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BRIEFING NOTE

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Using climate services in adaptation planning for the agriculture sectors

Overview

This brief provides an overview of climate services (CS) and how they can be used to assess risk and optimise adaptation decision-making in the agriculture sectors.[1] It highlights entry points to integrate CS across all elements of adaptation planning, while acknowledging the challenges and limitations of using CS, particularly in Least Developed Countries (LDCs). The brief also discusses key considerations in using climate services for planning and provides technical guidance on dealing with the uncertainty and confidence of climate projections.

Key messages

1. Climate services (CS) refer to the collection, analysis, interpretation and dissemination of information related to climate, including data on temperature, rainfall, humidity, wind and other factors. Interpreted along with other non-climate data, it allows users to assess and project current and future climate risks. CS are a key resource for decision-making and planning within the agriculture sectors.
2. There are multiple entry points for applying CS in the adaptation planning process, including in the development of National Adaptation Plans (NAPs). For example, climate information can be used to analyse current and future climate scenarios, assess vulnerabilities and identify adaptation options. CS can also be integrated into planning and budgeting processes to guide decision-making and capacity building activities within NAPs.
3. Key challenges for the effective application of CS in adaptation planning for the agriculture sectors include data availability, human capacity, information mismatches, ineffective institutional coordination, and farmers' access to finance, inputs and adaptive technologies.
4. Approaches need to recognize uncertainty in models and data and seek robust (beneficial under a range of climates), rather than optimal solutions, which are suitable/tailored for different farmers with different goals and access to resources.
5. Country experiences in Africa and Asia illustrate the importance of fully incorporating local contexts (language, customs and indigenous knowledge) to ensure that climate services and products are understood, trusted and used.

1. The term 'agriculture sectors' used throughout the document refers to crop-based farming systems and livestock systems, including rangelands and pasturelands; forestry and fisheries.

What are climate services?

Weather and climate information (collectively referred to as climate information) encompass data on temperature, rainfall, humidity, wind and other variables. Climate information is one of the main resources used to assess weather and climate-related risks, as well as plan adaptation actions across a range of sectors, including agriculture. It is generally sourced and produced through a variety of instruments and mathematical models such as weather stations, remote sensing, statistical and global/regional climate models. Climate information relates to a range of timescales that include:

- historical or past observations;
- weather forecasting, from 0 to 10 days into the future;
- seasonal forecasting, 1 to 6 months into the future; and
- multi-decadal projections, 20-80 years in the future.

The production of this information, its combination with other data (environmental, socioeconomic, measures of vulnerability), its interpretation and dissemination (via print, radio, TV, internet and mobile platforms) and communication (language, text, pictures) to users constitutes the supply side of what is collectively referred to as climate services (CS). The full range of CS also incorporates feedback from users to iteratively develop and revise products, communications and ensure it is relevant for required decision-making, as well as evaluating the costs and benefits of the outcomes of those decisions (WMO, 2019).

In the agriculture sectors, different users require different types of climate information and services (See Box 1). This brief focuses on the climate services used by actors at the policy and planning levels in agriculture,[2] who are making decisions related to agricultural systems over the short-, medium- and long-term to help society adapt to climate variability and change (GFCS, no date). These may be decisions such as:

- improving production and quality;
- controlling plant and animal pests and diseases;
- identifying populations vulnerable to weather and climate hazards; and
- identifying extreme weather and climate hazards that pose risks to agriculture and food security (WMO, 2015).

BOX 1

Examples of climate information and services based on different timescales

In general, farm-level CS tends to focus on the optimization of management practices to reduce the impacts during bad years and enhance the opportunities during better-than-average and average years, using short- and medium-term forecasts (Ramasamy, 2012). At national level, longer-term risks over decades and more widespread areas often need to be assessed to determine whether transformative changes are required, i.e. new production systems, new livelihoods and/or migration and involves the use of historical climate data, climate change projections, as well as crop, forestry and livestock suitability models. Data from observations of weather, climate variability and climate change can be compiled into multiple kinds of information and services, for example:

Weather
- days suitable for fieldwork;
- heat indices for livestock;
- fire danger ratings;
- pest/disease forecasts;
- cyclones and storms affecting safety at sea.

