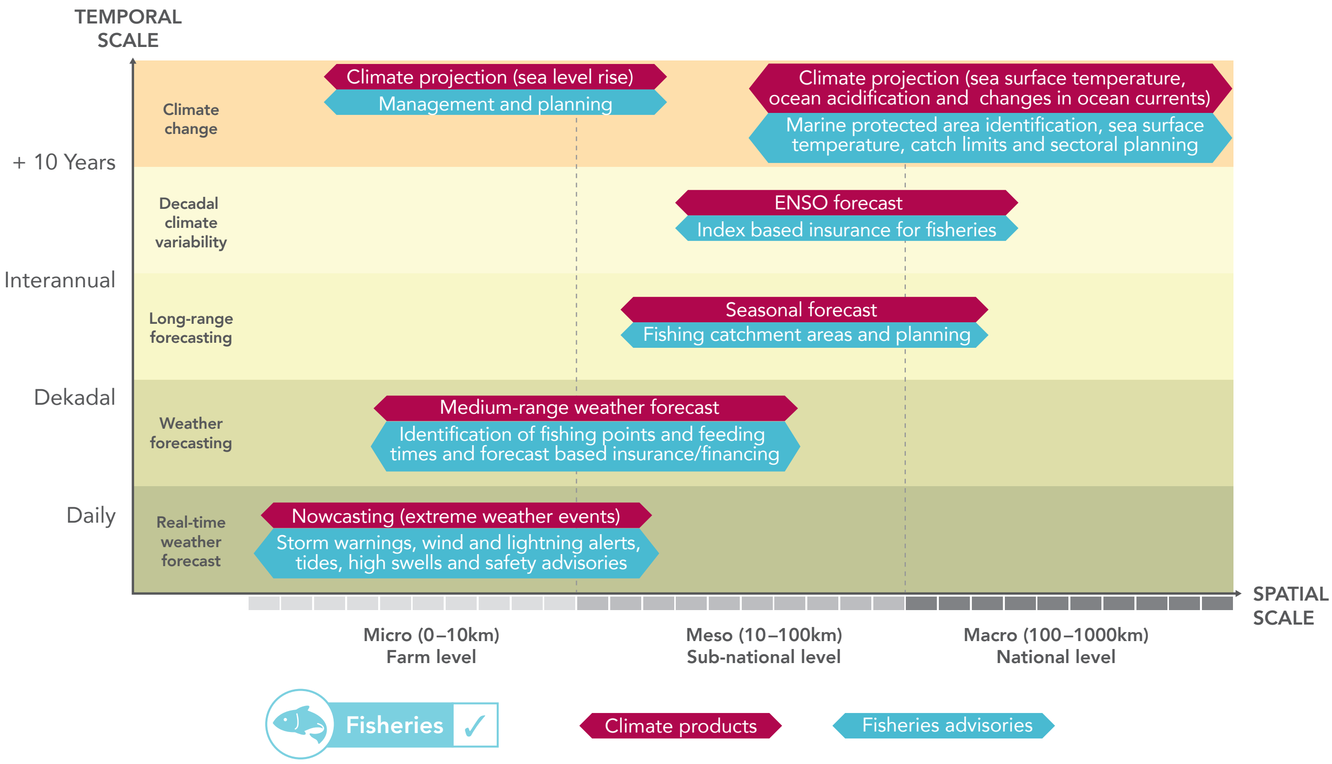
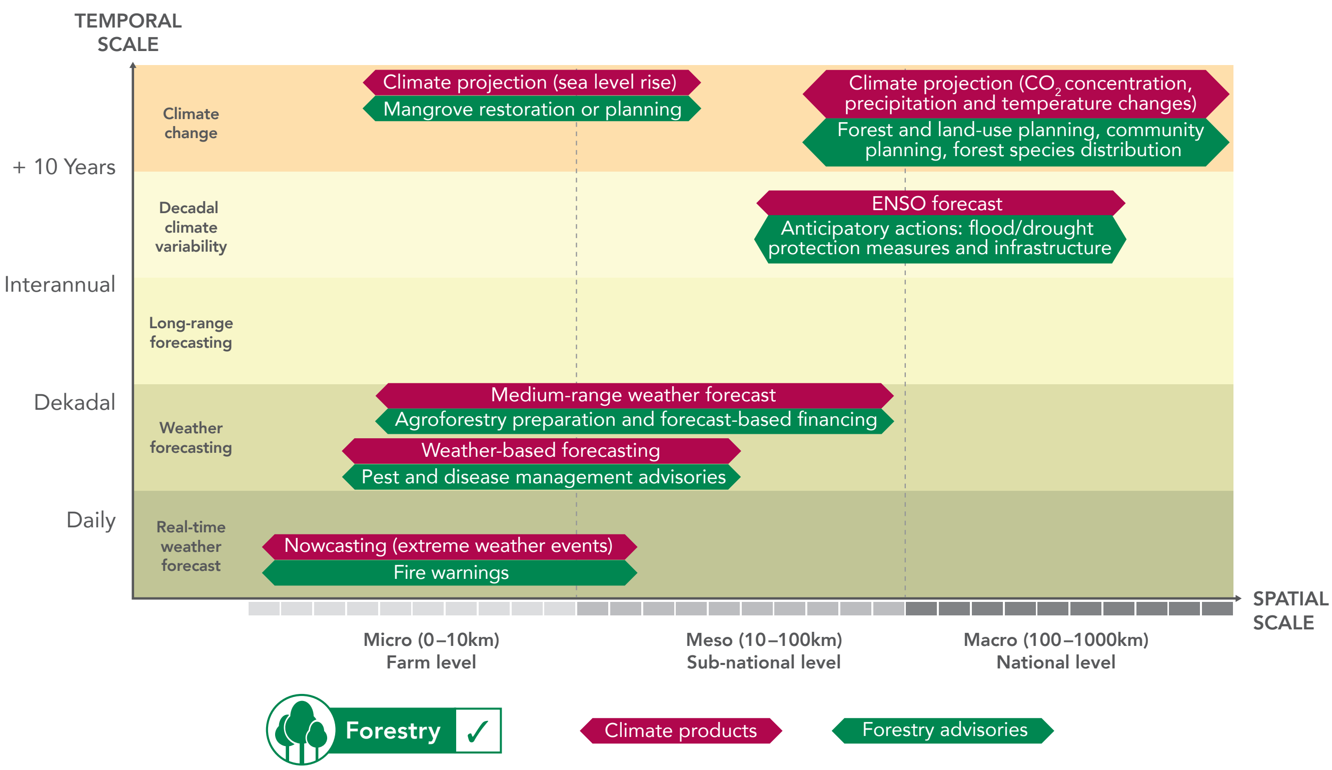


Figure 4



©FAO/Arete/Ismail Taxta

2 | Climate services framework for reaching the last mile

Framework for effective climate services provision

The schematic representation of climate services, which includes the production, translation, transfer, and use of climate knowledge and information will differ greatly depending on the country, agricultural sector and local context. The framework for effective climate service provision has been described as a 'value chain' (WMO, 2015) that links the production and delivery of services to users with the outcomes and the added value that results from the decisions made by the users. The framework put forward in Figure 5 highlights key steps for the effective provision of climate services, which are fulfilled by various actors depending on the local context. It is important to highlight that gaps at any stage of the framework will jeopardize efforts to develop services that are effectively delivered and applied by intended users. Every aspect of the climate services framework must be strengthened to ensure that the last mile barrier is overcome, and that information can lead to strategic agricultural decision-making.

Developing effective climate services for agricultural users is an interdisciplinary process that involves many steps and actors. The general process should be tailored to the local context and to the needs and preferences of the intended users. One major challenge is the communication and uptake of climate-informed advisories and early warnings. To become a service, a climate product needs to be deemed useful for the user. This requires appropriately testing and validating the services to ensure that they enhance decision-making. Addressing the wide variety of user needs is beyond the capacity of any single organization. It calls for major collaboration between the public and private sector, research institutions and agricultural communities. For instance, social scientists can play a key role in identifying the incentives and barriers to the uptake of information and the best communication channels for delivering information, while the private sector has the financial leverage to address any capacity gaps in public institutions or extension services.

The needs of the intended users and objectives of the proposed climate product should be clearly defined at the outset, before any investment or intervention is initiated. Based on this information, data collection, monitoring and data sharing carried out through national task forces are essential to ensure that the services are informed by the best available and most relevant data sets. The participation of agricultural communities in the early stages is necessary to co-design and co-develop data products that can be then interpreted and tailored to their needs.

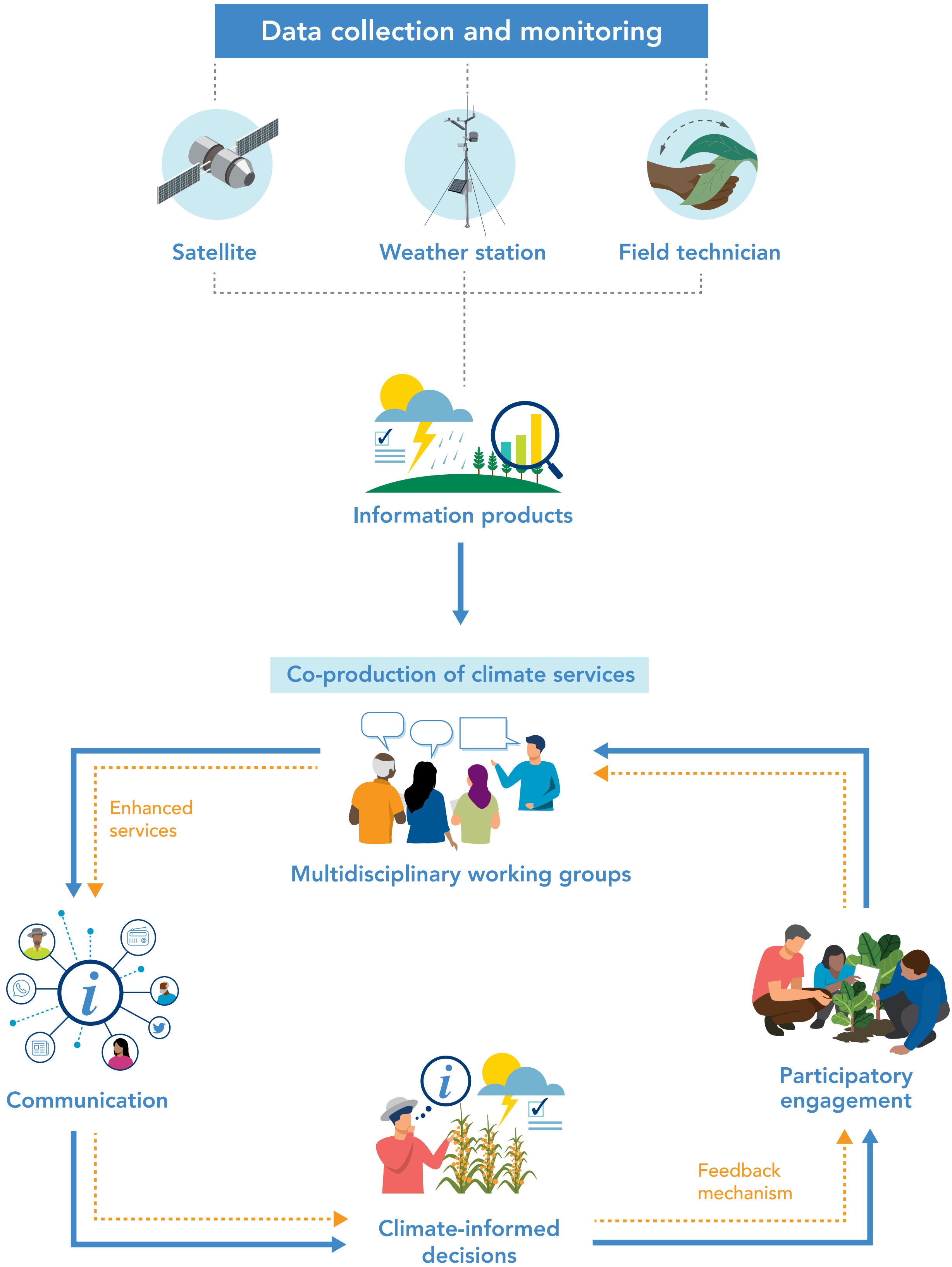
Tailored products require appropriate communication channels to effectively transmit the information and ensure uptake by the intended users. Digital technologies offer new opportunities to ensure that users have access to information to improve decision-making. ICTs have a tremendous potential to facilitate the timely communication of services to farming and rural communities. The next period of growth in mobile connections is expected to be focused on rural communities. Restrictions during the COVID-19 pandemic have further highlighted the need for innovative communication strategies. Nearly 70 percent of households among the poorest 20 percent have access to mobile phones (World Bank, 2016a). Hence, understanding the potential for enhanced access to information is essential to ensure equitable and widespread access to climate services.

The establishment or strengthening of functional agricultural extension services also play an integral role in ensuring that climate services are communicated to agricultural communities. Training and engaging extension personnel to deliver climate services have proven to be very effective for reaching last mile users and increasing information uptake (Vaughan *et al.*, 2019).

Figure 5 highlights the importance of participatory engagement and feedback mechanisms. Meaningful feedback mechanisms among actors and users (indicated by orange dotted lines) are necessary in the co-production process to ensure that users' preferences, experiences and needs are taken into account, and that climate services are continuously tailored and improved. Key challenges for increasing the uptake of climate services that are often neglected in the co-design, co-development and tailoring of climate services, are linked to cultural factors, education and literacy, and the financial means for purchasing services.

Figure 5 progresses from a linear representation of climate services to a more circular framework that is achieved through a series of feedback mechanisms that systematically integrate the producers and users of information in the co-design and co-production of climate services. While each link in the climate services framework can add value to services, it is important to determine the benefits of services once the users have responded to the information provided and validated. Ultimately, the value of climate services is based on how potential users receive and interpret the information, and how that information influences their decisions and actions.

Figure 5. Framework for effective climate services provision



How to read this report

This report identifies major gaps and investment needs that must be addressed to ensure that climate services in the agriculture sector reach the last mile. The chapters are organized by FAO regions: Africa; Near East and North Africa; Asia and the Pacific; Europe and Central Asia; and Latin America and the Caribbean. Each chapter follows the main steps in the framework for effective climate services provision, outlining the regional status of climate services and their communication to the last mile. The regional outlooks are accompanied by regional and national case studies with comprehensive information on how countries are overcoming the last mile barrier, as well as survey results. Finally, each chapter provides an overview of key investment opportunities and major challenges and recommendations for each step of the climate services framework.

Data collection and monitoring of weather and agronomic information

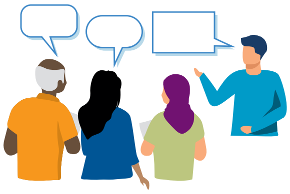
Data collection and monitoring of meteorological and agricultural information requires access to a diverse and dense meteorological observation network. Thanks to substantial progress in research and development, remote sensing technologies and earth observation systems systematically monitor ocean, atmosphere and land, and collect information of site-specific atmospheric conditions (e.g., precipitation and temperature), soils (e.g., soil water content), biological conditions (e.g., pest and diseases) and plant growth (e.g., phenological phases, NDVI, leaf wetness, and canopy cover).

Following the data collection phase, the information is processed and interpreted using tools, models and additional datasets to produce different types of forecasts (short-, medium- and long-term) and sector-specific products. For this purpose, capacity development for the use of tools, models, and methods for the assessment and interpretation of data is needed. Additional efforts in capacity building should assist in reducing the so-called 'space divide' that exists between those countries with significant development in their use of space, and those without.

Co-production and co-design of tailored services

The co-production of climate services has been increasingly recognized as an effective and important principle. It is particularly valuable for producing information that is relevant to users and building trust and ownership over the information. This step requires the participation of experts from many disciplines (e.g., climatologists, agrometeorologists, agronomists, plant pathologists, hydrologists, social scientists). The nature of the expertise will vary according to the specific needs of the users and the agrometeorological advisories being produced. The users or clients of these services become critical when preparing tailored products, as they ensure that the development is informed by their needs and preferences. Ideally, national working groups are created to ensure that the services are co-produced and developed with inputs from all relevant experts

Co-production and co-design of tailored services *(continued)*



and stakeholders, including social scientists. Co-production of climate services also involves cooperation among national stakeholders, agricultural ministries, meteorological services, non-governmental organizations (NGOs) and community-based organizations. Co-production serves to manage expectations and reach agreements on what is feasible or practically possible to achieve and to enhance ownership and uptake of the information.

Communication of services to the last mile

The engagement of farmers and other users in the production of services is needed to identify the predominant and preferred communication channels for accessing the information (e.g., agricultural extension services, radio, SMS, bulletins and digital applications). The effective mapping of communication channels is essential for understanding the local context and for effectively communicating information to agricultural communities. While digital and technological means are playing an increasing role in ensuring access to information in rural communities, it is also important to highlight the role of national agricultural extension services and their mandate to provide information and advisories to the last mile.

Customer satisfaction surveys, call services, and workshops can serve to gain an understanding of the target group's current and desired communication channels. This is particularly important when social disparities, which can inhibit the effectiveness of equitable communication, exist. Local assessments are essential to build an understanding of the social conditions and needs of vulnerable populations.

Participatory engagement for climate-informed actions

To guarantee the sustainability of climate services over time, extension services must respond to the needs of agricultural communities by establishing feedback mechanisms for the continuous evaluation and improvement of products and services. The two-way learning process between producers and users is a crucial step in bridging the last mile barrier. Very often multiple interactions between producers and users are required to arrive at a desirable product. This highlights once again the role of interface mechanisms that can facilitate the effective co-design and co-development services. Participatory engagement at the community level has proven necessary for maximizing last mile uptake and ensuring that services are relevant and understood. Participatory capacity building approaches include FAO Farmer Field Schools, WMO roving seminars, and the Participatory Integrated Climate Services for Agriculture (PICSA) approach of the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), among others.

©FAO/Arete/Ismail Taxta

Data and methods

This report has gathered information at the institutional and farm level to acquire a better understanding of the existing agrometeorological services and communication channels used to deliver information to the last mile, and to evaluate the needs and preferences of the last mile. One survey was directed to National Meteorological and Hydrological Services (NMHS), gathering responses from 36 NMHSs from the five FAO regions: ten from Africa, seven from Near East and North Africa, five from Asia and the Pacific, four from Europe and Central Asia, and ten from Latin America and the Caribbean. To ensure that the questions were fully understood, the surveys were provided in English, Arabic, French, and Spanish.

The surveys consisted of seven closed-ended questions, including questions on the: (i) availability of early warning systems for the agriculture sector, (ii) access to early warning systems by rural communities, (iii) communication channels used to deliver climate services, (iv) coverage of communication channels; (v) institutions involved in the provision of climate services; (vi) availability of tailored climate services; (vi) types of agrometeorological services and frequency of service delivery in each agricultural system (crops, livestock, fisheries and forestry).

Although this report planned to include surveys from agricultural communities and users in at least one country per FAO region, COVID-19 mobility restrictions hampered data collection and the ability to carry out face-to-face surveys. Nevertheless, two last mile or farmer surveys were conducted through a computer-assisted telephone system in Nepal and Tajikistan. The surveys were translated into Tajik and Nepalese. The respondents were mostly farmers and pastoralists with a smaller number working in the fishery and forestry sectors. In total, 840 responses were obtained from Nepal, and 302 from Tajikistan.

To compensate for the lack of last mile surveys, case studies were added to provide a more comprehensive understanding on how last mile barriers were being overcome by national institutions, United Nations agencies, the private sector and academia. The following case studies were selected to align with specific stages of the climate services provision provision.

Data collection and monitoring

- Tailored agrometeorological services in West Africa
- A data sharing and monitoring platform in Cambodia
- Institutional arrangements and agreements for strengthening climate services in Tajikistan
- Promoting partnerships for an enabling environment to link agrometeorological data with input services in Palestine

Co-production of tailored services

- Co-production of commodity tailored climate services in Kenya
- Proactive instead of reactive: moving towards an anticipatory approach for drought in the Philippines
- Co-production of tailored disease forecast in North Macedonia
- Local technical agroclimatic committees (LTAC) in Latin America

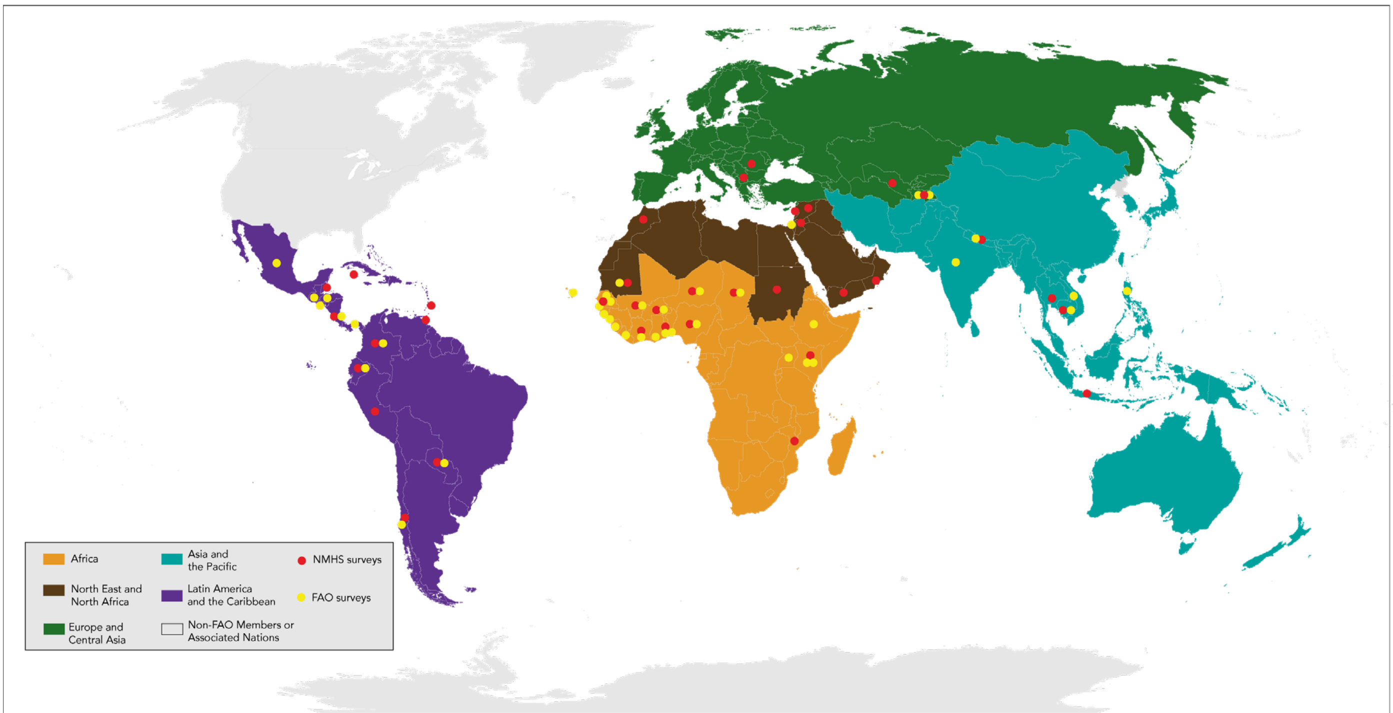
Communication of services to the last mile

- Communication and co-production of tailored climate services in Senegal
- Warnings for fisherfolk in India – GPS-Aided GeoAugmented Navigation Satellite System (GAGAN)
- Phone applications for sustainable water management in Egypt and Lebanon

Participatory engagement and climate-informed actions

- The Agriculture Climate Resilience Enhancement Initiative (ACREI) in Eastern Africa
- Perspective from farmers and pastoralists: last mile needs and the uptake of agrometeorological information in Nepal
- Strengthening Agroclimatic Monitoring and Information Systems (SAMIS) in the Lao People's Democratic Republic
- Perspectives from farmers and pastoralists: last mile needs and uptake of agrometeorological information in Tajikistan

Figure 6. Overview map of case studies and surveys conducted per region



*The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations. * Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the Parties. ** Final boundary between the Republic of Sudan and the Republic of South Sudan has not yet been determined.*

3 Regional outlooks

- Africa
- Near East and North Africa
- Asia and the Pacific
- Europe and Central Asia
- Latin America and the Caribbean

©FAO/ Arete Ismail Taxta

Africa

The African continent, which encompasses a wide range of eco-climatic regions, is exposed to many climatological, hydrological and meteorological hazards, as well as other weather-related hazards (e.g., pests and diseases).

The Sahel region is prone to extreme heat and high rainfall variability and is experiencing more frequent and prolonged droughts and dry spells during the rainy season whose onset and offset are constantly shifting. In Africa, over the past 50 years, droughts have accounted for 95 percent of the deaths related to climatological hazards (WMO, 2020). Coastal regions along South-eastern Africa are prone to tropical cyclones and intense flooding. High sea levels are already aggravating the impact of storm swells along the coastline. Changes in climate conditions and extremes are also altering the frequency and severity of pest and disease outbreaks in the region. Transboundary threats to animal and plant health (e.g., desert locust outbreaks) are affecting food production and compromising food security across the continent. The impacts of all these phenomena, which continue to increase in frequency and intensity, are high and are mostly felt in climate-sensitive sectors, such as agriculture. Because of their high reliance on climatic conditions, Africa's food production systems are among the world's most vulnerable to the impacts of climate change. Persistent poverty limits the capacity of agriculture producers to make adaptations to their livelihoods.

Data collection and monitoring

Africa, particularly the Sahel and the Great Horn of Africa, is highly vulnerable to the impacts of climate change because of the combination of high exposure to climatic hazards and low adaptive capacity. Climate and agrometeorological services are therefore particularly important. However, according to the WMO Integrated Global Observing System (WIGOS) repository on surface-based observing stations and platforms, there is a scarce meteorological observational network across the continent, particularly along the Sahel region, central and south-western Africa. Basic systems, including observing networks and data, as well as data management, are lagging significantly behind the global average. Africa has the highest percentage of non-reporting stations (stations that do not supply timely data to global modelling centres). Needs persist even for basic meteorological variables, such as temperature, pressure and precipitation (WMO, 2019). The data gaps in large parts of the continent, together with incomplete datasets, inadequate arrangement of the information, and lack of communication within countries and regions have created multiple deficiencies. There is a low capacity for the generation, provision, and contextualization of information derived from climate databases, research, and modelling. As a result, the number of climate services that are produced and disseminated to users remains insufficient. Overall, the lack of observational data significantly limits the quality of information used by governments and all stakeholders. This information serves as the basis for important decisions, such as those related to the climate services value chain to support agricultural production (WMO, 2019).

Some of the greatest efforts to make up for the previous are being orchestrated by WMO, together with the World Bank and Global Framework for Disaster Risk Reduction (GFDRR). A total investment of USD 600 million (2015-2023) is envisaged for the modernization of meteorological and hydrological services and systems in 15 sub-Saharan countries. These efforts are being mainstreamed by the Africa Hydromet Program, which is focused on improving weather, water and climate services to effectively ensure that regions, countries and communities can build climate and disaster resilience (World Bank, 2021). Other initiatives are supporting the development of new weather stations across the continent. For instance, regional programmes such as the Trans-African Hydrometeorological Observatory (TAHMO) are working to develop a vast network of 20 000 weather stations across Africa and strengthen hydrometeorological monitoring and climate resilience in agriculture (TAHMO, 2020).

In addition to investing in observing networks, viable methods for reconstructing historical records now make it feasible for an NMHS to derive historical information and forecast climate information at a spatial resolution that is useful for local decision-making. Data merging combines quality-controlled station data with proxy data, such as satellite estimates and climate model reanalysis products. The combined gridded datasets can be used to generate localized historical and forecast climate information tailored to user needs. The International Research Institute for Climate and Society (IRI) Enhancing National Climate Services (ENACTS) initiative has demonstrated the value of national merged data for climate services (Dinku *et al.*, 2017). The initiative has supported the NMHSs of 10 African countries (Ethiopia, Ghana, Guinea, Kenya, Madagascar, Mali, Rwanda, Senegal, the United Republic of Tanzania, and Zambia) to fill data gaps by merging quality-controlled station records with satellite proxy data and produce long-term high-resolution gridded historical data sets. The NMHS use this gridded data to generate suites of derived historical, monitored and in some cases forecast information. All the information is made available in the form of maps and analyses for grid cells or administrative boundaries that have been selected by the user through an interactive online 'map room'. Several countries (Ethiopia, Madagascar, Mali, Rwanda and Senegal) and two regional climate centres, the Intergovernmental Authority on Development (IGAD) Climate Prediction and Applications Centre (ICPAC) and AGRHYMET, have expanded their online 'map rooms' to include a range of agriculture-relevant products based on daily rainfall data analyses.

Co-production of tailored services

The large majority of Africa's NMHS have only explored to a limited extent the economic value and benefit of using the information provided by national agrometeorological bulletins (ACMAD, 2020). Nevertheless, at a regional level, several institutions and programmes are supporting the delivery of co-produced tailored agrometeorological services to farmers. For instance, the African Centre for Meteorological Application and Development (ACMAD) has made substantial progress in providing weather and climate information to various users in the fields of agriculture, water resources, health, public safety, and renewable energy. Similarly, IGAD in the Horn of Africa and ICPAC contribute to monitoring the weather (ICPAC, 2021). ICPAC offers services for early warning and strategic guidance on how to mitigate the impacts of extreme weather events in numerous fields, including agriculture and food security, water resources, energy, and health. In Western Africa, the Permanent Interstate Committee for Drought Control in the Sahel (CILSS), through the AGRHYMET regional centre, is responsible for delivering seasonal agricultural-hydrological-climatic bulletins and supports decision makers with information on the progress and perspectives for the agricultural and pastoral season (CILSS, 2020). Additionally, the Southern African Development Community Climate Services Centre (SADC-CSC) provides operational, regional services for monitoring and predicting climate extremes. SADC-CSC develops and disseminates meteorological, environmental, and hydro-meteorological products and ensures that its 10 member states are better prepared for climate risks.

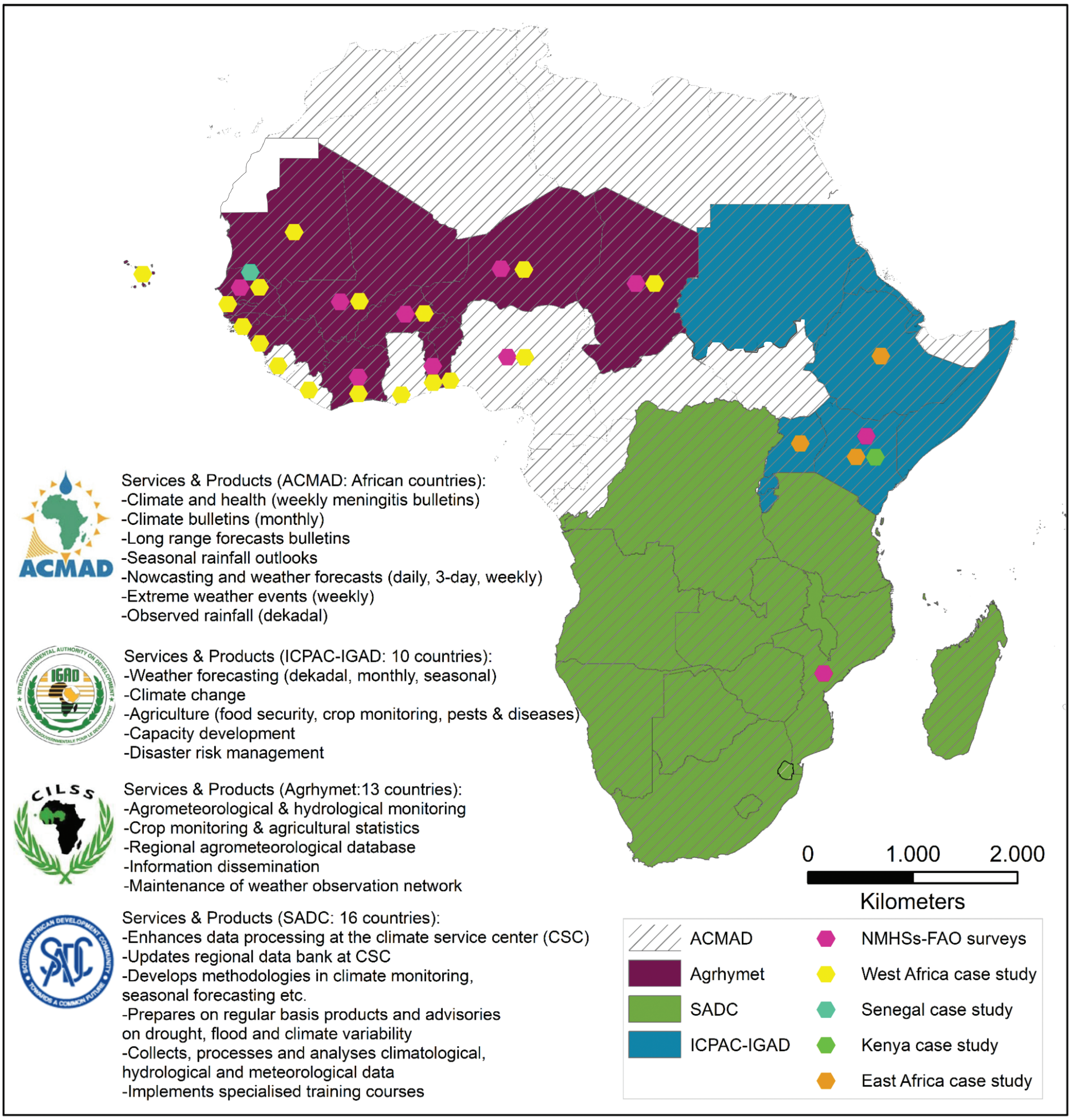
In several African countries, NMHSs, NGOs, community-based and agricultural associations are among the institutions that are actively collaborating in the co-production and co-design of climate services. Through this collaboration, participatory approaches for the co-production of information, strengthened collaboration, and equal two-way exchange of ideas between producers and users have been successfully demonstrated (Bacci *et al.*, 2020; Vincent *et al.*, 2018). This collaborative process highlights the engagement of users along the climate services production process, beyond increasing trust and credibility towards NMHSs **(see case study, *Co-production of commodity tailored climate services in Kenya*)**.

Communication of services to the last mile

Agrometeorological information, advisories and services are an integral part of agricultural decision-making and are needed to enhace agricultural productivity and achieve food security. Communication is particularly critical in Africa because it requires intensive training of extension agents, the share of rural population is high and operational agrometeorology must be carried out in the context of users' livelihood systems.

Experience in Eastern Africa, particularly in Ethiopia and Kenya, has shown that farmers often prefer indigenous or traditional forecasting knowledge over modern forecasts (Radeny *et al.*, 2019). Modern forecasting often uses scientific language, and services and products that are not easily understood by famers nor tailored to their needs. In farming communities, indigenous knowledge systems that are compatible with local culture are often more trusted. Other reasons for the preference of indigenous or traditional forecasting knowledge over modern forecasts include the simplicity of indigenous knowledge forecasts, their familiarity, their ease of understanding, and the inbuilt nature of indigenous knowledge forecasts compared to the complex, and sometimes difficult to understand, scientific forecasts. However, some studies suggest that increasing climate variability and climate change is likely to affect the accuracy and reliability of indigenous knowledge forecasting, underlying the need of an integrated approach in weather forecasting (Kalanda-Joshua *et al.*, 2011; Risiro *et al.*, 2012). The co-production and co-design process is therefore, important to deliver climate services in a language that is easily understood by rural communities. This will ensure a higher uptake of climate services and instil a sense of ownership by communities. In this sense, extension agents, which include agronomists and social scientists, play a critical role, as they are the trusted information intermediaries between producers of information on climate, weather, agriculture, and the last mile users.

Figure 7. Main regional institutions delivering agrometeorological services in Africa.



Note: NMHSs responses for Mauritania, Sudan and Morocco are included in the Near East and North Africa regional outlook.

The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.
** Final boundary between the Republic of Sudan and the Republic of South Sudan has not yet been determined.*

Western Sahel

In Niger, agrometeorological indices (e.g., cumulative dekadal rainfall, number of rainy days, maximum number of consecutive dry days, and number of rainy days above 20 mm) calculated by forecasts and issued by the Global Forecast System have been tested with users using a research-based methodology that identifies the advantages and gaps of services provided by text messages received on smartphones (Bacci *et al.*, 2020). The overall evaluation shows that the process of production and communication is sustainable and adapted to specific contexts. Additionally, users are willing to embrace dekadal weather forecasts, particularly for weather extremes (e.g., dry spells) that could have an imminent impact on crops. In Nigeria, studies show that rural women farmers are aware of the existing climate and agricultural information, but they are not always available in specific areas. The main sources of information are community group meetings and the mass media (radio and television) (Aliyu *et al.*, 2019).

In Senegal, a field study conducted in 30 districts has evaluated the engagement of producers and local authorities in the adoption of climate services (Ouedrago *et al.*, 2018). The results of this study show that 11 out of 13 communication channels already exist, and that 16 out of 27 types of climate services for different agricultural systems (farmers, livestock, and fisheries) have been developed. However, the lack of engagement of the private sector in the production chain of climate services, delivery, and training, coupled with the limited subscription to the weather-based index insurance by users is seen as a major constraint for scaling up climate services across the country **(see case study, *Communication and co-production of tailored climate services in Senegal*)**. Other studies in Senegal have evaluated the role of climate forecasts in driving decision-making at the farm level (e.g., decisions on whether to sow earlier to benefit from rain or delay sowing to avoid drought) (Roudier *et al.*, 2014). The previous study concludes that forecasts must be appropriately targeted to identify the best comparative advantage; packaged in ways that include various kinds of information at different scales and across multiple sectors; and demonstrate effectiveness when providing farmers with a wide range of response options.

A study in Burkina Faso shows that the provision of climate services needs to be mainstreamed by the NMHS – the National Meteorological Agency (ANAM) – and channelled, together with extension services, through existing communication means that have a dense coverage (e.g., radio, television, and mobile phone) (Alvar-Beltrán *et al.*, 2020). Another study in Mali, which evaluated the success and failure associated with the country's agrometeorological advisory programme, highlighted the importance of identifying the intended users of climate services prior to the diffusion of information. This study also emphasized the challenges that producers of climate services may face when identifying potential users and their specific needs when engaging with diverse populations – actions that demand sensitivity to roles, responsibilities, and power structures. A recent review on climate services in Western Africa underlined the level of access to climate services, which can range widely from about 6 to 75 percent depending on the study. The review shows that access in Western Africa is lower than in Eastern Africa (Vaughan *et al.*, 2019). Moreover, Vaughan *et al.* also found that the majority (74 percent, averaged across six studies in Africa) of farmers who report access to seasonal forecasts also acknowledge acting on the information, which indicates a strong demand for this type of information.

One of the largest initiatives conducted on agrometeorological products and services in Western Africa is the WMO METAGRI operational initiative, which provides advisory services with suitable climate and weather information, so that these services can offer effective support to farmers in their decision-making. Climate services, including early warnings, weather and seasonal forecasts, and agrometeorological products (e.g., 10-day agrometeorological advice, including sowing calendars associated with observed rainfall from rain gauges distributed to farmers) were provided to users through roving seminars, local media, and extension services (Tarchiani, 2019) **(see case study, *Tailored agrometeorological services in West Africa*)**.

©FAO/Arete Ismail Taxta

Eastern, Central and South Africa

In Eastern Africa, the lack of climate services communication is largely due to barriers associated with translating the products into local languages and the poor establishment of feedback loops between scientists and clients (Vogel *et al.*, 2019). To address this, the CGIAR has identified better ways of delivering services, and the need to brand and exploit different communication means at a lower cost (e.g., mobile phone technology, television, social media, radio, SMS service and updated websites). In the United Republic of Tanzania, extension officers provide agricultural advisory services to farmers through the Farmer Voice Radio (FVR). Existing feedback mechanisms through cell phones or questionnaires enhance the efficiency of radio programmes and allow farmers to share information on best practices through listening clubs for peer support (Sanga *et al.*, 2013). Another study in the United Republic of Tanzania assessed the cost-effectiveness of using alternative communication channels (radio and SMS) to deliver advanced and real-time agrometeorological information to farmers (Silvestri *et al.*, 2020).

