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Climate Risk in Africa

Adaptation and Resilience

Edited by

Declan Conway

Katharine Vincent

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Declan Conway • Katharine Vincent
Editors

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Foreword

As African scholars, we have a critical role to play in climate adaptation and resilience in Africa. Trained in environmental science, civil engineering (water) and climatology, our involvement in the Future Climate for Africa (FCFA) programme gave us the opportunities to broaden our skills, to question and to learn and network as part of multidisciplinary teams—essential for addressing the challenges posed by climate change. Critically, we were also able to focus on solutions and actions, recognising that the process of arriving at solutions is more robust when it is inclusive and based on dialogue.

This book is published at a time when record-breaking weather events related to global temperature trends and rainfall extremes in various regions are on the rise. The decade 2010–2019 was the hottest on record, with 2019 as the second hottest year on record. The impacts of climate change and weather extremes have adversely affected livelihoods, fragile ecosystems, landscapes and vulnerable communities in Africa, and these trends are likely to continue.

Climate Risk in Africa: Adaptation and Resilience brings to life the opportunities for promoting development that is resilient, inclusive and sustainable in the African context. Chapters variously address the distillation of climate information, co-production of decision-relevant knowledge, and approaches trialled under FCFA to support improved use of climate information in planning and decisions that enable resilience and adaptation.

We congratulate the editors, Declan Conway and Katharine Vincent, and all the authors for their initiative to capture the stories that set Africa apart, and for making a collection of expertise and experiences available that is going to be pivotal for all ongoing work across the continent and beyond.

The content is relevant for a wide audience. We encourage other researchers to read this book as it gives insights for Africa's climate risks, mitigation and adaptation measures that the continent requires us to act upon. For climate scientists, this book gives innovative distillation of climate risks and guidance on interactions with users to increase usefulness and usability. Policymakers and decision-makers will have to take climate risks into account and adapt to climate impacts if humanitarian and development goals are to be realised and sustained. For them, this book provides decision contexts and the climate information required to contribute to climate-resilient development, including under the United Nations Framework Convention on Climate Change (UNFCCC) process, as many countries commence the process of revising their Nationally Determined Contributions.

In the coming years, it is our hope that Africa will emerge at the forefront of the transformation of how we approach adaptation and resilience to climate change. We are all committed to being part of that process and, building on some of the approaches presented here, we invite you to join us.

Kornelia Ndapewa Iipinge (FRACTAL embedded researcher, now SADC Centre for Renewable Energy and Energy Efficiency), Rebecca Ilunga (FRACTAL researcher, now Civil Engineer, ZUTARI) and Geoffrey Sabiiti (AMMA-2050 researcher, Climate Change Adaptation Officer, Intergovernmental Authority on Development Climate Prediction and Applications Centre)

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The FCFA website contains full information about this major research programme; its people, projects and outputs https://futureclimateafrica.org/

FCFA was implemented by five consortia and a Coordination, Capacity and Knowledge Exchange Unit. We gratefully acknowledge the support, interactions and effort of the huge number of people involved in the whole programme.

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The editors thank Evyn Papworth for excellent support with editing, proofing and collating the book.

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Abbreviations

ACPC	Area Civil Protection Committee
ACRC	African Climate Risk Conference
AMMA-2050	African Monsoon Multi-disciplinary Analysis-2050
BRACED	Building Resilience and Adaptation to Climate Extremes and Disasters
CADECOM	Catholic Development Commission
CAN-U	Climate Action Network-Uganda
CARD	Churches Action in Relief and Development
CCD	Climate Change Department
CEPA	Centre for Environmental Policy and Advocacy
CISONECC	Civil Society Network on Climate Change
CMIP	Coupled Model Intercomparison Project
COMRECC	Comité Régionale du Changement Climatique (Regional Climate Change Committee)
COP	Conference of the Parties
CORDEX	Coordinated Regional Climate Downscaling
CRU	Climatic Research Unit
CSG	County Steering Group
DCCMS	Department of Climate Change and Meteorological Services
DCPC	District Civil Protection Committee
DEWS	Drought Early Warning System
DFID	Department for International Development (Now Foreign, Commonwealth and Development Office, FCDO)
DMUU	Decision-Making Under Uncertainty
DoDMA	Department of Disaster Management Affairs
DTC	Drought Tolerant Crops
EAC	East African Community