Climate Variability
- crop-yield forecasts;
- average dates of beginning and; end of rainy season;
- average first and last frost dates;
- drought indices/warnings.

Climate Change
- maps of changes in agroecological zoning;
- analyses of future crop impacts;
- long term changes in sea temperatures and salinities affecting fish migration. and abundance

Adapted from: WMO, 2019

2. WMO has found that 137 countries currently provide climate services tailored to the agriculture sector, however "most climate information and associated services do not reach small farmers due to a lack of adequate communication channels, because it has not been adequately tailored to community needs, or it has not been translated into the local language" (WMO, 2019). Meeting the needs of farmers, fishers and foresters with tailored climate services is a critical issue, however an in-depth discussion is beyond the scope of this brief.

BOX 2

Definitions

Climate Services involves the provision, communication and dissemination of weather and climate information in a way that assists individuals and organizations to assess, and prevent or prepare for, potentially impactful weather and climate events.

Climate Scenario is one representation of the future climate, based on assumed (plausible) future emissions of greenhouse gases and aerosols.

Uncertainty describes the range of possible future agricultural states (e.g. production, distribution and markets) due to unknown future aspects of climate, environment and socioeconomic circumstances. Uncertainty in climate arises due to possible future emissions (of greenhouse gases and aerosols) and responses of the earth-climate system to those emissions.

Climate Risk is the probability that an unfavorable meteorological (extreme temperature), climatological (drought) or hydrological (flood) event will occur within a particular location or region where vulnerable people, infrastructure and livelihoods are exposed to the weather/climate event.

Downscaling is a method that allows climate data/information to be generated at a finer resolution than the one generally obtained from global climate models.

National Hydro-Meteorological Services (NHMS) are national government institutions mandated to continuously generate and disseminate weather and climate data from across a country's territory, as well as develop and issue forecasts and warnings.

Entry points for integrating climate services in National Adaptation Plans

In the most recent indications of their adaptation priorities,[3] countries have signalled that, when it comes to the agriculture sector, climate services are a key part of their strategies. Ninety-four percent of African countries and ninety-one percent of Asian countries, as well as all South-West Pacific countries, mentioned climate services as a means for achieving adaptation in agriculture (WMO, 2019).

The reason for the emphasis on using CS for adaptation in agriculture is summarized clearly in the WMO supplementary guidelines for using CS in adaptation planning (WMO, 2015):

> Extreme weather, climate variability, and long-term climate change pose important challenges to future agriculture and food security. Climate-related disasters such as droughts and floods can lead to crop failure, food insecurity, destruction of key livelihood assets, mass migration of people, and negative national economic growth. Adverse weather and climate conditions directly affect agricultural productivity, livelihoods, water security, land use, agricultural marketing systems, market instability, food prices, trade and economic policies; and small-holder farmers, fishermen, livestock herders and forest dependent communities are often highly vulnerable to these impacts. Climate change is expected to affect all of the components that influence food security: availability, access, stability and utilization.

When integrating CS into adaptation planning processes, two considerations are important. Firstly, policymakers should be cognizant of the limitations of CS. Information should reflect uncertainties, both scientific (e.g. forecast skill) and technical (e.g. model or data limitations), as well as the risks and assumptions implied in each approach (Vaughan and Dessai, 2014). This is not to undermine the value of CS but to understand their limitations in order to maximise their effective use and to ensure that these limitations are conveyed in a transparent manner (Adams et al., 2015). Secondly, policy makers can seek ways to support enabling environments for CS provision, including creating multi-sectoral teams to develop and generate information based on user needs/feedback, as well as enabling data/information sharing between

3. Adaptation priorities are indicated in countries' Nationally Determined Contributions (NDCs), submitted to the United Nations Framework on Climate Change. NDCs are linked to National Adaptation Plans (NAPs) in that a NAP can indicate how NDC goals will be implemented.

government institutions and utilizing services and partnerships with the private sector (WMO, 2010; Selvaraju, 2012; Vaughan and Dessai, 2014).