Overall, radio and SMS only require a basic level of understanding and therefore work well for raising awareness on new seed varieties and planting decisions (e.g., land preparation and sowing density). In Kenya, the project "Decentralised climate information services for decision-making" in 2014 worked to increase fishers' ability to interpret weather information to appropriately address their day-to-day decisions. In Ethiopia, pastoralists rely on traditional indicators (e.g., transhumance corridors, water and fodder availability), as the agrometeorological services are rare and not easily accessible. In Malawi, agricultural decision-making is based on indigenous knowledge and personal experience. Current scientific climate information is not embraced because farmers see this data as less reliable and not sufficiently specific to be useful for their farming activities (Coulibaly *et al.*, 2015). Beyond providing farmers with climate information, surveyed farmers requested additional information on crop management, improved technologies and the availability and supply of farming inputs (e.g., fertilizers and seeds). In Uganda, weather forecasts are communicated by government institutions and civil society organizations mostly through the internet, FM radio, churches, mosques, community meetings and mobile phones. However, the means of communication varies according to the audience. For instance, while the internet targets government institutions, the radio reaches mass audiences (Tiitmamer and Mayai, 2018). The agrometeorological advisories are translated into local language and feedback mechanisms and surveys are constantly monitoring the quality of advisories and are key for its enhancement. Additionally, Somalia, South Sudan, and several other Eastern African countries are now developing a robust climate analysis and visualization tool for supporting decision-making through the approach used in the ENACTS project (Walsh, 2020). ENACTS aims to bring reliable and readily accessible climate knowledge into the hands of national decision makers by looking beyond the simple generation of climate data and considering its access and use by the intended users.

Participatory engagement of last mile and climate-informed actions

Over the last decade, many novel and successful approaches have been tested across Africa to support farmers in undertaking climate-informed actions. One example is the approach adopted by the PICSA project, which promotes farmers' decision-making based on accurate, site-specific, climate and weather information on crop production and livestock. The PICSA approach consists of a set of activities undertaken at different times:

(i) long before the growing season (seasonal calendars, resource allocation maps, historical climate information and crop and livestock options, participatory budgets, farmers' perception and hazard probability and risks);

(ii) just before the start of the growing season (identify and select possible responses to climate forecasts);

(iii) during the growing season (select possible responses to short-term forecasts and warnings); and

(iv) after the growing season (reviewing lessons learned to improve the overall PICSA approach) (Dorward *et al*., 2015).

This participatory approach has been applied in projects in several African countries, including Burkina Faso, Ethiopia, Ghana, Kenya, Mali, Niger, Rwanda, Senegal, Uganda, and the United Republic of Tanzania. The PICSA approach has also been adopted by the United Nations and regional agrometeorological institutions, including ICPAC, WMO and FAO through a regional project in Eastern Africa, where extension agents have been trained in climate information and interpretation and communication for guiding farmers **(see case study, *Agricultural Climate Resilience Enhancement Initiative (ACREI) project in East Africa*).** The GFCS Adaptation Programme in Africa, implemented in Malawi and the United Republic of Tanzania, promoted the PICSA approach as a means of providing climate services for agriculture and food security, which was done by delivering climate services to farmers and pastoralists through interactive radios (GFCS, 2017).

Dimitra Clubs are another important participatory approach. There are over 3 400 Dimitra Clubs with over 100 thousand members across sub-Saharan Africa. The Clubs support farmers in organizing themselves through an action-oriented and gender-sensitive approach that addresses local problems using local resources (FAO, 2015). FAO has extensively supported rural communities across Africa through Farmer Field Schools, a non-formal educational process characterized by hands-on group learning building on local knowledge systems.

Mozambique has one of the most extensive numbers of Farmer Field School programmes – there are more than a thousand Farmer Field Schools with around 27 500 producers all over the country (FAO, 2020). FAO supports Farmer Field School practitioners to better understand they ways in which local farming systems are exposed and sensitive to extreme weather events, and identify adaptive and context-specific strategies to reduce risk. The roving seminars conducted under the WMO METAGRI operational project have raised awareness on climate risks and the climate information and services that are available to farmers (Tarchiani, 2019). The seminars have also strengthened feedback mechanisms between small-scale agricultural producers and the NMHSs. As noted earlier, these feedback mechanisms are essential for improving climate information products for climate-informed actions. The seminars provide a forum for a frank and open exchange in which farmers and food producers can raise their concerns and provide input on the potential use of climate information products **(see the case study, *tailored agrometeorological services in West Africa*).**

Investment needs

Sub-Saharan Africa has been the largest recipient of public climate finance for small-scale agricultural producers. 91 percent of all tracked projects in sub-Saharan Africa were directed at adaptation to climate change, with approximately USD 1 billion committed annually to improve agricultural production, and USD 1.3 billion annually for climate-resilient infrastructure and rural livelihoods (Chiriac and Naran, 2020). A total of USD 3.6 billion was transferred annually from the Organisation for Economic Co-operation and Development (OECD) countries to non-OECD countries in sub-Saharan Africa. Some of the investment priorities identified in this report and key for strengthening the climate services framework in Africa include:

1. Avoid piecemeal investments and provide finance for every step of the climate services framework.
2. Increase investments in the installation of automated weather stations and radar across the continent, and on building national capacities for continuous monitoring and maintenance of weather stations.
3. Invest in weather, water, climate monitoring and weather forecasting, as well as in modelling crops, water, forests, and other sectors and combine this with climate projections.
4. Undertake the digitalization and check the quality of historical data to ensure usability of services and applications (e.g., forecasting, climate projections).
5. Invest in ICTs, including the development of mobile applications, SMS or other communication services that are considered essential in the digital agricultural transformation.
6. Increase the role of the private sector in addressing the resource limitations of NMHSs and many agricultural extension services.
7. Build private sector partnerships to support the increase of equitable access to communication channels and scale-up the number of recipients of climate services and agronomic advisories – with a focus on vulnerable groups, including women.
8. Invest in agricultural extensions and successful participatory approaches such as Farmer Field Schools, and develop climate curriculums for Farmer Field Schools that focus on applications for vulnerable groups, including women and youth.
9. Invest in research and development for tailored services that show evidence of the economic value and benefit of using climate services in key sectors.
10. Invest in research and development to develop efficient and scalable solutions for sustainable and climate-resilient agricultural practices and enhanced climate information data, including climate services to the last mile.
11. Make available the action plans with priorities and needs to all potential partners and donors so that investments are made in a consistent manner and not in a piecemeal way.

Regional conclusions

The challenges and the set of recommendations for investment provided below are based on an extensive search of literature that includes research papers, technical reports, United Nations flagship reports and regional workshops conducted by WMO as part of the GFCS. These actions and proposed recommendations are intended to improve the effective production and delivery of climate services. They have been formulated in consideration of the critical need to bridge the last mile gap and the socio-economic context of the region of interest.

Climate services framework step	Major challenges/barriers	Priority areas for action
Data collection, monitoring and forecasting	■ Insufficient and often declining agrometeorological observation network ■ Uneven distribution of existing observation stations with poor coverage in rural areas ■ Low funding of NMHSs and MoAs for the development and maintenance of infrastructure, observing systems, forecasting tools, staff competencies and service delivery mechanisms ■ Low performance of numerical models for weather forecasting due to data scarcity ■ Incomplete historical datasets for meteorological and agricultural parameters, data in different formats (including hard copy)	■ Digitize and harmonize a national repository for data, including data observed by various institutions and global sources ■ Use the same standards for equipment when installing observing networks and to facilitate integration with other datasets ■ Integrate diverse observation platforms, data processing computers, analysis and assimilation systems, numerical models, and forecaster work stations into and end-to-end system ■ Promote the expansion of innovative digital tools ■ Improve field data collection for real time decision-making both for the monitoring and control of desert locust outbreaks ■ Ensure software availability for data analysis and product development ■ Develop gridded databases and blending techniques with numerical reanalysis and satellite derived products ■ Use data merging techniques to fill gaps in historical observations, and use the resulting merged data as a foundation for localized information products and services ■ Invest in data merging by combining quality-controlled station data with proxies such as satellite estimates and climate model reanalysis products

Climate services framework step	Major challenges/barriers	Priority areas for action
Task force and data-sharing	■ Low accessibility of available climate and weather data by governmental institutions ■ Legal restrictions to share and access the data ■ High costs associated with data access ■ Insufficient support and incentives for institutions to participate in task force discussions (e.g., multidisciplinary working groups)	■ Support formal agreements between national institutions and long-term partnerships for institutional and financial support ■ Develop user-friendly interfaces where the intended user (government institutions, researchers, and the private sector) can interact with the software and/or tool ■ Invest in technologies and IT infrastructure for open data platforms for exchange of data and products ■ Build national and international collaboration necessary to run higher resolution regional numerical weather prediction models and product location specific forecasts ■ Establish or strengthen national working groups of governmental and non-governmental institutions, research, and private sector, through multi-disciplinary and regular coordination meetings
Co-production of tailored agrometeorological advisories	■ Poor communication among producers of climate information (NMHSs) and agricultural extension officers MoAs ■ Limited climate knowledge among government structures on the benefits of using climate services in agriculture ■ Existing interfaces are not intuitive and require training to operate	■ Co-production through engagement of users as a foundation for donor supported micro-projects addressing risk management for the small-scale agricultural producers ■ Promote user interface platforms and provide the means for engaging producers of climate services and users ■ Develop platforms with GIS features that are linked to the data library and 'map rooms' containing geospatial information of agricultural and weather variables ■ Support contracts with sectoral experts in order to ensure that climate and weather data is taken up by relevant models or methodologies to develop agro-products ■ Leverage digital innovations through the food value chain that have proven to work and have been successfully implemented in the agricultural sector

Climate services framework step	Major challenges/barriers	Priority areas for action
Communication of services to the last mile	- Lack of access to internet, phones, or other ICT means - Lack of awareness on the benefits of using climate services and agronomic advisories and insufficient engagement with users - Semantic barriers related to the information being delivered - Limited availability of technical advisors to communicate information - Weather information and agronomic advisories are not always in local language	- Build public-private partnerships in ICTs in order to scale-up the number of beneficiaries, such as governmental contracts with cell phone companies, for information services provision and enhanced utilization of local radio and ICTs - Invest in the development of communication channels with tailored agrometeorological content (e.g., radio products, content for television programmes, SMS texts) - Bridge the gap between early warnings and the last mile by identifying the most effective communication means and preferred communication channels by intended users - Identify the appropriate timing, language, and format for farmers, and enable its access to increase information uptake - Engage NGOs and community based organizations in education and awareness raising of the benefit and use of climate services - Invest in strengthening capacities of agricultural extension services
Participatory engagement of last mile	- Scarce visibility of NMHSs within the community - Non-reliable timely weather and climate information - Gender participation and knowledge gap - Lack of finance for farmer engagement and outreach	- Scale-up and roll-out participatory approaches and feedback mechanisms that have shown to be successful in the African continent, including FAO's Farmer Field Schools, Dimitra Clubs, WMO Roving Seminars, Participatory Integrated Climate Services for Agriculture (PICSA) approach - Conduct on a regular basis agrometeorological need assessments that are tailored to users, and find solutions for meeting these needs with regular feedback from users - Ensure meaningful participation of groups (e.g., women and youth) that are consistently underrepresented in the decision-making process but play an invaluable role in agriculture and digital innovation (e.g., promoting community consultations when conceptualizing, designing, and developing tailored agrometeorological advisories) - Fund farmer participation in workshops

Climate services framework step	Major challenges/barriers	Priority areas for action
Climate-informed actions	■ Use of scientific language that is not easily understandable and tailored to farmers needs ■ Gaps between farmer needs and available weather and seasonal climate forecasts ■ Climate services are not always relevant for specific types of agricultural practices	■ Promote digital learning and knowledge exchange between farmers and other stakeholders ■ Translate technical weather, climate, and agronomic information into actionable services for agricultural users, and ensure appropriate use of socio-economic and social science information ■ Fund farmer engagement at every stage of the development of climate services and ensure that services are user-centred ■ Invest in pilot programmes that create trust and understanding of the benefits of using climate services

Survey results: Agrometeorological advisories

This section presents the results obtained from the surveys in response to the following question: **Which type of information does the NMHS provide to the last mile?** Refer to Annex 1 to see the original survey template.

	Kenya	Mali	Mozam-bique	Togo	Niger	Nigeria	Ivory Coast	Chad	Senegal	Burkina Faso
Optimal sowing date	✓C		✓C		✓C	✓C	✓C	✓C		✓C
Onset rainy season	✓C	✓C	✓C	✓C	✓C	✓C	✓C	✓C	✓C	✓C
Offset rainy season	✓C	✓C	✓C	✓C	✓C	✓C	✓C	✓C	✓C	✓C
Dry spells	✓C	✓C	✓C	✓C	✓C	✓C	✓C	✓C	✓C	✓C
False start rainy season	✓C	✓C	✓C	✓C	✓C	✓C	✓C	✓C	✓C	
Cumulative precipitation	✓C	✓C	✓C	✓C	✓C	✓C	✓C	✓C	✓C	✓C
Evapotranspiration	✓C	✓C	✓C			✓C	✓C	✓C	✓C	
Cumulative. growing degree-days			✓C			✓C	✓C			
Soil moisture			✓C			✓C	✓C	✓C	✓C	✓C
Seasonal forecast	✓C ✓Fo		✓C ✓Fo		✓C	✓C ✓Fo	✓C ✓Fo	✓C	✓C ✓Fo	✓C ✓Fo
Precipitation forecast	✓C	✓C	✓C	✓C	✓C	✓C	✓C	✓C	✓C	✓C
Temperature forecast	✓C	✓C	✓C	✓C	✓C	✓C	✓C	✓C	✓C	✓C
Pest and Disease forecast			✓C				✓C	✓C		
Hail forecast	✓C		✓C							
Wind forecast	✓C		✓C ✓Fi	✓C	✓C		✓C ✓Fi	✓C	✓C	✓C
Water resource availability	✓L		✓L		✓L	✓L	✓L		✓L	✓L
Potential heat stress	✓L		✓L			✓L	✓L			
Potential disease occurrence zones	✓L ✓Fo		✓L ✓Fo				✓L ✓Fo	✓L		
Potential lightning zones	✓L ✓Fi ✓Fo						✓L ✓Fi ✓Fo		✓L ✓Fo	
Transhumance corridors							✓L		✓L	
Potential conflict zones									✓L	
Fodder availability							✓L	✓L		✓L
Potential extreme weather events	✓L		✓L	✓L	✓L	✓L	✓L	✓L		
High swell forecasts	✓Fi		✓Fi				✓Fi			
High tides forecasts	✓Fi		✓Fi				✓Fi			
Visibility forecasts			✓Fi			✓Fi	✓Fi			
Sea surface temperature							✓Fi			
Wildfire prone zones							✓Fo			✓Fo

Crops ✓ (C) | Livestock ✓ (L) | Fisheries ✓ (Fi) | Forestry ✓ (Fo)

Table 1: Agrometeorological advisory services provided to the last mile per agricultural sector (crops, livestock, fisheries and forestry), based on survey results. Refer to Annex 1 to see the original survey template.

Survey results: Communication channels

This section presents the results obtained from the surveys in response to the following question:
By which means are the weather information and weather alerts currently delivered to the last mile?

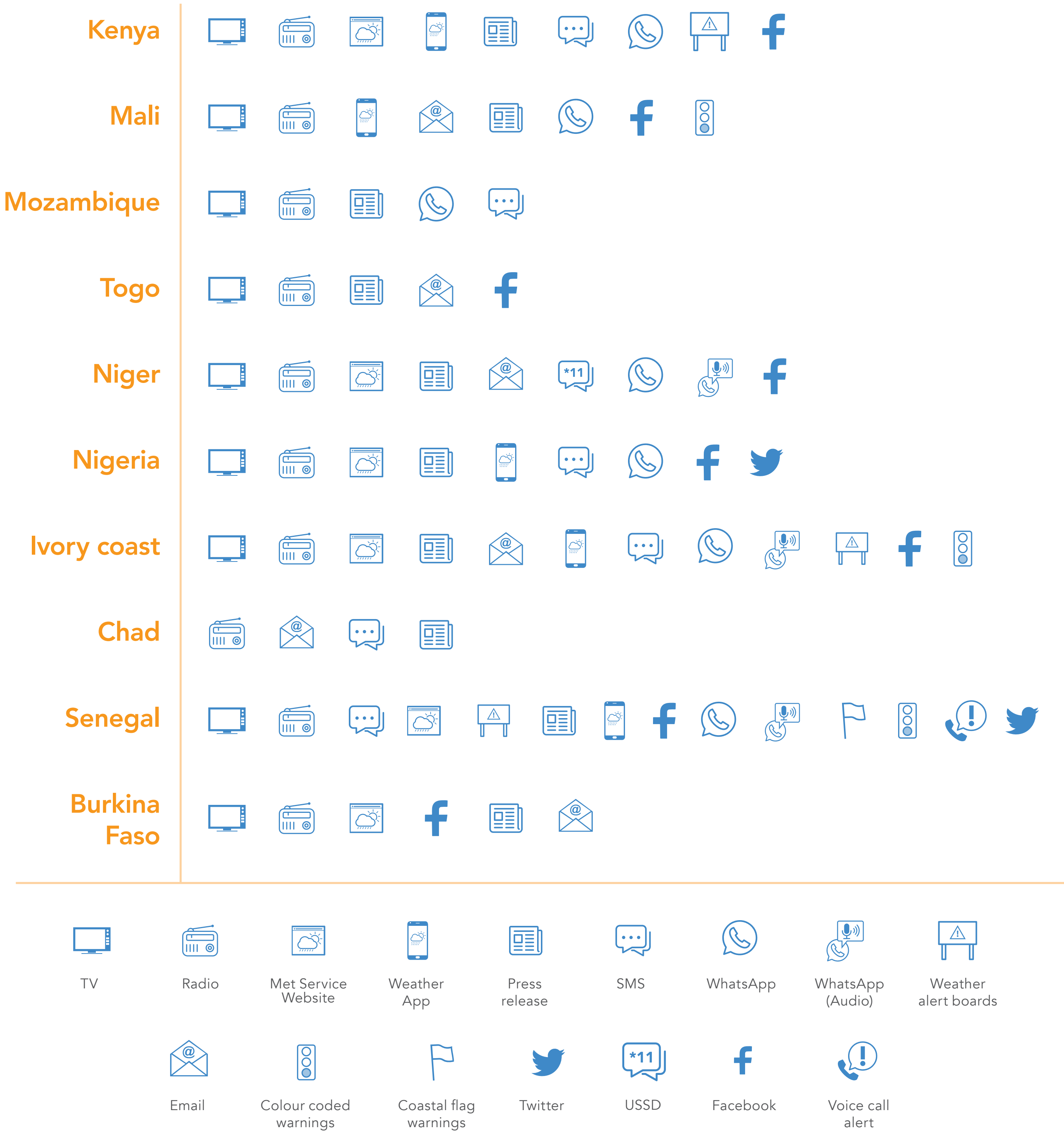


Figure 8. List of communication means used to deliver weather information and weather alerts to the farmers/end-users, based on survey results. Refer to Annex 1 to see the original survey template. *Note: The results contained herein do not represent all existing communication means such as agricultural extension officers, posters, public meetings, face-to-face, etc.*

CASE STUDY

Co-production of commodity tailored climate services in Kenya

Country:
Kenya

Institution(s):
Tea Board of Kenya (TBK), Tea Research Foundation (TRF), Kenyan Meteorological Department (KMD), Ministry of Agriculture, Kenya Tea Development Agency (KTDA), Kenya Tea Growers Association (KTGA) and the East African Tea Trade Association (EATTA)

Background

Tea production in Kenya accounts for one of the highest shares of the country's export earnings (26 percent) and contributed to four percent of the country's gross domestic product. The revenues generated from tea exports is important for sustaining cereals imports. The tea industry employs a high number of workers from marginal areas prone to food insecurity. The Tea Board of Kenya (TBK) promotes the production and marketing of high-quality tea from both domestic and international markets. Tea production is at high risk from weather and climate extremes. Risks are particularly high during sensitive phenological phases when frost and hailstorms may damage tea plantations. To cope with increasing weather extremes, scientists of the Tea Research Foundation (TRF) have developed drought-resistant tea varieties and yield prediction models that mitigate, to some extent, the potential impacts of climate change. The TRF has a strong collaboration with The Kenyan Meteorological Department (KMD) and uses data available from local weather stations at the TRF location in Kericho, Kenya. However, there are major challenges that need to be addressed to reach agricultural users with climate services that are tailored to a specific commodity.

Major challenges for reaching the last mile

- Climate information from KMD requires further tailoring with support from national experts to produce actionable advisories that tea farmers can use to make decisions in advance.
- Tea producers do not always understand weather and climate terminologies and/or do not fully understand the benefits of using climate information to base their decisions on reducing crop damage and improving yields.
- Training and demonstration plots for tea producers and farmer-to-farmer interaction is limited.

Benefits of using climate-informed advisories

- The KMD holds regular workshops, which are hosted by the Provincial Directors of Meteorology, with farming communities on weather information products and services (e.g. low minimum temperatures and heavy rainfall) that are pertinent to tea growers, including an outlook of the climate and weather impacts in tea growing areas.
- Tailored alerts that support farmers to adjust the time of sowing and harvesting are provided to tea producers at sensitive periods of the growing cycle. The alerts include frost warnings from January to March in western Kenya, and from December to March in eastern parts of the country.
- Information on the potential damage of hailstorms, which tend to occur between August and October, and on frost damage, can reduce yield losses.

CASE STUDY: Co-production of commodity tailored climate services in Kenya

Lessons learned

- Collaboration between the private sector, academic institutions and government bodies provides the essential expertise required for effectively co-designing and co-producing tailored climate services.
- Tailoring climate services to specific commodities makes the services significantly more valuable for farming communities and for society as a whole.
- Strengthen collaboration with NGOs and community-based organizations working in communities on issues related to food security and disaster risk reduction to vehicles to enhance awareness and facilitate the dissemination of information to users.

Future work and investment opportunities

- Increase investment in ongoing research with the TRF; test climate-resilient tea varieties and agricultural practices; and support their uptake by members of the KMD.
- Invest in assessments of the economic benefits that tea producers in Kenya derive from receiving tailored climate services from KMD.

References:

Kadi, M., Njau, L.N., Mwikya, J. & Kamga A. 2011. *The State of Climate Information Services for Agriculture and Food Security in East African Countries.* CCAFS Working Paper No. 5. Copenhagen, Denmark. (also available at https://ccafs.cgiar.org/sites/default/files/assets/docs/ccafs-wp-05-clim-info-eastafrica.pdf)

CASE STUDY

Communication and co-production of tailored climate services in Senegal

Country: Senegal

Timeframe: 2018

Institution(s): National Agency for Civil Aviation and Meteorology (ANACIM), FAO and WMO

Background

The National Agency for Civil Aviation and Meteorology (ANACIM) plays a key role in Senegal's food sector by delivering climate and weather information and providing early warning information to the agricultural sector. During the rainy season, ANACIM produces 10-day agrometeorological bulletins and coordinates multidisciplinary working groups with representatives from a wide range of institutions (Figure 1). Under the WMO's METAGRI operational project, the media coverage of the agrometeorological bulletins was evaluated as high compared to neighbouring countries. In fact, in Senegal, METAGRI activities had a large echo on the media, mostly thanks to the involvement of media in the activities and the production of a film with farmers as testimonies, boosting confidence in the audience. In 2015, climate information reached a total of 7.4 million rural people throughout Senegal. By 2018, ANACIM had conducted more than 500 workshops with farmers, pastoralists, and fishers across the country.

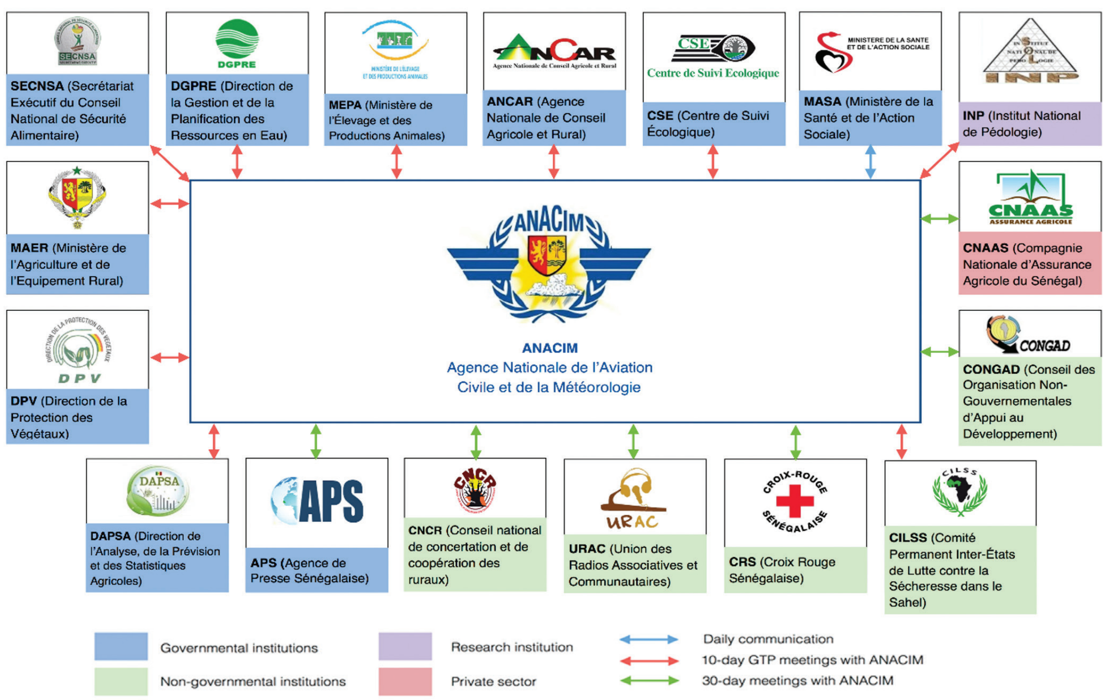


Figure 1. *Co-production of agrometeorological bulletins in Senegal.*

CASE STUDY: Communication and co-production of tailored climate services in Senegal

Major challenges for reaching the last mile

- Low spatial resolution of existing forecasting models for West Africa and limited availability of high-resolution satellite imagery.
- The socio-economic value and benefits of climate services are not publicized.
- SMS are the second most effective means of communication after community radios for reaching agricultural users, but they continue to be delivered in French and not in Wolof, the most widely spoken language in the country.
- ANACIM has an agreement with the international telecommunications operator, Orange, to deliver climate services to farmers, but the cost of delivering this information remains high, which limits the number of beneficiaries.

Benefits of using climate-informed advisories

- The multiple benefits of using climate services in Senegal have been acknowledged. For instance, climate services help streamline spending and farm labour. Seasonal forecasts, for example, can allow farmers to adjust their sowing dates and select the most suitable crop varieties. Senegal's Ministry of Agriculture now considers climate services to be an essential input to the agricultural sector.

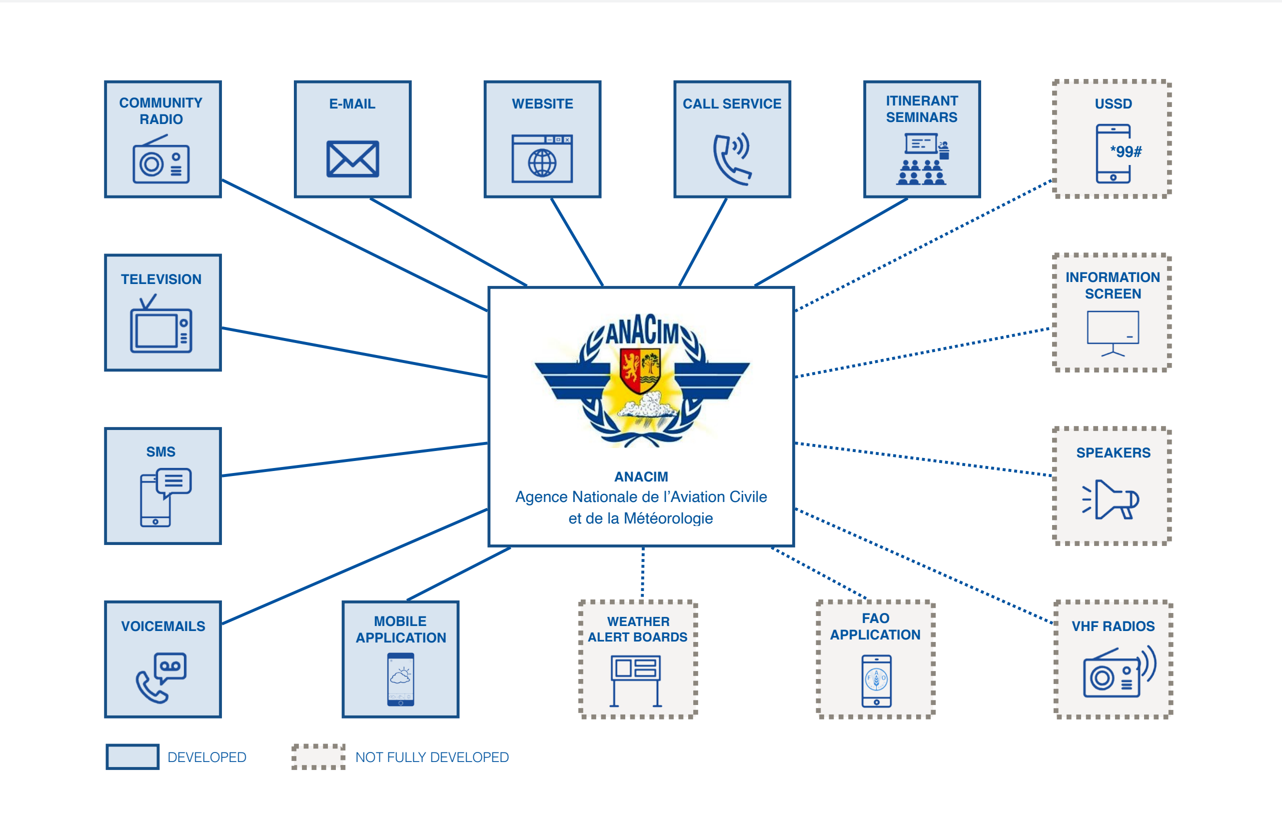


Figure 2. *ICTs used by ANACIM to deliver climate services to agricultural users.*

CASE STUDY: Communication and co-production of tailored climate services in Senegal

Lessons learned

- Sharing the communication strategy with working group partners, including local radios and community leaders, helped centralize and coordinate communication to agricultural users.
- Building partnerships with telephone operators, particularly Orange, which has 8 million mobile users in the country, can open up new opportunities for reaching more agricultural users.
- Lead farmers recognize the benefits of using climate services and can promote a wider uptake in their farming communities.
- Farmers should be trained prior to the onset of the rainy season to fully benefit from the training workshops conducted by ANACIM.

Future work and investment opportunities

- Perform a cost-benefit analysis on the use of climate services and on the willingness-to-pay for service delivery.
- Reinforce ANACIM's capabilities in numerical weather prediction models, and crop and water balance models.
- Further develop irrigation schemes for farmers, and crop strategies that balance cash and staple crops.
- Strengthen partnerships with phone operators (Orange and Tigo) and other companies (e.g., local start-ups) that propose ICT solutions for rural development.

References:

CCAFS. 2015. *The impact of Climate Information Services in Senegal*. CCAFS Outcome Study No. 3. Copenhagen, CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). (also available at https://ccafs.cgiar.org/outcomes/impact-climate-information-services-senegal)

Ouedraogo, I., Diouf, N. S., Ouédraogo, M., Ndiaye, O., & Zougmoré, R. B. 2018. Closing the gap between climate information producers and users: Assessment of needs and uptake in Senegal. *Climate*, 6(1); 13

WMO-FAO. 2018. Documents from WMO-FAO Senegal and Rwanda Project [online]. [Cited 11 March 2021]. http://www.wamis.org/agm/faoproj/

Prepared by: FAO, WMO, ANACIM.

CASE STUDY

The Agriculture Climate Resilience Enhancement Initiative (ACREI) in Eastern Africa

Countries:
Ethiopia, Kenya and Uganda

Timeframe:
2012-2015

Institution(s):
The Intergovernmental Authority on Development (IGAD) Climate Prediction and Applications Centre (ICPAC), FAO, WMO, NMHS and Ministries of Agriculture of Ethiopia, Kenya, and Uganda.

Background

The Agricultural Climate Resilience Enhancement Initiative (ACREI) is implementing adaptation strategies and measures to strengthen the adaptive capacity and resilience of vulnerable small-scale farmers, agro-pastoralists, and pastoralists in the Horn of Africa to climate variability and change. Through the co-production of forecast-based advisories, ACREI is improving the delivery of climate services to small-scale farmers to increase climate-informed decision-making. The participatory scenario planning approach that ACREI has adopted brings the co-production process down to sub-national levels by gathering together the producers and users of weather and climate information in each target location for two-day workshops that are held before the start of the agricultural season.

Major challenges for reaching the last mile

- Lack of location-specific climate advisories, and limited understanding of the terminology used by climate information producers.
- Limited availability of technical advisors to communicate information and support capacity building, as well as limited financial resources for extension services.
- Limited decentralization of NMHS.
- Limited capacity and technical knowledge of the intermediaries of climate information on issues such as the uncertainty of weather forecasts.

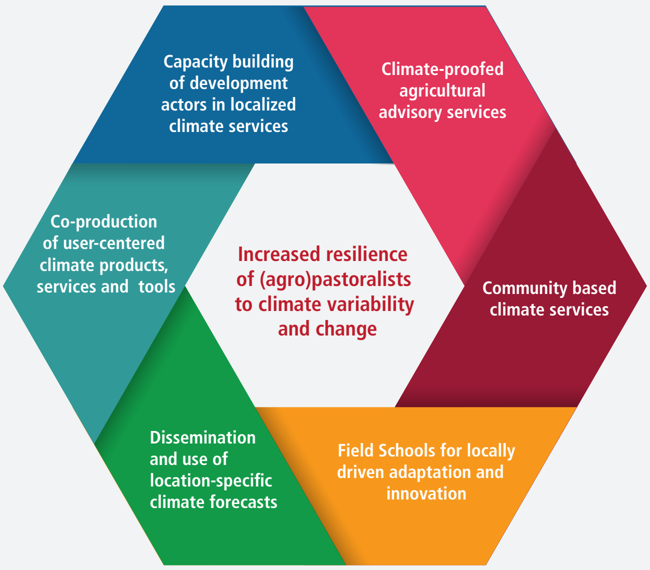


Figure 1. *Strengthening the resilience of (agro) pastoralists through climate-informed actions. Source: FAO, 2020*

CASE STUDY: The Agriculture Climate Resilience Enhancement Initiative (ACREI) in Eastern Africa

Benefits of using climate-informed advisories

- Bringing stakeholders together during the co-production workshop results in a collaboratively developed advisory for the upcoming season that is technically sound, locally relevant, useful, and tailored to user needs.
- Facilitating the participation of farmers in the development process of seasonal advisories creates trust, and the farmers gain a sense of ownership over the advisory, which leads to a gradual positive change in the perceptions farmers have of climate services.
- The participatory scenario planning process gives an opportunity for stakeholders to provide feedback on forecasts. Farmers can use this information to make decisions about the procurement of seed and inputs that are most suitable for the coming season, and improve the timing of agricultural activities (e.g., planting and harvesting) to minimize losses and improve yields.

Lessons learned

- Countries with a decentralized NMHS (e.g., Kenya) have an advantage in terms of engaging farmers on issues related to climate information.
- Only a few last mile representatives can be supported to participate in the seasonal co-production process, and consequently broader dissemination activities using a variety of communication channels is crucial. Engaging radio stations in disseminating climate information and identifying the times, languages and formats that are most appropriate for farmers is critical for enabling access to the information and increasing its uptake.
- Initial workshops are conducted at the beginning of the season, but inter-seasonal forecast updates available to farmers and other stakeholders enable strategies to evolve over the course of the season.
- Including experts in indigenous technical knowledge in the process allows for the blending of traditional and local knowledge with scientific information.
- Ensuring participation of both men and women in seasonal advisory development workshops is essential. ACREI baseline surveys found there was limited understanding of the gendered impacts of climate hazards, which is an area that warrants further awareness raising.


©FAO/Petterik Wiggers

CASE STUDY: The Agriculture Climate Resilience Enhancement Initiative (ACREI) in Eastern Africa


©FAO/Petterik Wiggers

Further work and investment opportunities

- Institutionalize participatory climate advisory development processes at the sub-national level. This will include ensuring that national and sub-national governments have the budget for downscaling; undertaking co-production processes at the local level; carrying out farmer outreach on climate and weather information; engaging with local media engagement; and capacity for monitoring and evaluation.
- Continue to build and institutionalize partnership between NMHSs and the ministries of agriculture and livestock.
- Support the decentralization of staff from the NMHS, as was done in Kenya.
- Establish effective feedback mechanisms and strengthen communication to increase the uptake of climate and weather information by the last mile.
- Strengthen capacity building on the interpretation and use of information to increase the uptake of climate information by farmers.
- Support farmers or farming communities to own and use rain gauges for local climate monitoring to enhance their understanding on how local climatic conditions relate to the sub-national and national forecasts.
- Leverage existing ICTs and strengthen the participation of media practitioners in the participatory scenario planning process through media partnerships to further enhance the dissemination of climate information and the development of feedback mechanisms.

References:

CARE. 2018. *Practical guide to Participatory scenario planning: Seasonal climate information for resilient decision-making.* (available at https://careclimatechange.org/wp-content/uploads/2019/06/Practical-guide-to-PSP-web.pdf)

WMO. 2021. Enhancing Climate Advisories for Resilience in East Africa. In: *WMO* [online]. [Cited 11 March 2021]. https://public.wmo.int/en/enhancing-climate-advisories-resilience-east-africa

Prepared by: Sebastian Grey (WMO), Oliver Kipkogei (IGAD-ICPAC), Deborah Duveskog (FAO Kenya).

CASE STUDY

Tailored agrometeorological services in West Africa

Countries:
Benin, Burkina Faso, Cape Verde, Chad, Ivory Coast, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, and Togo

Timeframe:
2012-2015

Institution(s):
WMO, NMHS of the 17 countries, AGRHYMET, the French Agricultural Research Centre for International Development (CIRAD), and the Spanish State Meteorological Agency (AEMET)

Background

In 2008, WMO launched the METAGRI project, which offered roving seminars to subsistence farmers in 14 West Africa countries. The initial project was later expanded to 17 countries through the METAGRI operational project (2012-2015), which provided agrometeorological services to a wide range of rural users including farmers, livestock herders, foresters, and traditional fisherfolk. The project successfully conducted 428 roving seminars. Over 18 000 farmers in 7 258 villages received training, and over 8 000 rain gauges were distributed to individuals. The main funding was provided by the Government of Norway and Spain.

Major challenges for reaching the last mile

- Agrometeorological services are growing in the region, but they are often not easily accessible to the majority of small-scale farmers or not relevant to support their decision-making.
- The time gap between the issuing of advisory services and their reception by farmers is long, particularly in large countries where information networks are weak and distances are vast.
- Agrometeorological services are not sufficiently translated into local languages or presented in a manner that can be easily understood by farming communities.

Benefits of using climate-informed advisories

An external assessment on farmers' behavior and performance indicated that farmers used agrometeorological information in their operations for a variety of reasons:

- To make strategic choices on crop selection and the distribution of their plots based on seasonal climatic forecasts and sowing calendars.
- To make tactical choices related to sowing dates to avoid sowing failures. The project overcame sowing failures through an integrated use of sowing calendars and training on how to use the information from the rain gauges.
- To better adjust crop development and the growing cycle to rainfall patterns, and select the most favourable periods for carrying out cultural operations based on weather forecasts and rain gauges.