EAM	Evangelical Association of Malawi
ESMs	Earth Systems Models
FbA	Forecast-based Action
ForPAc	Forecast-based Preparedness Action
FCFA	Future Climate for Africa
FRACTAL	Future Resilience for African Cities and Lands
FREE	Flexible, Robust, Economic no/low Regrets, Equitable
GCMs	Global Climate Models
GHACOF	Greater Horn of Africa Climate Outlook Forum
GPCC	Global Precipitation Climatology Centre
HEA	Household Economy Approach
HyCRISTAL	Integrating Hydro-Climate Science into Policy Decisions for Climate-Resilient Infrastructure and Livelihoods in East Africa
ICCSAP	Integrated Climate Change Strategy and Action Plan
IDAPS	Integrated Database for African Policymakers
IHM	Individual Household Method
ISRA	*Institut Sénégalais de Recherches Agricoles* (Senegal Institute for Agricultural Research)
IPCC	Intergovernmental Panel on Climate Change
JNHPP	Julius Nyerere Hydropower Project
LCC	Lusaka City Council
LDC	Least Developed Country
LEAD SEA	Leadership in Environment and Development for Southern and Eastern Africa
LuWSI	Lusaka Water Security Initiative
LVBC	Lake Victoria Basin Commission
LWSC	Lusaka Water and Sewerage Company
LZ	Livelihood Zones
MAAIF	Ministry of Agriculture, Animal Industry and Fisheries
MoAIWD	Ministry of Agriculture, Irrigation and Water Development
MWE	Ministry of Water and Environment
NAP	National Adaptation Plan
NAPAs	National Adaptation Programmes of Action
NDCs	Nationally Determined Contributions
NDMA	National Drought Management Authority
NDP	National Development Plan
NEMA	National Environment Management Authority
NERC	Natural Environment Research Council
NIMP	National Irrigation Master Plan
NPA	National Planning Authority
PICSA	Participatory Integrated Climate Services for Agriculture
PIPA	Participatory Impact Pathways Analysis

PSP	Participatory Scenario Planning
RCM	Regional Climate Model
RCP	Representative Concentration Pathway
RDM	Robust Decision-Making
SADC	Southern African Development Community
SAGCOT	Southern Agricultural Growth Corridor of Tanzania
SD	Statistical Downscaling
SHEAR	Science for Humanitarian Emergencies and Resilience
SPI	Standard Precipitation Index
TOT	Training of Trainers
UMFULA	Uncertainty Reduction in Models for Understanding Development Applications
UNCST	Uganda National Council for Science and Technology
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNMA	Uganda National Meteorological Agency
UNZA	University of Zambia
VCPC	Village Civil Protection Committee
WASCAL	West African Science Service Centre on Climate Change and Adapted Land Use
WASH	Water, Sanitation and Hygiene
WEAP	Water Evaluation and Planning
WHO	World Health Organization
WMO	World Meteorological Organization

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CHAPTER 1

Key Issues and Progress in Understanding Climate Risk in Africa

Katharine Vincent and Declan Conway

Abstract Adaptations and strategies to build resilience are needed to manage current impacts and will be increasingly vital as the world continues to warm. But making adaptation decisions can be complex, requiring careful consideration of multiple factors and perspectives, and balancing different priorities over different timescales. Society is embarking on a learning process that will continue for decades. This chapter and the book it introduces aim to contribute to this process. The book draws extensively from the Future Climate for Africa (FCFA) research programme that aimed to support adaptation and resilience in sub-Saharan Africa. In this chapter, we first briefly review the planning landscape for adaptation and building resilience and then consider how applications are changing the nature of climate information and the context of its use. This is followed

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by a review of the current status of climate information, particularly future projections for Africa and the enduring challenge that uncertainty represents to their active use. We then ask how we can improve the use of climate information for resilience building and adaptation and present an overview of the coming chapters. The demand for information and guidance on adaptation is continuing to grow, and is highlighting the need for new types and formats of data, and more innovative interactions with users to increase usability and application. Climate plays a dynamic role within complex, rapidly evolving social-ecological systems; this requires the climate science, resilience and adaptation communities to engage widely with other sectors and actors to make the agenda relevant and tractable for policy and practice.

Keywords Future Climate for Africa • Adaptation • Building resilience

Introduction

Our climate is changing—with major consequences for ecosystems and society. Adaptations and strategies to build resilience are needed to manage current impacts and will be increasingly vital as the world continues to warm. But making adaptation decisions can be complex, requiring careful consideration of multiple factors and perspectives, and balancing different priorities over different timescales. In particular, the fact that many adaptation benefits will accrue more acutely in the future means that they are often deprioritised relative to more immediate development challenges, particularly in Africa. This occurs against a context of uncertainty around the specific ways in which climate change will manifest at the local scale. Societies are only at the start of a learning process that will continue for decades.