National Adaptation Plans, or NAPs, were established under the UNFCCC, as a framework to enable countries to identify and address medium-and long-term adaptation needs. Both the UNFCCC and associated guidance for the agriculture sectors (for example the FAO, 2017) have organized the process of developing a NAP around four elements:

Element A: Lay the groundwork and address gaps
Element B: Preparatory elements
Element C: Implementation strategies
Element D: Reporting, monitoring and review

The clearest entry point for CS in the NAP framework is **Element B**, which includes climate risk and vulnerability assessments and analyses. At this stage in the development of a NAP, climate models and projections of future climate scenarios can be used to assess future potential risks to agriculture, in order to identify strategies to prepare for those risks. Uruguay, for example, used climate information in analyses that informed the development of its NAP for agriculture (see Box 3).

Beyond the analytical phase of adaptation planning as mapped out under the NAP guidelines, there are entry points for the integration of CS into every phase of adaptation planning in agriculture (Tadross, 2017 and Karttunen *et al.*, 2017) (see Table 1 on entry points for integrating CS into the NAP process).

In **Element A**, policymakers can assess the gaps and need for CS and initiate a dialogue between providers and users of climate information services and products. CS depends on the target users of these services and it is critical that the providers of CS, including government and National Hydro-Meteorological Services (NHMS), are aware of user needs. Likewise, not all climate information can be provided within required timeframes (due to technical and scientific limitations) and users need to be aware of this. This requires initiating a dialogue between providers and users of CS which can be undertaken as part of Element A. Ideally this dialogue should result in a list of potential CS products as well as a roadmap to produce and disseminate those products.

Under Element B the focus of CS is on providing climate-related information which is used for long-term adaptation planning. Knowledge of these risks forms one of the key building blocks on which adaptation planning is based; with this knowledge continuously and iteratively updated when new data and information becomes available. Furthermore, the capacity to assess these risks by combining climate data with other environmental and social vulnerability data is also useful for developing tailored advisories using short-term weather and seasonal forecasts, as part of Element C.

Element C relates to the prioritization of adaptation options in national planning, the development of long-term adaptation implementation strategies and enhancing capacity to plan and implement adaptation action. For example, CS can be integrated into planning and budgeting processes to facilitate the provision of climate information at national and local levels. Projects to strengthen CS can be designed in alignment with goals and priorities identified in long-term adaptation strategies. Technical capacity to generate, disseminate and communicate climate information can also be enhanced as part of the NAP process.

Monitoring and reviewing CS – as part of **Element D** – is a clear requirement for successful development of CS; product development and dissemination needs to be based on user feedback, which is periodically reviewed. As climate risks are constantly changing, retrieving feedback is a way of developing high quality services and engaging users in the decision-making process in order to scale-up its dissemination.

BOX 3

Uruguay's NAP for Agriculture integrates analysis from the Food and Agriculture Organization's (FAO) MOSAICC tool

In 2019, Uruguay launched its National Adaptation Plan to Climate Variability and Change for the Agricultural Sector (Plan Nacional de Adaptación a la Variabilidad y el Cambio Climático para el sector Agropecuario – PNA-Agro). A key analytical step in the preparation of the PNA-Agro was the analysis of climate scenarios and the related potential impacts of climate change on crop production in Uruguay using the Modelling System for Agricultural Impacts of Climate Change (MOSAICC) (Government of Uruguay, 2019).

MOSAICC is an integrated package of models, developed by FAO, which allows users to assess the impact of climate change on agriculture (FAO, 2015). By combining multiple models in one modelling system, MOSAICC enables researchers to assess different aspects of climate change impacts. The models integrated in the MOSAICC platform are categorized into five main components:

- **Climate data processing tools:** statistical downscaling and spatial interpolation tools aimed at preparing the data for the crop, hydrology, and forestry models.
- **Crop models:** simulates crop growth under different climate change scenarios (with different CO_2 representation concentration pathways), using the data produced by the climate data processing tools.
- **Hydrological models:** simulates the hydrology of river basins under climate change scenarios, using the data produced by the climate data processing tools.
- **Economic models:** simulates the impact of yield variations due to climate change on national economies.
- **Forest models:** assesses the impacts of climate change on forest dynamics.