CASE STUDY: Tailored agrometeorological services in West Africa

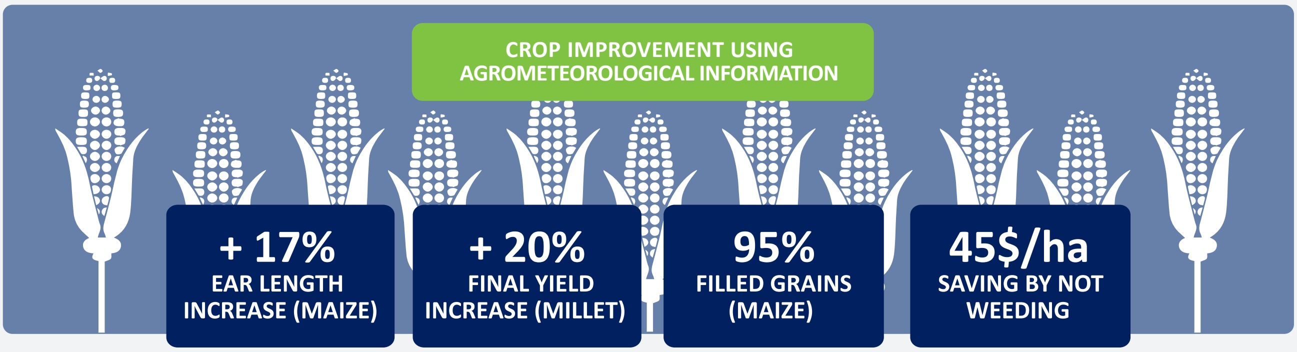


Figure 1. *Observed benefits of using agrometeorological services in 17 West African countries during the METAGRI Operational project. Source: WMO, 2019*

The effects of these good practices and behavioral changes led to an increase in crop productivity and a decrease in costs in terms of agricultural inputs and working time. For example, in Mauritania in 2016, the added value of using agrometeorological services was estimated at USD 260 per hectare.

Lessons learned

- When the relationship between NMHSs, agricultural extension services and farmers is strong, the agrometeorological services produced are more likely to have an impact on farming communities.
- Two-way training and awareness-raising activities can strengthen the relationships and trust between NMHS and media and, consequently, between farmers and NMHS.
- Local radios are the most powerful ICTs for disseminating agrometeorological services and building awareness among the last mile users (Fig. 2).
- Lack of translated forecasts and advisories into local languages can be overcome by preparing a glossary of weather terminology in local languages.
- Communicating agrometeorological advisories or meteorological warnings through text messaging has a high success rate.

Country	Local radio	National radio	TV	Press Agency
Benin	✗			✗
Burkina Faso	✗	✗	✗	
Cape Verde		✗	✗	✗
Chad	✗	✗		
Gambia	✗	✗		
Ghana	✗	✗	✗	
Guinea	✗			✗
Guinea Bissau	✗	✗		
Ivory Coast	✗	✗	✗	
Liberia	✗			
Mali	✗			
Mauritania	✗	✗	✗	✗
Niger	✗			
Nigeria	✗	✗	✗	✗
Senegal	✗	✗	✗	✗
Sierra Leone		✗		
Togo	✗	✗	✗	✗

Figure 2. *Most extended ICT means for delivering agrometeorological information in countries covered by METAGRI. Source: WMO, 2019*

- Taking advantage of the high number of mobile phone subscribers can reduce the time delays and costs associated with the dissemination of advisory services to farmers.
- A multidisciplinary approach can help to provide a clear understanding of the underlying cultural and contextual factors that influence the perceptions that the last mile have of climate services.

CASE STUDY: Tailored agrometeorological services in West Africa

METAGRI roving seminar participant registration, Owerri, Imo State, 2011.

Future work and investment opportunities

- Customize the existing information to specific needs of last mile users, and tailor the information in ways that will have an impact on a large scale.
- Enhance the collaboration between NMHSs with local radios to ensure coverage in rural areas; and build upon existing relationships through workshops with meteorologists and the media, with awareness-raising activities for journalists.
- Invest in interpretation and translation to overcome language barriers and enable local leaders to contribute and promoting the uptake of climate services; and continue to improve communication strategies (e.g., visualization, podcasting, messaging) and dissemination channels (e.g., radio, social media, SMS, WhatsApp).
- Invest in improving the usability of climate services through public-private partnerships, and increase the allocation of resources for climate services. The ability to attract investment will depend on clear evidence of the economic value and benefits of climate services in key sectors. Public-private partnerships with media and ICT enterprises can decrease the costs of communication and dissemination, and support the design of more user-friendly agrometeorological services.
- Develop a new business model that is based on evidence of last mile users' access to climate services, the uses they make of these services, and the short- and long-term impacts these services have.

References:
Bacci, M., Ousman Baoua, Y. & Tarchiani, V. 2020. Agrometeorological Forecast for Smallholder Farmers: A Powerful Tool for Weather-Informed Crops Management in the Sahel. *Sustainability*, 12(8): 3246.

Tarchiani, V., Camacho, J., Coulibaly, H., Rossi, F. & Stefanski, R. 2018. Agrometeorological services for smallholder farmers in West Africa. *Advances in Science and Research*, 15: 15-20.

WMO. 2019. *Evaluation Report of METAGRI Operational Project (2012-2015).* CAgM Report, 107. WMO. Geneva, 94 pp.

Prepared by: Vieri Tarchiani (IBIMET) and Jose Camacho (WMO).


©FAO/Mohammed Abdulkhaliq Ameen Alghabri

Near East and North Africa

In the Near East and North Africa, limited freshwater resources, urbanization, population growth, conflict and migration have increased pressure on human settlements and ecosystems.

Climate change and climate variability are adding to the pressure, particularly on the quantity and quality of freshwater resources, and on the region's ability to ensure food security and sustain rural livelihoods (ESCWA *et al.*, 2017). The Near East and North Africa region has the lowest availability of water and arable land per capita in the world, and projections estimate that availability of renewable water per capita will drop by half (Banerjee *et al.*, 2014). Increased frequency and intensity of extreme heat, droughts, floods, and other extreme weather events have been observed in many countries in the region. While the Near East is affected by droughts, North Africa is increasingly exposed to floods. For instance, droughts in Jordan and Syria in 2007–2010 had devastating impacts on the agricultural sector, and floods in Yemen in 2008 increased the poverty rate and resulted in a 15 percent increase in the number of food insecure people (Verner, ed., 2012). Higher temperatures and shifting rainfall patterns also present increasing challenges for livestock activities within the region. These changes may increase the spread of vector-borne diseases, ticks and macro-parasites, and lead to the emergence of new diseases.

Data collection and monitoring

A high-density network of weather observation stations monitors climate in Jordan, Lebanon Morocco and Tunisia. However, in much of the Near East and North Africa, there are gaps in data sharing among authorities and stakeholders that hamper the development of effective end-to-end and people-centred early warning systems that are based on data that is generated, communicated and received by both farmers and herders. The availability of both observational data for research and the number of studies analysing changes in climate extremes remains limited. For instance, in Algeria, Egypt and Iraq weather data is not readily accessible (Donat *et al.*, 2014).

The 30th Meeting of the Arab Permanent Committee on Meteorology in 2014 called for the organization of a consultation meeting to discuss the establishment of an Arab Climate Outlook Forum. Following a scoping meeting and the review of its outcomes, the first session of the ArabCOF was convened in September 2017 in Beirut (ESCWA, 2014). The forum gathers Arab meteorological services twice a year to prepare seasonal forecast consensus statements. The forum also serves as a platform that allows for regional exchange, lessons learned and consensus building on common concerns facing Arab Meteorological Services. Capacity building activities are often organized alongside official sessions.

Forecasts and projections of weather and climate are currently constrained by insufficient monitoring of meteorological variables. The Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report noted that climate predictions in the region are among the weakest, even though they are necessary for building more rigorous weather forecasting and modelling systems (Christensen *et al.*, 2013). According to the Mountain Partnership and FAO, the Near East and North Africa region has several efficient and well-tested tools and approaches in the field of agrometeorology that can be used for climate characterization, crop forecasting, climate risk management, and for improving crop production through a better use of

water and land resources (Balaghi, 2012). However, there are very few countries within the region that are part of the World Agrometeorological Information Service (WAMIS), and consequently little information remains publicly accessible (WAMIS, 2021).

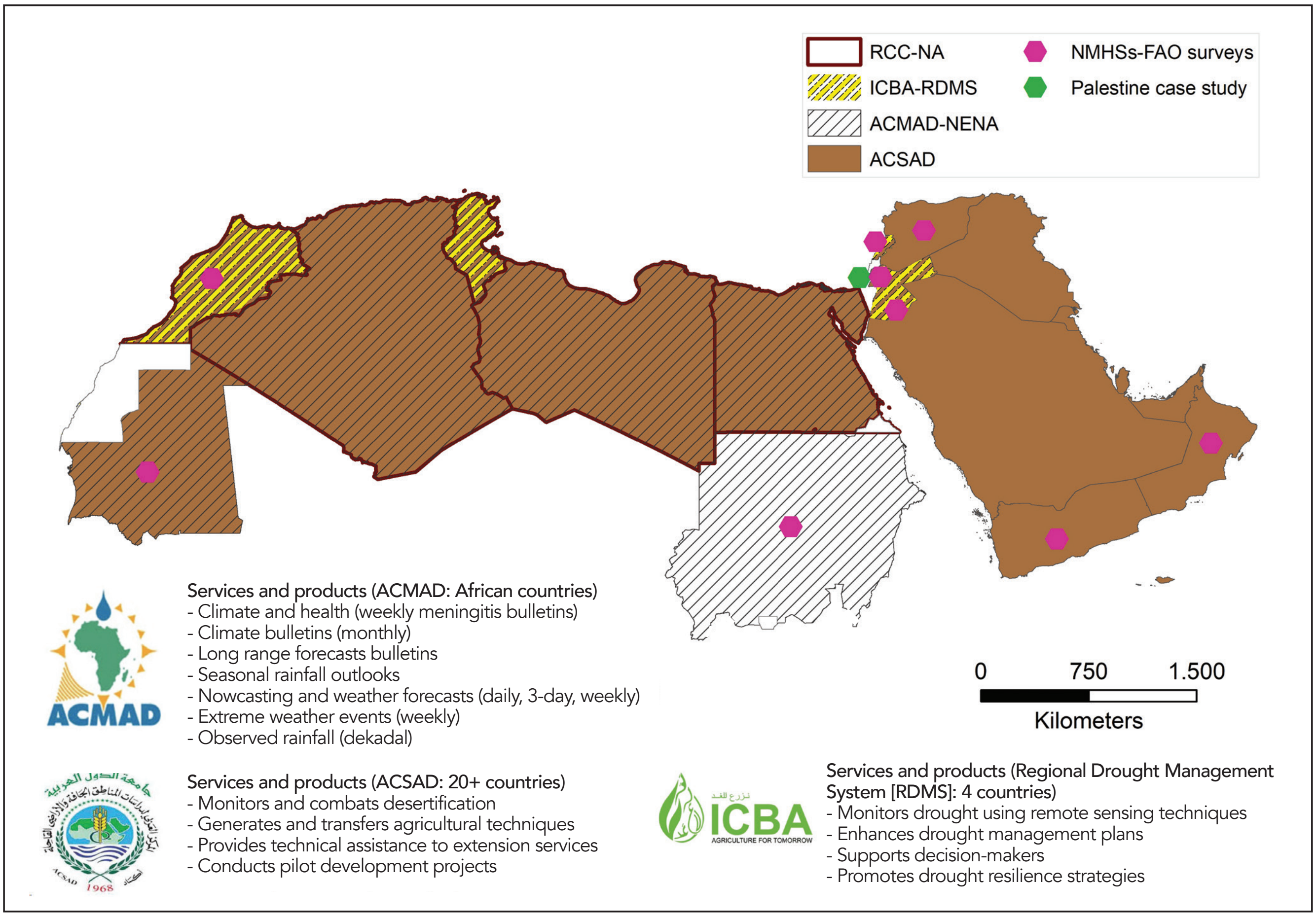
Due to the challenges faced by farmers related to water availability and water scarcity, services tailored to irrigation efficiency, water storage through aquifer recharge, and water harvesting are a top priority for the region (Durrell, 2018). Projected increases in evapotranspiration rates will lead to even higher irrigation requirements in the future even though this will lower even more the water table across the region. Climate services tailored to maximize water use efficiency and irrigation scheduling will allow farmers to optimize water resources, reduce water use during dry periods, and harvest water during rainy periods.

The national adaptation plan in Palestine indicates capacity gaps in climatological forecasting and a mismatch between the knowledge supply and demand side. The Palestine Meteorological Department was tasked with generating data to develop climate services that can provide high-quality assessments on precipitation and temperature conditions and information on impending climate-related threats **(see case study, *Promoting partnerships for an enabling environment to link agrometeorological data with input services in Palestine*)**.

Co-production of tailored services

In recent years, increasing efforts have been made in the co-production of tailored agrometeorological products and services in the Near East and North Africa. An example is the Regional Drought Monitoring and Early Warning System (RDMS) developed by the International Center for Biosaline Agriculture (ICBA, 2020) in Jordan, Lebanon, Morocco and Tunisia. This system is based on 5 km by 5 km gridded dataset produced on a monthly basis in which the input parameters are weighted differently: vegetation stress – 20 percent (using the NDVI anomaly derived from eMODIS), precipitation deficit – 40 percent (using two-month standardized precipitation index values from CHIRPS), evapotranspiration anomalies - 20 percent (using the evaporative stress index), and soil moisture anomaly - 20 percent (using the Land Information Systems modelled data) (Fragaszy *et al*., 2020). However, assessments have characterized the drought monitoring systems in the region as nascent. This is due to their over-reliance on precipitation-based indices, besides identifying an urgent need for the participatory development of these systems and more in-depth cross-sectoral engagement of stakeholders.

Figure 9. Main regional institutions delivering agrometeorological services in the Near East and North Africa region.



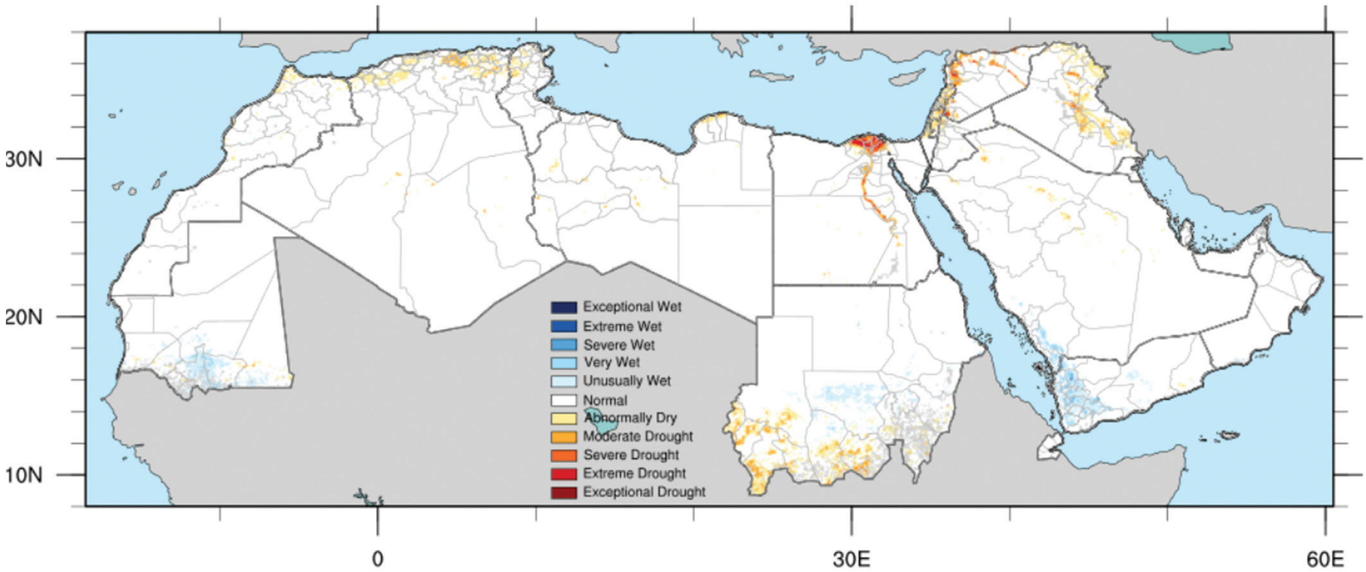
Note: EU JRC MARS bulletins are also provided for North Africa but are not included in the above map.
Map conforms to United Nations World Map 4621, Feb 2021.

The Arab Centre for the Studies of Arid Zones and Dry Lands (ACSAD) is a regional research centre focusing on the advancement of arid zones and semi-arid areas across the Arab League countries (ACSAD, 2020). ACSAD monitors drought using the vegetation health index and develops plans for areas vulnerable to drought and salinity. It also carries out research on climate-resilient seeds. The Regional Centre for Climate in North Africa (RCC-NA) provides climate services and products in Algeria, Egypt, Libya, Morocco and Tunisia. The main climate services of the RCC are seasonal outlooks (temperature and precipitation forecasts) that are produced on a quarterly basis.

In Morocco, the National Institute for Agronomic Research (INRA) has developed crop forecasting products to support decision makers to prepare in advance for abnormal deviations in climate. For instance, non-parametric and parametric approaches based on precipitation, temperature and NDVI are used for cereal yield forecasting (Balaghi *et al.*, 2013). As a result, INRA can provide decision makers with bulletins that integrate the different approaches: a similarity approach using rainfall and NDVI; regression models using rainfall and NDVI as predictors of yield; and forecasting yields using crop growth models and the World Food Studies Simulation Model (WOFOST).

There are good examples of effective collaboration and capacity building on agricultural monitoring and information systems between North African and European countries. Since the late 80s, the European Union (EU) Joint Research Centre (JRC) has provided agricultural policy support to countries in the Near East and North Africa region through the Monitoring Agriculture ResourceS (MARS) crop yield forecasting system. Several North African countries (Algeria, Morocco and Tunisia) have used this information to strengthen the agricultural monitoring and capacity of national and regional institutions. In recent years, the United States Agency for International Development (USAID) and the National Aeronautics and Space Administration (NASA) have also strengthened drought monitoring across the region. Improvements in drought monitoring have been achieved by equipping national experts from Jordan, Lebanon and Morocco with tools, data, and planning skills to better guide hydrologists and decision makers across governmental agencies with timely and effective mitigation measures for combating drought (USAID, 2020).

Figure 10. Composite Drought Index for the North East and North Africa region (2016). Source: Center for Biosaline Agriculture (ICBA), 2016.



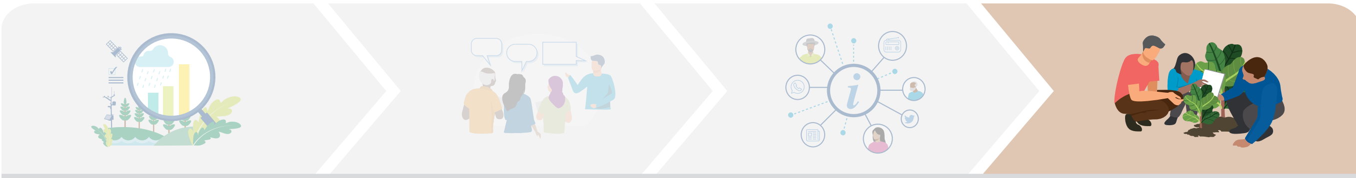
Communication of services to the last mile

In the Near East and North Africa region, government agricultural extension services have been strong. In Tunisia, farmers' union representatives have a formal role in governmental drought monitoring systems. In Morocco, the private sector insurance firm *Mutuelle Agricole Marocaine d'Assurance* (MAMDA) works with government officials to assess drought impacts on the ground (Fragaszy *et al.*, 2020). However, areas with low population densities have always lacked an adequate flow of technical and market information. In recent years, however, some countries have piloted computer-linked dissemination of farm management information. Farmer training has lagged in the region, and this is holding back the adoption of technology and increased farming efficiency.

In many countries in the region, policies or regulations hinder the introduction of digital technology (Trendov *et al.*, 2019). Lack of internet access in least developed countries (e.g., Mauritania and Yemen), particularly in rural areas, is of great concern because the benefits of connectivity are generally higher for rural communities in remote areas. Second to sub-Saharan Africa, the Near East and North Africa region has the lowest percentage of subscriber penetration (64 percent) and smartphone adoption (52 percent) (Trendov *et al.*, 2019).

In Mauritania, the NMHS, together with the agricultural extension service, NGOs, farmers' organizations, national and local radios, phone operators and traditional *griots* (storytellers) are providing users with information for supporting agricultural decision-making. This includes advice based on seasonal forecasts and crop calendars for land preparation; information for determining the date for sowing; the use of field-placed rain gauges; advice on crop phenological phases; soil moisture; and weather forecasts for effective weeding and fertilizer application (Tarchiani *et al.*, 2017). Mauritanian farmers are also using agrometeorological information for diverse reasons. For instance, farmers use

this information when deciding the quantity of agricultural inputs needed, selecting crops and cultivars, determining planting dates, adjusting the crop development cycle to be in tune with rainfall patterns, and choosing favourable periods for conducting cultural operations. Another example is the information promoted by the Egyptian Meteorological Agency (EMA) in cooperation with the Ministry of Environment and Agricultural Research Center of the Ministry of Agriculture. These institutions issue periodical agrometeorological reports and bulletins on meteorological services for agriculture. Some of the applications of these agrometeorological products include chilling requirements, cotton planting dates, yield prediction using heat units, early warnings to avoid frost injury, and desert locust pathways (EMA, 2020).



Participatory engagement of last mile and climate-informed actions

The governments of Jordan, Lebanon, Morocco and Tunisia have established consultative bodies that are chaired by government agencies. Community-based organizations, businesses, NGOs and other stakeholders participate in these consultative bodies and contribute to drought declarations and mitigation planning (Ouassou *et al.*, 2007; Louati *et al.*, 2005). Water user associations promote the engagement and coordination of farmers throughout the region. These associations also support sustainable water management by establishing abstraction rules, coordinating canal operations and releases, and informing farmers on irrigation plans (Durrell, 2018). In Yemen, water user associations provide customer-oriented water distribution and seasonal rationing services for communal harvested water. They have also reintroduced traditional water harvesting techniques that ensure the active engagement of communities.

The International Center for Agricultural Research in the Dry Areas (ICARDA) Mashreq/Maghreb project provided training on the community-based development approach in eight countries: Algeria, Iraq, Jordan, Lebanon, Libya, Morocco, Syria, and Tunisia. Over 800 farmers and over 160 staff members (extension staff, decision makers, local administration) participated in the training activities.

Key lessons from this experience include:

(i) the participatory characterization of communities is essential for ensuring cooperation and building trust among stakeholders,

(ii) recognition of local knowledge is an important step for successful diagnosis,

(iii) annual and long-term development plans approved by communities are efficient tools to mobilize resources and facilitate project implementation,

(iv) the capability of communities to identify appropriate technical solutions and to solve internal conflicts particularly relating to property rights and land use should not be overlooked, and

(v) the success and the sustainability of the approach depends on the promotion of elected community-based organizations that play a key interface role between communities and other actors (e.g., government agencies and decision makers, NGOs, donors and other communities).

In Sudan, the development of village development committees and revolving funds created linkages between research institutions, agricultural extension officers and farmers, all of which are all being involved in future projects in Sudan. These village development committees can be further developed to ensure farmers engagement in the use of climate information (Durrell, 2018).

©FAO/Jafar Almerei

Investment needs

In the Near East and North Africa, most (83 percent) of the small-scale agricultural adaptation and mitigation finance from the public sector has been focused on adaptation. It receives the least amount of finance devoted to climate change mitigation (USD 91 million) compared to other regions (Chiriac *et al.*, 2020). Overall, a total of USD 0.3 billion was transferred annually from OECD countries to non-OECD in the Near East and North Africa region. Some of the investment priorities identified in this report, and key for strengthening the climate services framework in the region include:

1. Avoid piecemeal investments and provide finance at every step of the climate services framework.
2. Invest in climate information data collection and hard infrastructure, including high performance computers to systematically keep up with scientific developments and update forecasting and prediction skills.
3. Invest in skills and analytic capacities at the national level to support the development and implementation of early warning systems.
4. Invest in the cross-sectoral (e.g., hydrology, weather, agriculture, health, infrastructure, transport) operation of climate services and enhance inter-regional coordination and agrometeorological data-sharing platforms.
5. Invest in tailored services for increasing water use efficiency in agriculture, including the deployment of GIS digital tools for identifying transhumance corridors and water zones for livestock.
6. Foster growth in agriculture and pastoralism by supporting extension services to guide sustainable practices and promote the adoption of adaptation technologies (e.g., rainwater harvesting, drip irrigation systems, etc.).
7. Involve regional climate centres and drought monitoring systems in the development of a framework that makes use of the capacities of each NMHS for delivering climate services to the users.

Regional conclusions

The challenges and set of recommendations for investment provided in the table below are based on an extensive search of literature that includes research papers, technical reports, United Nations flagship reports and regional workshops conducted by WMO as part of the GFCS. These actions and proposed recommendations aim to enhance the effective production and delivery of climate services, and have been carefully selected to bridge the last mile gap while considering the socio-economic context of the region of interest.

Climate services framework step	Major challenges/barriers	Priority areas for action
Data collection, monitoring and forecasting	■ Challenges related to data reliability, calibration of climate monitoring stations or consistent methodologies for data collection ■ Uneven distribution of weather stations ■ Insufficient monitoring of meteorological variability, which constrains weather forecasts and climate projections ■ Over reliance on precipitation-based indicators (standardized precipitation index) for drought monitoring ■ Lack of electronic data management, as most of this data is still collected manually on paper spreadsheets ■ Lack of agricultural information at the field level, which is critical for developing agrometeorological advisories	■ Build a more rigorous weather forecasting and modelling system ■ Strengthen drought monitoring and apply different drought indicators across the region ■ Develop improved early warning systems to inform anticipatory actions ahead of meteorological events and agricultural droughts ■ Provide a self-assessment of institutional capacity to monitor drought impacts ■ Build capacities for monitoring and collecting agricultural sector specific data depending on the needs of agricultural users ■ Systematically monitor evapotranspiration

Climate services framework step	Major challenges/barriers	Priority areas for action
Task force and data sharing	■ Gaps in data sharing across authorities and stakeholders for effective end-to-end and user-centred early warning systems ■ Insufficient timely and accessible meteorological information through open platforms ■ Lack of interaction between relevant institutions and stakeholders	■ Support countries develop and regularly deliver agrometeorological bulletins ■ Start sharing agrometeorological bulletins in the publicly accessible World Agrometeorological Information Service (WAMIS) ■ Involve a wide range of stakeholders and promote participatory development in the production of tailored services ■ Strengthen the collaboration between NMHSs and other institutions, research organizations, private sector, NGOs and farmers' associations for integrating user-tailored products in agriculture ■ Promote the collaboration among NMHSs within the region ■ Develop data-sharing platforms and transfer knowledge at the national and regional levels ■ Ensure continuous information exchange among existing technical working groups with complementary objectives, such as the ones on forecasts, climate services and anticipatory action
Co-production of tailored agrometeorological advisories	■ Limited climate knowledge among government structures of the benefits of using climate services in agriculture ■ Lack of engagement of agricultural users, farmers, pastoralists, fishers, in the co-production and co-design of climate services	■ Foster partnerships between government and non-government entities for the co-production of tailored services for farmers ■ Promote a more in-depth engagement of cross sectoral stakeholders for developing environmental monitoring tools ■ Support formal agreements and long-term partnerships for institutional and financial support ■ Build regional and national roadmaps for the co-production of tailored agrometeorological advisories ■ Prioritize the scaling up of tailored climate services for livestock ■ Invest in engagement and awareness activities for sector stakeholders and agricultural communities ■ Develop irrigation advisories based on crop growth models

Climate services framework step	Major challenges/barriers	Priority areas for action
Communication of services to the last mile	■ Low access to communication channels based primarily on the resources of the last mile ■ Low network coverage in arid areas ■ Gender disparities in access to ICTs and other communication channels	■ Prepare climate services in diverse formats for wider communication to the agricultural sector ■ Disseminate climate advisory services through SMS technology and rural radio broadcasts to maximize coverage in remote areas ■ Sensitize potential users about the benefits of ICTs through climate-sensitive groups, including women
Participatory engagement of last mile	■ Lack of participatory development and intersectoral engagement between farmers and government institutions ■ Lack of engagement of national institutions with farming communities	■ Promote a two-way communication between the government and farmers ■ Develop curriculum and invest in participatory peer-to-peer learning and farmer engagement through Farmer Field Schools or other approaches on the ground ■ Build interface platforms that allow users to access and use agrometeorological products more efficiently
Climate-informed actions	■ Climate services often do not reach local communities with tailored information to support strategic and tactical agricultural management decisions ■ Lack of trust or awareness of options to address climate impacts at the farm level	■ Provide relevant and more useful and tailored drought-related information ■ Develop weather index insurance schemes and climate advisory services to help farmers prepare and recover from extreme weather events ■ Carry out awareness raising campaigns on climate risks and engage with farming communities ■ Support the establishment of Anticipatory Action plans, linking early warning thresholds to action and outlining clear guidelines on how to protect the lives and livelihoods of the most vulnerable ahead of hydrometeorological hazards

Survey results: Communication channels

This section presents the results obtained from the surveys in response to the following question:
By which means are the weather information and weather alerts currently delivered to the last mile?

Figure 11. List of communication means used to deliver weather information and weather alerts to the last mile, based on survey results. Refer to Annex 1 to see the original survey template. *Note: The results contained herein do not represent all existing communication means such as agricultural extension officers, posters, public meetings, face-to-face, etc.*

Survey results: Agrometeorological advisories

This section presents the results obtained from the surveys in response to the following question:
Which type of information does the NMHS provide to the last mile?

	Morocco	West Bank Gaza	Mauri-tania	Sudan	Yemen	Lebanon	Oman	Jordan	Syria
Optimal sowing date	✓ (Crops)		✓ (Crops)			✓ (Crops)		✓ (Crops)	
Onset rainy season	✓ (Crops)	✓ (Crops)	✓ (Crops)	✓ (Crops)		✓ (Crops)		✓ (Crops)	✓ (Crops)
Offset rainy season	✓ (Crops)		✓ (Crops)			✓ (Crops)		✓ (Crops)	✓ (Crops)
Dry spells	✓ (Crops)		✓ (Crops)	✓ (Crops)		✓ (Crops)		✓ (Crops)	✓ (Crops)
False start rainy season	✓ (Crops)		✓ (Crops)			✓ (Crops)		✓ (Crops)	✓ (Crops)
Cumulative precipitation	✓ (Crops)	✓ (Crops)	✓ (Crops)	✓ (Crops)	✓ (Crops)	✓ (Crops)	✓ (Crops)	✓ (Crops)	✓ (Crops)
Evapotranspiration	✓ (Crops)	✓ (Crops)	✓ (Crops)	✓ (Crops)		✓ (Crops)			✓ (Crops)
Cumulative growing degree-days	✓ (Crops)							✓ (Crops)	✓ (Crops)
Soil moisture	✓ (Crops)		✓ (Crops)	✓ (Crops)			✓ (Crops)		
Seasonal forecast	✓ (Crops) ✓ (Forestry)	✓ (Forestry)	✓ (Crops) ✓ (Forestry)	✓ (Crops) ✓ (Forestry)	✓ (Crops) ✓ (Forestry)	✓ (Crops)	✓ (Crops)		✓ (Crops)
Precipitation forecast	✓ (Crops)	✓ (Crops)	✓ (Crops)	✓ (Crops)	✓ (Crops)		✓ (Crops)	✓ (Crops)	✓ (Crops)
Temperature forecast	✓ (Crops)	✓ (Crops)	✓ (Crops)	✓ (Crops)	✓ (Crops)	✓ (Crops)	✓ (Crops)	✓ (Crops)	✓ (Crops)
Pest and disease forecast	✓ (Crops)		✓ (Crops)	✓ (Crops)	✓ (Crops)	✓ (Crops)		✓ (Crops)	
Hail forecast	✓ (Crops)	✓ (Crops)				✓ (Crops)	✓ (Crops)	✓ (Crops)	✓ (Crops)
Wind forecast	✓ (Crops) ✓ (Fisheries)	✓ (Crops) ✓ (Fisheries)	✓ (Crops)	✓ (Crops) ✓ (Fisheries)	✓ (Crops) ✓ (Fisheries)	✓ (Crops) ✓ (Fisheries)	✓ (Crops) ✓ (Fisheries)	✓ (Crops)	✓ (Crops) ✓ (Fisheries)
Storm surge					✓ (Crops) ✓ (Fisheries)				
Water resource availability	✓ (Livestock)							✓ (Livestock)	
Potential heat stress	✓ (Livestock)	✓ (Livestock)	✓ (Livestock)	✓ (Livestock)	✓ (Livestock)	✓ (Livestock)		✓ (Livestock)	
Potential disease occurrence zones	✓ (Livestock) ✓ (Forestry)		✓ (Livestock) ✓ (Forestry)					✓ (Livestock)	
Potential lightning zones	✓ (Livestock) ✓ (Fisheries) ✓ (Forestry)			✓ (Livestock) ✓ (Fisheries)			✓ (Livestock) ✓ (Fisheries)		✓ (Livestock) ✓ (Fisheries) ✓ (Forestry)
Fodder availability	✓ (Livestock)		✓ (Livestock)						
Potential extreme weather events	✓ (Livestock)	✓ (Livestock)	✓ (Livestock)	✓ (Livestock)		✓ (Livestock)	✓ (Livestock)	✓ (Livestock)	✓ (Livestock)
High swell forecasts	✓ (Fisheries)		✓ (Fisheries)		✓ (Fisheries)		✓ (Fisheries)		✓ (Fisheries)
High tides forecasts	✓ (Fisheries)		✓ (Fisheries)	✓ (Fisheries)	✓ (Fisheries)	✓ (Fisheries)	✓ (Fisheries)		✓ (Fisheries)
Visibility forecasts	✓ (Fisheries)	✓ (Fisheries)	✓ (Fisheries)				✓ (Fisheries)		✓ (Fisheries)
Sea surface temperature	✓ (Fisheries)		✓ (Fisheries)				✓ (Fisheries)		✓ (Fisheries)
Wildfire prone zones	✓ (Forestry)		✓ (Forestry)					✓ (Forestry)	✓ (Forestry)

Crops ✓ Livestock ✓ Fisheries ✓ Forestry ✓

Table 2. Agrometeorological advisory services provided to the last mile per agricultural sector (crops, livestock, fisheries and forestry), based on survey results. Refer to Annex 1 to see the original survey template.

©FAO/Marco Longari

CASE STUDY

Promoting partnerships for an enabling environment to link agrometeorological data with input services in Palestine

Country:
Palestine (West Bank and Gaza Strip)

Institution(s):
Palestine Environment Quality Authority (EQA), Ministry of Agriculture, Palestinian Meteorological Department (PMD), Palestinian Water Authority (PWA)

Background

The success of seasonal food production in Palestine depends on the replenishment of water and the ability of the soil to retain water under irrigated agriculture. The agriculture sector was responsible for nearly 30 percent of all exports in 2019, and accounted for 6.1 percent of total employment. Climate change, particularly higher temperatures and increased rainfall variability, can directly lead to the contraction of the agro-industrial sector, and indirectly affect water and food supplies in the country. Under a fragile security situation, the West Bank and Gaza strip, where the majority of the population lives, faces a long-standing economic crisis and food access crisis. The high costs of inputs (e.g., fertilizer and animal feed) compromise the profitability of agricultural activities and inflate market prices.

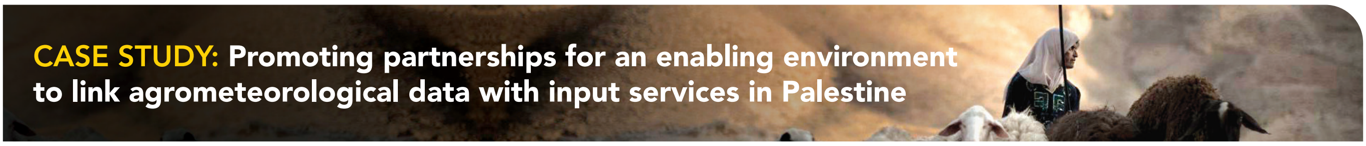
The following case study explores an initiative in Palestine that aimed at improving the delivery of accessible and actionable agrometeorological information, and crafting early warning messages to support early action and weather-informed decision-making. The initiative is the result of a partnership between the PMD, the Ministry of Agriculture, line ministries, and FAO, with funds leveraged by the Global Climate Fund (GCF). By strengthening the enabling environment for climatological data sharing and collaboration, the partnership addresses the problems of missing data, the lack of digitized records, and the lack of historical data to indicate changes in climate over time.

Major challenges for reaching the last mile

- Agricultural users only have access to communication channels based on their own resources.
- Fostering cooperation requires contextual sensitivity and familiarity on the part of stakeholders with various national mandates to complement climate services.
- Subsistence farmers have limited capacity to act on early warning.
- Poor households with few skills and assets struggle to maintain the resources required to implement early actions.

Benefits of using climate-informed advisories

- Timely climate services increase knowledge of control measures to withstand climate shocks.
- From the supply side, capacity is built to deliver climate services, while on the demand side, knowledge is increased on how to deal with and withstand impending weather-related shocks.



CASE STUDY: Promoting partnerships for an enabling environment to link agrometeorological data with input services in Palestine

Lessons learned

- Climate services and early warning products are strengthened when sound preparatory work is carried out to assess the capacity, the research, and community support that is needed to deliver and use the product.
- Initial assessment of current roles and mandates of key institutions involved in the production and provision of climate services is essential to identify investment needs and determine the actions that need to be taken to strengthen the enabling environment.
- Coordinated and recurring communication between institutions is critical to ensure mutual understanding and collaboration.

Future work and investment opportunities

- Ensure the plan for monitoring and evaluation is suitable for obtaining feedback and making adjustments to the climate services when required.
- Enhance partnerships between the private sector, and support collaboration from national institutions to ensure the stability of networks and the sustainability of the delivery of climate services.
- Further employ the small-scale farmer networks of the Ministry of Agriculture to engage the community in developing tailored climate services that address user needs and preferences.

References:

PCBS. 2021. The labour force survey results 2019. In: *The Labour Force Survey Results, 2019* [online]. [Cited 26 March 2021]. http://www.pcbs.gov.ps/post.aspx?lang=en&ItemID=3666

PCBS. 2021. Detailed indicators of foreign trade in Palestine* 2017-2019. In: *Detailed Indicators* [online]. [Cited 26 March 2021]. http://www.pcbs.gov.ps/Portals/_Rainbow/Documents/detailed-indicators-english.html

Prepared by: FAO Palestine

CASE STUDY

Phone applications for sustainable water management in Egypt and Lebanon

Country:
Egypt and Lebanon

Institution(s):
IWMI, SWERI, MSA, FAO, LARI

Background

In the Near East and North Africa (NENA) region, high costs and low accessibility remain major barriers to the effective use of Information and communication technologies (ICTs) in agriculture. FAO and the International Water Management Institute (IWMI) have conducted studies and applied new technologies for water management in Egypt and Lebanon, including FAO's "WaPOR" tool that uses remote sensing data to assist countries in monitoring water productivity and identifying water productivity gaps.

In Egypt, in the framework of the WaPOR project, the IWMI-MENA office developed a phone application, IRrigation Water Information (IRWI), together with the Soil, Water and Environment Research Institute (SWERI) and the University for Modern Sciences and Arts (MSA). The application was co-designed to provide irrigation water requirements, expected yields based on crop types, soil characteristics, suitable irrigation systems, soil salinity levels, and more. Seven crops (wheat, rice, maize, beetroot, soybean, potato and cotton) were included in the first version of the application. Farmers from different governorates received training on how to use the application and provided feedback during the design and test phases. This feedback contributed to the effective and user-driven development of IRWI. Following the release of the application, training workshops were held with different stakeholders, including smallholder farmers, technicians, agronomists, and university students.