This book aims to contribute to this process by developing our understanding of climate risk and its implications for approaches to adaptation and building resilience in Africa. We draw heavily on experiences from Future Climate for Africa (FCFA, https://futureclimateafrica.org/), an applied research programme that aimed to support adaptation and resilience in sub-Saharan Africa through better understanding of climate risk and promotion of climate information use to inform planning decisions over the medium (5–40 years) term future. Projects under this programme worked to improve the availability, accessibility and use of climate information in different decision-making contexts—from cities to water infrastructure to agriculture—in a range of countries. The book presents learning and experiences from this programme, focusing specifically on what does and does not work and why. In doing so, we critically reflect on a selection of trans-disciplinary approaches that bring together researchers and decision-makers to manage climate risk in the context of complex multi-dimensional problems. Our aim is that insights from these experiences can inform resilience building and adaptation across sub-Saharan Africa.

This chapter sets the scene by briefly reviewing the planning landscape for adaptation and building resilience in the following section. Afterwards, we consider how the range of potential uses of climate information is changing the nature of information that is produced, and then assess the current status of climate information, particularly future projections for Africa. Following that, we ask how we can improve the use of climate information for resilience building and adaptation, and then the final section provides an overview of the coming chapters.

Planning for Adaptation and Building Resilience

Recognition of the need for adaptation and building resilience has grown concurrently with awareness of climate change and the policy instruments that are in place to address it. The United Nations Framework Convention on Climate Change (UNFCCC) is the global policy arena for managing climate change. The framework convention addresses mitigation of the causes of climate change, and adaptation to the consequences of those changes. The latest legal instrument under the UNFCCC, the Paris Agreement, defines a Global Goal on Adaptation (Article 7).

The Global Goal on Adaptation aims to enhance adaptive capacity and resilience and to reduce vulnerability, with a view to contributing to sustainable development, and particularly ensuring that adaptation is adequate in light of the goal of limiting global warming to 2 °C (and pursuing efforts to limit it to below 1.5 °C). To ensure that this takes place, each Party to the UNFCCC is obliged to plan for adaptation (e.g. with a National Adaptation Plan) and communicate progress in those plans and their implementation through Adaptation Communications. Progress towards the Global Goal on Adaptation will be monitored every five years through a global stocktake. This complements Nationally Determined

Contributions (NDCs) under the Paris Agreement, whose primary aim is to outline mitigation commitments but may also contain adaptation priorities. It also builds on National Adaptation Programmes of Action (NAPAs), which were submitted by Least Developed Country (LDC) Parties to outline their most pressing adaptation needs and inform the direction of adaptation finance under the UNFCCC.

Commitments for adaptation at the international level have been reflected at the national level, with countries around the world putting in place policies, strategies and legislation to address the challenges of climate change (e.g. see Averchenkova et al. 2017). As well as promoting adaptation, there is recognition that planning processes need to take into account the potential risks posed by climate change to ensure that the intended benefits of plans remain sustainable in the face of these risks. Given the significant role of international aid in some cases, this means that not only national governments but also multilateral and bilateral donors need to ensure that their plans are taking into account future climate conditions.

National governments are not the only actors considering climate risk. Many donors are now screening for climate risk among their aid portfolios, but this is still piecemeal and rather ad hoc. In theory, the World Bank and African Development Bank, who are among the major investors in infrastructure projects, require that all projects are screened for climate risk, and that design modifications are instituted if required to sustain the intended benefits, before funding can be approved. There is also increasing commitment within the private sector to identify and address climate risk; however, these assessments are not done routinely and their rigour and outcomes are not easy to establish as the results are rarely published (e.g. for hydropower, Lumbroso et al. 2015) and often insufficient for investors (TCFD 2019).

Planning for adaptation and screening for climate risk generally requires information about future climate. Demand for climate information is thus growing, and raising questions about what types and how much information is necessary, how to engage with this demand, and how to develop methods to promote its effective use in ways suitable for the diversity of situations in sub-Saharan Africa.