In Uruguay, a study using MOSAICC was carried out to downscale projections from four global climate models and two emissions scenarios to weather station level. The study results concluded that precipitation, minimum temperature and maximum temperature would increase over time, independent of the baseline scenario and season, altough different magnitudes of change were noted. MOSAICC was then used along with related studies to estimate the potential impacts of the climate change projections on the agriculture sub-sectors of cattle raising, dairy farming, dry lands and rice cultivation, forestry, horticulture and artisanal fishing.

The researchers noted challenges in evaluating the impacts of climate change on the different regions of the country – including limited sources of information on past and future climate conditions as well as the dominant interannual climate variability and the complexity of the agriculture sector. Nevertheless, the analysis of potential impacts was used to set priorities for developing less vulnerable production systems. A key activity in relation to this will be the development of climate information systems so that agricultural producers can make decisions for different types, scales and zones of production (Government of Uruguay, 2019).

Table 1

Entry points for integrating CS into the NAP process

Steps of the NAP Process	Entry Points	Integration of CS
Element A: Lay the groundwork and address gaps	• Stocktaking (identifying existing information on climate change impacts and vulnerabilities, assessing gaps and needs for undertaking the NAP process). • Addressing capacity gaps and weaknesses.	• Assess gaps and needs for CS. • Initiate dialogue between providers and users of CS to better understand user needs.
Element B: Preparatory elements	• Analysing current climate and future climate scenarios. • Assessing climate vulnerabilities and identifying adaptation options. • Reviewing and appraising adaptation options.	• Develop and use climate projections for vulnerability assessments. • Strengthen production and use of CS to assess risks and appraise adaptation options.
Element C: Implementation strategies	• Prioritizing adaptation in development plans and budget allocations at the national and local levels. • Developing a long-term adaptation implementation strategy. • Enhancing capacity for planning and implementing adaptation.	• Integrate CS into planning and budgeting processes. • Design and implement projects to strengthen CS in alignment with long-term adaptation priorities. • Enhance capacity to produce, analyse and disseminate CS.
Element D: Reporting, monitoring and review	• Monitoring and reviewing the NAP process to assess progress, effectiveness and gaps.	• Develop indicators and monitoring systems for CS • Review and update CS based on feedback.

Challenges of integrating climate services into adaptation planning

CS have the potential to reduce climate-related impacts at all stages of the agricultural value chain, as well as support planning processes at the farm and national levels (Hansen *et al*., 2018 and Damen, 2017). However, to effectively support these decisions related to adaptation planning, high quality, consistent and timely data is usually needed (Huongo, 2015; Hoedjes, 2017; Chipeta, 2017). While some countries already have policies and technical capacities in place for the use of CS, challenges related to climate information product development, the dissemination of climate information and incorporating user requirements, often impact their effective provision and application.

Limited availability of local climate data

One of the biggest hurdles faced by LDCs is a lack of historical climate data. Problems in producing reliable and accurate data lead to further difficulties in developing agricultural models for climate change analyses and information which is useful for the NAP planning processes (Adams *et al*., 2015). The reduced availability of climate data is often due to a lack of financing and maintenance of data capture, storage and processing infrastructure. For example, the network of weather stations in Africa is not as dense as other regions of the world and NHMS have often focused on collecting data for global forecasting models and/or climate observations, rather than for local early warning systems which may require less accurate but more timely and wider coverage data collection (Ramasamy, 2012). Satellite and remote sensing data can provide a low-cost solution in such circumstances especially if combined with station observations to reduce biases, as well as providing environmental monitoring of ongoing climate-related crises. The provision of climate services, therefore, needs to utilise all available data sources and be adapted for different country contexts and data availability (Adams *et al*., 2015).

Limited human capacity and poor infrastructure

Limitations in local human capacity and poor infrastructure have been noted to reduce the effective collection and use of CS in several countries (Ramasamy, 2012). Skilled personnel leave to pursue other more appealing opportunities, are often burdened with too much work, or are not properly trained. Unsuitable equipment, inaccessible stations, often due to a lack of available transport for carrying out maintenance, as well as insufficient quality control and installation procedures all remain as lingering technical and infrastructural challenges. Readings from synoptic weather stations are often collected manually and then sent to NHMS offices via telephone, instead of using automatic data feeds or message switching services (*ibid*.). A second and just as important aspect is the involvement of sector-specific expertise to translate and interpret the climate data into sector-specific information, utilising available environmental and socioeconomic data e.g. on local farming systems, market prices, poverty levels and vulnerability to climate hazards. In addition to technical expertise this requires frequent meetings and work programmes to develop and refine products for communication to users, incorporating their views and needs.