In Lebanon, the Lebanese Agricultural Research Institute (LARI) has a network of over 60 automated weather stations. With FAO inputs, the IWMI conducted a stakeholder mapping and needs assessment of ICT tools in agriculture. The LARI application was developed as a result, providing weather forecasts, early warnings on main pests as well as pest management advisories. Since 2015, LARI has worked to develop LARI-LEB, a mobile application that would also provide irrigation advice. LARI-LEB was developed with support from the WaPOR project and resulted in adding two modules for irrigation requirement and scheduling and crop yield. LARI-LEB was first tested on the Bekaa valley, one of the main agricultural areas in the country. The upgraded LARI-LEB application included evapotranspiration data for the Bekaa valley, information on crop-water requirements for wheat, potatoes, and table grapes, as well as data on crop health and development during the growing season.

Major challenges for reaching the last mile: Egypt

- Lack of pest and disease monitoring information and pest management advisories at local scale.
- Limited information on crop-tailored net irrigation requirements.
- Low access to market price information, which needs to be timely updated to facilitate the marketing of products.

CASE STUDY: Phone applications for sustainable water management in Egypt and Lebanon

Lebanon

- The LARI-LEB application lacks information related to on-farm irrigation, important to support local farmers to better manage their farm and, consequently, improve their yields.
- Crop water estimations should be provided on a regular basis – e.g., every three days, whereas the WaPOR database currently publishes evapotranspiration (ET) data every 10 days.
- Limited face-to-face consultations with the last mile due to COVID-19 restrictions constrains the ability to meet user needs.
- Information on few crops is available on the application, reducing the potential number of users.

Lessons learned

- Identifying different agricultural stakeholders working with ICT tools through stakeholder mapping and needs assessment.
- Investing in the development and/or improvement of a well-known and widely used application successfully increased the number of users reached.
- Processing WaPOR ET and reference ET (ETo) data in a way to extract the crop coefficient (Kc) allows to accurately determine net irrigation requirements for each crop.
- Partnership between research, government and academic provide practical solutions to the target communities that can be easily adapted.
- Integrating feedback from end-users at design phases contributes to boosting a sense of ownership and, consequently, to increasing the usability and level of uptake.

Future work and investment opportunities

- Add a module in LARI-LEB related to crop status in terms of primary production (grams of biomass per m^2) from WaPOR. This would help farmers understand if a crop is growing adequately and, consequently, how it might perform in terms of yields.
- Introduce more crops and associated relevant information into both applications in Egypt and Lebanon.
- Provide live assistance on crop status by allowing picture-sharing through the application and immediate expert-advisory on how to manage the crop accordingly.
- Organize workshops across Egypt and Lebanon to raise awareness on the importance of both applications for agriculture and sustainable water management.
- Peer-to-peer knowledge transfer between well-trained farmers who can use the applications and other farmers.
- Use seasonal forecasts to determine net irrigation requirements in advance.
- Further research on crop forecasting price and feasibility studies for different crops to assist farmers with crop selection and prediction of revenues at harvesting.
- Further investment on extreme weather alerts for agricultural communities (for instance for heat waves, sandstorms, frost) as well as on advisories with relevant climate resilient practices to reduce risk.

References:
Ali, M., Abd El Hafez, S., Elbably, A., Tawfik, A., Elmahdi, A. 2021. Implementation of on-farm water management solutions to increase water productivity in Egypt. ICT- Phone Application "IRWI-اروي "for Water Management in Agriculture. (available at https://irwicrop.com/Technical-Report-IRWI.pdf)

Prepared by: Marwa Ali and Amgad Elmahdi (IWMI Egypt).


©Adobe Stock/Saravut

Asia and the Pacific

The Asia and Pacific is the most disaster-prone region in the world (Kreft *et al.*, 2019). The region is characterized by vast coastlines and low-lying areas and includes many Small Island Developing States (SIDS).

This makes the region particularly vulnerable to rising sea levels and weather extremes. In Asia, approximately 2.4 billion people live in low-lying coastal areas threatened by increasing floods and storms, which are often exacerbated by sea level rise (UNDP, 2019). In recent years, the region has experienced unprecedented high temperatures. For example, Afghanistan, India and Pakistan recorded temperatures above 50°C in 2020, and August 2020 was the wettest month on record in Pakistan (WMO, 2021). Heatwaves and droughts together with shifting rainfall patterns have had large impacts on the agricultural sector. Additionally, in the Asia and Pacific region, around 200 million people depend on fisheries for their livelihoods (ESCAP, 2019). Increases in sea surface temperature, ocean acidification and coral bleaching all have detrimental impacts on marine ecosystems and the livelihoods dependent on them.

Data collection and monitoring

Almost all the Pacific Island Countries have national meteorological and hydrological services (NMHSs). However, forecasts and early warning systems are poorly developed or non-existent. A number of these countries rely on external support to provide basic climatological services. In general, the NMHSs are small compared to world standards and they have limited resources, budget and staff (WMO, 2020). In South Asia and Southeast Asia, the major barriers for data collection and monitoring and communication to the last mile include: (i) the lack of NMHS capacity to routinely provide tailored local information, (ii) gaps in historical climate data, (iii) challenges in translating raw climate data into locally specific information that is relevant for agriculture, and (iv) insufficient institutional and governance arrangements to sustain co-production (Krupnik *et al.*, 2018). Furthermore, the weather observational network among the 10 countries belonging to the Association of Southeast Asian Nations (ASEAN) remains weak. A relatively low number of technical staff are available to operate and maintain the existing observational network (MSS, 2017). Only five of the ten ASEAN countries affirm having the capacities to design and implement large-scale remote sensing and other observation systems (e.g., satellites and buoys), and less than half can develop and manage regional or global specialized climate databases. However, most of the NMHSs in the region have access to observational data from neighbouring countries and have access to interpolated gridded data, satellite data, reanalysis data and model data from regional and global climate models (MSS, 2017).

The Global Information System Centres (GISCs) in Tokyo and Beijing, which are hosted by the Japan Meteorological Agency (JMA) and the China Meteorological Administration (CMA), are regional coordinators in WMO Region II (Asia, excluding the South-West Pacific) for the real-time operations of the WMO Information System network. The Data Collection and Production Centre (DCPC) in Bangkok, which is connected to the GISC in Tokyo and hosted by the Thai Meteorological Department (TMD), is responsible for coordinating the meteorological telecommunication network, and serves as the regional telecommunication hub (RTH). The regional WIGOS centre in Tokyo, which is hosted by the JMA, is designated to assist WMO NMHSs members in WHO Region II in enhancing the availability and quality of surface, climate, upper-air, and hydrological observations (World Bank, 2018).

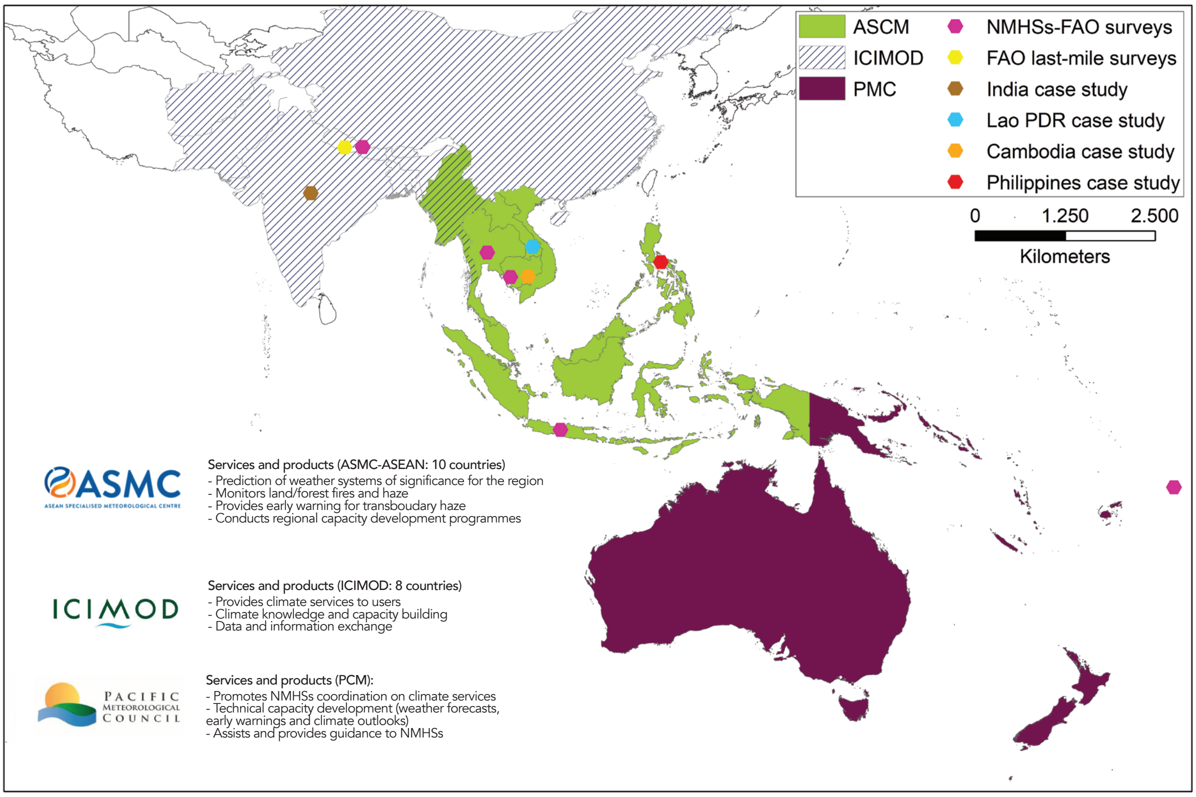
In the Pacific region, data management and digitalization remain a major challenge for the long-term assessment and forecasting of down-scaled climate information (SPREP, 2016). For instance, monitoring of climate data in Samoa has been ongoing for more than 100 years. However, a significant portion of these historical records are written in hard copy and are vulnerable to destruction (SPREP, 2016). Missing data are a major challenge especially in remote areas. In Vanuatu, the NMHS trains local rainfall volunteers to collect data. However, due to the manual data collection process, the data often has gaps or errors. The Fiji Meteorological Service is designated as a WMO Regional Specialized Meteorological Centre (RSMC) for tropical cyclones. In addition to serving the citizens of Fiji, the RSMC also serves another six Pacific Island Countries and Territories: Cook Islands, Kiribati, Nauru, Niue, Tokelau, and Tuvalu. The RSMC is also the special advisor to Samoa, Tonga, and Vanuatu.

Co-production of tailored services

In Asia, the International Centre for Integrated Mountain Development (ICIMOD) facilitates the implementation of the GFCS across the Hindu-Kush-Himalayan (HKH) region. It brings together providers and users of climate information across eight HKH countries and strengthens the institutional and technical capacities among member states, particularly to improve the generation, processing, and use of climate services, and co-develop and co-design appropriate solutions (ICIMOD, 2020). In Southeast Asia and Southwest Pacific, the ASEAN Specialised Meteorological Centre (ASCM) is responsible for weather predictions and climate systems of significance to the region (ASMC, 2020). In addition, ASMC monitors land management and forest fires, and provides early warnings on the occurrence of transboundary haze affecting the southern ASEAN region.

The Pacific Meteorological Desk and Partnership (PMDP) supports NMHSs in the South Pacific by providing information pertaining to the Pacific Meteorological Council (PMC) (PMC, 2020). The PMC is formed by 14 NMHSs and provides weather, climate, and early warning services through sustained observing systems, telecommunications, data processing and management systems. The PMC has different panels: (i) Pacific Island Climate Services (PICS), (ii) Pacific Island Education, Training and Research (PIETR), (iii) Pacific Island Marine and Ocean Services (PIMOS), (iv) Pacific Island Aviation Weather Services (PIAWS), and (v) Pacific Hydrology Services (PHS). For instance, PICS dialogues are workshops designed to share climate knowledge and enhance the existing climate services. These workshops inform regional and local decision makers on the impacts of climate change and highlight key messages and best practices for the development and delivery of climate services (PICS, 2020). Overall, regional cooperation in the Pacific is strong, and the role of regional centres is particularly important for operational support and technical assistance to PICS.

Figure 12. Main regional institutions delivering agrometeorological services in Asia and the Pacific.



The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.
** Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the Parties.*

Communication of services to the last mile

Asia

Weather advisories and climate information, together with weather-based insurance, are key elements for managing risks in South Asia because they reduce farmers' losses and stabilize farmers' income. However, the preferences amongst farmers differ by crop and region (Taneja *et al.*, 2019). Rice and wheat farmers in the eastern Indus-Gangetic-Plain prefer crop insurance and weather advisory services, whereas farmers in western Indus-Gangetic-Plain prefer receiving information on irrigation scheduling, and support with weather risk insurance for crops. Another study across five Indian states has assessed farmers' access to ICTs-based climate information and agro-advisory services pertaining to a variety of topics (e.g., heat and drought tolerant varieties, water conservation, pest and disease control) (Gangopadhyay *et al.*, 2019). Among ICTs, television and cell phones are the main communication channels for weather information and agro-advisory services. A cell phone-based agro-advisory system for use in horticulture, which has been developed by Michigan State University, is intended to be of practical use in countries like India, Nepal and Sri Lanka (Ramakrishna, 2013).

The Indian Meteorological Department started issuing district level weather forecasts twice a week in 2008 and the Agromet Advisory Services today use three disseminatoin channels – mass media, group awareness campaigns and individual contacts – to increase outreach. Around 19 million farmers were subscribed to SMS advisories in 2016 (WMO, 2016). Additionally, Reuters Market Light (RML) is one the largest and most well-established private providers of agricultural price, weather and crop advisory information in Maharashtra, India. RML subscribers (25 000) are provided with 75 to 100 mobile phone SMS per month (USD 1.50 per month) in English or, if required, in the local language (Fafchamps and Minten, 2012). Major barriers for improving access to mobile alerts include both the range of coverage and available languages **(see case study, *Warnings for fishers in India – GAGAN*)**

In Pakistan, the Regional Agrometeorological Center (RAMC) regularly advises the farming community through electronic and print media on issues related to sowing times and irrigation schedules (Khan and Hanif, 2007). *Sohni Dharti* is the first agricultural television channel in Pakistan that provides information on agriculture and rural development. A television channel and an FM radio station are also being set up in the public sector to educate farmers about modern farming technologies. The channel is expected to reach an estimated 6.6 million farmer households across the country and will mainly telecast agriculture-related programmes (Ramakrishna, 2013).

The Nepalese Agricultural Research Council (NARC) is mandated to provide agrometeorological advisory services to farmers. The delivery of information starts once the Department of Hydrology and Meteorology generates weather outlooks for the upcoming week. The weather outlooks are then coupled with crop and livestock information provided by agricultural extension services located across the country. Expert meetings take place every week and bulletins containing weather, crop and livestock information are produced in Nepalese to maximize the number of users (Timilsina *et al.*, 2019). NARC also deploys tailored agrometeorological advisories that bridge, to some extent, the gap between climate information producers (NARC) and the last mile **(see case study, *Perspectives from farmers and pastoralists: last mile needs and uptake of agrometeorological information in Nepal*).**

In Bangladesh, agrometeorological information is provided by the Bangladesh Meteorological Department (BMD), the Bangladesh Water Development Board (BWDB) and the Department of Agriculture Extension (DAE) (Krupnik *et al.*, 2018). Throughout the country there are 1 500 integrated pest management clubs, and 30 000 lead farmers are receiving information via SMS. In addition, the Climate Services for Resilient Development (CSRD) programme in Bangladesh, together with BMD and DAE, are now producing interactive map-based agrometeorological bulletins (CCAFS, 2019). They are also developing a mobile phone app with numerical weather forecasting with easy-to-understand crop-specific management advisories to farmers (CCAFS, 2019). Private and international agencies are increasingly playing a role in supporting farming communities in South Asia by initiating ICT use in agriculture for agro-advisory communication (Ramakrishna, 2013).

In Afghanistan, the Ministry of Agriculture, Irrigation and Livestock (MAIL) has installed 108 agrometeorological stations in 34 provinces across the country and provides farmers with essential information to determine the irrigation needs of different crops. The automated weather stations are connected to satellites that automatically relay every hour the recorded information through the internet to the administrator's website (World Bank, 2016b).

The Islamic Republic of Iran Meteorological Organization (IRIMO) is responsible for providing weather, climatological, and agrometeorological services to agricultural users. Users are provided with agrometeorological news (in Farsi), including agronomic recommendations on several subjects, such as effective rainfall, weekly forecasts, seasonal temperature and precipitation forecasts, as well as information on growing degree days and advisory services on planting and harvesting dates.

In Myanmar, agricultural advisory services are disseminated by the Department of Agriculture to farmers through multiple communication channels, including radio, television, newspapers, posters, pamphlets, and agricultural fairs (Krupnik *et al.*, 2018).

In Philippines, the Farm Weather Services Section (FWSS) prepares and disseminates products such as farm weather forecasts (3-day forecasts); agrometeorological reviews and outlooks (dekadal weather information including rainfall, temperature, relative humidity and evaporation); and dekadal regional agrometeorological advisories combining weather and agricultural information (Basco, 2020). It allows farmers and users to plan farming operations in advance, besides providing agronomic guidance to farmers on the most suitable crops based on seasonal forecasts. The FWSS also provides warnings to agricultural communities to modulate the impacts and losses in agriculture from extreme weather events.

In the Lao People's Democratic Republic, the co-production of agrometeorological bulletins involve a variety of government actors working at multiple scales. The Department of Meteorology and Hydrology hosts a database, called LaCSA (Laos Climate Service for Agriculture) with climatological data from the last 30 years and systematically receives automatic and manually collected weather data **(see case study, *Strengthening agroclimatic information and monitoring systems-SAMIS in Lao*)**. The same database automatically produces seasonal and weather forecasts and converts them into monthly and weekly bulletins. In the Lao People's Democratic Republic, the Department of Agricultural Land Management (DALaM) produces soil maps and district-level crop calendars. District-level agricultural statistics produced by the Statistic Center for Agriculture help tailor the model outputs. To provide climate services for farmers, the bulletin also counts on the support of the National Agriculture and Forestry Research Institute (NAFRI). The outcome is a list of recommendations for seven crops and three livestock species. Additionally, the Plant Protection Center (PPC) uploads a monthly pest and disease outbreak report in LaCSA. District-level offices produce monthly agronomic data through a KoBo questionnaire that is automatically uploaded into the database.

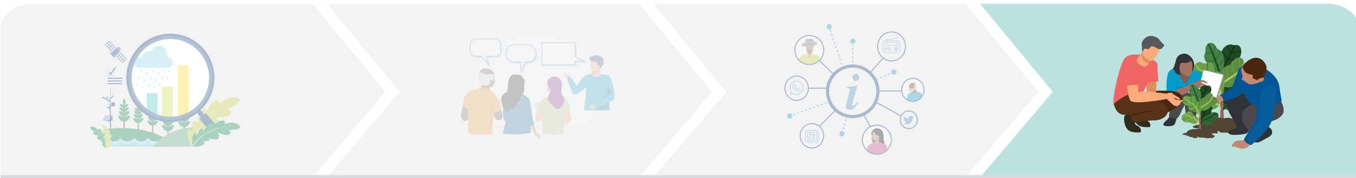
The Pacific Islands

To enhance the uptake of climate services by the last mile users, the Vanuatu Meteorology and Geohazards Department (VMGD) and partner organizations are using short animations called the '*klaod nasara*' and 'climate crab' to explain difficult climate and weather concepts, and the different applications and benefits of using climate services. While the '*klaod nasara*' is tailored to the context of Vanuatu, the 'climate crab' animation has a wider Pacific focus. The 'klaod nasara' animation features local characters in local settings. It connects climate and weather activities to the daily lives of people in Vanuatu and provides recommendations for minimizing climate impacts. The animation is in Vanuatu's three official languages (Bislama, English, and French) and has contributed to the communication of climate information to farmers in a comprehensive and clear way (SPREP, 2016).

As part of the Finnish Pacific (FINPAC) Project in the Pacific Islands, since 2013, the communication of climate and disaster information has been enhanced in diverse ways depending on the local context. In the Cook Islands, a siren has been installed in the cyclone-prone village of Tautu, and disaster drills and roof tie-down exercises for households are regularly conducted to test community's response. In the remote islets of Ribono and Nuotaea in Abaiang, Kiribati, the traditional communicator, *Wiin Te Kaawa*, and the island councillor have been equipped with a bicycle and a loudhailer to reach the community with early warning information (SPREP, 2016).

In Tuvalu, advances in information communication have led to the development of a climate bulletin available in local language, as well as a radio programme from the Tuvalu Meteorological Services that explains the messages contained in the climate bulletins in a more detailed way. A Facebook page hosted by the Tuvalu Meteorological Service is also available to the public and updated every morning by a climate officer.

In Samoa, an SMS system has been developed by Samoa's Meteorological Department in collaboration with the Bluesky and Digicel mobile networks. The new system has significantly decreased the time it takes for early warnings to reach the users and supported tailor-made messages that can be diffused simultaneously either as SMS or as a pdf file through emails, fax, and cell phones (SPREP, 2016).



Participatory engagement of last mile and climate-informed actions

To enhance the adoption and uptake of climate information among farming communities it is critical to include agricultural extension, social support networks and financial incentives (e.g., weather-related insurance schemes) (FAO, 2018). Participatory engagement of farmers has proven valuable throughout the region **(see case study, *Perspectives from farmers and pastoralists: last mile needs and uptake of agrometeorological information in Nepal*)**. One successful approach for fostering farmer engagement on climate information decisions are Climate Field Schools and Farmer Field Schools (Krupnik *et al.*, 2018).

An assessment of the effectiveness of training and awareness raising in Indonesia found that harvest production increased by 30 percent among farmers with access to climate services. The Indonesian Agency for Meteorology Climatology and Geophysics (BMKG), together with extension workers from the Ministry of Agriculture, has conducted numerous training sessions through Climate Field Schools to raise the awareness and climate literacy of small-scale farmers (Krupnik *et al.*, 2018). In Viet Nam and Cambodia, the Agriculture Climate Information Service (ACIS) has been developed to involve national institutions and farmers in the co-design and co-production of climate services. In these two countries, the participatory scenario planning process has been implemented. It consists of an interactive and iterative learning process that includes the following phases: (i) design and process, (ii) preparing workshops, (iii) facilitating a participatory scenario planning process workshop, (iv) communicating the advisories, (v) implementing feedback mechanisms, and monitoring and evaluation. Key products identified by farmers for driving agricultural decision-making include seasonal forecasts for determining the sowing date, variety selection, harvesting time, and nowcasting for day-to-day agricultural management activities. Some of the main challenges reported by producers of climate services are related to the tailoring of weather information, and the quality and accessibility of downscaled national weather forecasts.

In Sri Lanka, weather forecasts are the most effective climate services to drive climate-informed decisions. Seasonal forecasts from the NMHS are shared at meetings before the start of the rainy season, and where farmer leaders, irrigation operators, agricultural extension officers and local officials are part of the participatory engagement process. As a result, the forecast is blended with local knowledge and market information that is pertinent to the local context. For example, farmers are empowered to make risk-sensitive decisions in the case of forecasted below-average rainfall.

As a result, farmers apply a collective drought management strategy called 'bethma'. Their fields are then divided and supplied with water during the season in equal amounts among all the participating families, regardless of their ownership. Empirical studies suggest that farmers who participated in 'bethma' have a higher adaptive capacity to drought compared to farmers who have not (ESCAP, 2019).

Other important mechanisms for providing social protection to vulnerable communities include affordable agricultural insurance schemes for small-scale producers. These schemes offer tremendous potential for ensuring that actions based on climate services can be effectively implemented. Crop weather index insurance (CWII) offers an alternative approach to crop insurance and uses climate-related proxies or indices (e.g., rainfall, temperature, wind speed) to trigger pay-outs to farmers. Micro level CWII has been tested or commercially scaled up in eight countries in Asia and the Pacific region (FAO, 2011). For example, CWII is commercially implemented in India and Thailand through the rainfall-deficit in maize and rice cumulative rainfall deficit CWII programme. Additionally, the implementation of the MicroEnsure initiatives in the Philippines, in conjunction with the Malayan Insurance Company, offers rice producers (micro level) with rainfall deficit insurance **(see case study, *Proactive instead of reactive: moving towards an anticipatory approach for drought in the Philippines*).**

In the Pacific Islands, farmers highlighted trust as a key aspect for the effective uptake of climate services. Trust developed by spending time together in '*talanoa*' (talking and sharing stories and ideas) with mutual respect were identified as key lessons of the FINPAC project (SPREP, 2016). Another lesson from the FINCAP project is to strengthen the two way-learning processes used by the NMHs along the Pacific Islands to display weather and climate information in an understandable way that integrates the community's traditional knowledge.

Investment needs

In East Asia and the Pacific, most of the finance provided by the public sector to small-scale agriculture (including forestry, land use, livestock and fisheries) was focused on adaptation (USD 830 million annually), with similar weight given to climate change mitigation projects (USD 500 million annually). Nevertheless, up to USD 1.4 billion in investment was directed annually to climate-resilient infrastructure at the farm level for agricultural production, and climate-resilient infrastructure necessary for the post-production storage, transport and processing of agricultural products (Chiriac and Naran, 2020). Public climate finance in South Asia also favoured climate-resilient infrastructure, with approximately USD 905 million channelled annually to the region. Overall, a total of USD 3.5 billion was transferred annually from OECD countries to non-OECD in East Asia, the Pacific and South Asia. To enhance investment in the delivery of climate services to the last mile, this report suggests the following actions:

1. Avoid piecemeal investments and provide finance in every step of the climate services framework.
2. Invest in the establishment of free and unrestricted data sharing platforms and agreements at the national level.
3. Invest in early warnings with longer lead times to allow for early response and preparedness.
4. Harmonize climate services across the region to enhance transboundary basin and asset management.
5. Increase the role of NGOs, private sector and public institutions and extension services in providing information at the district level to ensure engagement and uptake by farming communities.
6. Enhance government engagement of stakeholder participation to encourage bottom-up participation and strengthen the influence of marginalized community members, including women and youth.
7. Invest in social support networks, financial incentives (e.g., weather-related insurance schemes) and the use of localized weather data for climate index insurance that is based on smart contracts to simplify the process and give instant pay-outs.

Regional conclusions

The challenges and set of recommendations for investment provided below are based on an extensive search of literature that includes research papers, technical reports, United Nations flagship reports and regional workshops conducted by WMO as part of the GFCS. These actions and proposed recommendations aim to enhance the effective production and delivery of climate services, and have been carefully selected to bridge the last mile gap while considering the socio-economic context of the region of interest.

Climate services framework step	Major challenges/barriers	Priority areas for action
Data collection, monitoring and forecasting	■ Insufficient observational network (automated and manual) with essential weather variables required for developing agrometeorological services ■ Weak technical capacity for data storage ■ Poor temporal and spatial scales of weather and climate forecasts ■ Low coverage of ocean observation networks	■ Rehabilitate existing weather stations and improve technical capacity for the maintenance of weather stations ■ Upgrade the forecasting capabilities by improving the access and use of global and regional datasets, products and tools ■ Develop dynamic cropping calendars that integrate forecasted precipitation with sufficient time for farmers to adjust their planting dates and support the selection of most suitable crops and varieties as well as other actions to protect crops/livestock/fisheries from weather-related shocks ■ Improve the monitoring and prediction of ENSO events
Task force and data sharing	■ Limited technical, financial, and human resources that can be committed to agrometeorological services ■ Lack of visibility of NMHSs within the community and governmental institutions	■ Establish a technical working group with institutional coordination between information providers, mediators, and users ■ Ensure continuous information exchange among existing technical working groups with complementary objectives, such as the ones on forecasts, climate services and anticipatory action ■ Strengthen governance arrangements, including coordination and communication mechanisms within NMHSs and stakeholders across sectors ■ Promote the use of WMO regional climate centre platforms for access and sharing of data and services

Climate services framework step	Major challenges/barriers	Priority areas for action
Co-production of tailored agrometeorological advisories	■ Lack of mechanisms for exchange of information among governments ■ Lack of standard operating procedures for the coordination and co-production of agrometeorological services by multiple stakeholders ■ Weak collaboration between MoAs and NMHSs	■ Prepare concrete national roadmaps towards strengthening and operationalizing agrometeorological services ■ Propose a strategic collaboration between WMO and FAO to develop a regional guidance on agrometeorological services, in which a standardized framework for data collection, sharing, analysis, translation into actionable services, and last mile communication processes is systematically documented
Communication of services to the last mile	■ Challenges related to translating climate and agronomic information ■ Inadequate means for communicating the information	■ Use the state-of-the-art information communication technologies or platforms to drive digital agricultural transformation ■ Establish an effective two-way communication and timely data collection and sharing between information providers and users ■ Build the capacity of smallholder farmers, women, poor and socially marginalized groups to use ICT tools
Participatory engagement of last mile	■ Lack of awareness of climate and agronomic information generated by NMHSs and MoAs ■ Lack of effective two-way communication between agrometeorological service providers and users	■ Promote participatory approaches such as the PICSA approach or FAO Farmer Field Schools to ensure information uptake ■ Support participatory scenario planning process consisting of different interactive and iterative learning
Climate-informed actions	■ Scarce resources to translate the collected data from agriculture and meteorology sectors into agrometeorological services ■ Lack of access by farming communities to forecasting information that is translated into actionable climate-resilient practices ■ Lack of timely climate information to the last mile, as it usually reaches households too late to make decisions (e.g., planting and harvesting dates)	■ Promote the use of data on risks and impacts to drive climate-informed decisions ■ Develop applications with numerical weather forecasting with easy-to-understand crop-specific management advisories to farmers

Survey results: Communication channels

This section presents the results obtained from the surveys in response to the following question:
By which means are the weather information and weather alerts currently delivered to the last mile?

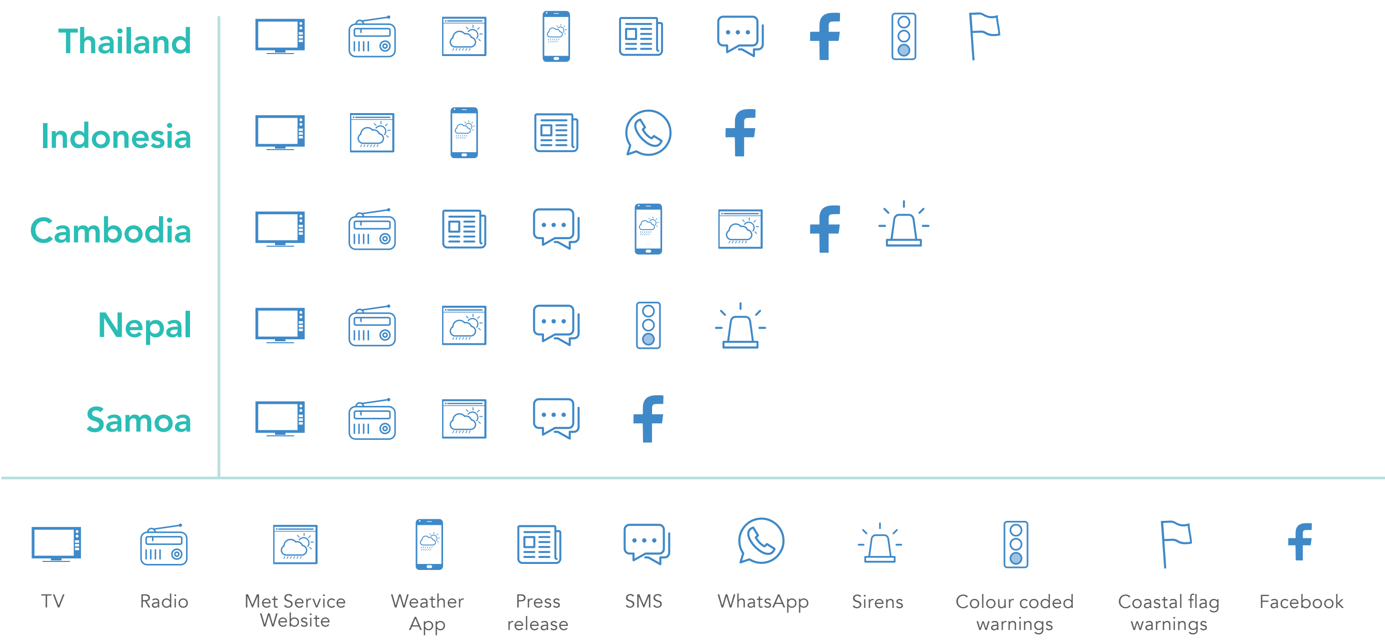


Figure 13. List of communication means used to deliver weather information and weather alerts to the last mile, based on survey results. Refer to Annex 1 to see the original survey template. *Note: The results contained herein do not represent all existing communication means such as agricultural extension officers, posters, public meetings, face-to-face, etc.*

Survey results: Agrometeorological advisories

This section presents the results obtained from the surveys in response to the following question:
Which type of information does the NMHS provide to the last mile?

	Thailand	Indonesia	Cambodia	Nepal	Samoa
Optimal sowing date	✓				
Onset rainy season	✓	✓	✓	✓	
Offset rainy season	✓		✓	✓	
Dry spells	✓	✓	✓		✓
False start rainy season	✓				✓
Cumulative precipitation	✓	✓	✓	✓	✓
Evapotranspiration	✓	✓	✓		
Cumulative. growing degree-days			✓		
Seasonal forecast	✓	✓	✓	✓	✓ ✓
Precipitation forecast	✓	✓	✓	✓	✓
Temperature forecast	✓		✓	✓	
Hail forecast	✓			✓	
Wind forecast	✓ ✓		✓	✓	✓ ✓
Potential lightning zones				✓	
High swell forecasts	✓				✓
High tides forecasts					✓
Storm surge	✓				
Visibility forecast					✓
Wildfire prone zones					✓

Crops ✓ Livestock ✓ Fisheries ✓ Forestry ✓

Table 3. Agrometeorological advisory services provided to the last mile per agricultural sector (crops, livestock, fisheries and forestry), based on survey results. Refer to Annex 1 to see the original survey template.

CASE STUDY

A data sharing and monitoring platform in Cambodia

©Adobe Stock/Akturer

Country: Cambodia

Timeframe: 2017 – ongoing

Institution(s): World Food Programme (WFP)

Background

The Platform for Real-Time Impact and Situation Monitoring (PRISM) combines on-the-ground data with satellite information. PRISM provides tools to estimate the impacts of extreme weather, inform an early response, and reduce the impacts of climate-related disasters. PRISM, which is one of the WFP's climate hazard monitoring systems, has been developed and piloted by WFP in the Asia-Pacific region. The system produces near real-time risk and impact maps based on earth observation data and key information on different aspects of socio-economic vulnerability, including poverty and food insecurity. The maps are displayed in an interactive dashboard that enables decision makers to identify and prioritize effective disaster mitigation strategies and early response mechanisms. PRISM gives the government the data it needs to lead the disaster response in a coordinated way together with United Nations partners, NGOs and other groups.

An innovative component of PRISM-Cambodia is the use of field-based impact assessments gathered by government disaster management agencies. These assessments, collected on mobile devices and published on PRISM, provide dynamic information on current conditions and needs on the ground.

Major challenges for reaching the last mile

- Climate information usually reaches communities too late for households to make decisions on when to plant and/or harvest, and, critically, when to take action to move their families and assets out of harm's way in case of severe weather.
- Ethnic minority women are especially at risk of marginalization, particularly due to language barriers, and because extension agents more often engage with men.
- Meteorologists and extension officers often lack the necessary skills to package climate services in an understandable manner for farmers.

Lessons learned

- The recent integration of earth observation data for PRISM is the result of a collaboration with the SERVIR programme, a NASA and USAID initiative that has brought the strength of NASA's research capacity to the Government of Cambodia and WFP.
- In 2020, WFP launched an upgraded version of PRISM with the National Committee for Disaster Management (NCDM). The NCDM will be able to rapidly capture and disseminate critical information on the potential impacts of a disaster. This will provide key information for decision-making, which is an important new capability given the frequent floods and droughts that have severely affected the country in the past few years.

CASE STUDY: A data sharing and monitoring platform in Cambodia

- PRISM also provides critical information to the Humanitarian Response Forum in Cambodia, a coordination mechanism on droughts and floods. United Nations agencies and international NGOs work closely with the NCDM during humanitarian crises. PRISM monitors droughts and floods, enabling Cambodia to be better prepared and undertake actions in advance to respond to extreme weather events.

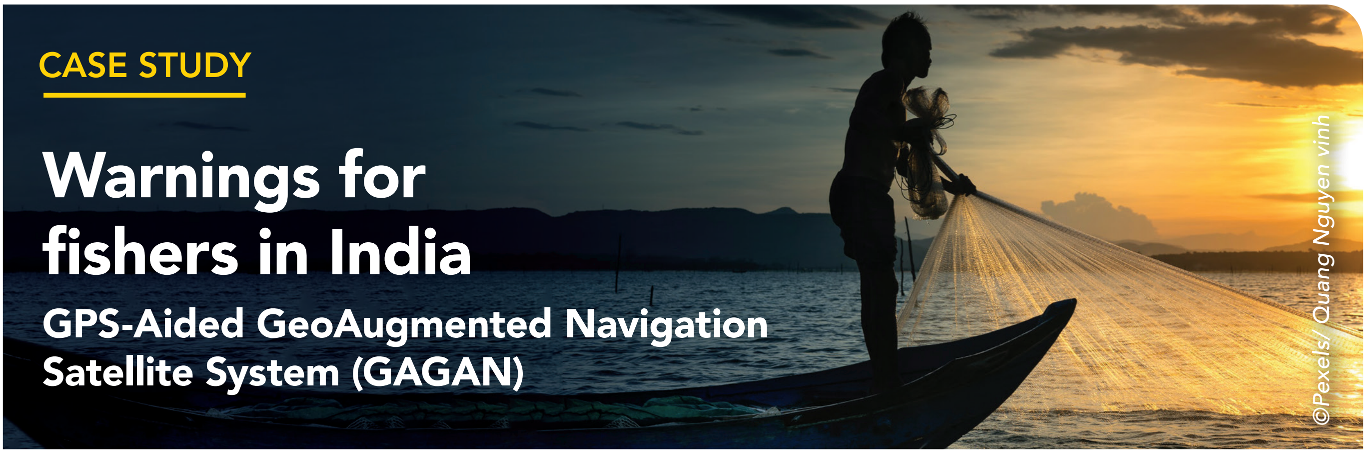

©Adobe Stock/StockerZ

Future work and investment opportunities

- PRISM is actively used by other countries within the region, including Indonesia and Sri Lanka. It is currently being launched in Mongolia and will soon be deployed in Myanmar.
- A logical next step for PRISM is to develop the core technology of the system and connect it to climate and disaster risk reduction programmes, such as forecast-based financing and anticipatory actions, and shock-responsive social protection.
- Strategic partnerships will be key to ensuring PRISM's continued success. This will involve strengthening partnerships with the government and with the scientific and research communities to improve the reliability of the platform. New private sector partnerships need to be explored to improve the technology and gain access to more dynamic data generated through mobile phones and high-resolution satellite imagery.
- WFP also works alongside research partners to improve the risk and impact analyses used in the system. This ongoing research examines the historical impact of climate hazards on vulnerable populations over time. The outcome of this research will inform more rigorous analyses generated by PRISM.
- Ongoing research on users is critical to understand how current decisions are made, and how future decisions can be informed by data on risks and impacts. Through design workshops, interviews, and consultations, WFP is developing a deeper understanding of user needs. This will, in turn, lead to improved design of the system and the development of new features that ultimately will help governments better serve vulnerable communities, save lives, and protect livelihoods.

References:
O'Brien, C. 2020. *10 things you wish you'd always known about shock-responsive social protection.* WFP. (available at https://www.wfp.org/publications/10-things-you-wish-youd-always-known-about-shock-responsive-social-protection)

Prepared by: Ria Sen and Giorgia Pergolini (WFP).