Decisions and Planning Needs Are Changing the Nature of Climate Information That Is Required

There has been a significant improvement over recent decades in scientific capacity to understand the climate system and model the details of future climate. However, this improved scientific capacity for generating forecasts and projections does not simply translate into the type of information that is required by decision-makers for planning (Conway 2011; Nissan et al. 2019). Instead, there is often a "usability gap" resulting from a mismatch in temporal and spatial scales of information, and the ways in which uncertainty is embodied, as well as whether demand is fully appreciated and how information is communicated (Lemos et al. 2012).

We can take two cases for illustration. When planning for the coming season, a small-scale farmer might want to know when the rains are likely to start, and how long they are likely to last. This will determine what to plant (either what crop, or what variety of a crop e.g. an early maturing or normal duration variety) and when to plant it in order to ensure maximum production. When planning a water storage and distribution system to ensure availability for a growing urban population, a government ministry will want to know where it should place a dam and the associated infrastructure, and what their design should look like (e.g. in terms of dam capacity) in order to ensure maximum efficiency and reduce the risk of losses or excessive maintenance and repair costs due to floods and drought. Although there is scientific capacity to generate information to inform these decisions, it rarely matches the decision-makers' desired accuracy, format and presentation. Across Africa, the development and dissemination of seasonal climate forecasts has long been a particularly active area of climate research and applications, with important lessons for addressing the usability gap (Hansen et al. 2011). However, the nature of seasonal forecasts means that they are not always easy to interpret and use.

There are several reasons for a mismatch in information supply and demand with seasonal forecasts. Seasonal forecasts are probabilistic rather than deterministic, meaning that they provide the likelihood that the total volume of rainfall in a season will be above normal, normal and below normal. This poses several challenges for decision-making. Firstly, the rainfall patterns in sub-Saharan Africa are variable over time, and thus the medium- or long-term average that represents the 'normal' volume of seasonal rainfall against which the forecast for the coming season is compared can disguise significant variability. Comparing a coming season with an average is thus often difficult to visualise. Secondly, the probabilistic nature of the forecast is difficult to interpret. Dividing up 100% into three probabilistic terciles often results in negligible differences—for example, a forecast might say there is 40% likelihood of above normal rainfall, 30% likelihood of normal rainfall, and 30% likelihood of below normal rainfall. The limited difference between the three categories means that it does not often give farmers usable information on what to expect. Thirdly, the spatial scale for the seasonal forecast is often large. Regional Climate Outlook Fora develop collectively agreed (consensus-based) seasonal forecasts at regional level, which are then contextualised by countries and sometimes downscaled to sub-national level. However, the large areas covered by seasonal forecasts are unlikely to have uniform conditions, which reduces the likelihood that the information will be accurate at high spatial resolution. Fourthly, seasonal forecasts focus on the total amount of rainfall that is likely to fall within a season (the variable for which forecast skill is most accurate), when it is the distribution of the rainfall that matters the most for planting decisions (which generally has low forecast skill).

Similar challenges of mismatch between supply and demand are evident for longer-term climate projections. Global Climate Models (GCMs) project future climates over the long term, typically until 2100 and beyond, which is longer than the timeframe of most planning decisions. The average lifespan of a dam, for example, is around 50 years, so the priority would be to know the future climate until around 2070. Typically the spatial resolution of GCMs has been coarse, with grid cells of hundreds of kilometres squared (although this has reduced over time). One of the biggest challenges with climate projections is that they embody multiple sources of uncertainty. Indeed, modelling anything into the future is subject to uncertainty. Future climate will depend on the concentrations of greenhouse gases in the atmosphere which depend on the evolution of human activities and any policy decisions to limit emissions. There is then uncertainty in how the multi-faceted components of the climate system will respond to those concentrations, and how they will interact with each other. Each of the over 60 GCMs in the world will capture these processes differently—adding an additional element of uncertainty. Unfortunately, uncertainty tends to increase at finer spatial and temporal scales, which is a problem because it is often finer-scale information that stakeholders request and which leads to the most significant risk (i.e. from extreme floods and droughts). More information on the background, use and presentation of GCM projections can be found in FCFA guides (e.g. FCFA 2016; Conway et al. 2017).

As a result of these uncertainties, there is often disagreement between models. While all models project warming, there is considerable divergence in rainfall conditions, with the model range including wetting and drying in most of Africa. This uncertainty makes it difficult for planners to know what they need to plan for. Added to this, the ways in which scientists visualise the outputs of GCMs with different plots is not always easy for non-specialists to understand and interpret (Fig. 1.1).