Information mismatch

A further challenge is the communication of data to end users, whether policymakers or communities. There is often an information mismatch between what NHMS provide and what policymakers and farmers expect to receive. For instance, farmers expect to receive information on the start of the rains whereas NHMS provide a seasonal forecast for the *average* expected rainfall over a 3-month period. This can lead to misinterpretation of forecasts/information. Expanding the network of weather stations with the engagement of farmers, the private sector and government can be one approach to closing the information gap (see Box 4). Active two-way communication is also needed to ensure that climate information products are relevant for making decisions. In Uganda, for example, farmers expressed that the seasonal forecast was not as relevant to them as the weekly forecast (Ramasamy, 2012). Also, relevant information for farmers, such as when to spray crops to prevent diseases, is often not provided. This may be complicated when using overly technical language, which is difficult to comprehend, or due to issues in understanding the risk implications of probabilities e.g. for rainfall, a situation which also occurs in developed countries (Coventry and Dalgleish, 2014).

BOX 4

Targeted, localised planting and harvesting information for Canadian wheat producers

While mechanization and land management policies have rapidly advanced agricultural productivity around the world, developed economies have also begun to establish richer and more relevant weather and climate data sets to further improve crop yields. The introduction of similar techniques could have an impact on food security and rural livelihoods within Africa as well.

One such example is a service called Weatherfarm, an online weather data and agricultural information resource operated on behalf of farmers throughout Western Canada by Weather Innovations Consulting and Glacier Media. Originally introduced as a public-private partnership between the Canadian Wheat Board (a public agency of the Canadian national government) and WeatherBug (a private weather services firm), Weatherfarm deployed a network of more than 1 000 weather stations delivering real-time weather observations to wheat farmers in Canada. This network of low-cost, automatic weather stations provided growers throughout Western Canada with weather observations much closer to, if not directly on, their farms than ever before. Additionally, this rich data set was used to enhance the quality of weather forecasts, and as input into basic models for planting, irrigation and harvesting decisions, and more advanced models for pest and disease management.

Today, each automatic weather station in the Weatherfarm network is managed by a farmer or an organization that has a vested, economic interest in keeping the data flowing to the broader community. This community-based model for the creation and distribution of weather information could be one way for least developed African countries and their respective NHMS to sustainably establish weather and climate networks and enhance economic development for the agricultural sector and the national economy.

For more information, please see: Snow, John T.; Bonizella Biagini, Greg Benchwick, Georgie George, Joost Hoedjes, Alan Miller, Jeremy Usher, 'A New Vision for Weather and Climate Services in Africa', UNDP, New York, USA, 2016. Available online at: https://www.undp.org/content/undp/en/home/librarypage/climate-and-disaster-resilience-/weather-and-climate-systems---africa.html)

Institutional coordination and scaling up

Challenges in coordination can arise due to the lack of effective data sharing between institutions, clear institutional mandates, and fragmented and contradictory policies (Vaughan and Dessai, 2014). In general, when making policy decisions, assumptions should not be made about exclusion and avoidance of risks, which is often dependent on the particular end user, their risk management options and appetite for risk. Upscaling is often limited by human and financial constraints (Vaughan and Dessai, 2014). While there are several good examples of piloting CS in specific geographic locations, scaling up these projects at a national level remains a challenge because of either insufficient funding, a failure for widespread end users to see the benefits, or unaffordable costs placed on the end user (Damen, 2017). Partnering with the private sector and/or institutions which can subsidise running costs, e.g. for SMS-based advisories, in exchange for publicity and attracting new customers, is one example of how public private partnerships can help to expand the coverage and scope of CS.