©Pexels/ Quang Nguyen vinh

CASE STUDY

Warnings for fishers in India

GPS-Aided GeoAugmented Navigation Satellite System (GAGAN)

Country:
India

Institution(s):
Indian National Centre for Ocean Information Services (INCOIS), Ministry of Earth Sciences (MoES), Airports Authority of India (AAI)

Background

Information and Communication Technologies (ICTs) and satellite technologies have proliferated among fishing communities in India. However, access to warnings on extreme weather and the development of climate services for fisherfolk have lagged behind. In 2017, lives were lost at sea during the Ockhi Cyclone due to the limited range of mobile connections, which made it impossible to reach fishers far from shore. Existing technologies and devices issuing weather-related alerts only reached fishers who were within 10 to 12 km of the coastline, which is the typical range of mobile phones and very high frequency (VHF) radios.

To respond to this challenge, the Indian National Centre for Ocean Information Services (INCOIS), an autonomous body under the Ministry of Earth Sciences (MoES) joined efforts with the Airports Authority of India (AAI) to develop the GAGAN Enabled Mariner's Instrument for Navigation and Information (GEMINI). The device is capable of receiving weather information through geosynchronous communication satellites and transmitting this information to a smartphone application through Bluetooth to distances up to 6 000 km from the shoreline. GEMINI allows for the seamless and effective dissemination of emergency information and communication on disaster warnings, potential fishing zones and ocean state forecasts to fishers. GAGAN is made up of a satellite system consisting of three communication satellites: GSAT-8, GSAT-10 and GSAT-15. With the GEMINI device fitted in fishing boats, fishers can receive information on potential fishing zones and ocean state forecasts at 16:00 every day and extreme weather alerts (e.g., cyclones) every hour. A mobile application developed by INCOIS decodes and displays the information in nine regional languages.

©Facebook/INCOISofficial

CASE STUDY: Warnings for fisherfolk in India – GAGAN

Major challenges for reaching the last mile

- Climate services are not tailored to both shallow and deep-sea fishers.
- Information is usually not translated into local languages, which makes it ineffective or unreliable for users.

Lessons learned

- Through GEMINI-transmitted weather information, the significant limitations in terms of the range of offshore coverage of climate services were overcome.
- Services were tailored to provide information that was pertinent to both shallow and deep-sea fishers.
- Information translated in local language ensured uptake by fishers.

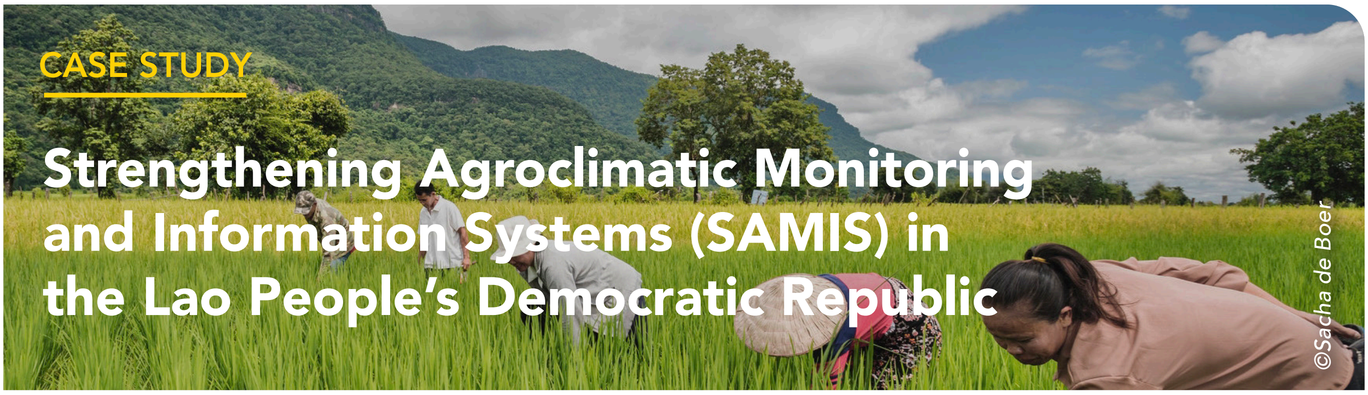
Future work and investment opportunities

- Investments in essential devices and Bluetooth technology should be scaled up to ensure increased and equitable access to information in fishing communities.
- Investment in further tailoring of services beyond extreme event warnings is needed to support sustainable and resilient practices.
- Scaling up at the national, regional and global levels requires investments in coordination between the research community, government entities and the private sector.

References:

Amrita, C. & Karthickumar, P. 2016. Need for mobile application in fishing. *International Journal of Science, Environment and Technology*, 5(5): 2818-2822.

Ayobami, A. S. & Sheikh Osman, W. R. 2013. Functional Requirements of Mobile Applications for Fishermen. *UACEE Second International Conference on Advances in Automation and Robotics–AAR*. 13.



CASE STUDY

Strengthening Agroclimatic Monitoring and Information Systems (SAMIS) in the Lao People's Democratic Republic

©Sacha de Boer

Countries:
Lao People's Democratic Republic

Timeframe:
2016 – ongoing

Institution(s):
FAO, Ministry of Natural Resources and Environment (MONRE), Department of Agricultural Land Management (DALaM), Department of Meteorology and Hydrology (DMH), The Global Environment Facility (GEF)

Background

Building upon recent progress on strengthening climate services in Lao People's Democratic Republic, the SAMIS project supports agrometeorological data collection and monitoring, communication, and analytic facilities at the national and provincial level. The project also reinforces institutional and technical capacities for sharing data, and archiving, analysing, and interpreting agrometeorological advisories. The project has developed a system, the Laos Climate Services in Agriculture (LaCSA), which archives and processes agrometeorological information. The system generates agrometeorological services for farmers by combining meteorological and agricultural data to produce seasonal forecasts at the provincial level (18 provinces) and weekly bulletins at the district level (141 bulletins). The bulletins include weather outlooks, climate-smart agriculture recommendations and pest and disease risk advisories for several crops and three livestock species.

Major challenges for reaching the last mile

Dissemination and uptake of services and information were the main challenges for reaching the last mile. The SAMIS project conducted household surveys with a total of 343 farmers. The surveys highlighted the dissemination channels used for delivering agrometeorological services, and the preferred means for receiving these services. Two districts, which included 31 percent of the farmers surveyed, had Farmer Field Schools where farmers were able to access weather information in addition to the information provided through loudspeakers. The remaining farmers (69 percent) received weather information only through loudspeakers.

Benefits of using climate-informed advisories

- Farmers who attended the FFS had a better understanding of weather forecasts for decision-making at farm level and, as a consequence, a greater awareness of their importance. FFS also helped farmers have a better understanding of how weather forecasts are produced and how to interpret agrometeorological advisories more effectively.
- The uptake and use of climate services by FFS farmers was higher across all types of communication means. The DMHs Facebook site was the most accessed mean of dissemination (61 percent), while the loudspeakers were only used by 33 percent of the farmers. SAMIS agrometeorological bulletins were mainly accessed through WhatsApp (55 percent) and the LaCSA mobile phone application (32 percent).

CASE STUDY: Strengthening Agroclimatic Monitoring and Information Systems (SAMIS) in the Lao People's Democratic Republic

Despite having participated in FFS, most of the farmers (more than 80 percent) reported adjusting their farming practices based on the SAMIS bulletins received directly from a community loudspeaker system.

Opportunities for scaling up

In the Lao People's Democratic Republic, FFS are used as scientific tools for training farmers throughout the climate-smart villages, which aims to generate evidence on climate-smart agriculture. Due to its costs, the extension system is not yet fully developed, and is often dependent on existing cooperation projects. Some of the opportunities for scaling up the approach are linked to the following points:

- LaCSA data awareness is raised through a mobile phone application, a Facebook page and a weekly television programme. The use of local radios stations has yet to be scaled up. However, these channels cannot ensure detailed local information due to broadcast time constraints. More than 70 of the villages had a loudspeaker system managed by the village authority, and this offers an opportunity for scaling up the number of recipients of agrometeorological information.
- The National Agriculture and Forestry Research Institute (NAFRI) trains all district authorities (141 districts) so that extension officers are available locally for projects or investors.

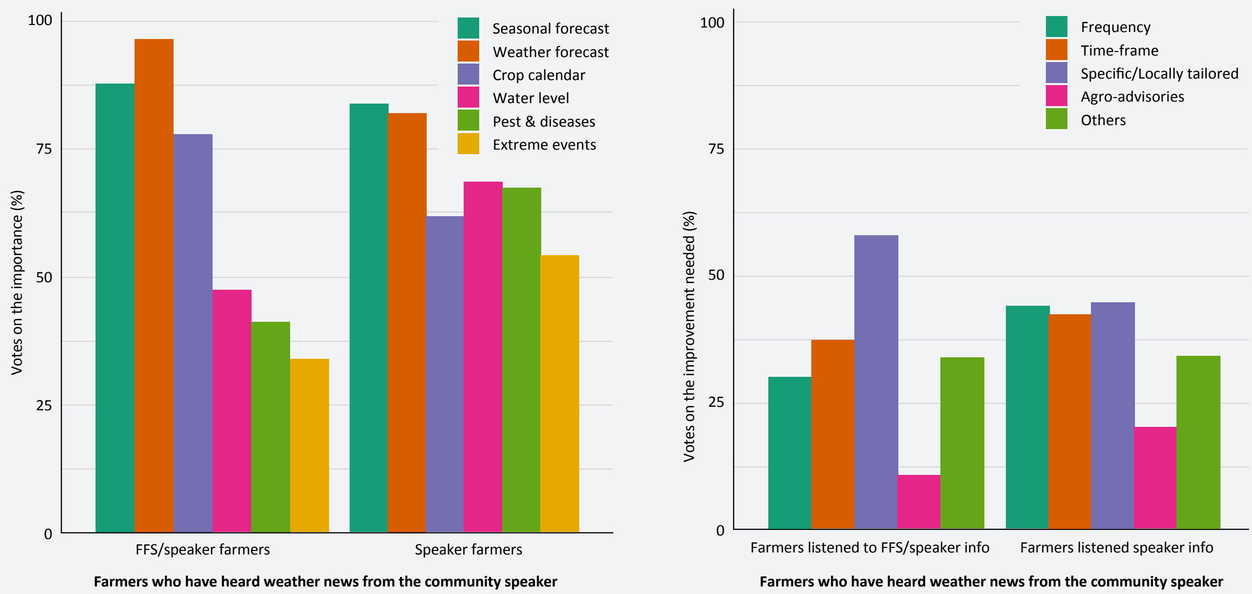


Figure 1. *Agrometeorological services and requirements by farmers (left) and areas for advisories improvement identified by farmers (right)*

Lessons learned

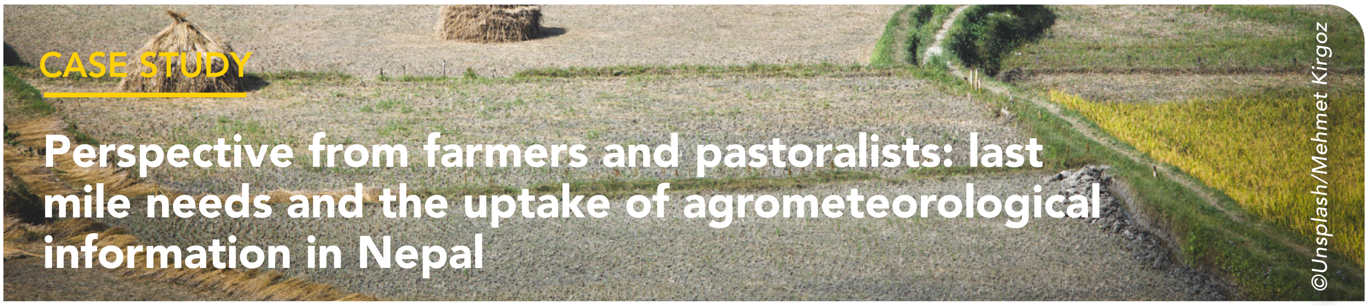
- Farmers participating in FFS are more likely to understand and use climate services for making climate-informed decisions in the field.
- Farmers participating in FFS requested advisories that included information on farm management operation such as (i) seed/variety selection; (ii) use of fertilizers, pesticides, pest and disease control measures; (iii) agriculture advisories for livestock and not only climate and weather information for crops.

CASE STUDY: Strengthening Agroclimatic Monitoring and Information Systems (SAMIS) in the Lao People's Democratic Republic

Future work and investment opportunities

- The diversification of dissemination channels will increase the equitable access of rural communities to climate services. Although climate services are available across the entire country through the LaCSA system, investments are needed to scale up the use and uptake of climate services.
- Investment in farmers groups will ensure the uptake of climate services and scaling up of the lessons learned. However, the government needs to strike a balance between capacity development (e.g., Farmer Field Schools) and long-term economic sustainability.
- There are some opportunities to improve the information delivered through existing climate services by providing more understandable, less technical and especially more localized and tailored advisories for farm management practices. Investment in the tailoring of climate services is necessary to address the needs of the last mile.
- Investments in infrastructure may give farmers, who currently do not have access to information, greater opportunities to obtain climate and weather information.

Prepared by: Monica Petri, Kim Kuang Hyung (FAO LA) and Leo Kris Palao (CIAT).



CASE STUDY

Perspective from farmers and pastoralists: last mile needs and the uptake of agrometeorological information in Nepal

Country: Nepal

Timeframe: 2020

Institution(s): FAO

Background

In Nepal, the Nepal Agricultural Research Council (NARC) is the principle institution responsible for mainstreaming agrometeorological advisories into agricultural sectors, mainly crop and livestock production. The primary objectives of NARC are to (i) provide farmers and other stakeholders with timely agro-climatic and weather information, (ii) expand the use of early warning systems in agriculture and reduce production risks resulting from extreme weather events and climate change, and (iii) provide the latest agricultural technology. The most popular product disseminated by NARC is the Agro-Advisory Bulletin (AAB). The AAB is a technical bulletin prepared by experts that strengthens the capacities of farmers so that they can cope more effectively with adverse weather conditions. Before disseminating the AAB, extensive consultation is carried out among government institutions including the Department of Hydrology and Meteorology (DHM); Department of Agriculture (DoA); the Department of Livestock Services (DoLS). Experts on other biotic stresses (e.g., pests and diseases) that can affect the development of crops and productivity of livestock also contribute.

This case study highlights the challenges and opportunities for enhancing the communication of agrometeorological information to last mile users in Nepal. Assessing user needs is a prerequisite for bridging the demand and supply sides of the climate services framework. This case study provides producers of agrometeorological information (DHM, NARC, DoA, DoLS) with a thorough identification of user-needs necessary for establishing meaningful feedback mechanisms for improving existing extension advisories, as well as developing new ones. Recommendations to make agrometeorological information more accessible and useful to user communities are offered. Findings in this case study are based on surveys from 840 farmer households in the Koshi River basin in Nepal. The information was gathered in person using the KoBot tool together with the support of a consulting firm hired by FAO.

Farmers' perceptions of climate hazards

Agricultural systems are increasingly affected by climate change and variability. Although Nepal has abundant rainfall, farmers and pastoralists perceive drought as the main hazard affecting agricultural activities, followed by heavy rain, pests and diseases, frost, hail and heavy winds (Figure 1).

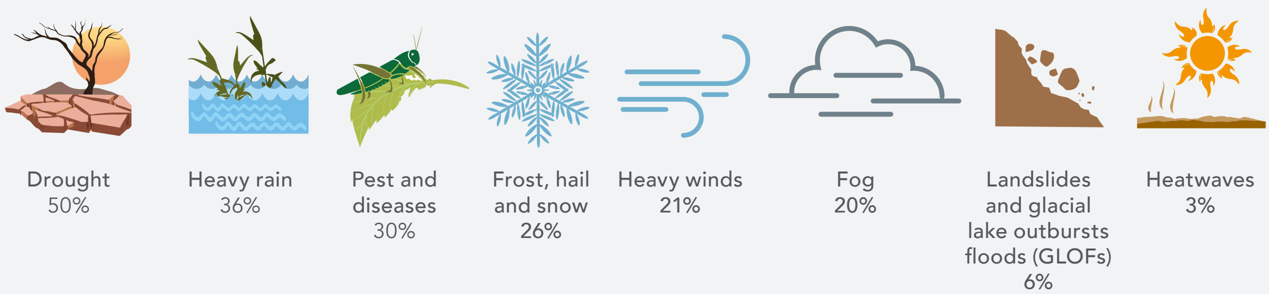


Figure 1. *Natural hazards affecting the development of agricultural activities in Nepal as perceived by farmers. Note: Responses for each hazard are reported as a percentage of the total number of respondents*

CASE STUDY: Perspective from farmers and pastoralists: last mile needs and the uptake of agrometeorological information in Nepal

Existing communication channels: needs and preferences of last mile users

NARC notes that agrometeorological information is mainstreamed at national level through television and radio programmes, SMS, colour-coded warnings and sirens. Farmers and pastoralists acknowledge receiving the information predominantly from television and radio. Overall, NARC's existing communication channels for delivering agrometeorological advisory services are the most effective and accepted by agricultural users. However, to increase the number of beneficiaries, farmers and pastoralists have suggested using a call service that they can use to request and receive information tailored to their needs from experts at any given moment. Farmers also recommend scaling up and enhancing already existing communication means, such as SMS and loudspeakers (Figure 2).

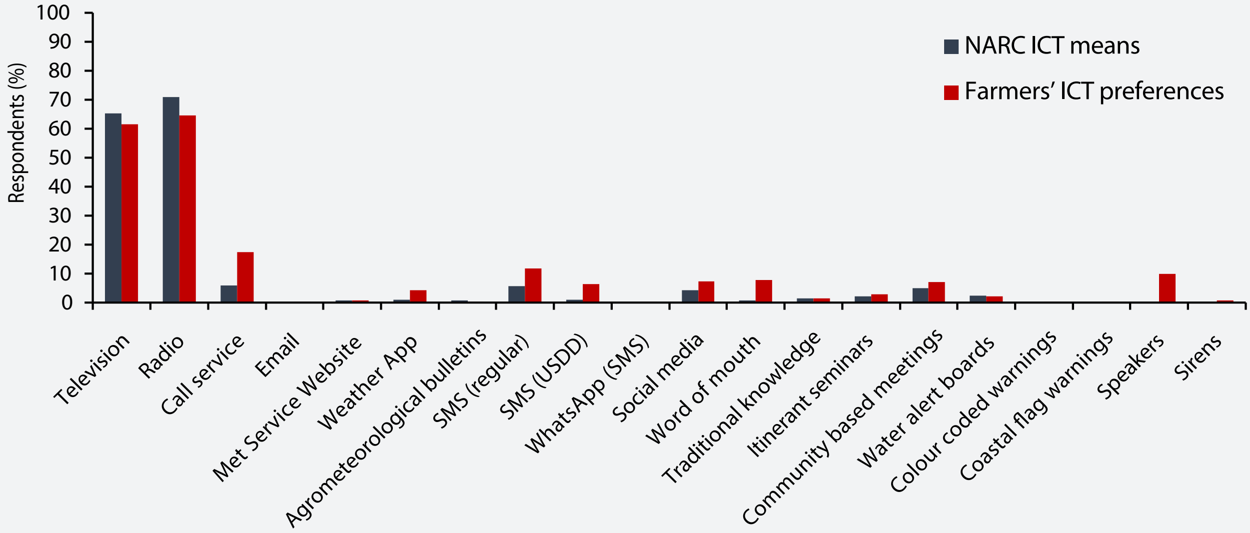


Figure 2. *ICTs used by NARC to deliver agrometeorological information versus farmers' desired means of communication.*

Agrometeorological services tailored to crop systems

To effectively implement targeted and tailored agrometeorological services that support farmers' strategic decisions (e.g., when to prepare the field and and sow the crops, and what crops and varieties to cultivate), it is essential to provide farmers with seasonal forecasts and crop calendars, and monitor other climatic parameters that can bolster the ability of farmers to prepare and respond to hazards during the growing season.
Survey findings show that farmers prioritize agrometeorological information on:

- rainy season onset (69 percent)
- seasonal forecasts (31 percent)
- optimal sowing date (24 percent)
- temperature forecasts (24 percent)
- pest and disease forecast (20 percent)
- information on dry spells (18 percent)

CASE STUDY: Perspective from farmers and pastoralists: last mile needs and the uptake of agrometeorological information in Nepal

These advisories are crucial for reducing input losses (e.g., economic and time losses associated with untimely land preparation, and seed losses due to sowing failure); optimizing agricultural management strategies (e.g., fertilizer, pesticide and insecticide applications that more precisely match weather conditions); and improving yields.

The desired frequency for the delivery of advisories was:

- seasonal for the onset of the rainy season; and
- seasonal and/or whenever relevant for optimal sowing dates, temperature forecasts, pest and diseases forecasts, and dry spells.

All of these advisories have already been developed by NARC, except rainy season onset and pest and disease forecasts.

Agrometeorological advisories tailored to livestock systems

In the livestock sector, six agrometeorological services were identified. The principle services were: fodder availability, potential diseases occurrence zones, water resource availability, and transhumance corridors.

The desired frequency for the delivery of advisories from the perspective of livestock herders was:

- daily, seasonal and/or whenever relevant for fodder availability;
- daily for water resource availability and potential lightning zones; and
- when relevant for potential diseases occurrence zones and transhumance corridors.

Although these services have been requested by pastoralists, so far NARC has only developed one agrometeorological advisory for pastoralists; potential disease occurrence zones, which is delivered on a daily basis.

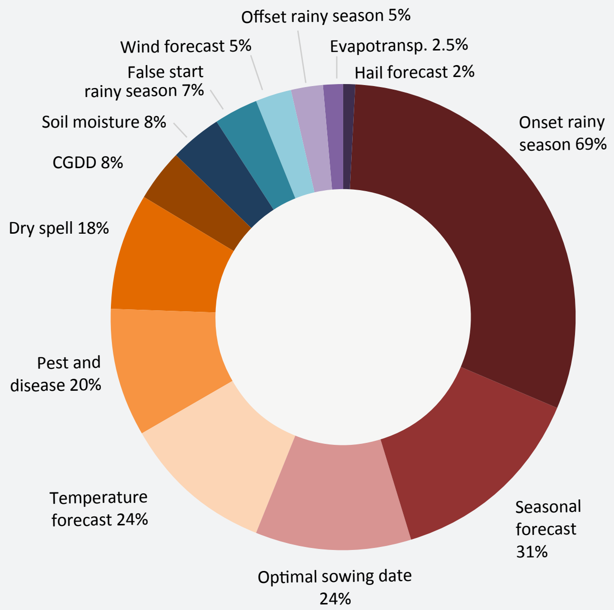


Figure 3. *Farmer's agrometeorological advisory preferences to better adapt to hydrometeorological hazards and associated disasters.*

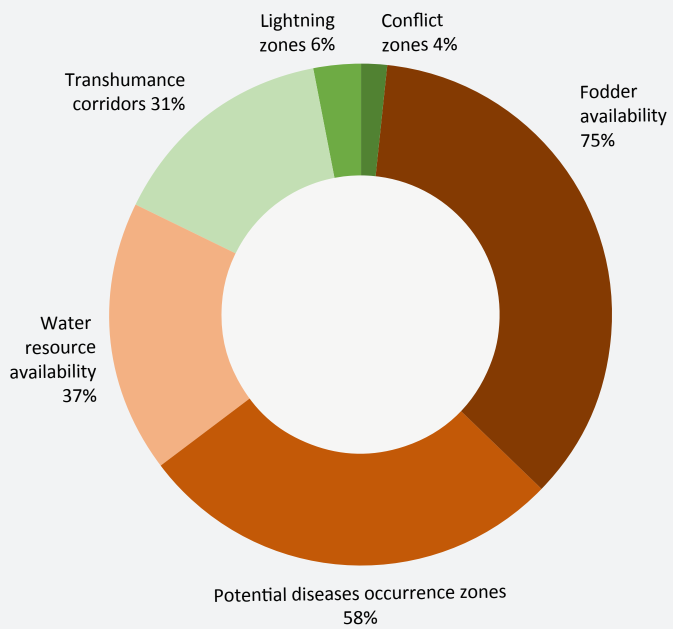


Figure 4. *Pastoralist's agrometeorological advisory preferences to better adapt to hydrometeorological hazards and associated disasters.*

CASE STUDY: Perspective from farmers and pastoralists: last mile needs and the uptake of agrometeorological information in Nepal

Future steps and investment opportunities

Recommendations to enhance dissemination and uptake of information by farmers and pastoralists include:

- Information producers need to have a better understanding of the requirements of users, and further tailor the advisories to ensure an increase in the uptake of climate services.
- Explore low-cost and high-benefit communication means such as call services and other voice-call platforms.
- Although farmers have not yet adopted or have access to a wide range of ICTs, there are many benefits associated with investing in the ICTs that farmers found desirable (Figure 2). Digital services allow for economic savings and can support the scaling up of information. In this case, this process has been mainstreamed by government institutions.
- In the livestock sector, where agrometeorological services have not been significantly developed, there is a need to create multidisciplinary working groups to explore the most appropriate tools and approaches (e.g., remote sensing and GIS).
- Use satellite-based images to generate agrometeorological indices that can support short- to medium-term advisories for farmers and pastoralists. This can be done in partnership with the International Centre for Integrated Mountain Development's (ICIMOD) Agricultural Information Dashboard (AID). These institutions can facilitate centralized decision-making and make it easier for agricultural experts to translate weather and crop information into understandable agricultural advisories.
- Extend the use of the drought monitoring and early warning system developed by the USAID together with ICIMOD across the Hindu-Kush region.
- The Institute of Foreign Affairs (IFA) has developed a platform (SMILES-Nepal) with SMS and android-based products to provide users with a wide range of agricultural advisories that can be synchronized with weather information and support farmers in their day-to-day farming activities. This platform could be further explored as part of the digitalization process in agriculture.

References:

Institute of Foreign Affairs (IFA). 2020. *IFA*. [online]. [Cited 02/02/2021]. http://www.ict4agri.com

Timilsina, A., Shrestha, A., Gautam, A., Gaire, A., Malla, G., Paudel, B., Rimpal, P.R., Upadhyay, K. & Bhandari, H. 2019. A practice of agro-met advisory service in Nepal. *Journal of Bioscience and Agriculture Research*, 21(02): 1778-1785.

Timilsina, Amit & Shrestha, A & Gautam, A & Gaire, Achyut & Malla, G & Paudel, B & Rimal, P.

Prepared by: Krishna Pant and Jorge Alvar-Beltrán (FAO).

CASE STUDY

Proactive instead of reactive: moving towards an anticipatory approach for drought in the Philippines

©Unsplash/Casey McCoy

Country:
The Philippines

Institution(s):
Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA), Department of Agriculture (DoA), FAO, National Technical Working Group on Forecast-based Financing/ Anticipatory Action, including Philippines Red Cross Society, the Start Network and WFP

Background

El Niño Southern Oscillation (ENSO) events can cause intense droughts in the Philippines. Shorter and more erratic rainy seasons have led to major crop failures and serious damage to the livestock and aquaculture sector. During the 2015-16 ENSO episode, farmers in the Philippines lost 1.5 million tonnes of yield, and more than 400 000 people needed assistance to recover from the impacts of drought.


©Unsplash/Michael Rivera

Against this backdrop, between 2018 and 2019, FAO designed an early warning system to anticipate drought across the island of Mindanao. The system drew from national data from PAGASA and regional and global forecasting and monitoring models. The early warning system indicated a strong likelihood of drought in Mindanao that would threaten the food security of vulnerable families. Mindanao has experienced armed conflict, which has contributed to insecurity and fragility. In October 2018-19 when signs were pointing towards another El Niño-induced drought, FAO carried out a set of anticipatory actions that included the distribution of drought-tolerant seeds, vegetable gardening kits, irrigation equipment and livestock support (ducks and goats). Traveling information caravans gave farmers across Mindanao the opportunity to attend workshops about El Niño episodes and to implement agricultural management strategies (planting and irrigation) for limiting the losses during droughts.

Major challenges for reaching the last mile

- Farmers do not always correctly interpret climate terminology or receive specific information on how their agricultural assets can be affected.
- Farming communities need to have access to forecasting information that is translated into legible climate-resilient practices.
- Early warning information must reach the most vulnerable families in Mindanao, particularly female-headed households and those located in conflict zones.

CASE STUDY: Proactive instead of reactive: moving towards an anticipatory approach for drought in the Philippines

Progress toward overcoming the last mile barrier

- FAO and government partners led an anticipatory action public awareness campaign to alert farmers in most provinces along Mindanao on how to prepare for upcoming droughts and of the importance of early action measures.
- In addition to El Niño workshops, 21 informative billboards were installed, displaying rain forecasts and recommendations on drought-adaptive rice and vegetable production.
- To ensure that early warnings reached the most vulnerable households, gender-senstive and conflict-sensitive approaches were employed, targeting women-headed households or households that had been affected by conflict.
- FAO increased the capacity of five local government units in Lanao del Sur in the Bangsamoro Autonomous Region in Muslim Mindanao (BARMM) by mainstreaming anticipatory action in local government plans (e.g the municipal disaster risk reduction and management plan). Standard operating procedures were developed to indicate triggers and identify appropriate interventions to respond to El Niño along the different municipalities.
- In 2018, the Department of Agriculture developed a drought early warning system. However, it still needs further refinement and scaling up across the Philippines.

Lessons learned

- Gathering information at the national, regional and global levels helps build the confidence of stakeholders on investing in early warning and early action. Every USD 1 invested in early warning and early action had a return of up to USD 4.4 in terms of avoided disaster impacts.
- Acting early can help vulnerable families feel more secure and confident about overcoming the impacts of drought.

Further work and investment opportunities

- The dissemination channels for early warnings (e.g., agrometeorological bulletins, mobile phones, radio and television) need to be strengthened. Updates can provide information not only on the forecast itself, but on the actions farmers can take to protect their assets.
- Anticipatory action protocols should be aligned with local government plans to help facilitate access to funds from the government's emergency budget, the Quick Response Fund (QRF), even without an official declaration of a state of emergency.
- Establish anticipatory action protocols for drought with the government and partners to ensure that early warnings systems are acting upon ahead of drought conditions. Other hazards (e.g., typhoons and floods) can also be considered, as has been done by the Philippines Red Cross Society, WFP and the Start Network. Harmonization of these systems among different agencies and the government is essential to move towards a more systematc anticipatory approach and actions.
- Establish feedback mechanisms for farmers to participate in setting up the early warning system and on the trigger mechanisms for anticipatory action; allow farmers to give their views on what kind of information is most needed; provide opportunities to farmers based on their knowledge and field observations.

References:

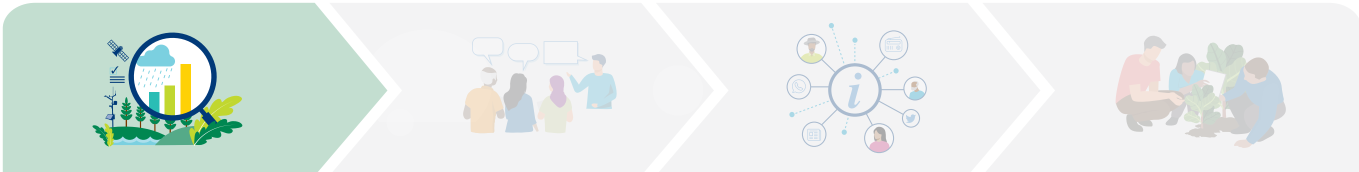
FAO. 2020. The Philippines - Impact of Early Warning Early Action In: *FAO* [online]. [Cited 11 March 2021]. http://www.fao.org/emergencies/resources/documents/resources-detail/en/c/1287660/

Prepared by: Maria Quilla, Catherine Jones, Niccolò Lombardi and Nora Guerten.


©FAO/Vyacheslav Oseledko

Europe and Central Asia

The climate across Europe is mainly temperate, followed by subtropical conditions in southern regions and polar climate conditions along the northern coast. In the Mediterranean region, warmer temperatures and summer precipitation deficits have a notable impact on crop production, as well as on livestock grazing and forage. The central and northern regions have experienced increased exposure to flooding with risks of damage and losses to agricultural production and food value chains. Climate change will lead to increased risk of disturbances from storms, fire, and outbreaks of pests and diseases. This will have implications for forest growth and production. Increases in extreme climate events (e.g., prolonged droughts) will heighten the volatility of agricultural production and have an impact on the economic situation of farmers. For instance, in 2020, dry conditions affected north and central parts of Europe, and April was the driest month on record in many European countries (WMO, 2021). With climate change, projections show that the number of citizens in the UK and EU exposed to heatwaves will grow from 10million/year (average 1981-2010) to nearly 300million/year, or half of the European population, in a scenario with 3°C global warming by the end of the century (JRC, 2020). Central Asian countries, which are heavily agrarian societies characterized by an arid to semi-arid climate, are particularly prone to drought and sand and dust storms, especially in areas outside the highlands. Temperature and precipitation changes are expected to reduce glaciers and snowpacks. This will diminish river flows, which will pose significant risks to rainfed and irrigated agriculture. High soil salinity and desertification also threatens agricultural productivity within the region.



Data collection and monitoring

Europe

The European Copernicus programme provides climate monitoring products throughout Europe. Copernicus information services are based on data from a constellation of six families of satellites known as sentinels. These orbiting measuring devices, which operate alone and/or in combination with sensors placed in the sea, air, and land are owned by NMHSs, research institutions and private organizations. The EU JRC MARS meteorological database contains observations from weather stations interpolated on a 25 km by 25 km grid. The observations have been recorded daily since 1979 both for the EU and neighbouring countries. Recent developments are presented and put in historical perspective in monthly bulletins in the annual State of the European Climate Services reports (C3S, 2021).

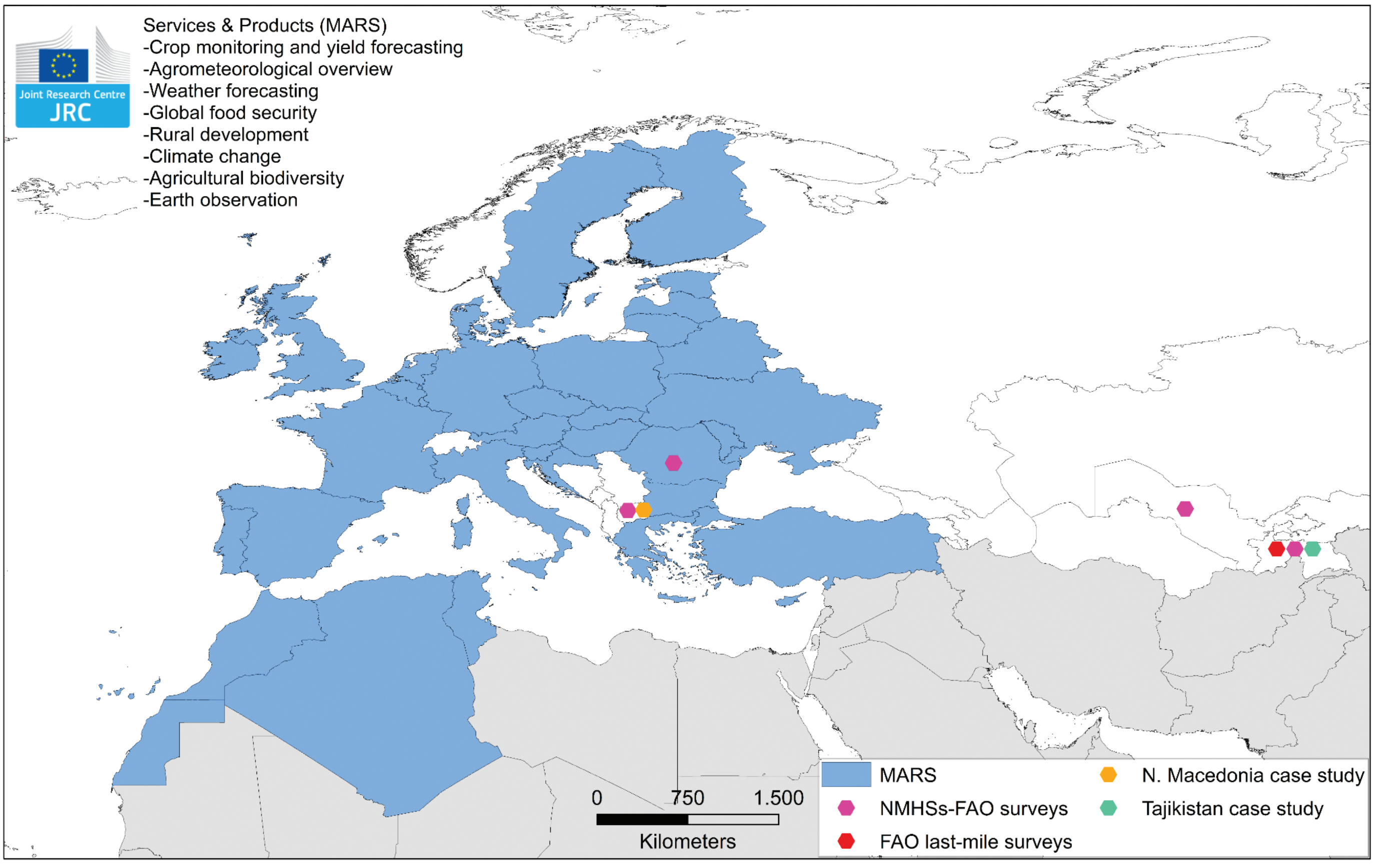
The European Centre for Medium-Range Weather Forecasts (ECMWF) produces global numerical weather predictions for its members, co-operating countries and the global community. The Centre, which has one of the largest supercomputer facilities and meteorological data archives in the world contributes to providing advanced training and assists the WMO in implementing its programmes. The JRC provides near real-time crop growth monitoring and yield forecasting information, and assesses the impacts of climate change on agriculture by integrating crop models and future climate scenarios. It also provides scientific advice and early warning on agricultural production in food-insecure regions around the world. These warnings are updated on a dekadal basis and adjusted according to the phenological phase of the crop. By providing a broad range of technical support services to Ministries of Agriculture and Member States, the JRC activities in the agriculture sector have contributed to the management of the Common Agricultural Policy (CAP) (Himics *et al.*, 2020).

Central Asia

In Central Asia, the maintenance of station networks and data collection remains under the mandate of NMHSs. The NMHSs in Central Asia have a common and well-established structure that was set up during the Soviet era. They use an integrated approach that combines meteorological, hydrological and environmental observations. After gaining their independence, some Central Asian countries have not been able to maintain the same level of funding, and the number of functional stations and equipment has declined. Other countries, however, have managed to maintain their networks. Urgent investments are needed to upgrade infrastructure operational routines and staff capacities. The decline in NMHSs is particularly pronounced in eastern Central Asia (World Bank, 2008). In practice, each NMHS continues to operate largely according to procedures established during the Soviet era. Staffing levels are high overall, but staff do not have sufficient skills to provide data for diverse users and the knowledge to use modern technologies. Technical qualification and training in specific sectors are often inadequate, and there is limited experience in providing effective user interfaces in the agriculture sector (World Bank, 2019). Across the region, the density of observational network is insufficient for agricultural applications. In many countries, there has been a persistent downward trend in the quantity and quality of measurements due to the deterioration of the measurement facilities, equipment and communication (World Bank, 2019).

Tashkent, which now serves as the WMO regional specialized meteorological centre (RSMC), was previously the scientific hub for all Central Asian NMHSs. The regional centre on hydrology (RCH) is supporting hydrometeorology modernization projects and promotes information exchange within the region. Among the current regional needs are glacier monitoring, regional climate outlooks and assessments, reliable seasonal water assessments for cross-border rivers, and the forecasting and early warnings for flash flooding, droughts and dust storms at the regional scale (World Bank, 2019). Each country has a different governance structure for its national hydrometeorological service. For example, in Kyrgyzstan, the NMHS is part of the Ministry of Emergencies; in Tajikistan, the NMHS is a state agency (enterprise) of the Committee for Environmental Protection; in Turkmenistan, a national committee under the Turkmenistan Cabinet of Ministers governs the NMHS.