Status of Climate Model Projections

While there is clearly a need to better match climate information supply with the demands of users, there has been significant progress in the availability and quality of information over time. Temperature remains easier to project with confidence than rainfall, which is subject to the interaction of a wider range of factors acting at the local level. One of the first reviews was published 25 years ago (Hulme 1994), showing GCM results with a mid-range greenhouse gas emission scenario for 2050 that projected warming of most of tropical Africa by less than 1.2 °C (from 1990). Rainfall was projected to increase over Africa, except for the northern third where drier conditions were projected, although with high uncertainty, particularly over the Sahel. This situation prompted the observation that 'This wide range of possible precipitation changes for Africa makes it problematic to develop sensible response strategies to greenhouse gas induced climate change in Africa' (Hulme 1994, p. 39).

Given the different capacities of different models to represent and project the climate, best practice has always been to use collections of models, or "ensembles", and to consider the multi-model mean and the inter-model range. By 2001, with a sample of ten updated or new GCMs, Hulme et al. (2001) revised projections for Africa showing consistent patterns of warming from 2° to 6 °C by 2100. Confidence in the magnitude and direction of change in regional rainfall was still low, leading the authors to suggest concentrating on vulnerability reduction and strengthening capacity to adapt to climate variability would bring immediate benefits and build capacity to adapt to longer-term changes in climate. However, broad spatial patterns appeared for the December to February season indicating wetting over East and central Africa and drying over parts of southern Africa. These results established spatial patterns of change that have

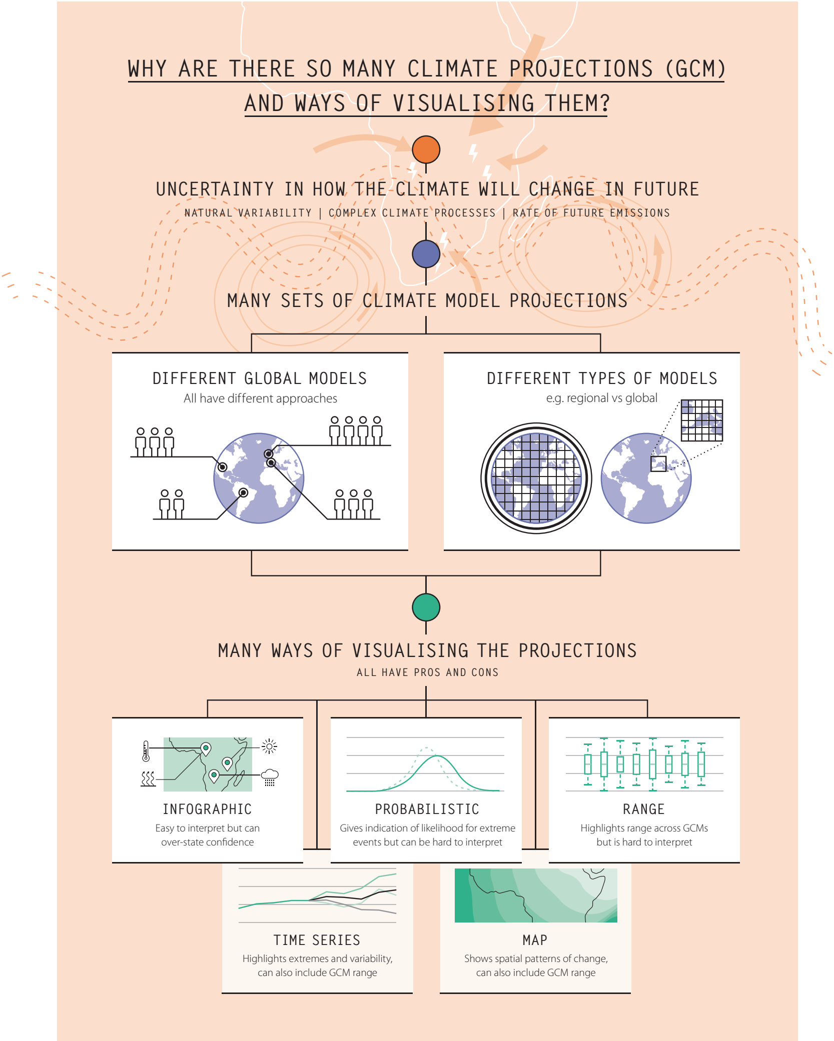

Fig. 1.1 The various ways of presenting Global Climate Model outputs

remained fairly stable throughout the subsequent multi-model assessments reported in the Fourth and Fifth Intergovernmental Panel on Climate Change (IPCC) reports (Coupled Model Intercomparison Project (CMIP) CMIP3, Christensen et al. 2007; CMIP5, Christensen et al. 2013).