Considerations in producing climate information[4]

Available data

In many developing countries the ability to quantitatively model the future is limited, among other things, by available data. Nevertheless, assessments can be made using freely available global model data including:

- Weather forecasts: available through the Global Forecast System (GFS) (NOAA, 2019) and other global forecasting centres.
- Seasonal forecasts: available through the Climate Forecasting System (CFS) (NOAA, 2019b) and the International Research Institute (IRI) for Climate Prediction (IRI, 2019).
- Climate change projections: available through the CMIP5 archive (CMIP citation) and other portals.
- Agricultural modelling systems: available through the Modelling System for Agricultural Impact of Climate Change (MOSAICC) (FAO, 2019a).
- Remote sensing of water availability and vegetation health: available through the Global Information and Early Warning System on Food and Agriculture (GIEWS) as well as the Agricultural Stress Index (ASI), which is a quick-look indicator for the early identification of agricultural areas probably affected by dry spells (FAO, 2019b).

The more difficult part is then to use these data in a meaningful way to assess possible sub-national impacts and guide discussions on sensible responses. In the case where no downscaled climate or agricultural impact data/information is available for a particular country, it is necessary to re-construct such data using the most accessible, available and useable techniques. If the downscaling of weather and/or seasonal forecasts is needed to develop CS products for short-term farm management, then this expertise needs to be developed at the NHMS so that it can be used in an operational capacity. If the climate

4. Note that producing climate information is one element of the value chain underpinning climate services; for additional insights on delivery of climate services and the needs of end-users like farmers, see WMO, 2019.

downscaling is needed for long-term scenario development and assessing the risks due to climate change, then this may be done at institutions outside the NHMS as the data only needs to be generated infrequently.

Several downscaling techniques are available, including the use of Model Output Statistics – often used to downscale weather and seasonal forecasts – and weather generators, some of which have been incorporated into standardised tools (CCAFS, 2019; Climatic Research Unit, 2009). Using these techniques and tools requires specialised knowledge and training which can be part of the NAP process and associated capacity building. Climate change impact assessments are further complicated as they need to cover as much uncertainty (see Box 2 on definitions) in possible futures conditions as are realistically possible. This requires the use of multiple General Circulation Models (GCMs) run under different assumed future greenhouse gas and aerosol emission pathways, multiple Regional Climate Models (RCMs) and statistical downscaling techniques, as well as multiple agricultural impact models to translate changes in climate into agricultural impacts.

Producing climate information for agricultural models

The same considerations apply to the use of agricultural production models with the generated climate data; if it is an operational CS product then this is usually generated by either the NHMS or by the Ministry of Agriculture (MoA), depending on where the relevant expertise and modelling capacity resides. Ideally, the MoA and NHMS should collaborate on the development and issuance of these products, as well as the sharing of climate and other data. Often these operationally generated products need to cover wide regions encompassing several agroecological zones. There is a wide range of models of varying complexity which may be used. The choice of crop growth model (e.g. AquaCrop) depends on agricultural management strategies (e.g. irrigation, fertilization, weeding, land preparation, sowing methods, etc.) as well as the availability of climate data and data on the physical/chemical properties of the soil, the purpose of the assessment, and the scale of the assessment (e.g. field, farm, district, national).

Impacts on the agricultural value chain

Weather and climate-related hazards not only affect agricultural production but also other aspects of the value chain e.g. harvesting operations, drying, storage and transport to market. However, it is difficult to explicitly model the impact of these hazards on the value chain because no causative models exist, or the modelling requirement may be too complex e.g. modelling the impact of extreme rainfall on localized flooding and road/infrastructure integrity. This can be attempted where such models and their required data exist, or a simpler analogue approach may be sufficient. The latter requires analyzing previous events and relating experienced damages or disruptions to the available climate data for a range of experienced weather/climate events.

Approaches to dealing with the uncertainty and confidence of climate forecasts and projections

Probabilistic and risk management approaches to using seasonal forecasts

Whereas weather forecasts of 0-3 days in the future are deterministic (they provide a precise estimation of variables), seasonal forecasts and longer-term climate projections are inherently probabilistic due to the chaotic nature of the troposphere. This means that seasonal forecasts are usually presented as the probability of being above/below a threshold. Using this information requires a risk management approach i.e. how should a farmer adapt their crops, planting and farm management practices in light of *probably* more or less rainfall? The answer often depends on the farmer, their cultural preferences, their appetite for risk and the options they have at their disposal (Ingram *et al.*, 2002; Dorward *et al.*, 2015).