Figure 14. Main regional institutions delivering agrometeorological services in Europe and Central Asia



Note: MARS monthly bulletins also include Morocco, Algeria, and Tunisia.
Map conforms to United Nations World Map 4621, Feb 2021.

Co-production of tailored services

Europe

Several programmes within the Copernicus Climate Change Service (C3S) are tailoring their climate data and models to help the agricultural sector better respond to climate change. C3S provides data in almost real-time to support on-farm decision-making and crop assessment. The data available can be used directly in crop models and for several indicators relevant to the agricultural sector. Available information includes historical data, future climate data, crop yield data, and water indicators and statistics.

The JRC Agri4Cast provides data sets that include crop modelling, crop calendars, phenological data and heating and cooling degree days. The data is available for free for EU countries and neighbouring countries. The JRC MARS bulletins offer near real-time information and operational analyses on crop growth conditions and yield forecasts for the EU and neighbouring countries. Individual member countries and non-member countries in the region maintain NMHSs that collect climate data, whereas Ministries of Agriculture and Statistics maintain agricultural census and databases. Countries with information available from the WMO WAMIS platform include Albania, Belgium, Bulgaria, Croatia, Germany, Greece, Hungary, Ireland, Italy, Moldova, Portugal, Serbia, Slovakia, Slovenia, Spain, Switzerland and Turkey. Also available through WAMIS is the Drought Management Centre for Southeastern Europe (DMCSEE), which was established in 2007 and produces a standard precipitation index, and precipitation and percentile maps from 1951 to the present. Each country in Europe has different capacities and produces unique tailored products for farmers **(see case study, *Co-production of tailored disease forecasts in North Macedonia*).**

In Europe, the private sector plays a key role in every step of the climate services framework, including data collection, monitoring, co-production and communication of climate services and agricultural advisories to farmers. Start-up companies in the field of agrometeorology are forming across Europe with the purpose of ensuring that farming decisions are informed by up-to-date climate information. An example is Sencrop, a platform that provides farmers with reliable site-specific data about the weather for increased day-to-day efficiency of field management activities. The product developed by Sencrop assesses in real time the meteorological and agronomic risks, predicts any variations, and supports farmers in planning their activities according to weather observations. Sencrop has the largest network of agrometeorological stations in Europe. Due to its dense observational network, Sencrop has developed tailored commodity agrometeorological services that are easily accessible by farmers. Sencrop services cover:

- **Cereal crops** (wheat, corn, barley): The Sencrop service provides farmers with information to prevent the appearance of fungal diseases (pest and rust) on crops and waterlogging during heavy rains. Agrometeorological indices that trigger alerts include humidity and temperature depending on the growth stage (for the risk of frost), cumulated temperatures (for wheat leaf rust or wheat yellow rust), cumulated rainfall and temperatures (for powdery mildew), and thermal amplitude and humidity (for weeding). The application also uses connected weather stations to assess the degree of ripeness and provides farmers with information on the best time for harvesting.
- **Potato:** Agricultural weather data for potato cultivation prevents diseases and helps optimize decisions regarding treatment windows and options. For instance, potato blight thrives in alternating periods of heavy rainfall (when humidity is above 90 percent) and warm temperatures (average temperatures above

11°C). Leaf wetness sensors and rain gauges placed in potato fields allows the product to determine the risk of potato blight, and to trigger different alerts based on weather alerts through the phone alarms, SMS and email.

- **Grape vine:** Agricultural service advisories protect farmers from hazards (e.g., frost, downy mildew, powdery mildew, grey rot, and pests such as leafhoppers) that have an adverse impact on the development of the plants and reduce the quality and yields of grapes. The alerts reduce expenditures on agrochemical inputs by supporting farmers in adjusting the timing of chemical applications to better match the weather conditions.
- **Tree crops:** The Sencrop product allows farmers to make the best decisions regarding the risk of tree diseases (e.g., scab, monilinia fungi and codling moth), frost or post-spraying washout. The Sencrop service provides farmers with two types of solutions based on leaf-crop wetness sensors and rain gauges that indicate wet-bulb temperature. Farmers can then set up an alert to counteract the effects of frost and take actions, including installing wind turbines, heaters or sprinkler systems that prevent crops from frost conditions.

Sencrop has also created partnerships with national research institutions (NIAB in the UK) and with the RIMpro Cloud Service to integrate a set of decision support tools for farmers. NIAB enhances the Sencrop product by providing real-time irrigation scheduling advice, and RIMpro uses real time information and forecasts of pest and disease development. This partnership highlights the importance of establishing institutional arrangements and cooperation for effective co-production of user-tailored climate services.

Central Asia

In Central Asia, meteorological and hydrometeorological services play a key role in providing information on river flows, which are the major water and energy resources in the region. Snow and glacier melt from the Pamir, Hindu Kush and Tien Shan Mountain ranges supply the Syr Darya and Amu Darya rivers. Therefore, tailored products that are of use to agricultural producers require hydrological experts and close monitoring of snow accumulation and melt. Flash floods are caused by several local factors, which makes them difficult to forecast. However, flash floods are consistently a major threat to vulnerable communities, especially in mountainous regions of Central Asia. Advances in numerical forecasting combined with flash flood guidance systems are improving forecasts and increasing the potential for early action in the region. In Central Asia flash flood warnings with improved accuracy are being provided 3 to 36 hours in advance (World Bank, 2019).

In Kyrgyzstan, hydrometeorological services provide dekadal agrometeorological forecasts and bulletins, including outlooks of air temperatures, humidity and information on soil moisture. Bulletins also include information on the phenological phases of crops – expected time of flowering, as well as seasonal reviews and yield forecasts. When necessary, a newsletter is sent by e-mail to the Ministry of Agriculture; however, there are no feedback mechanisms in place and as a consequence the existing agrometeorological product is not enhanced. Due to the sparse observational network and weak numerical weather prediction models, the country has some difficulties to monitor and forecast main hydrometeorological and climatological hazards affecting the agricultural sector – heatwaves, drought, hail and fog. The existing interdepartmental cooperation and data exchange remains weak, and early warning systems and early action plans do not necessarily reduce the risk of disasters in the agricultural sector. Additionally, there is an existing need to increase the capacity of Kyrgyz hydrometeorological and agrometeorological services, including the transfer of knowledge and methodologies, coordination, communication and development of user interfaces of relevance for the agricultural community.

In Azerbaijan, hydrometeorological services provide weather and climate services to agricultural associations and farmers. Agrometeorological bulletins include information on crop development, air and soil temperature and are prepared on dekadal basis. Some of the main gaps identified include: lack of coordination between the Ministry of Agriculture, Ministry of Emergency Situations and Ministry of Ecology and Natural Resources; need to improve the existing agrometeorological infrastructure and need to establish a systematic agrometeorological training program for the NMHS staff.

The Central Asia Climate Information Platform (CACIP) is a regional initiative developed under the Climate Adaptation and Mitigation Program for the Aral Sea Basin (CAMP4ASB) project of the Central Asia Regional Environmental Center (CAREC) and ICARDA, funded by the World Bank. CACIP is an online database designed to be user-driven that enables stakeholders to access, analyse, and visualize public domain data. CACIP also promotes data sharing and knowledge exchange to strengthen networks among the stakeholders.

The development of CACIP involved farmer consultations in Tajikistan and Uzbekistan in 2019. Workshops presented the features of the platform, and surveys were conducted to consider farmers' insights. Since CACIP requires internet access, and farmers may not have access or know how to use it, the platform ensures that appropriate material will be made available, printable and downloadable by more experienced farmers or intermediary institutions (e.g., extension departments and NGOs). Information is only available in Russian and English, but CACIP plans to make content available in five Central Asian languages (CACIP, 2021).

CAREC has actively engaged regional actors on agrometeorological monitoring and forecasting and involved agricultural communities in the production of climate services through the CAMP4ASB project. CAREC has sought for many years to introduce modern forecasting models into agrometeorological applications in Kazakhstan, Tajikistan, Turkmenistan and Uzbekistan. As a result of co-production and regional knowledge exchange between research institutions from Kazakhstan and Ukraine, the NMHS revised a dynamic model for forecasting the yield of corn and sugar beets for southern Kazakhstan in 2019 (CAREC, 2020a). In 2020, a study was conducted by specialists from NMHS in Belarus, the Russian Federation and Ukraine on the possible applications of modern weather forecasting, with a view to choose the yield forecast model most suitable for the region and operationalize it through training seminars for NMHSs in Central Asian countries (CAREC, 2020b).

In Kazakhstan, the private sector covers some of the costs associated with the production of agricultural meteorological data, statistics and bulletins. Payment for meteorological and hydrometeorological data is common throughout the region, but there is considerable potential for supporting formal agreements and strengthening institutional arrangements between public institutions **(see case study, *Institutional arrangements and agreements for strengthening climate services in Tajikistan*)**.

Communication of services to the last mile

Europe

It is common for farmers to pay for extension services in OECD countries, and this approach is becoming increasingly viable from an economic perspective (Hone, 1991; Marsh and Pannell, 2000). In countries with economies in transition, however, many producers are unable or unwilling to pay for services because they do not see the benefits first-hand. Another constraint limiting private extension is the lack of extension service providers outside the public sector, and public institutions have incentives and institutional arrangements in place to encourage programme cost-recovery (Anderson and Feder, 2003).

Because market products vary greatly by country in Europe, there are a wide range of organizations delivering extension services and offering information and advice. Examples include the specialized agricultural extension institutes that are fully funded and managed by government within the Ministry of Agriculture; private registered companies or consultants who are supervised by the Ministry of Agriculture; and regional extension centres that are given government funding for programmes requested by farmers.

Field observations offer evidence that small-scale farmers have limited access to face-to-face advisory services (Labarthe *et al*., 2013). Specific programmes in the region have been created to address this barrier. However, despite public financial support, the challenge remains. Access to advisory services is even lower for smaller-scale producers with limited resources. Large-scale farms can rely on networks and obtain financial contributions and services from the landowners. Private consulting or advisory services generally address the needs of commercial farmers. Making these services available for small-scale farmers requires public investment to develop capacities of service providers and establish markets for services (Anderson and Feder, 2003).

There is growing recognition in Europe that public financing of extension services is justified. It is commonly understood that the general public benefits more than the extension client, and the government can provide services more cheaply or more effectively (van den Ban, 2000). However, private service delivery is often more efficient in serving the clients. Private sector extension strategies can function in different ways, but most involve public funding for private service delivery (Rivera, Zijp and Alex, 2000). Prager *et al*. (2015) highlight that climate services from the private sector, driven by the needs of farmers and targeted to ensure the best product, can provide a valuable resource to those who can afford the costs. On the other hand, public organizations that focus on ensuring the most accurate data and sustainable solutions sometimes lack the resources and incentives to provide targeted and client-driven services.

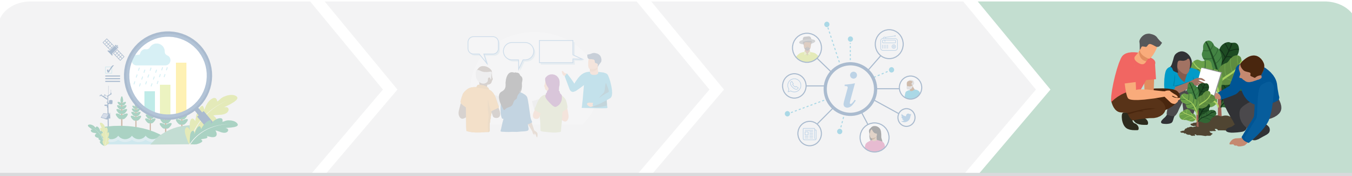
In Moldova, the Hydrometeorological Service and the National Agency for Rural Development (ACSA) have implemented a system where potentially hazardous conditions are shared in real-time to ACSA's regional and local consultants – who then share via SMS the information with farmers that have subscribed to phone alerts (FAO, 2021b). Some of the products shared to farmers include weather warnings, hydrological alerts, daily and weekly forecasts, dekadal weather assessments and status of soil moisture reserves. ACSA has recently signed a contract with phone operators (Orange, Moldcell and Unite) to provide low-cost agrometeorological packages to interested parties. Although this innovative solution was tested and introduced, very few farmers have subscribed to the alerts thus far and this is due to the high costs associated with receiving the information. Another barrier for scaling-up the service is that ACSA does not pay-off the costs of providing tailored agrometeorological advisories. As a result, the service is not fully operational and the number of users remains limited.

In Georgia and Armenia, the whole climate services framework needs to be enhanced, from data collection (expanding the agrometeorological observation network) to communication of climate information (identifying the most effective communication channels in order to increase uptake of information). In Armenia, agrometeorological information needs to be integrated into existing hydrometeorological bulletins. Both countries require an improvement in the access and use of weather, climate and agrometeorological information by agricultural users, where extension services playg a pivotal role.

Central Asia

In Central Asia, NMHSs maintain official weather websites, but most services do not yet offer mobile applications or SMS services for users. Agrometeorological bulletins are often produced separately by the NMHS and the Ministry of Agriculture, and there is a need for coordination or formalized agreements in this area. The communication of climate services to farmers varies from country to country. Many have identified the need to diversify the way services are reaching farmers. Communication requirements also vary from country to country, depending on topography, the availability of cell phone networks, and other socio-economic factors. Communication with remote areas is particularly difficult, especially the mountainous and underpopulated the Arctic region and the mountainous areas of the Caucasus and Central Asia (World Bank, 2008). The availability and affordability of ICTs, mobile telephones and internet access is increasing significantly along the Central Asian region, notably in mountainous countries due to the growth in tourism (University of Central Asia, 2012).

A regional assessment in Central Asia (Kyrgyzstan, Tajikistan and Turkmenistan) has compared user needs for weather, climate, and water-related information in multiple sectors (Rogers *et al.*, 2016). In Kyrgyzstan, the agricultural sector requires weather forecasts up to five days or longer; daily standard meteorological data; emergency forecasts and warnings for water management and crop protection; and seasonal forecasts for crop management. In Tajikistan, weather forecasts up to five days or longer and weather forecasts for transhumance corridors are among the most requested services. In Turkmenistan, long-range forecasts, agriculture-specific products related to crops and climate outlooks are among the services most requested by farmers. In all three countries, there is an overall need to improve the communication channels used to deliver information services. For instance, in Turkmenistan, there is a need to develop technologies and procedures for disseminating information on natural disasters and technologies; present weather forecasts on television; and update the NMHS website. In Tajikistan and Uzbekistan, farmers are receiving information through mobile applications developed by local NGOs, but these are often not linked to NMHSs services.



Participatory engagement of last mile and climate-informed actions

Given the growing market for climate services in Europe, the engagement of the intended users in pilot studies becomes essential. For instance, to build the European market framework, pilot studies are integrating measures to facilitate the engagement of the climate service community in the co-production, including co-design, co-development, co-evaluation, and co-dissemination stages of the climate services framework. Instruments for engaging the users of climate services include pilot studies, workshops, training activities, and capacity building programmes (EC, 2015). The EU is at the forefront in the development of a market framework and has a clear roadmap for climate service delivery. It is essential for this market framework to be driven by economic analyses and founded on a business model that responds to the demand from users. A specific example of user engagement in Europe is the MED-GOLD Horizon 2020 project that engages communities working in different sectors of the Mediterranean region in the production of tailored products, including tools that are easily accessible by olive, wheat and grape producers.

Implementation of adaptation measures at the national, regional and farm levels in Europe is supported by the rural development programmes. These programmes, which are funded by the European Agriculture Fund for Rural Development (EAFRD), receive about 20 percent of the overall CAP budget (EC, 2017). Rural development programmes support EU Member States and regions in their climate change adaptation efforts with co-financing provided by the EU. Support includes providing information, raising awareness and offering farm advice; fostering farm modernization (e.g., irrigation efficiency programmes); enhancing measures to combat adverse effects of weather events; improving risk management (e.g., insurance); and promoting agricultural, environmental and climate measures for adaptation and organic farming. In the EU, agricultural cooperatives play an important role in engaging with and supporting agricultural producers and marginalized groups, such as women and youth.

For non-EU member states, the implementation of adaptation and mitigation measures at the farm level depends on available knowledge, programmes and pilot projects. In Central and Eastern Europe, the Farmer Field School approach was introduced through a FAO project in seven countries in 2003. The project explored and supported farmers' roles in managing maize pest, the western corn rootworm, through integrated pest management (IPM) strategies. The project also contributed to strengthening farmers' long-term business management and supported innovation in agroecological practices. Although Farmer Field Schools in the region have not been focused on climate services, various pilot programmes and demonstration plots have been initiated. In Central Asia, The CAMP4ASB project organizes platforms for farmers to discuss adaptation measures to climate change and prepares brochures developed especially for farmers.

Investment needs

East Europe and Central Asia were the regions, along with the Near East and North Africa, that received the least finance (USD 0.38 billion) from OECD countries for climate change adaptation and mitigation projects (Chiriac and Naran, 2020). To enhance investment in the last mile, this report suggests the following actions:

1. Avoid piecemeal investments and provide finance at every step of the climate services framework.
2. Invest in rehabilitating hydrometeorological stations across Central Asia to strengthen the weather, climate and water information services that are critical for agriculture, and other sectors.
3. Invest in decentralizing hydrological, weather and climate data among centralized states for reducing and better managing disaster risks.
4. Invest in adequate infrastructure for leveraging digital technologies and ICTs.
5. Increase investments in flash flood warnings to trigger early action in vulnerable communities.
6. Develop climate services that are specific to a particular commodity or agricultural practice.
7. Support engagement of the private sector and build on the potential for commercialization of climate services through collaboration between the public and private sectors.
8. Invest in extension services and NGOs that are providing advice and services to farmers to ensure they have access and training on climate information and advisories.
9. Support agricultural cooperatives and organizations that create participatory communities of practice for producers and value chain actors who are involved in similar types of agricultural activities.
10. Invest in more user-friendly and demand-driven services and products by making it possible for users to search and review this information in a more systematic way.
11. Invest in pilot programmes to increase awareness of the benefits of applying climate services on the ground.

Regional conclusions

The challenges and set of recommendations for investment provided below are based on an extensive search of literature that includes research papers, technical reports, United Nations flagship reports and regional workshops conducted by WMO as part of the GFCS. These actions and recommendations aim to enhance the effective production and delivery of climate services along the climate services framework and have been carefully selected to bridge the last mile gap while considering the socio-economic context of the region of interest.

Climate services framework step	Major challenges/barriers	Priority areas for action
Data collection, monitoring and forecasting	▪ Density of observing networks in Central Asia is insufficient for agricultural applications, with a persistent downward trend in the quantity and quality of measurements ▪ Lack of weather and climate-related risk information ▪ Lack of accurate and timely predictions in Central Asia ▪ Insufficient human and technical capacity in NMHS staff to prepare information products	▪ Enhance capacity of NMHSs on monitoring and transmitting real-time weather, climate and water measurements ▪ Strengthen the technical capacity of hydrometeorological agencies especially in the area of agricultural products ▪ Increase forecast accuracy in Central Asia by installing and enhancing regional numerical weather prediction capacity ▪ Create regional hydrometeorological distance learning systems ▪ Develop primary indicators and information systems (e.g., agricultural statistics and market information systems) in Central Asia ▪ Invest in appropriate data and high-performance computing infrastructures ▪ Train staff to improve the modelling and analytical capabilities needed to inform decisions and decision-making processes ▪ Improve modelling and predicting capacity relevant to climate services ▪ Enhance appropriate data and high computing infrastructures, mostly in Central Asia

Climate services framework step	Major challenges/barriers	Priority areas for action
Task force and data sharing	■ Lack of formal institutional arrangements and identification of roles in the production and communication of climate services in Central Asia ■ Lack of dialogue between stakeholders involved in the production of climate services in Central Asia ■ Lack of engagement with farming communities	■ Assess the climate services market (demand and supply) ■ Organize sensitization workshops and discuss institutional arrangements and formal agreements for data sharing ■ Support Central Asian countries to participate in WMO's World Agrometeorological Information Service (WAMIS) ■ Foster regional coordination towards building a regional drought monitoring centre in Central Asia ■ Enhance coordination for the development of agrometeorological bulletins between NMHS, the Ministry of Agriculture and other institutions ■ Develop a regional database for ICTs based on agricultural services and projects, including a repository for e-agriculture-related projects and functioning services at a national and regional level that can further support the implementation of a comprehensive e-agriculture strategy ■ Ensure continuous information exchange among existing technical working groups with complementary objectives, such as the ones on forecasts, climate services and anticipatory action
Co-production of tailored agrometeorological advisories	■ Lack of a comprehensive understanding of the demand and supply side of the climate services market across Europe ■ Lack of engagement with farming and rural communities	■ Co-design and co-produce services engaging users, providers and researchers ■ Map the climate services market, the potential for growth and the support required to grow that market ■ Clearly define the responsibilities on the production and delivery of climate services ■ Invest in enhanced collaboration to co-design and co-produce services by engaging stakeholders across various scales

Climate services framework step	Major challenges/barriers	Priority areas for action
Communication of services to the last mile	■ Lack of technologies and procedures for disseminating urgent information on natural disasters, and lack of technologies to present weather forecasts on television in Central Asia ■ Lack of understanding of how agricultural and rural communities access information in Central Asia	■ Develop and implement national strategies for digital agricultural as part of national ICT and/or agricultural strategies ■ Enhance the production and communication of agrometeorological services based on communication means identified by users and relevant for farmers ■ Enhance real-time site-specific data for increased day-to-day efficiency of field management activities in Europe ■ Use data and ICTs to develop, deliver and support access and use of climate services
Participatory engagement of last mile	■ Lack of user engagement, particularly in Central Asia ■ Low capacity of agricultural extension and limited access to extension services in some countries	■ Develop a viable climate services community that engages users, providers and researchers ■ Support agricultural extension capacities ■ Reinforce tailored commodity agrometeorological services throughout Europe
Climate-informed actions	■ Few field initiatives have been taken to improve the digital skills of farmers, and the level of digital skills in the sector are almost non-existent ■ Lack of awareness and engagement of the last mile	■ Translate user needs into tailored agrometeorological services ■ Develop agricultural advisories, particularly in countries where digital services are expected to have a key role in helping small-scale farmers ■ Enhance access to private and public sector services for small-scale farmers in Europe ■ Support the establishment of Anticipatory Action plans, linking early warning thresholds to action and outlining clear guidelines on how to protect the lives and livelihoods of the most vulnerable ahead of hydro-meteorological hazards

Survey results: Communication channels

This section presents the results obtained from the surveys in response to the following question:
By which means are the weather information and weather alerts currently delivered to the last mile?

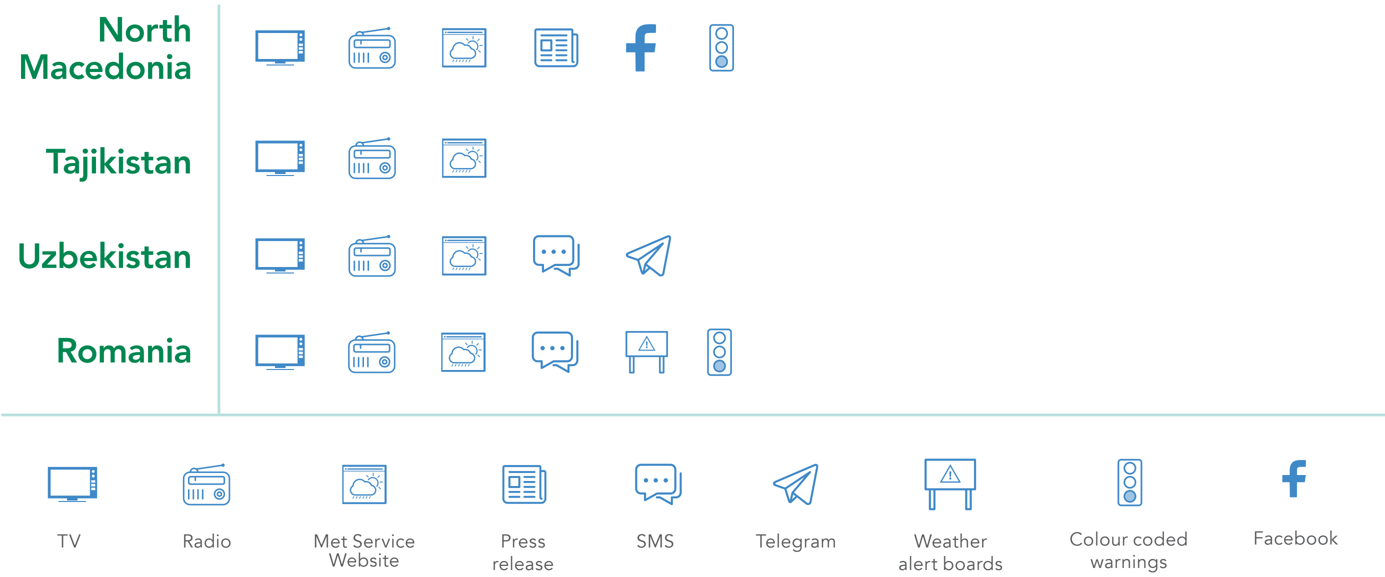


Figure 15. List of communication means used to deliver weather information and weather alerts to the last mile, based on survey results. Refer to Annex 1 to see the original survey template. *Note: The results contained herein do not represent all existing communication means such as agricultural extension officers, posters, public meetings, face-to-face, etc.*

Survey results: Agrometeorological advisories

This section presents the results obtained from the surveys in response to the following question:
Which type of information does the NMHS provide to the last mile?

	N. Macedonia	Tajikistan	Uzbekistan	Romania
Optimal sowing date			✓ (Crops)	
Onset rainy season		✓ (Crops)		✓ (Crops)
Offset rainy season		✓ (Crops)		✓ (Crops)
Dry spells	✓ (Crops)	✓ (Crops)		
Cumulative precipitation	✓ (Crops)		✓ (Crops)	✓ (Crops)
Evapotranspiration	✓ (Crops)			
Cumulative. growing degree-days	✓ (Crops)	✓ (Crops)	✓ (Crops)	
Soil moisture	✓ (Crops)	✓ (Crops)		✓ (Crops)
Seasonal forecast	✓ (Crops)		✓ (Forestry)	✓ (Crops)
Precipitation forecast	✓ (Crops)	✓ (Crops)	✓ (Crops)	✓ (Crops)
Temperature forecast	✓ (Crops)	✓ (Crops)	✓ (Crops)	✓ (Crops)
Hail forecast	✓ (Crops)	✓ (Crops)		✓ (Crops)
Wind forecast	✓ (Crops)	✓ (Crops)	✓ (Crops)	✓ (Crops) ✓ (Fisheries)
Pest and disease forecast	✓ (Crops)			✓ (Crops)
Water resource availability		✓ (Livestock)	✓ (Livestock)	✓ (Livestock)
Potential heat stress		✓ (Livestock)		✓ (Livestock)
Transhumance corridors				✓ (Livestock)
Potential disease occurrence zones				✓ (Livestock) ✓ (Forestry)
Potential extreme weather events		✓ (Livestock)	✓ (Livestock)	✓ (Livestock)
Sea surface temperature				✓ (Fisheries)
Wildfire prone zones				✓ (Forestry)

Crops ✓ Livestock ✓ Fisheries ✓ Forestry ✓

Table 4. Agrometeorological advisory services provided to the last mile per agricultural sector (crops, livestock, fisheries and forestry), based on survey results. Refer to Annex 1 to see the original survey template.

©Unsplash/JK Baseer

CASE STUDY

Institutional arrangements and agreements for strengthening climate services in Tajikistan

Country:
Tajikistan

Timeframe:
2019

Institution(s):
National Agency for Hydrometeorology, Agency on Statistics, Ministry of Agriculture, State Organization for Plant Protection and Agriculture Chemicalization, Committee for Environmental Protection, Neksigol (national NGO), farmer organizations, FAO, WMO

Background

Tajikistan is becoming increasingly exposed to hydrometeorological disasters, such as droughts, floods and landslides. The country is having difficulties managing these risks due to technical challenges, limited technologies for automating procedures, and the lack of high quality data. Weather stations have become degraded because of insufficient resources and technical capacities to rehabilitate them following extreme weather events. A set of institutional arrangements have been established to effectively deliver climate information to last mile users in Tajikistan.

FAO established a pilot agrometeorological network with three automatic agrometeorological stations in Tajikistan, with support from the European Union and in close collaboration with the Agency for Hydrometeorology of Tajikistan's Committee for Environmental Protection. The aim of this pilot network was to increase awareness about the relevance and potential benefits of climate services for agriculture. A national level workshop jointly hosted by FAO and the WMO brought together key stakeholders involved in the collection and production of agrometeorological services, and validated the outcomes of the pilot programme. The dialogue between the Agency for Hydrometeorology, the Ministry of Agriculture and national NGOs on the need for formal agreements for data sharing and the production of tailored climate services has paved the way forward for scaling up the system across the country.

Major challenges for reaching the last mile

- In Tajikistan, a major challenge for effectively delivering climate services to farmers and rural communities is the lack of institutional coordination and the clear mapping of responsibilities along the climate services value chain. The Agency for Hydrometeorology has technical capacities and expertise in the area of hydrometeorology, but limited capacities for applying its work to support agriculture.
- The Agency for Hydrometeorology does not coordinate closely with the Ministry of Agriculture, which is responsible for agricultural services, and NGOs that provide services related to ICT tools and extension services for farmers.
- The baseline capacities to produce climate services for farmers were in place, but there was a need for coordination, formal agreements between agencies, and investment in the analysis and production of services.

CASE STUDY: Institutional arrangements and agreements for strengthening climate services in Tajikistan

Lessons learned

- The pilot agrometeorological network has increased awareness nationally. It also highlighted the fact that increased dialogue and cooperation between national institutions and the private sector is needed to deploy a full agrometeorological system in the country.
- The identification of capacities of each technical institution is an essential first step in mapping out different responsibilities for the production of climate services.
- Dialogue among key stakeholders is needed to sensitize all stakeholders on existing activities and create an exchange of knowledge. This dialogue should include representatives from farmers' organizations and farmers to ensure a user-driven approach.
- A pilot programme provides a mechanism for awareness raising and builds confidence for scaling up activities.

Future work and investment opportunities

- The preparation and ratification of formalized agreements between the Agency for Hydrometeorology, the Ministry of Agriculture and NGOs based on identification of responsibilities of each institution.
- Investment in scaling up the pilot programme.
- Investment in training of staff in the Agency for Hydrometeorology to produce services that are relevant for the agricultural sector.
- Wider surveys of communication channels for farmers and rural people.

Prepared by: Fadi Karam (international consultant), Jovidon Aliev (FAOTJ), Ana Heureux (FAO).

CASE STUDY

Co-production of tailored disease forecasts in North Macedonia

©FAO

Countries:
North Macedonia

Timeframe:
2016-2019

Institution(s):
Hydrometeorological Service, Ministry of Agriculture, Macedonian Ministry of Agriculture, Forestry and Water Economy (MAFWE), FAO, Cyril and Methodius University, Consiglio per la Ricerca in Agricoltura e l'Analisi dell'Economia Agraria (CREA), Rural Development Network (RDN) of North Macedonia

Background

The agricultural sector in North Macedonia is characterized by subsistence and semi-subsistence farming, and is dominated by small and highly fragmented family farms. A 2017 FAO study on smallholder and family farms in North Macedonia revealed that 89 percent of all farms are smaller than 3 hectares, with the average farm size being 1.6 hectares. These farms are generally inefficient, have low production potential and are making slow progress in meeting minimum standards for quality products. Increased sustainability in the agricultural sector is essential to meet agricultural demand and to comply with the requirements for accession into the EU.

In addition to water use efficiency, one of the main challenges for farmers is dealing with the emergence of agricultural pests and diseases. This case study outlines how collaboration between different institutions has enabled the co-production of tailored pest and disease advisories for the last mile. The advisories have enabled farmers to increase productivity and reduce environmental pollution caused by the overuse of herbicides and pesticides. In addition to increasing the network of automatic agrometeorological stations in North Macedonia, the project on strengthening agrometeorological services and early warning systems implemented by the above institutions supported the digitalization of weather and phenological data from the past 20 years and contributed to the development and testing of pest and disease models. A publicly available online platform (agrometeo.mk), which is hosted by the Hydrometeorological Service, was set up to provide access to real-time and historical data. The platform offers historical climate data, agrometeorological alerts, and phenological monitoring and forecasting to cope with major climate-induced pests and diseases.

Major challenges for reaching the last mile

- Agricultural production in North Macedonia is having difficulties in meeting marketing standards, experiencing major rural migration and ecosystem degradation.
- To produce tailored and actionable advisories that are meaningful to farming communities, experts must analyse and process raw climate and phenological data.

CASE STUDY: Co-production of tailored disease forecasts in North Macedonia

Benefits of using climate-informed advisories

- Timely and accurate information help farmers in the pilot regions to make decisions that can contribute to sustainable farm management and deliver environmental co-benefits.
- Co-produced pest and disease advisories are key for ensuring that farmers have a sense of ownership over the advisories and, as a consequence, help increase the uptake of information.

Lessons learned

- The collaboration between national institutions and organizations is essential to process raw agrometeorological data and produce tailored and actionable advisories. Collaboration with the Department of Plant Pathology in Cyril and Methodius University supported the review and development of key agricultural disease models that were used to produce disease alerts and advisories. Further collaboration with CREA also enhanced the modelling of phenological data and developed the capacities of Hydrometeorological Service and MAFWE experts.
- All available historical data needs to be digitalized and the quality checked to allow in-depth analysis and modelling, which are critical for producing tailored advisory products.
- Advisors at the National Extension Agency were also trained on agrometeorology, pest and animal disease control (bluetongue and lumpy skin disease) and on measures to increase the adaptive capacity of the livestock sector to extreme heat events.
- Identifying the needs of farmers at an early stage by adopting bottom-up and user-driven approaches is crucial for producing tailored climate services.
- Agrometeorological services should be tailored to meet a range of contexts that are shaped by different factors including the types of agricultural production in the region, the ecoclimatic zone and for addressing farmers needs and preferences.

Future work and investment opportunities

- Farmer consultations highlighted that most rural farmers do not use the internet, and that information should be made available on web application, SMS or television.
- Investment is needed to extend work to other pests and diseases, and tailor advisories to specific crops.
- Investment is needed to maintain feedback mechanisms among the farmers receiving services, the producers and the extension advisors, and validate modelling results.
- Collaboration with international research institutions should be enhanced to support capacity development among Macedonian institutions in the areas of modelling and service production.

References:
Smallholders and Family Farms in the former Yugoslav Republic of Macedonia, Country study report 2017
http://web.worldbank.org/archive/website01354/WEB/0__CO-41.HTM

NSARD of FYR Macedonia 2014-2020

Prepared by: Silvana Stevkova (HMS), Goran Basovski (HMS) and Ana Heureux (FAO).

CASE STUDY

Perspectives from farmers and pastoralists: last mile needs and the uptake of agrometeorological information in Tajikistan

Country: Tajikistan

Timeframe: 2020

Institution(s): FAO

Background

In Tajikistan, one of the major challenges for delivering climate services to farmers is the lack of institutional coordination. A scarce observation network and a lack of maintenance for the existing infrastructure also limits the collection of data and, consequently, the production of climate services. Little work has been done to better understand the ways in which weather and forecasted information is being used, and the benefits deriving from its use. This case study explores the level of use by agricultural communities and the preferable channels of communication for receiving climate and agricultural advisories in Tajikistan. Through a computer-assisted telephone interviewing method, 302 farmers have been surveyed in four regions of Tajikistan: the Gorno-Badakhshan Autonomous Region, Sughd, Khatlon and Districts of Republican Subordination. The data collection process was carried out in November 2020 with the support of a local consulting company with experience in farmer surveys.

Major challenges for reaching the last mile

- Communication channels are critical for delivering agrometeorological information to agricultural users and to increase the number of beneficiaries.
- It is essential to strengthen the connections between the producers of information and agricultural users across the climate services value chain. Information providers need to ensure that the information is being used, besides assessing users' preferences for obtaining the information. Climate information producers need to engage user communities and build institutional and technical capacity.

Existing communication channels: needs and preferences of last mile users

In Tajikistan, the National Agency for Hydrometeorology delivers weather information and weather alerts to last mile users through television and social media (60 to 70 percent, respectively) (Figure 1). Although there is consistency between the dissemination channels used by the NMHS and the preferences of last mile users, the NMHS could leverage other communication means to maximize the uptake of climate information by agricultural users. For instance, an increasing number of farmers would prefer receiving the information through the radio and/or through regular SMS, including USSD. The previous methods are not yet fully developed and could be further deployed and used to deliver information to farmers living in remote areas where access to the internet remains limited.

CASE STUDY: Perspectives from farmers and pastoralists: last mile needs and the uptake of agrometeorological information in Tajikistan

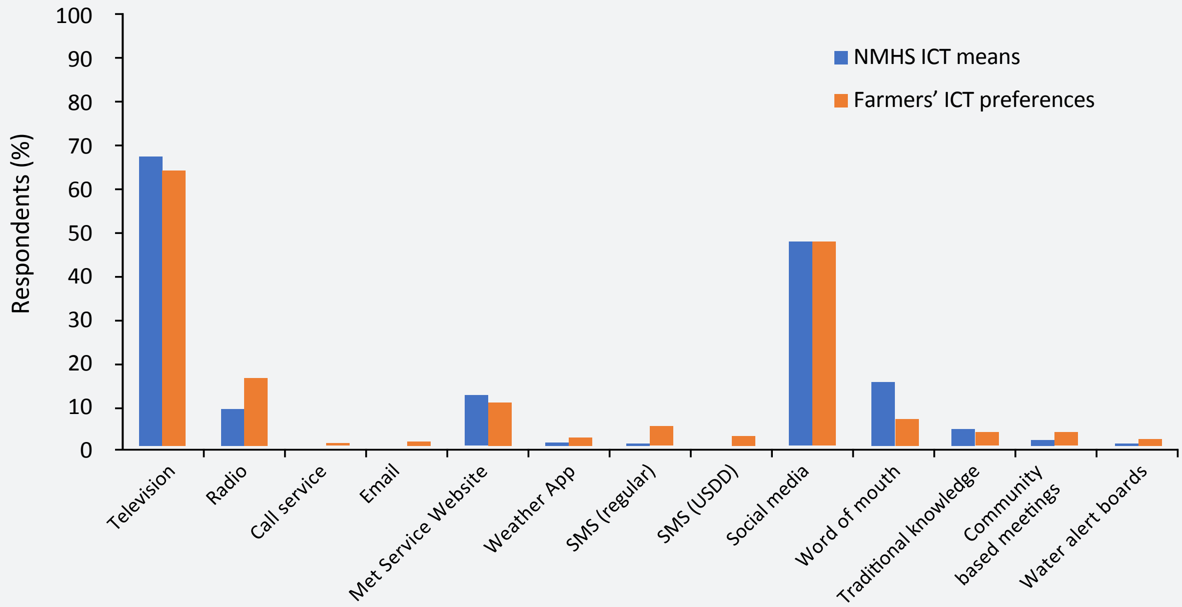


Figure 1. *NMHS communication means for delivering agromet information versus farmer's desired means.*

Agrometeorological advisories tailored to crop systems

Once the desirable dissemination channels are identified, the next step is to identify the quality and usefulness of the agrometeorological services provided at a local level. User feedback mechanisms are necessary to enhance these services, meet stakeholder needs, and assess the level of uptake and the type of agrometeorological information required by users. The surveys indicate that the most relevant climate services needed for planning and managing agricultural activities in Tajikistan are: precipitation forecast (64 percent), temperature forecast (43 percent), and pest and disease forecast (40 percent). Although farmers would prefer receiving this information whenever is relevant or available, daily and dekadal frequency is seen as the most appropriate timing. Other services related to specific hazards are increasingly demanded by farmers, including hail forecasts (26 percent) and wind forecasts (20.5 percent). Additionally, a large number of farmers require information on the optimal sowing date (31 percent) and on the soil moisture (21 percent) so as to better anticipate crop water needs.

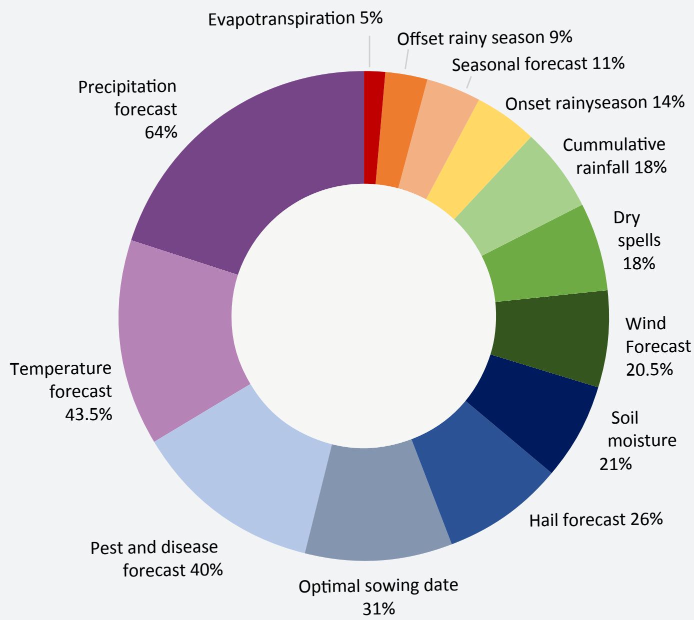


Figure 2. *Farmer's agrometeorological advisory preferences to better adapt to hydrometeorological hazards and associated disasters.*

CASE STUDY: Perspectives from farmers and pastoralists: last mile needs and the uptake of agrometeorological information in Tajikistan

Agrometeorological advisories tailored to livestock systems

In the livestock sector, six different agrometeorological advisories have been identified. The advisories that are most in demand by pastoralists are fodder availability (64 percent) and potential diseases occurrence zones (46 percent). These are followed by water resource availability (38.5 percent) and transhumance corridors (31 percent). This information is critical for identifying the most suitable grazing lands without compromising the mobility of the herd and avoiding the intrusion of cattle in cultivated areas, which could potentially result in conflict between pastoralists and farmers. In fact, advisories on potential conflict zones are increasingly in demand by pastoralists (18 percent) in Tajikistan. While most of these services are required on a daily basis, information on potential diseases occurrence zones is required on dekadal basis. Additionally, critical livestock migration routes together with geospatial information on groundwater resources (e.g., wells, ponds, lakes, streams) are highly supported in the face of increasing heat and drought stress conditions across the country.

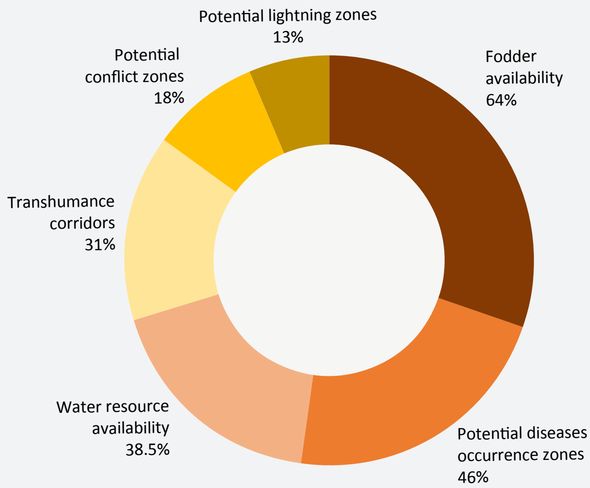


Figure 3. *Pastoralist's agrometeorological advisory preferences to better adapt to hydrometeorological hazards and associated disasters.*

Future work and investment opportunities

- Efforts have been made to produce meaningful advisories for the livestock sector. The NMHS provides information on potential heat-stress zones and extreme events and water resource availability. Nevertheless, only the water resource availability advisory meets pastoralists demands. As a result, strengthening the coordination between NMHS and the Ministry of Agriculture to produce tailored services responding to the needs of pastoralist should be prioritized.
- Enhance non-governmental support for delivering agrometeorological advisories in Tajikistan. Much of this non-governmental support (e.g., weather information, agronomic inputs, training) is being provided by NGOs and private companies. Building partnerships between the private sector and public sector that foster collaboration rather than competition is needed to strengthen agrometeorological services, increase the number of services available, and generate revenues for all stakeholders.
- Tajikistan can now maximize and scale up the number of beneficiaries and types of agrometeorological services by incorporating the recent improvements on weather forecasting accuracy (30 percent increase) within the region following the implementation of the Central Asia Hydrometeorology Project (CAHMP), which was supported by the Global Facility for Disaster Risk Reduction (GFDRR) and the World Bank.
- Pastoralists are not given priority when it comes to the use of climate-smart technologies in Central Asian countries. The public and private sector need to continue strengthening the resilience of agricultural producers by regularly disseminating a wider range of agrometeorological services. The likelihood of adoption of climate-smart technologies is highest in drier areas of Central Asian countries than in wet areas.

References:

Mirzabaev A. 2018. Improving the Resilience of Central Asian Agriculture to Weather Variability and Climate Change. In: L. Lipper, N. McCarthy, D. Zilberman, S. Asfaw S., Branca G. (eds) Climate Smart Agriculture. *Natural Resource Management and Policy*, 52. Springer, Cham. https://doi.org/10.1007/978-3-319-61194-5_20

World Bank. 2021. Central Asia hydrometeorology modernization project. In: *World Bank* [online]. [Cited 11 February 2021]. https://projects.worldbank.org/en/projects-operations/project-detail/P120788


©FAO Colombia

Latin America and the Caribbean

Latin America and the Caribbean is the second most disaster-prone region in the world. Floods are the most common disaster, followed by storms and drought (OCHA, 2020; FAO, 2016a).

In South America, floods and landslides account for 73 percent of climate-related disasters (WMO, 2020). Most Caribbean States are Small Island Developing States (SIDS) and are among the countries at highest risk when it comes to climate-related hazards (e.g., strong winds, storm surges, flooding, and droughts) (FAO, 2016b). Agriculture is predominantly rainfed and, therefore, increases the vulnerability of SIDS to variable and unpredictable weather patterns, particularly during El Niño/La Niña years. In 2020, La Niña brought below-average precipitation to large areas of South America, which resulted in a notable decrease in agricultural productivity (WMO, 2021). The region has focused mainly on disaster response and prevention for floods and storms. However, the region has a low capacity to respond to the impacts of drought, which have become increasingly significant. Inequality and social exclusion remain major challenges to reducing disaster risk.

Data collection and monitoring

There is increasing consensus among countries in Latin America and the Caribbean that it has become urgent to integrate climate information into decision-making, and that this needs to be done by improving coordination between providers and users on the range, timing, quality, content and delivery of climate products and services (Miralles-Wilhelm and Muñoz Castillo, 2014). The uptake and application of remote sensing data for climate and agroclimatic analysis is increasing. However, the provision of climate services is mainly done through ground data collected by national institutions, with NMHSs performing the primary role. Many countries in the region, particularly the less economically developed countries, are constrained by limited availability of high-quality observations, which is a prerequisite to produce accurate climate services (Miralles-Wilhelm and Muñoz Castillo, 2014).

In Latin America and the Caribbean, 16 out of 21 countries have included early warning systems as a priority in their intended nationally determined contribution (INDC) plans to the UNFCCC (UNFCCC, 2015). Agriculture disaster risk management plans for Caribbean countries exist, but they are not widespread. The existing plans prioritize hurricanes and flooding, and place little focus on drought despite its major implications for these countries, which are highly dependent on rainfall for agricultural production (FAO, 2016b). Although there is adequate meteorological data, information on agricultural impacts remains largely insufficient in the region, and data on the capacities of climate services from many SIDS remains inadequate (Vogel *et al.*, 2017). Caribbean organizations have tended to be focused on meteorology. Consequently, influencing the development of climate service activities towards more technical aspects and less on user participation and critical areas of capacity development to tailor climate services for the agricultural sector (Mahon *et al.*, 2019).

The regional climate centres recognized by the WMO include: the Caribbean Meteorological Organization (CMO), the Caribbean Institute for Meteorology and Hydrology (CIMH), the International Research Centre on El Niño (CIIFEN) in western South America, and the Regional Climate Centre Network for southern and northern South America. CIIFEN has consolidated its presence in Central and South America by providing climate services designed for users and decision makers. In the Caribbean and SIDS, the CIMH has become the primary provider of climate services and products for several socio-economic sectors. Since 2017, the CIMH has acted as the WMO regional centre for climate for the CMO and contributes to the GFCS. Eight CMO Member States (Antigua and Barbuda, Barbados, Belize, Cayman Islands, Guyana, Jamaica, Saint Lucia, Trinidad and Tobago) have weather forecasts and warning offices, and many of these offices have responsibilities for other CMO member states (CMO, 2020). CIMH liaises with national and regional stakeholders in the development and delivery of critical products and climate services for agriculture and food security. CIMH developed a strong research and development programme in climate variability, which has led to the development and delivery of (i) drought and precipitation monitoring and forecast products, (ii) the development of climate data products and services, (iii) the development of agrometeorological products and services; and (iv) applied meteorology and climate training services (CIMH, 2020).

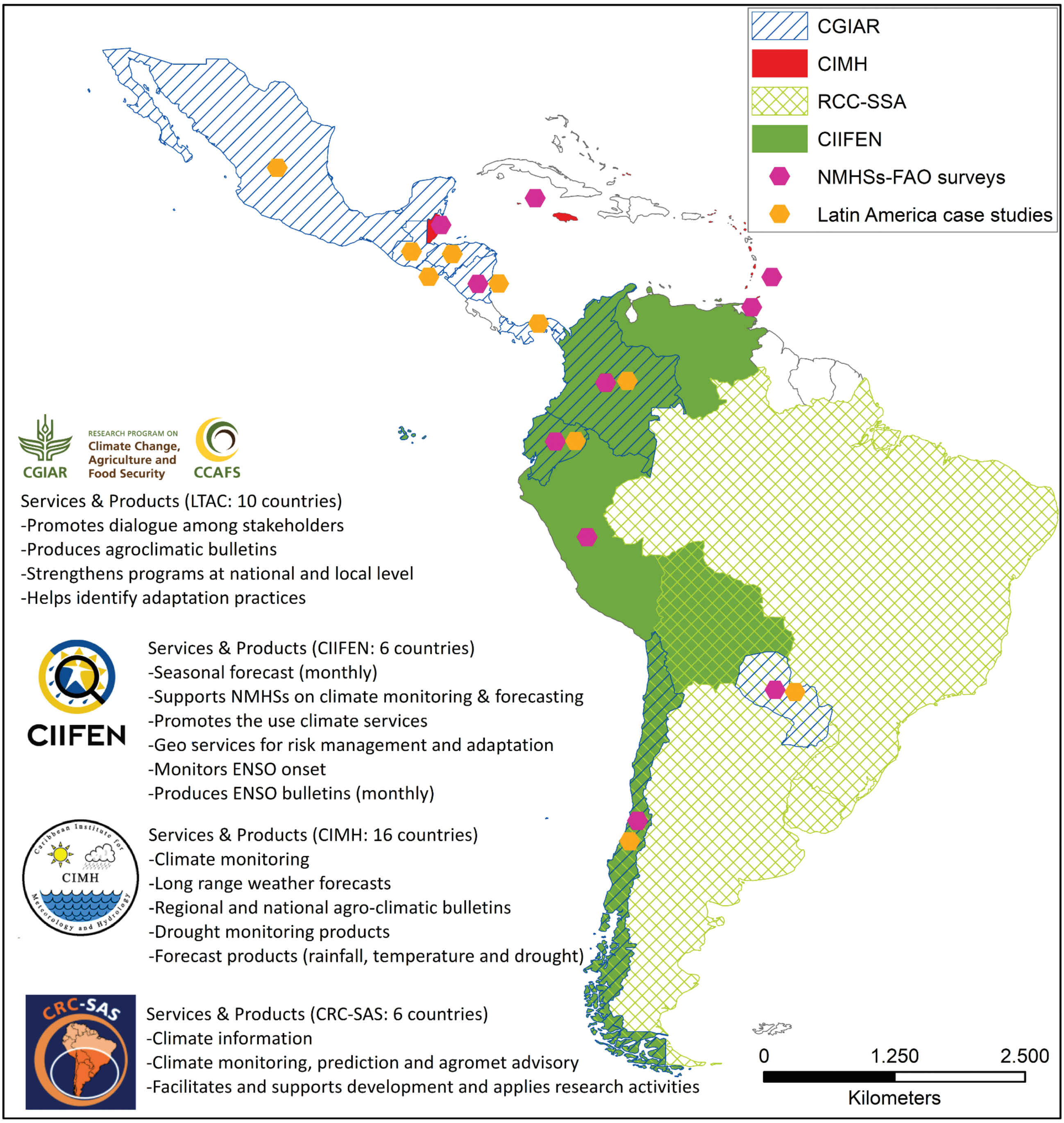
Co-production of tailored services

Few studies have assessed the capacity of NMHSs to provide climate services in SIDS, and none have been carried out in the Caribbean region even though it is one of the most disaster-prone areas in the world. NMHSs in the Caribbean have limited resources, knowledge, and expertise for the implementation of climate services. The production and delivery of user-driven climate services place new responsibilities on NMHSs and require new coordination mechanisms and institutional infrastructure. The CMO plays an important role in guiding members in the implementation of the GFCS and coordinates several climate-related projects in the Caribbean on climate change and disaster risk reduction. A priority area of these projects is improving the communication and application of climate information. An example is the Caribbean Agrometeorological Initiative (CAMI), which is implemented by CIMH. The Pilot Programme for Climate Resilience (PPCR), the Climate Risk and Early Warning Systems (CREWS) Initiative, and the Multi-Hazard Early Warning System (MHEWS) for the Meteorological, Hydrological and Climate Hazards Programme have also made progress in improving climate services and climate resilience in the region.

In Latin America, projects such as CLIMANDES in the Peruvian Andes were specifically implemented to promote user-centred climate services through the GFCS. CLIMANDES, which was led by the WMO, the Peruvian NMHS, *Servicio Nacional de Meteorología e Hidrología* (SENAMHI), and the Swiss Federal Office of Meteorology and Climatology (MeteoSwiss), focused on developing a user interface platform as a two-stage approach to co-develop and tailor climate services to specific users and user groups (Rosas *et al.*, 2016). Under this project, case studies were conducted to assess the socio-economic benefits of user-tailored early warning systems for small-scale coffee and maize farmers in the rural Andean

region of Cusco. The work targeted two rural communities for the development of user-tailored climate services with the involvement of farmers. Climate field school workshops were held to establish regular input and feedback and raise farmers' awareness on information products. An external evaluation of the project found that co-developed climate services had significantly increased trust in SENAMHI and improved the use of scientific information in agricultural decision-making. Additionally, in Latin America, Local Technical Agroclimatic Committees (LTACs) have allowed farmers to participate in open dialogues on climate variations and co-design measures to reduce crop losses, particularly through improved agronomic practices **(see case study, *Local Technical Agroclimatic Committees in Latin America*)**. With regards to the co-production of agroclimatic bulletins, the LTAC approach recognizes the distinct roles and responsibilities of public and private institutions, academic and research institutions, and other agencies in the provision of climate services (Giraldo and Sarruf Romero, 2020).

Figure 16. Main regional institutions delivering agrometeorological services in Latin American and the Caribbean



Map conforms to United Nations World Map 4621, Feb 2021.

Communication of services to the last mile

Latin America

Access to ICTs has rapidly expanded across Latin America. However, challenges remain in reaching rural populations in poorly serviced areas, as well as populations with low computer literacy and limited formal education (Trendov *et al*., 2019). In 2018, mobile phone subscriptions reached 67 percent, and smartphone adoption stood at 65 percent in Latin America (Trendov *et al*., 2019). There is a great urban-rural digital divide within countries. This is true even in the more economically developed countries such as Brazil and Argentina, where despite the enhanced weather and climate monitoring capabilities, large rural areas still have low rates of ICT penetration. Internet access is limited in rural households, with access rates lower than five percent in most countries, and almost non-existent in Bolivia (Plurinational State of), Colombia, El Salvador, Nicaragua and Peru (Trendov *et al*., 2019).

Climate Forums are one of the frameworks used to enhance the provision of consensus-based and user-relevant climate outlooks. In Latin America, three Climate Forums are conducted on a regular or quasi-regular schedule: the South-eastern South America Climate Outlook Forum (SSACOF), the Western Coast of South America Climate Outlook Forum (WCSACOF) and the Central America Climate Forum (FFCA). The RCC-Network for southern South America provides regional climate products and services to support NMHSs, including climate monitoring, long-range forecasting, climate data and application.

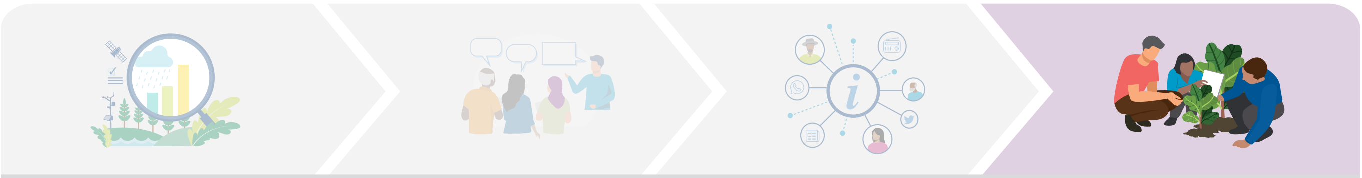
The AgroClimas project in Colombia aims to build knowledge on agroclimatic forecasts and strengthen capacities by exploring the benefits of generating and sharing information at a local level and determining the usefulness and usability of agrometeorological information services. AgroClimas also seeks to measure the impact of these services on farmers' livelihoods and incorporate tailored information on crop production based on seasonal weather forecasts. These services are tailored to the needs of maize and bean farmers who require specific agrometeorological information (e.g., high-resolution precipitation, temperature and humidity forecasts). Farmers have affirmed that local radio broadcasts and text messages are the most effective communication means for receiving this information (CCAFS, 2016; Blundo Canto *et al*., 2016).

Caribbean

Information uptake by farmers is one of the most difficult steps in the process of delivering tailored services in the region. A major impediment is the lack of appropriate communication channels (Guido *et al*., 2018; Loboguerrero *et al*., 2018). Most Caribbean farmers are older people, who have little education and little motivation to change their current practices. However, effectively providing key information (e.g., the agricultural implications of using the climate information) to farmers increased their engagement in farmers' forums. While it is generally believed that text messaging and cell phone alerts are popular means to share information, empirical research indicated that farmers or agriculture officers did not perceive text messaging as common. In farmers' forums and interviews, the most popular information sharing channels were informal networks, one-on-one outreach, and radio programming.

Another major limiting factor is the lack of data on agricultural impacts. This data is needed to support the development of actionable information packages suitable for Caribbean farming practices. In Jamaica, the Meteorological Service of Jamaica (MSJ) currently distributes information about the climate, including tercile seasonal weather forecasts through its webpage. The MSJ also produces weather and seasonal weather forecasts at regional and island-wide scales. However, location-specific information, the quantification of climate risks, and the correlation between climate impacts and agricultural losses are largely insufficient. In the Blue Mountains, where about 80 percent of the country's coffee is cultivated, farmers are highly vulnerable to outbreaks of crop diseases (e.g.,

coffee leaf rust). Farm-level decisions are based on crop management calendars, and few farmers routinely consult weather information. Seasonal weather forecasts on the onset of spring rains are critical for reducing the risk of the coffee leaf rust epidemics. These epidemics can be mitigated by informing farmers of the optimal time to apply fungicides, but this agrometeorological product is not yet fully developed by the MSJ and its collaborators.



Participatory engagement of last mile and climate-informed actions

A major challenge in developing user-centred services is the lack of feedback mechanisms between farmers and national institutions, and a lack of trust between the two. Options for making these mechanisms operational include requesting feedback at farmers' forums; keeping records of questions on radio programmes; setting up automated web-based surveys; having agricultural extension officers actively distribute surveys; and sharing websites, email addresses, or telephone numbers where users can provide feedback. During the three-year CAMI intervention in the Caribbean, extension agents worked directly with farmers in Guyana and Jamaica to describe the seasonal precipitation outlook and what it would mean for the farmers' particular circumstances. Farmers in the region are significantly affected by variations in the dry and wet seasons, and weather forecasts related to these seasons were identified as the most useful.

LTACs are the most extended participatory approach for delivering agrometeorological information in Latin America. The LTACs put the emphasis on knowledge-intensive practices, interactions and shared understanding among diverse actors, including farmers' associations, national institutions and universities. They are a priority issue for the implementation of the Regional Strategy for Disaster Risk Management in the Agriculture Sector and Food and Nutrition Security in Latin America and the Caribbean (2018-2030), which is being facilitated by FAO. To bridge the gap between production and delivery of climate information, the CGIAR, together with national institutions, have promoted the creation of farmer groups and experts who interact in person or virtually in real time **(see case study, *Local Technical Agroclimatic Committees in Latin America*)**.

Investment needs

The small island states in the Caribbean are among the most exposed to the impacts of climate change in the region. However, these countries, together with other Latin American countries receive only USD 0.83 billion from the public sector to adapt and mitigate the impacts of climate change on agriculture, forestry, land use and fisheries (Chiriac and Naran, 2020). To enhance investments in the last mile, the findings of this report suggest the following actions:

1. Invest in overcoming disparities in access to ICTs and other communication channels, particularly in the Caribbean.
2. Carry out community awareness and outreach campaigns on the use of climate services for farm-level decision-making.
3. Invest in participatory approaches that have proven to be successful (e.g., LTACs) to enhance trust between producers and users of climate services.
4. Invest in strategic alliances between farmers' organizations, national partners and the private sector to enhance the tailoring of climate services to specific food value chains.
5. Invest in pilot programmes to test and increase awareness of climate-informed actions.

Regional conclusions

The challenges and set of recommendations for investment provided below are based on an extensive search of literature that includes research papers, technical reports, United Nations flagship reports and regional workshops conducted by WMO as part of the GFCS. These actions and proposed recommendations aim to enhance the effective production and delivery of climate services, and have been carefully selected to bridge the last mile gap while considering the socio-economic context of the region of interest.

Climate services framework step	Major challenges/barriers	Priority areas for action
Data collection, monitoring and forecasting	▪ Lack of accurate forecasts and precipitation indexes derived using the European Centre for Medium-Range Weather Forecasts (ECMWF) ensemble mean ▪ Limited availability of high-quality observations, particularly in least developed countries ▪ Insufficient maintenance of automatic weather stations ▪ Lack of consistent and standardized monitoring of agricultural variables	▪ Enhance the performance of numerical weather prediction models ▪ Invest in the agrometeorological observation network ▪ Invest in new climate services by increasing the information available to policymakers, agricultural technicians so as to enhance the adaptive capacity of farmers ▪ Develop open platforms for data collection, coordination and sharing
Task force and data sharing	▪ Lack of coordination between the NMHSs and Ministries of Agriculture ▪ Lack of financing mechanisms to engage stakeholders in taking part in multidisciplinary working groups (e.g., Local Technical Agroclimatic Committees)	▪ Integrate climate information into decision-making by improving coordination between providers and users on the range, timing, quality, content and delivery of climate products and services ▪ Promote a regional action plan for the implementation of climate services ▪ Promote regional training workshops for NMHS technicians ▪ Support the systematic development of the institutions, infrastructures and human resources needed for effective climate services ▪ Further promote and share forecasts and recommendations based on the discussions and analysis technical agroclimatic platforms ▪ Ensure continuous information exchange among existing technical working groups with complementary objectives, such as the ones on forecasts, climate services and anticipatory action

Climate services framework step	Major challenges/barriers	Priority areas for action
Co-production of tailored agrometeorological advisories	■ Lack of funding for national institutions to work in a coordinated way to produce and communicate relevant information ■ Difficulties in identifying and addressing a wide range of user needs and effectively co-design and tailor climate services regionally	■ Promote a strategic guidance on the institutional arrangements, partnerships and processes that are required to operationalize climate services at regional and national levels ■ Recognize the distinct roles and responsibilities of the public and private sector, academic institutions, research organizations, and technological agencies in the provision of climate services
Communication of services to the last mile	■ Lack of funding and infrastructure for processing and disseminating data in the region ■ Low access to ICTs and climate and forecast information by last mile users ■ Challenges related to translating (brevity and clarity of language used) and tailoring of the information ■ Lack of appropriate communication channels within Caribbean countries	■ Improve the communication and application of climate information through, for example, the Caribbean Agrometeorological Initiative (CAMI) ■ Build infographic layouts that convey statistical and graphical results in a more friendly way and communicate the results more efficiently ■ Move away from paper-based delivery formats and promote the use of trusted and publicly available data ■ Reinforce virtual agrometeorological platforms
Participatory engagement of last mile	■ Low information uptake by Caribbean farmers ■ Poor face-to-face interaction between farmers and agricultural extension officers	■ Promote participatory approaches for farmers (e.g., LTACs and climate field schools) ■ Establish regular input and feedback mechanisms and to raise farmers´ awareness on the benefits of using climate information ■ Promote the use of weather and climate information by agricultural communities ■ Foster the use of innovative digital farmer advisory services, and the potential of mobile applications for engaging in a two-way dialogue

Climate services framework step	Major challenges/barriers	Priority areas for action
Climate-informed actions	■ Inaccessible knowledge as much of the information is not publicly available nor digitized ■ Insufficient outreach and training on climate information and/or mechanisms used to relate this information to the impacts that climate variations can generate at the local level ■ Lack of data on agricultural impacts necessary to support the development of actionable information packages suitable for use in Caribbean farming	■ Produce user needs assessments on agrometeorological services ■ Design user-centred processes and avoid developing products that are disconnected, unusable, redundant or that do not address existing information needs

Survey results: Communication channels

This section presents the results obtained from the surveys in response to the following question:
By which means are the weather information and weather alerts currently delivered to the last mile?

Figure 17. List of communication means used to deliver weather information and weather alerts to the last mile, based on survey results. Refer to Annex 1 to see the original survey template. *Note: The results contained herein do not represent all existing communication means such as agricultural extension officers, posters, public meetings, face-to-face, etc.*

Survey results: Agrometeorological advisories

This section presents the results obtained from the surveys in response to the following question:
Which type of information does the NMHS provide to the last mile?

	Chile	Colombia	Peru	Paraguay	Nicaragua	Ecuador	Belize	Trinidad and Tobago	Cayman Islands	Barbados
Optimal sowing date		✓ (Crops)	✓ (Crops)		✓ (Crops)	✓ (Crops)				
Onset rainy season		✓ (Crops)		✓ (Crops)	✓ (Crops)	✓ (Crops)		✓ (Crops)		
Offset rainy season		✓ (Crops)				✓ (Crops)		✓ (Crops)		
Dry spells		✓ (Crops)	✓ (Crops)			✓ (Crops)	✓ (Crops)	✓ (Crops)		
False start rainy season		✓ (Crops)								
Cumulative precipitation	✓ (Crops)	✓ (Crops)	✓ (Crops)	✓ (Crops)	✓ (Crops)	✓ (Crops)	✓ (Crops)	✓ (Crops)	✓ (Crops)	
Evapotranspiration	✓ (Crops)		✓ (Crops)	✓ (Crops)		✓ (Crops)				
Cumulative. growing degree-days	✓ (Crops)									
Soil moisture		✓ (Crops)			✓ (Crops)	✓ (Crops)				
Seasonal forecast	✓ (Crops)	✓ (Crops)	✓ (Crops)	✓ (Crops)		✓ (Crops)	✓ (Crops) ✓ (Forestry)	✓ (Crops) ✓ (Forestry)	✓ (Crops)	✓ (Crops) ✓ (Forestry)
Precipitation forecast	✓ (Crops)				✓ (Crops)		✓ (Crops)	✓ (Crops)	✓ (Crops)	✓ (Crops)
Temperature forecast	✓ (Crops)				✓ (Crops)		✓ (Crops)	✓ (Crops)	✓ (Crops)	✓ (Crops)
Pest and Disease forecast							✓ (Crops)	✓ (Crops)		
Hail forecast		✓ (Crops)		✓ (Crops)			✓ (Crops)			
Wind forecast	✓ (Crops)	✓ (Crops)		✓ (Crops)	✓ (Crops)		✓ (Crops) ✓ (Fisheries)			✓ (Crops) ✓ (Fisheries)
Water resource availability		✓ (Livestock)	✓ (Livestock)			✓ (Livestock)	✓ (Livestock)			
Potential heat stress		✓ (Livestock)	✓ (Livestock)	✓ (Livestock)			✓ (Livestock)	✓ (Livestock)		
Potential disease occurrence zones		✓ (Livestock)					✓ (Livestock)			
Potential lightning zones	✓ (Livestock)	✓ (Livestock)		✓ (Livestock)			✓ (Forestry)			
Potential extreme weather events	✓ (Livestock)	✓ (Livestock)	✓ (Livestock)	✓ (Livestock)	✓ (Livestock)		✓ (Livestock)	✓ (Livestock)		
High swell forecasts					✓ (Fisheries)		✓ (Fisheries)	✓ (Fisheries)		✓ (Fisheries)
High tides forecasts					✓ (Fisheries)		✓ (Fisheries)	✓ (Fisheries)	✓ (Fisheries)	✓ (Fisheries)
Visibility forecasts					✓ (Fisheries)		✓ (Fisheries)	✓ (Fisheries)		✓ (Fisheries)
Sea surface temperature							✓ (Fisheries)			
Wildfire prone zones			✓ (Forestry)		✓ (Forestry)		✓ (Forestry)	✓ (Forestry)		

Crops ✓ Livestock ✓ Fisheries ✓ Forestry ✓

Table 5. Agrometeorological advisory services provided to the last mile per agricultural sector (crops, livestock, fisheries and forestry), based on survey results. Refer to Annex 1 to see the original survey template.

CASE STUDY

Local Technical Agroclimatic Committees (LTACs) in Latin America

Countries:
Colombia, Guatemala, Chile, Honduras, Mexico, Panama, Paraguay, Nicaragua, Ecuador and El Salvador

Timeframe:
2013 - ongoing

Institution(s):
About 300 institutions, including NMHSs and Ministries of Agriculture; producers' associations (e.g FEDEARROZ, Anacafe); academic and research institutions (e.g., the International Research Institute for Climate and Society (IRI); the Alliance of Bioversity International and the International Center for Tropical Agriculture (CIAT); the CGIAR Research Programme on Climate Change Agriculture and Food Security (CCAFS); international agencies (e.g., FAO, WFP, the International Fund for Agricultural Development (IFAD), USAID); and civil society.

Background

Local Technical Agroclimatic Committees (MTA in Spanish and herein LTACs) were first initiated in Colombia from 2013 to 2015, and were developed as part of the CGIAR Research Programme on Climate Change Agriculture and Food Security (CCAFS) to improve the management of local agrometeorological information and identify the best adaptation practices to climate change. LTACs are platforms for local stakeholders to exchange knowledge on best climate-sensitive practices for reducing the risks associated with climate variability. NMHSs and international and national technical institutions provide information on the likelihood of different climate scenarios, which is complemented with local farmer and expert knowledge to arrive at best crop management options.

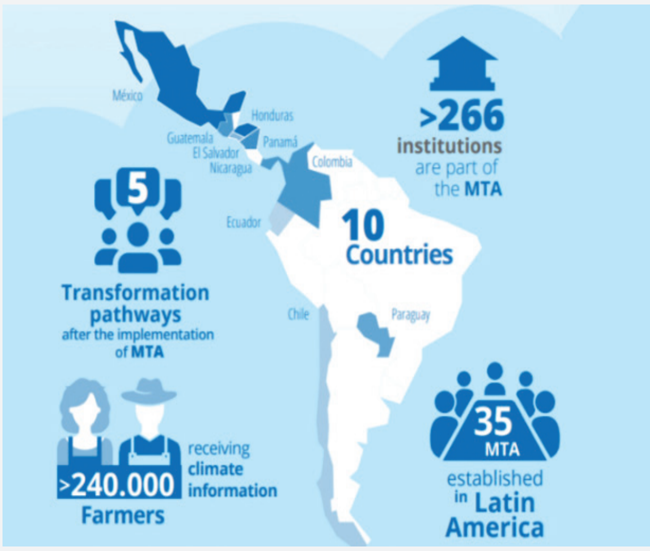


Fig. 1. *Outcomes and impacts of LTAC approach (Hiles et al., 2020).*

Major challenges for reaching the last mile

- Identifying financing mechanisms and engaging relevant actors to take part in LTACs with coordination and facilitation from leading organizations. Human and financial resources are necessary to develop context-specific tools and robust agrometeorological advisories.
- Technical aspects related to an agrometeorological advisory, for example by combining climate forecasts with crop development information to provide the most suitable recommendations on agricultural management.
- Despite the positive feedback collected on the benefits of LTAC farm-level recommendations, data for assessing farm changes over time is scarce.

CASE STUDY: Local Technical Agroclimatic Committees (LTACs) in Latin America

Benefits of using climate-informed advisories

- Confidence in the quality of climate and agrometeorological information has increased, and the information has become more integrated into agricultural decision-making processes.
- Research studies show that about 40 percent of farming families that receive information from LTACs are effectively changing their agricultural practices, which tends to reduce crop losses and increase crop productivity and incomes.
- Agrometeorological knowledge becomes more democratized, which make the existing information more understandable and connected to the last mile.
- LTACs are significantly influencing national and institutional policy changes, and fostering inter-institutional alliances to deal with climate risks.

Lessons learned

- The active participation of local organizations and a variety of farming communities was crucial for making climate knowledge accessible and understandable for farmers and technicians, including women and youth. The integration of the knowledge of experts, farmers and other stakeholders contributes to bridging the gap between climate information producers and farmers.
- Farmers can make decisions on farming practices and productive assets based on climate information.
- Technicians and rural advisors enhance their capacities to provide agricultural advisory services. This is achieved by incorporating their knowledge and understanding on climate variability and crop productivity. Technicians and rural advisors are also able to better monitor changes in the agricultural activities of rural households after integrating information on local climate variability.

©IRI/Elisabeth Gawthrop

CASE STUDY: Local Technical Agroclimatic Committees (LTACs) in Latin America

Future work and investment opportunities

To scale up regional climate services, a comprehensive strategy must be adopted that includes the following key actions:

- Improve the predictive capacity of climate forecasts. This can be achieved by scaling up participatory approaches, such as the Participatory Integrated Climate Services for Agriculture (PICSA) approach. CGIAR Research Program on CCAFS has successfully strengthened the capacity of over 20 organizations in four countries using this approach, and established new collaborative arrangements to expand this work.
- Increase research to improve knowledge on the demand and supply of agrometeorological services, and tailor information according to the needs of agricultural users. Competency models should take into account the knowledge and skills required by farmers to clearly define the goals for capacity building on climate risk management. Currently, CCAFS, the Alliance of Biodiversity International and CIAT, and scientist with the Catholic Relief Services (CRS) are working on developing these methodologies.
- Foster strategic alliances with farmers' organizations, the public sector and private sector groups to deliver improved and accurate climate services to users. The LTAC approach has motivated stakeholders from the finance and insurance sector to participate in activities to improve agrometeorological information. The participation of the private sector offers an important opportunity for further scaling up and increase the uptake of agrometeorological information. The design and implementation of financial instruments and insurance mechanisms that take into account agrometeorological information will be a pathway for supporting farmers to effectively build resilience to climate change.

References:

Dorward, P., Clarkson, G. & Stern R. 2015. *Participatory Integrated Climate Services for Agriculture (PICSA): Field Manual.* Walker Institute, University of Reading (available at: https://hdl.handle.net/10568/68687)

Hiles X, Navarro-Racines C, Giraldo DC. 2020. *MTA: Transforming Farmers' Lives In Latin America.* CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) (available at: https://hdl.handle.net/10568/108948)

Loboguerrero, A., Boshell, F., León, G., Martinez-Baron, D., Giraldo, D., Recaman Mejía, L., Díaz, E. & Cock, J. 2018. Bridging the gap between climate science and farmers in Colombia. *Climate Risk Management,* 22: 67-81. https://doi.org/10.1016/j.crm.2018.08.00

4 | Conclusion

Climate change and its impacts are being observed all over the world. However, the severity and consequences of these impacts vary drastically depending on many factors and on the capacity of individuals, communities and ecosystems to respond and recover. The rural poor, including small-scale farmers and producers, remain particularly vulnerable to the adverse impacts of climate change and environmental degradation on their livelihoods and are disproportionately affected by these impacts. The impacts of climate change differ by region and by country, as well as the challenges faced by each country in providing and delivering climate services.

The findings of this report highlight that in Africa, a major barrier in the provision of climate services is the lack of availability of high-quality data that can serve as a basis for climate services and the limited access to information from different communication channels. In Asia and Latin America major challenges remain in tailoring climate information to agricultural practices and ensuring that users are continuously providing feedback to improve climate services. The findings highlight that Central Asia and the Near East and North Africa regions have challenges related to data sharing, the co-production, co-design and co-development of sector-specific services, and the effective delivery of information to users. In Europe, data is more available and access to information is high, but many agricultural users affirm that services are often not effectively tailored to support farm-level decision-making or available in a user-friendly format. A global challenge is to ensure people with vulnerable livelihoods living in remote areas have better access to climate services and agricultural advisories. Technology has been critical in shaping and driving development in this area and has contributed to increasing climate resilience. However, progress towards a digital agricultural transformation remains slow in many regions. To be effective, investments designed to overcome the barriers in delivering climate services and agricultural advisories to last mile users need to consider regional differences, as well as finer scale contextual, cultural and socio-economic factors.

Overcoming the last mile barrier requires a dynamic and continuous system that is driven by the needs and preferences of the intended users and a clear objective to meet and respond to these needs. In addition to the investment needs identified by region at the end of each regional outlook, the literature review, case studies and data collected globally have identified key gaps and challenges that are widespread across regions, and these are outlined below. This global assessment points to a significant gap in investments geared to tailoring climate services to specific agricultural practices, and an absence of participatory engagement of agricultural communities at every stage of the process. There is also insufficient investment in the selection and development of appropriate communication channels based on the requirements of users and available communication means. Finally, the availability and accessibility of necessary data remains a global challenge that requires investment and engagement from a wide range of actors.

The benefits derived from investments made to overcome the last mile barriers are essential to guarantee that funds continue to be allocated upstream in the climate services framework.

Investments in monitoring networks, capacity development and service production should not be made in isolation but support the entire climate services framework. The key areas of investment for funding entities, international agencies and project developers have been identified earlier in this report. A national investment roadmap will be shaped by local data and consultations. However, the major steps that will be involved are outlined below. As an overall recommendation, investments need to be effectively distributed across the entire climate services framework in a coordinated and comprehensive manner. A lack of investment at each stage of the framework will undermine efforts to bridge the last mile gap, and lead to inefficiencies and a lack of sustainability in efforts to provide climate services in the medium and long term.

Challenges to reaching the last mile and recommendations for project developers and investments

Challenge

Lack of effective institutional arrangements or institutional capacities

Priority areas for action across all regions

- Strengthen institutional arrangements and develop formalized agreements between NMHSs, Ministries of Agriculture, Livestock and Environment, and other stakeholders (e.g., research institutions, private institutions and NGOs).
- Establish national plans that identify priorities and needs to enable the effective development and application of climate services. The plans should inform investments along the whole value chain; clearly identify needs in terms of the observing networks and capacity development; and should have clear monitoring and evaluations indicators to enable assessment of progress over time.
- Prepare roles and responsibilities maps of each institution involved in the development and provision of climate services.
- Support and finance engagement of users and different stakeholders in the development of climate services.
- Ensure that climate investments systematically and sustainably strengthen operational systems and provide an overarching framework and tracking mechanism.