Adaptation planning should take into account the way seasonal forecast information is communicated; which media, language, and the format (textual messages, images and theatre) of these communications plays a critical role in whether it is understood and acted on (Hansen *et al.*, 2011). Practical issues, such as network coverage in remote areas where vulnerable people may be located, can be a barrier to the dissemination of climate information and the most effective way for delivering climate and weather information may vary depending on the sub-sector (e.g. livestock managers may be more likely to use radios, whereas crop managers may be more likely to use phones or TVs). When combined with or described in terms of indigenous knowledge, uptake is further enhanced.

Incorporating the range of uncertainty and confidence in model projections of climate change

Current policy approaches often focus on reducing the uncertainty of future projections i.e. the range (maximum – minimum) or measures of spread (e.g. the standard deviation) of predicted climate variables, obtained from multiple climate models and/or emission scenarios. One common assumption is that downscaling climate simulations from global models reduces the uncertainty and narrows the spread of possible predicted futures. However, examples from southern Africa show that climate data obtained from different types of downscaling do not necessarily converge and reduce uncertainties in the projected climate (Tadross *et al*., 2017).

An alternative approach to focusing on uncertainty is to look at the confidence in projected climate. This approach, used by the Intergovernmental Panel on Climate Change (IPCC), recognizes that it is not only the range/spread of projected climate that affects confidence, but also the number of models that simulate future climates above/below particular thresholds. This allows a rough assessment of the likelihood of these positive/negative changes or risk above/below particular thresholds (Jones and Mearns, 2004).

A further consideration is that, while reductions in uncertainty are desirable, it is important not to close off consideration of futures which, though unlikely, are still plausible. Agricultural adaptation should thus take place within the co-evolution of climate, environmental and associated human systems, rather than envisaged as a 'predict and adapt' approach (making a single prediction of the future and adapting to it immediately). This promotes an iterative approach, where adaptation options are tested for robustness against a range of future climates and possible agricultural systems. Adaptation options can be repeated now and in the future as climate observations, projections and agricultural systems and options themselves change (Wilby and Dessai, 2010). In turn, such approaches also require systematic ways to be able to regularly monitor changes, evaluate and test adaptation options and their effectiveness, and learn from what does and does not work. Such monitoring, evaluation and learning frameworks are required for the successful implementation of NAPs in general, and the use of climate and agricultural scenarios within these frameworks is a key component.

Exploring future pathways using models and narrative approaches

Adaptation planning should consider a wide range of future climates, from both well-established models as well as narratives which explore possible scenarios that may not be explicitly modelled but are considered realistic/plausible. This provides a useful means of conveying uncertainty and exploring future climate through expert judgement (Dessai *et al*., 2018).

When faced with multiple possible futures, policymakers may find taking a 'no regrets' approach a good starting point, as this will not unnecessarily limit future options and avoid the risk of maladaptation (adaptation which is more harmful than beneficial). Narratives can also further help to reduce the risk of maladaptation by incorporating changes in environmental and human systems, which both affect the impact of a particular change in climate and/or may have a greater impact themselves, as well as incorporating alternative ethical and cultural priorities (Sheppard *et al*., 2011).

Conclusion

CS refer to the production, communication and dissemination of weather and climate information, which can be used to assess current and projected climate risks and inform planning and decision-making in different sectors, including agriculture. CS can be integrated into every stage of the NAP process, particularly in analysing current and future climate scenarios, assessing vulnerability and identifying adaptation options. While efforts have been made to improve the provision of CS in many countries, challenges remain in data availability at the local level, human capacity, infrastructure, institutional coordination and data sharing as well as information mismatch between data that is provided and data and information that are expected (by end users). Policymakers can seek to strengthen enabling environments for CS by creating multi-sectoral teams to develop and generate information based on user needs/ feedback, facilitating data/information sharing between government institutions and utilizing services and partnerships with the private sector.

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