Challenge

Insufficient data availability or monitoring capacity

Priority areas for action across all regions

- Prepare technical evaluations of observation networks, monitoring capacities, quality databases and forecasting systems to identify gaps in data monitoring.
- Ensure the procurement of equipment is in line with investment plans of national institutions.
- Support data collection of agricultural variables (e.g., soil temperature, pH, salinity, and moisture, leaf wetness, evapotranspiration, chlorophyll content) and agribusiness data (e.g., availability and price of fertilizers, machinery, seed and fodder availability) and marketplace information to develop actionable products.
- Invest in open access platforms and remove barriers to using climate and agriculture sector data as a public good.

Challenge

Gaps between climate information and usability

Priority areas for action across all regions

- Provide incentives for the establishment of multi-disciplinary working groups, including all the relevant state extension technical services and organizations engaged in service production.
- Establish permanent user interface platforms to enable systematic interaction of users, providers, researchers and other disciplines.
- Develop triggers for early action according to the potential risk expected in each agricultural system (crops, fisheries, livestock and forestry).
- Invest in engagement of sector-specific experts (e.g., agronomists, plant pathologists, veterinarians, foresters, social scientists) that can effectively translate climate products into sector-relevant information.
- Enhance support for the modelling of climate information based on user needs (e.g., the use of climate data for plant disease modelling to provide early advisories about potential disease outbreaks).
- Invest in tailoring products into languages, figures, animations, cartoons and other media that are easily understood and actionable by farming communities.
- Invest in forecasts and early warnings with longer lead times to ensure that users have sufficient time to act before disasters occur.
- Tailor information by level of expertise (e.g., advisors, scholars, policymakers, last mile users).

Challenge

Information at national level not reaching users

Priority areas for action across all regions

- Mapping of effective communication channels for delivering information and services (e.g., television, radio, SMS, sirens, coastal warnings, social media).
- Undertake surveys to understand how target communities are receiving information and how they would like to receive the information in the future.
- Connect with national private sector companies who play a role in providing rural communities with access to telephone networks, radios and other channels of communication.
- Invest in outreach campaigns to ensure that women and men, youth and other vulnerable groups have equitable access to information.

Challenge

Services not effectively informed by users

Priority areas for action across all regions

- Promote user-centred feedback mechanisms, including (i) user-focused workshops where the benefits of using climate-informed actions are highlighted, (ii) digital learning and knowledge exchange between farmers and other stakeholders, (iii) processes that allow last mile users to co-design and co-produce services and provide feedback (e.g., call services).
- Establish participatory approaches (e.g., the PICSA approach, Farmer Field Schools) to enhance the usability of climate services and ensure that farmers can offer feedback on their effectiveness.

Challenge

Effective services are limited geographically or only available to certain groups

Priority areas for action across all regions

- Invest in increasing the number of recipients and users of climate services by increasing outreach, private sector and farmer engagement.
- Support lowering the costs associated with service delivery and improving network coverage.
- Strengthen the cooperation with mobile operators and enhance access to ICTs in rural areas.
- Develop bundled products that integrate weather forecasts and agronomic information.
- Leverage existing digital technologies and ensure the equitable access of women and youth.

References

ACMAD (African Center for Meteorological Applications for Development). 2020. *ACMAD* [online]. [Cited 25 January 2021]. http://acmad.net/new/

ACSAD (Arab Center for the Studies of Arid Zones and Dry Lands)**.** 2020. *ACSAD* [online]. [Cited 19 August 2020]. https://acsad.org/

Aliyu, H. K., Olawepo, R. A. & Muhammad, S. 2019. Climate change information for farmers in Nigeria: what challenges do women face? *Earth and Environmental Science*, 399 (1): p. 012001.

Alvar-Beltrán, J., Dao, A., Dalla Marta, A., Heureux, A., Sanou, J. & Orlandini, S. 2020. Farmers' Perceptions of Climate Change and Agricultural Adaptation in Burkina Faso. *Atmosphere*, 11(8): 827.

Anderson, J. & Feder, G. 2003. *Rural Extension Services.* Policy research working paper. 10.1596/1813-9450-2976.

ASMC (ASEAN Specialised Meteorological Centre). 2020. About ASMC. In: *ASMC* [online]. [Cited 04 February 2021]. http://asmc.asean.org/asmc-about/

Bacci, M., Ousman Baoua, Y. & Tarchiani, V. 2020. Agromet forecast for smallholder farmers: a powerful tool for weather-informed crops management in the Sahel. *Sustainability,* 12(8): 3246.

Balaghi, R. 2012. *Climate change impacts and adaptation in mountain regions in the MENA region*. Presentation at the Strategic Initiative on Climate Change Impacts, Adaptation, and Development in Mountain Regions. MENA Regional Meeting, Marrakech (Morocco), 16-18 December 2012.

Balaghi, R., Jlibene, M., Tychon, B. & Eerens, H. 2013. *Agrometeorological cereal yield forecasting in Morocco.* Institut National de la Recherche Agronomique du Maroc (INRA).

Banerjee, A., Bhavnani, R., Burtonboy, C. H., Hamad, O., Linares-Rivas Barandiaran, A., Safaie, S. & Zanon, A. 2014. *Natural disasters in the middle East and North Africa: a regional overview.* Global Facility for Disaster Reduction and Recovery (GFDRR). Washington, DC, World Bank.
Basco, D. 2020. *Farm weather services.* International Society for Agricultural Meteorology (INSAM).

Blundo Canto, G., Giraldo, D., Gartner. C., Alvarez-Toro, P. & Perez. L. 2016. *Mapeo de Actores y Necesidades de Información Agroclimática en los Cultivos de Maíz y Frijol en sitios piloto -Colombia.* Documento de Trabajo CCAFS, No. 88. Cali, Colombia, CCAFS.

C3S. 2021. Climate Change. In: *Copernicus* [online]. [Cited 10 May 2021] https://climate.copernicus.eu

CCAFS. 2016. Tailored Agro-Climate Services and Food Security Information for Better Decision Making in Latin America. In: *CCAFS Projects* [online]. [Cited 25 January 2021] https://ccafs.cgiar.org/research/projects/tailored-agro-climate-services-and-food-security-information-better-decision-making-latin-america

CCAFS. 2019. Climate Services for Resilient Development (CSRD) in South Asia. In*: CCAFS: Projects* [online]. [Cited 04 February 2021].https://ccafs.cgiar.org/research/projects/climate-services-resilient-development-south-asia

Christensen, J.H., Krishna Kumar, K., Aldrian, E., An, S-I., Cavalcanti, I.F.A., de Castro, M. & Dong, W., et al. 2013. Climate Phenomena and their Relevance for Future Regional Climate Change. In Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex & P.M. Midgley, eds. *Climate Change 2013: The Physical Science Basis.* Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Chapter 14. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

CMO (Caribbean Meteorological Organization)**.** 2020. Organization. *In*: *CMO* [online]. [Cited 25 January 2021]. http://www.cmo.org.tt/organization.html

CMIH. 2020. About the Caribbean Regional Climate Centre (RCC). *In*: *About the RCC* [online]. [Cited 25 January 2021]. https://rcc.cimh.edu.bb/about/about-the-rcc/

Chiriac, D., Naran, B. & Falconer, A. 2020. *Examining the Climate Finance Gap for Small-Scale Agriculture*. Climate Policy Initiative (CPI) and the International Fund for Agricultural Development (IFAD)**.**

CILSS (Permanent Interstate Committee for Drought Control in the Sahel). 2020. AGHRYMET regional center. *In: CILSS Publications: Bulletins* [online]. [Cited 25 January 2021]. https://agrhymet.cilss.int/index.php/bulletins/

Coulibaly, Y.J., Kundhlande, G., Tall, A., Kaur, H. & Hansen, J. 2015. *Which climate services do farmers and pastoralists need in Malawi? Baseline Study for the GFCS Adaptation Program in Africa*. CCAFS Working Paper, No. 112. Copenhagen, Denmark, CCAFS.

CPI (Climate Policy Initiative)**.** 2019. *Global Landscape of Climate Finance 2019 - Methodology.*

CRED (Centre for Research on the Epidemiology of Disasters). 2021. *EM-DAT: International Disaster Database* [online]. Brussels. [Cited 07 May 2021] http://www.emdat.be/database

Donat, M. G., Peterson, T. C., Brunet, M., King, A. D., Almazroui, M., Kolli, R. K. & Nada, T. A. A. 2014. Changes in extreme temperature and precipitation in the Arab region: long-term trends and variability related to ENSO and NAO. *International Journal of Climatology*, 34(3): 581-592.

Dorward, P., Clarkson, G. & Stern R. 2015. *Participatory Integrated Climate Services for Agriculture (PICSA): Field Manual.* Walker Institute, University of Reading.

Durrell, J. 2018. *Investing in resilience: addressing climate-induced displacement in the MENA region. Discussion Paper.* Beirut, Lebanon. ICARDA.

EC (European Commission). 2015. *A European research and innovation: Roadmap for climate services.* Directorate-General for Research and Innovation. Brussels

EC. 2017. *The European Union Explained: Agriculture.*
A partnership between Europe and farmers. Directorate-General for Communication. Brussels.

ESCAP (United Nations Economic and Social Commission for Asia and the Pacific). 2017. *Leave No One Behind: Disaster Resilience for Sustainable Development.* Asia-Pacific Disaster Report 2017. Bangkok.

ESCAP. 2018. *Mid-term Review of the Asian and Pacific Ministerial Declaration on Population and Development.* (APPC/2018/4). Bangkok.

ESCWA (United Nations Economic and Social Commission for Western Asia)**.** 2013: *Strengthening national capacities to manage water scarcity and drought in West Asia and North Africa: The analysis, mapping and identification of critical gaps in pre-impact and preparedness drought management planning in water-scarce and in-transitioning settings countries in West Asia/North Africa*. (E/ESCWA/SDPD/20 13/WG.4).

ESCWA *et al.* 2017. Arab Climate Change Assessment Report – Main Report (E/ESCWA/SDPD/2017/RICCAR/Report). Beirut.

Fafchamps, M. & Minten, B. 2012. Impact of SMS-based agricultural information on Indian farmers. *The World Bank Economic Review*, 26(3): 383-414.

FAO. 2011. *Agricultural insurance in Asia and the Pacific region.* Regional Office for Asia and the Pacific (RAP) Publication 2011/12. Bangkok. (also available at www.fao.org/docrep/015/i2344e/i2344e00.pdf)

FAO. 2015. *Dimitra Clubs: A unique approach.* Rome. (also available at www.fao.org/3/a-i4706e.pdf)

FAO. 2016a. *Damage and losses from climate-related disasters in agricultural sectors.* Rome. (also available at www.fao.org/3/a-i6486e.pdf)

FAO. 2016b. *Drought characteristics and management in the Caribbean.* FAO Water Reports, No. 42. Rome. (also available at www.fao.org/3/a-i5695e.pdf)

FAO. 2017. *The future of food and agriculture. Trends and challenges.* Rome. (also available at www.fao.org/3/i6583e/i6583e.pdf)

FAO. 2020. *FAO in Mozambique.* In: *FAO* [online]. Rome [Cited 25 January 2021]. www.fao.org/mozambique/

FAO. 2021. *The impact of disasters and crises on agriculture and food security.* Rome. https://doi.org/10.4060/cb3673en

FAO, IFAD, UNICEF, WFP & WHO. 2020. *The State of Food Security and Nutrition in the World 2020. Transforming food systems for affordable healthy diets.* Rome, FAO. https://doi.org/10.4060/ca9692en

FAO-ITU. 2017. *E-agriculture strategy guide: A summary.* Bangkok. (also available at www.fao.org/3/i6909e/i6909e.pdf)

Ferdinand, T., E. Illick-Frank, L. Postema, J. Stephenson, et. al. 2021. *A Blueprint for Digital Climate Informed Advisory Services: Building the Resilience of 300 Million Small-Scale Producers by 2030.* Working Paper. Washington, DC: World Resources Institute. doi.org/10.46830/wriwp.20.00103.

Fragaszy, S. R., Jedd, T., Wall, N., Knutson, C., Fraj, M. B., Bergaoui, K. Svoboda, M., Hayes, M. & McDonnell, R. 2020. Drought Monitoring in the Middle East and North Africa (MENA) Region: Participatory Engagement to Inform Early Warning Systems. *Bulletin of the American Meteorological Society*, 101(7): E1148-E1173.

Gangopadhyay, P. K., Khatri-Chhetri, A., Shirsath, P. B. & Aggarwal, P. K. 2019. Spatial targeting of ICT-based weather and agro-advisory services for climate risk management in agriculture. *Climatic change*, 154: 241-256.

Giraldo, D. & Sarruf Romero, L. 2020. Strengthening Climate Services for Agriculture in Latin America. *In: CCAFS: News* [online]. [Cited 25 January 2021] https://ccafs.cgiar.org/news/strengthening-climate-services-agriculture-latin-america

GFCS. 2017. GFCS Adaptation Programme in Africa (GFCS APA), Phase I, - Building Resilience in Disaster Risk Management, Food Security and Health. In: *GFCS: Projects* [online]. [Cited 11 May 2021]. https://gfcs.wmo.int/Norway_2

GFCS. 2020. What are Climate Services? In: *GFCS* [online] [Cited 07 May 2021] https://gfcs.wmo.int/what-are-climate-services

Guido, Z., Finan, T., Rhiney, K., Madajewicz M., Rountree, V., Johnson, E. & McCook, G. 2018. The stresses and dynamics of Smallholder Coffee Systems in Jamaica's Blue Mountains: A Case for the Potential Role of Climate Services. *Climatic change,* 147: 253-266.

Himics, M., Fellmann, T. & Barreiro-Hurle, J. 2020. Setting Climate Action as the Priority for the Common Agricultural Policy: A Simulation Experiment. *Journal of Agricultural Economics*, 71(1): 50-69.

Hone, P. 1991. Charging for agricultural extension services. *Review of Marketing and Agricultural Economics*, *59*(3): 297-307.

ICBA (International Center for Biosaline Agriculture). 2020. Regional Drought Management System for Middle East and North Africa (DRMS). In. *ICBA: Projects* [online]. [cited 1 February 2021]. https://www.biosaline.org/projects/regional-drought-management-system-middle-east-north-africa

ICIMOD (International Centre for Integrated Mountain Development). 2020. Climate Services. In: *ICIMOD* [Online]. [Cited 04 February 2021]. https://www.icimod.org/initiative/climate-services

ICPAC. 2021. *ICPAC* [online]. [Cited 25 January 2021]. https://www.icpac.net/

Kalanda-Joshua, M., Ngongondo, C., Chipeta, L. & Mpembeka, F. 2011. Integrating indigenous knowledge with conventional science: Enhancing localised climate and weather forecasts in Nessa, Mulanje, Malawi. *Physics and Chemistry of the Earth, Parts A/B/C*, 36(14-15): 996-1003.

Khan, U & Hanif, M. 2007. Weather and wheat development in Faisalabad region: rabi season (2006-2007). Islamabad, Pakistan, National Agromet Centre.

Kreft, S., Eckstein, D. & Melchior, I. 2019. *Global Climate Risk Index 2017. Who suffers most from extreme weather events? Weather-related loss events in 2015 and 1996 to 2015*. Bonn, Germany, Germanwatch.

Krupnik, T. J., Alam, A., Zebiak, S., Khanam, F., Hossain, M. K., Kamal, M., Miah, A.A., Shahriar, S.M., Khan. M.S.H, & Hussain, S.G. 2018. Participatory and Institutional Approaches to Agricultural Climate Services: A South and Southeast Asia Regional Technical & Learning Exchange. Dhaka, Bangladesh, The International Maize and Wheat Improvement Center (CIMMYT).

Labarthe, P., & Laurent, C. 2013. Privatization of agricultural extension services in the EU: Towards a lack of adequate knowledge for small-scale farms? *Food policy*, 38,:240-252.

Labarthe, P., Caggiano, M., Laurent, C., Faure, G, & Cerf, M. 2013. *Concepts and Theories to Describe the Functioning and Dynamics of Agricultural Advisory Services.* Brussels, European Union.

Loboguerrero, A., Boshell, F., León, G., Martinez-Baron, D., Giraldo, D., Mejía, L-R., Díaz, E & Cock, J. 2018. Bridging the gap Between Climate Science and Farmers in Colombia. *Climate Risk Management*, 22: 67-81.

Louati, M. E. H., Mellouli, H. J. & El Echi, M. L. 2005. Tunisia. In A. Iglesias & M. Moneo, eds. *Drought preparedness and mitigation in the Mediterranean: Analysis of the organizations and institutions*, pp. 155–190. (Options Méditerranéennes: Série B. Etudes et Recherches, No. 51). Zaragoza, Spain, International Center for Advanced Mediterranean Agronomic Studies (CIHEAM).

Mahon, R., Greene, C., Cox, S-A., Guido, Z., Gerlak, A., Petrie T. J-A., Trotman, A., Liverman, D., Meerbeek J. V. C. & Scott, W. 2019. Fit for purpose? Transforming National Meteorological and Hydrological Services into National Climate Service Centers. *Climate Services,* 13: 14-23.

Marsh, S. P. & Pannell, D. 2000. Agricultural extension policy in Australia: the good, the bad and the misguided. *Australian Journal of Agricultural and Resource Economics*, 44(4): 605-627.

Miralles-Wilhelm, F. & Muñoz Castillo, R. 2014. *Climate Services: a tool for adaptation to climate change in Latin America and the Caribbean – Action plan and case study applications.* Inter-American Development Bank (IDB).

MSS. 2017. *Climate Information and Services Survey Results: review on the current status of climate information and services provided by the national meteorological and hydrological services of southeast Asia* [online]. [Cited 04 February 2021]. http://asmc.asean.org/wp-content/uploads/2016/10/Climate-Services-Survey-Results-for-ASEAN-NMHSs-2016-17.pdf

OCHA (United Nations Office for the Coordination of Humanitarian Affairs)**.** 2020. *Natural disasters in Latin America and the Caribbean 2000-2019.*

Ouedraogo, I., Diouf, N. S., Ouédraogo, M., Ndiaye, O. & Zougmoré, R. B. 2018. Closing the gap between climate information producers and users: Assessment of needs and uptake in Senegal. *Climate*, 6(1): 13.

Ouassou A., Ameziane T., Ziyad A. & Belghiti M. 2007. Application of the drought management guidelines in Morocco [Part 2. Examples of application]. In A. Iglesias, M. Moneo & A. López-Francos, eds. *Drought management guidelines technical annex*, pp. 343-372. (Options Méditerranéennes: Série B. Etudes et Recherches, No. 58) Zaragoza, Spain, International Center for Advanced Mediterranean Agronomic Studies (CIHEAM)/EC MEDA Water.

PICS (Pacific Island Climate Services)**.** 2020. *PICS* [online]. [Cited 04 February 2021]. http://pacificislandsclimate.org/csdialogs/

PMC (Pacific Meteorological Council)**.** 2020. *PMC* [online]. [Cited 04 February 2021]. https://www.pacificmet.net/pmc

Prager, K., Labarthe, P., Caggiano, M. & Lorenzo-Arribas, A. 2016. How does commercialisation impact on the provision of farm advisory services? Evidence from Belgium, Italy, Ireland and the UK. *Land Use Policy*, 52: 329-344.

Radeny, M., Desalegn, A., Mubiru, D., Kyazze, F., Mahoo, H., Recha, J., Kimeli, P. & Solomon, D. 2019. Indigenous knowledge for seasonal weather and climate forecasting across East Africa. *Climatic Change*, 156: 509-526.

Ramakrishna, Y.S. 2013. *Current status of agromet services in South Asia, with special emphasis on the Indo-Gangetic Plains.* CCAFS Working Paper No. 53. Copenhagen, Denmark, CCAFS.

Risiro, J., Mashoko, D., Rurinda, E. & Tshuma, D. 2012. Weather forecasting and indigenous knowledge systems in Chimanimani District of Manicaland, Zimbabwe. *Journal of Emerging Trends in Educational Research and Policy Studies*, 3(4): 561-566.

Rivera, W., Zijp, W. & Alex, G. 2000. *Contracting for Extension: Review of Emerging Practice*. Agricultural Knowledge and Information Systems (AKIS) Good Practice Note. Washington, DC, World Bank.

Rogers, D., Smetanina, M. & Tsirkunov, V. 2016. *Improving weather, climate, and hydrological services delivery in Central Asia (Kyrgyz Republic, Republic of Tajikistan, and Turkmenistan)*. Washington, DC, World Bank.

Rosas, G., Gubler, S., Oria, C., Acuña, D., Avalos, G., Begert, M. & Castillo, E. Croci-Maspoli, M. Cubas, F. Dapozzo, M., Díaz, A., van Geijtenbeek, D., Jacques, M., Konzelmann, T., Lavado, W., Matos, A., Mauchle, F., Rohrer, M., Rossa, A., Scherrer, S.C., Valdez, M., Valverde, M., Villar, G. & Villegas E. 2016. Towards implementing Climate Services in Peru – The project CLIMANDES. *Climate Services*, 4: 30-41

Roudier, P., Muller, B., d'Aquino, P., Roncoli, C., Soumaré, M. A., Batté, L. & Sultan, B. 2014. The role of climate forecasts in smallholder agriculture: lessons from participatory research in two communities in Senegal. *Climate Risk Management*, 2: 42-55.

Sanga, C., Kalungwizi, V. & Msuya, C. 2013. Building agricultural extension services system supported by ICTs in Tanzania: Progress made, Challenges remain. *International Journal of Education and Development using Information and Communication Technology*, 9(1): 80-99.

Silvestri, S., Richard, M., Edward, B., Dharmesh, G., & Dannie, R. 2020. Going digital in agriculture: How radio and SMS can scale-up smallholder participation in legume-based sustainable agricultural intensification practices and technologies in Tanzania. *International Journal of Agricultural Sustainability*, 1-12.

SPREP (Secretariat of the Pacific Regional Environment Programme). 2016. *Pacific Islands Meteorological Services in Action. A Compendium of Climate Services Case Studies*. Apia, Samoa

Stigter, C. J. 2011. *Agrometeorological services: reaching all farmers with operational information products in new educational commitments*. Commission For Agricultural Meteorology Report No. 104. Geneva, WMO.

TAHMO (Trans-African Hydrometeorological Observatory). 2020. *TAHMO* [online]. [Cited 25 January 2021]. https://tahmo.org/

Taneja, G., Pal, B. D., Joshi, P. K., Aggarwal, P. K. & Tyagi, N. K. 2019. Farmers' Preferences for Climate-Smart Agriculture: An Assessment in the Indo-Gangetic Plain. In B.D. Pal, A. Kishore, P.K. Joshi, & N.K. Tyagi, eds. *Climate Smart Agriculture in South Asia*, pp. 91-111. Singapore, Springer.

Tarchiani, V. 2019. *Evaluation Report of METAGRI Operational Project (2012-2015*), CAgM Report, 107. Geneva, WMO.

Tarchiani, V., Rossi, F., Camacho, J., Stefanski, R., Mian, K. A., Pokperlaar, D. S. & Adamou, A. S. 2017. Smallholder farmers facing climate change in West Africa: decision-making between Innovation and Tradition. *Journal of Innovation Economics Management*, 3 (3): 151-176.

Tiitmamer, N. & Mayai, A. T. 2018. *Climate Service Model for South Sudan's Rural Farmers and Agro-pastoralists*. The SUDD Institute.

Timilsina, A. P., Shrestha, A., Gautam, A. K., Gaire, A., Malla, G., Paudel, B., Rimal, P.R. Upadhyay, K. & Bhandari, H. L. 2019. A practice of agro-met advisory service in Nepal. *Journal of Bioscience and Agriculture Research*, 21(02): 1778-1785.

Trendov, N.M., Varas, S. & Zeng, M. 2019. *Digital technologies in agriculture and rural areas. Status report*. Rome. FAO (also available at http://www.fao.org/publications/card/en/c/CA4887EN/)

UNFCCC. 2015. *Climate Risks and Early Warning Systems* [online]. [Cited 9 April 2021] https://unfccc.int/sites/default/files/climate-risks-early-warning-systems-flyer.pdf

USAID. 2020. Strengthening Drought Monitoring Across the Middle East and North Africa. In: *USAID Global Waters* [online]. [Cited 1 February 2021]. https://medium.com/usaid-global-waters/strengthening-drought-monitoring-across-the-middle-east-and-north-africa-6a1d0033204b

van den Ban, A.W. 2000. *Different Ways of Financing Agricultural Extension*. Agricultural Research & Extension Network Paper 106b, pp. 8-19. London, Overseas Development Institute (ODI).

Vaughan, C., Hansen, J., Roudier, P., Watkiss, P. & Carr, E. 2019. Evaluating agricultural weather and climate services in Africa: Evidence, methods, and a learning agenda. *Wiley Interdisciplinary Reviews: Climate Change*, 10(9): e586.

Verner, D., ed. 2012. *Adaptation to a Changing Climate in the Arab Countries: A Case for Adaptation Governance and Leadership in Building Climate Resilience*. MENA Development Report. Washington, DC, World Bank.

Vogel, J., Letson, D. & Herrick, A. 2017. A framework for Climate Services evaluation and its application to the Caribbean agromet Initiative. *Climate Services*, 6; 65-76.

Vincent, K., Daly, M., Scannell, C. & Leathes, B. 2018. What can climate services learn from theory and practice of co-production? *Climate Services*, 12: 48-58.

Walsh, K. 2020. ENACTS Climate Services initiative ripples across East Africa with WISER support. In: *International Research Institute for Climate and Society (IRI): News* [online]. [Cited 25 January 2021]. https://iri.columbia.edu/news/enacts-climate-services-initiative-ripples-across-east-africa/

WAMIS (World AgroMeteorological Information Service)**.** 2021. *WAMIS.* [Online]. [Cited 04 February 2021]. http://www.wamis.org/index.php

WFP & FAO. 2021. *Hunger Hotspots. FAO-WFP early warnings on acute food insecurity: March to July 2021 outlook*. Rome.

WMO. 2011. *Climate knowledge for action: A Global Framework for Climate Services – empowering the most vulnerable. Report of the High-Level Taskforce for the Global Framework for Climate Services*. WMO No. 1065. Geneva.

WMO. 2015. *Valuing Weather and Climate: Economic Assessment of Meteorological and Hydrological Services.* WMO No. 1153. Geneva.

MSS. 2017. *Climate Information and Services Survey Results: review on the current status of climate information and services provided by the national meteorological and hydrological services of southeast Asia* [online]. [Cited 04 February 2021]. http://asmc.asean.org/wp-content/uploads/2016/10/Climate-Services-Survey-Results-for-ASEAN-NMHSs-2016-17.pdf

WMO. 2019. *2019 State of Climate Services.* WMO No. 1242**.** Geneva.

WMO. 2020. *2020 State of Climate Services*. WMO No. 1252. Geneva.

WMO. 2021. *State of the Global Climate 2020.* WMO No. 1252. Geneva.

World Bank. 2008. *Weather and Climate Services in Europe and Central Asia: A Regional Review.* World Bank Working Paper, No. 151. Washington, DC, World Bank.

World Bank. 2016a. *World Development Report 2016: Digital dividends*. Washington, DC, World Bank.

World Bank. 2016b. Automated Agro-meteorological Data Improve Agricultural Production in Afghanistan. In: *World Bank* [online]. [Cited 6 September 2021].

World Bank. 2018. *Strengthening the Regional Dimension of Hydromet Services in Southeast Asia: A Policy Note with a Focus on Cambodia, Lao PDR, and Vietnam*. Washington, DC, World Bank.

World Bank. 2019. *Weather, Climate and Water in Central Asia A Guide to Hydrometeorological Services in the Region*. Washington, DC, World Bank.

World Bank. 2021. Africa Hydromet Program. In: *World Bank* [online]. [Cited 25 January 2021]. www.worldbank.org/en/programs/africa_hydromet_program

Annex 1: Surveys to producers of climate information

1. *Does the Met Service/Ministry of Agriculture deliver warnings for extreme weather events to farmers?*

☐ Yes
☐ No

2. *Are those warnings accessible for rural communities?*

☐ Yes
☐ No

3. *By which mean is the weather information & weather alerts currently delivered to farmers/end-users?*

☐ TV
☐ Radio
☐ SMS
☐ Met Service Website
☐ Weather App
☐ Press release
☐ SMS (regular)
☐ SMS (USDD)
☐ WhatsApp (SMS)
☐ WhatsApp (voicemail)
☐ Social media (Facebook)
☐ Weather alert boards
☐ LED panels
☐ Colour coded warnings
☐ Coastal flag warnings
☐ Coast light warnings
☐ Speakers
☐ Sirens
☐ Other means (specify):

4. *Please list the top-5 communication means (in order of highest coverage) and the approximate number of beneficiaries:*

☐
☐
☐
☐
☐

5. *Are there any other institutions (NGO´s, extension services, private sector) providing the last-mile with climate information services?*

☐ Yes (specify the name of the institution)
☐ No
☐ Do not know

6. *Are the Met Service/Ministry of Agriculture climate information products (CIP) tailored according feedback from final users and stakeholders needs?*

☐ Yes, if there is one for agriculture, livestock and fisheries
☐ No

7. *Which type of information does the Met Service/Ministry of Agriculture provide to farmers/end-users with and how often?*

CIP REQUESTED AGRICULTURE	FREQUENCY
☐ Optimal sowing date	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ Onset rainy season	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ Offset rainy season	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ Dry spells	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ False start of the rainy season	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ Cumulative rainfall	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ Evapotranspiration	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ Cumulative growing degree-days	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ Soil moisture	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ Seasonal forecast	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ Precipitation forecast	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ Temperature forecast	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ Pest & Disease forecasts	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ Wind forecast	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ Hail forecast	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant

CIP REQUESTED LIVESTOCK	FREQUENCY
☐ Fodder availability	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ Water resource availability	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ Potential lightning zones	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ Potential diseases occurrence zones	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ Transhumance corridors	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ Potential conflict zones	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant

CIP REQUESTED FISHERIES	FREQUENCY
☐ High swell forecasts	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ High tides forecasts	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ Visibility forecasts	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ Wind forecasts	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ Potential lightning zones	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ Sea surface temperature	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant

CIP REQUESTED FORESTS	FREQUENCY
☐ Seasonal forecasts	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ Potential lightning zones	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ Potential disease occurrence zones	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ Wildfire prompt zones	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant

Annex 2: Surveys to the last mile

1. Where are you from (country/province/village)?

☐
☐
☐

2. Which of the following agricultural systems fits you best?

☐ Agriculture (specify type of crop and/or fruit tree)
☐ Livestock (specify farm animal)
☐ Fisheries & Aquaculture (specify)
☐ Forests (specify)

3. Do you receive climate and weather information?

☐ Yes
☐ No
☐ No answer

4. By which communication mean do you receive climate and weather information services (CIS)?

☐ TV
☐ Radio
☐ VHF radio
☐ Call service
☐ Email
☐ Met Service Website
☐ Weather App
☐ Press release
☐ Agromet bulletins
☐ SMS (regular)
☐ SMS (USDD)
☐ WhatsApp (SMS)
☐ WhatsApp (voicemail)
☐ Social media (Facebook)
☐ Word of mouth (markets)
☐ Traditional knowledge (observation)
☐ Itinerant seminars
☐ Community based meetings
☐ Weather alert boards
☐ LED panels
☐ Colour coded warnings
☐ Coastal flag warnings
☐ Coast light warnings
☐ Speakers
☐ Sirens
☐ Other means (specify):

5. By which communication mean would you like to receive climate and weather information?

☐ TV
☐ Radio
☐ VHF radio
☐ Call service
☐ Email
☐ Met Service Website
☐ Weather App
☐ Press release
☐ Agromet bulletins
☐ SMS (regular)
☐ SMS (USDD)
☐ WhatsApp (SMS)
☐ WhatsApp (voicemail)
☐ Social media (Facebook)
☐ Word of mouth (markets)
☐ Traditional knowledge (observation)
☐ Itinerant seminars
☐ Community based meetings
☐ Weather alert boards
☐ LED panels
☐ Colour coded warnings
☐ Coastal flag warnings
☐ Coast light warnings
☐ Speakers
☐ Sirens
☐ Other means (specify):

6. Which CIS are required in your agricultural system and how often do you need them?

CIS REQUESTED AGRICULTURE	FREQUENCY
☐ Optimal sowing date	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ Onset rainy season	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ Offset rainy season	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ Dry spells	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ False start of the rainy season	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ Cumulative rainfall	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ Evapotranspiration	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ Cumulative growing degree-days	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ Soil moisture	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ Seasonal forecast	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ Precipitation forecast	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ Temperature forecast	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ Pest & Disease forecasts	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ Wind forecast	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ Hail forecast	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant

CIS REQUESTED LIVESTOCK	FREQUENCY
☐ Fodder availability	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ Water resource availability	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ Potential lightning zones	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ Potential diseases occurrence zones	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ Transhumance corridors	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ Potential conflict zones	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant

CIS REQUESTED FISHERIES	FREQUENCY
☐ High swell forecasts	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ High tides forecasts	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ Visibility forecasts	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ Wind forecasts	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ Potential lightning zones	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ Sea surface temperature	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant

CIS REQUESTED FORESTS	FREQUENCY
☐ Seasonal forecasts	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ Potential lightning zones	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ Potential disease occurrence zones	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant
☐ Wildfire prompt zones	☐ Daily ☐ Dekadal ☐ Quarterly ☐ Seasonal ☐ when relevant

7. Which natural hazard affect's the most your activities and how recurrent are they?

☐ Heat waves	☐ Monthly ☐ Quarterly ☐ Yearly ☐ Lustrum
☐ Frost waves	☐ Monthly ☐ Quarterly ☐ Yearly ☐ Lustrum
☐ Precipitation	☐ Monthly ☐ Quarterly ☐ Yearly ☐ Lustrum
☐ Drought (including dry spells)	☐ Monthly ☐ Quarterly ☐ Yearly ☐ Lustrum
☐ Hail	☐ Monthly ☐ Quarterly ☐ Yearly ☐ Lustrum
☐ Freezing rain	☐ Monthly ☐ Quarterly ☐ Yearly ☐ Lustrum
☐ Pest & Diseases	☐ Monthly ☐ Quarterly ☐ Yearly ☐ Lustrum
☐ Fogs	☐ Monthly ☐ Quarterly ☐ Yearly ☐ Lustrum
☐ Winds	☐ Monthly ☐ Quarterly ☐ Yearly ☐ Lustrum
☐ Sea level rise	☐ Monthly ☐ Quarterly ☐ Yearly ☐ Lustrum
☐ Ocean acidification	☐ Monthly ☐ Quarterly ☐ Yearly ☐ Lustrum
☐ Saline intrusion	☐ Monthly ☐ Quarterly ☐ Yearly ☐ Lustrum
☐ Earthquakes	☐ Monthly ☐ Quarterly ☐ Yearly ☐ Lustrum
☐ Tsunamis	☐ Monthly ☐ Quarterly ☐ Yearly ☐ Lustrum
☐ Volcanic eruptions	☐ Monthly ☐ Quarterly ☐ Yearly ☐ Lustrum
☐ Landslides	☐ Monthly ☐ Quarterly ☐ Yearly ☐ Lustrum
☐ Avalanches	☐ Monthly ☐ Quarterly ☐ Yearly ☐ Lustrum
☐ Wildfires	☐ Monthly ☐ Quarterly ☐ Yearly ☐ Lustrum

8. Do you consider yourself vulnerable to climate change?

☐ High
☐ Substantial
☐ Moderate
☐ Low
☐ Not vulnerable at all

9 a) *Is the government supporting you to adapt to changes in climate?*

☐ Yes
☐ No
☐ No answer

9 b) If yes, how is the government supporting you and how useful is their support?

☐ Extension services	☐ Very useful ☐ Useful ☐ Not useful ☐ n/a
☐ Information services related to climate/weather	☐ Very useful ☐ Useful ☐ Not useful ☐ n/a
☐ Training or farmer field schools	☐ Very useful ☐ Useful ☐ Not useful ☐ n/a
☐ Government insurance, loans or credits	☐ Very useful ☐ Useful ☐ Not useful ☐ n/a
☐ Agronomic inputs (seeds, fodder, machinery)	☐ Very useful ☐ Useful ☐ Not useful ☐ n/a
☐ Irrigation (access to the irrigation network)	☐ Very useful ☐ Useful ☐ Not useful ☐ n/a
☐ Other (specify)	☐ Very useful ☐ Useful ☐ Not useful ☐ n/a

10 a) *Do you receive any support/advisory services from non-government actors that help you adapt to changes in climate*

☐ Yes
☐ No
☐ No answer

10 b) *If yes, how are the non-government actors supporting you?*

	Private company	NGO	Research Institution	Union / Association	Other
Extension services	☐	☐	☐	☐	☐
Information services related to climate/weather	☐	☐	☐	☐	☐
Information related to market access	☐	☐	☐	☐	☐
Training or farmers field schools	☐	☐	☐	☐	☐
Insurance, loans or credits	☐	☐	☐	☐	☐
Agronomic inputs (seeds, fodder, machinery)	☐	☐	☐	☐	☐
Other (specify)	☐	☐	☐	☐	☐

11.Do you embrace any of the following agricultural practices and/or agrometeorological instruments?

AGRICULTURE

a) Seeds

☐ Drought resistant varieties
☐ Short cycle varieties
☐ Heat tolerant varieties
☐ Pest resistant varieties
☐ Others (specify)

b) Soil management

☐ N-fixation plants
☐ Half moons
☐ Stone bunds
☐ Crop residues
☐ Agroforestry
☐ Crop rotation
☐ Minimum tillage
☐ Raised bed cropping
☐ Inter cropping
☐ Furrows
☐ Terracing
☐ Embankments
☐ Dredges
☐ Others (specify)

c) Water management

☐ Water well
☐ Water reservoir
☐ Programmed irrigation
☐ Sprinkler irrigation
☐ Surface irrigation
☐ Drip irrigation
☐ Others (specify)

d) Plant growth regulators

☐ Fertilizers (organic/inorganic)
☐ Pesticides (biological/chemical)
☐ Herbicides (biological/chemical)

e) Research & Development

☐ Mechanical tillage
☐ Seed drilling machine
☐ Mechanical harvesting
☐ Mechanical weeding
☐ Mechanical fertilizer spreader
☐ Mechanical pesticide spreader
☐ Ground laser levelling
☐ Tensiometer sensors (soil moisture)
☐ NDVI sensors (plant nutrient)
☐ Electrochemical sensors (pH & soil nutrient)
☐ Leaf wetness sensors
☐ Soil temperature sensors
☐ Airflow soil sensors (bulk density)
☐ Seed drying machines
☐ Others (specify)

LIVESTOCK

a) Soil management

☐ Transhumance corridors
☐ Grazing rotation
☐ Others (specify)

b) Animal feeding

☐ Concentrate feeding
☐ Fodder management
☐ Adequate storage
☐ Others (specify)

c) Water management

☐ Reservoirs
☐ Basins
☐ Others (specify)

d) Animal health

☐ Animal tracking
☐ Acceptable water quality
☐ Adequate shelter
☐ Veterinary medicines
☐ Pest & vermin control measures
☐ Adequate animal separation
☐ Minimised chemical exposure
☐ Chemical disinfectants
☐ Others (specify)

FISHERIES & AQUACULTURE

a) Harvesting methods

☐ Pole catching
☐ Wire mesh traps (not dragged)
☐ Reef nets
☐ Trolling
☐ Purse seining
☐ Longlining
☐ Others (specify)

b) Population & control

☐ Monitoring population
☐ Non-target species
☐ Plentiful species
☐ Fish cages (sea)
☐ Fish ponds
☐ Others (specify)

c) Stocking & processing

☐ Handling
☐ Drying
☐ Smoking
☐ Ice
☐ Others (specify)

FORESTS

a) Management methods

☐ Forest inventory
☐ Controlled timber exploitation
☐ Veld management
☐ Controlled fires
☐ Forest thinning
☐ Payment for ecosystem services
☐ Others (specify)

b) Restoration methods

☐ Reforestation
☐ Regeneration
☐ Afforestation
☐ Others (specify)

c) Wild-life protection

☐ Anti-poaching measures
☐ Wild-life management
☐ Others (specify)

ISBN 978-92-5-135011-9

9 789251 350119

CB6941EN/1/10.21