However, similarities between model results do not necessarily indicate accuracy of projections. For example, there is a discrepancy between an observed drying trend in East African March to May rainfall and the projections for increasing rainfall in the future (the East African paradox; Rowell et al. 2015). For the Sahel, the observed multi-decadal variability is a crucial test for GCMs, and while this is simulated by many, they do not capture the scale of observed oscillations at multi-decadal timescales (Biasutti 2013). For southern Africa, projections of drying in early summer are robust, but extreme drying simulated by some models appears unlikely because these models simulate too much rainfall in the present climate (Munday and Washington 2018). Some approaches therefore consider constraining model selection by identifying those that most accurately represent the climate of a particular region or the mechanisms by which it changes. But, constraining models in this way is contentious (it requires explicit value judgements) and may have a limited effect on the range of uncertainty, as found for East Africa (Rowell et al. 2016; Chap. 6).

How Can We Improve the Use of Climate Information for Adaptation and Building Resilience?

There are various ways to overcome the usability gap and ensure that the improved availability of climate information translates into effective adaptation and resilience building. The important factors for successful information use can be broadly categorised as credibility (perceived technical quality of information), legitimacy/trust (belief that the information seeks to serve the users' interests) and salience (relevance to users' needs) (Cash et al. 2003). Another categorisation uses fit, interplay and interaction (Lemos et al. 2012). Fit includes users' perceptions of how climate information fits with the organisational context; interplay considers how well information can integrate with pre-existing knowledge or information in the organisation; and interaction deals with the relationship between the information producers and the users (Soares and Dessai 2016). Development and dissemination of seasonal climate forecasts has been a particularly active area of climate research and applications in Africa. The importance of framing any new information in the context of existing risk management practices is a key lesson from this work.

As outlined earlier, uncertainty—how to characterise it and how to deal with it—has been and continues to be a defining feature of research and practice on adaptation. The wide spread in model results over much of Africa has remained a stubborn feature since the earliest days of multi-model comparisons and has implications for the credibility of information. The key role that rainfall plays in livelihood systems across Africa makes this particularly challenging for decision-making. There are limits to the accuracy of projections that can be obtained about the future, which will always be subject to some uncertainty. This calls into question the top-down, supply-driven "predict then act" approach, whereby climate projections determine risk, and then adaptation options are identified to respond to that risk.

Turning this approach on its head, a variety of decision-driven approaches have arisen that look at the planning decision that needs to be made and ensure that the decision will be resilient in the context of a range of potential futures (thereby addressing the uncertainty of any future projections). One branch is known as Robust Decision-Making (RDM) or Decision-Making Under Uncertainty (DMUU). These approaches recognise that planning decisions with long-term lifespans need to be made, with deep uncertainties that cannot be reduced by gathering more information, but can be addressed by moving from predict-then-act approaches to assess-risk-of-policy approaches (Lempert et al. 2006). RDM methods can involve a combination of top-down and bottom-up approaches in which modelling methods are informed by stakeholder consultation processes. Presenting information about future risks and uncertainty can be approached in different ways, such as through narratives or storylines that combine process-based understanding of physical climate communicated in a bespoke manner, within hypothetical settings or using expert judgement techniques (e.g. Chap. 2).

On shorter timescales some humanitarian and development agencies are developing decision protocols that use forecast information for advance release of finance or other types of early action for disaster risk management (Forecast-based Action, FbA; Wilkinson et al. 2018). Examples of FbA use a variety of financing tools, including dedicated funds, specially allocated funds in emergency response funds, insurance and direct links to regular resource allocation processes. FbA programmes have been deployed through various delivery mechanisms, including social protection systems. There has also been a move in this field to frame actions as 'no regrets' or 'low regrets' which are likely to result in humanitarian or wider development benefits irrespective of how the situation plays out, especially for seasonal timescales given high levels of uncertainty (Wilkinson et al. 2018).

Legitimacy issues such as defining aims, involvement in processes and ownership of outcomes are critical to agendas promoting climate information use. This includes engaging in climate science and the development of GCM projections or being able to tailor them to their national contexts. Increasing availability of projection-generating toolkits has contributed to 90% of 189 countries including climate projections in their vulnerability and adaptation assessments that form part of their National Communications to the UNFCCC (Skelton et al. 2019). However, the wide adoption of GCM projections obscures major differences in capacity to generate and customise global climate science to national/local context: capacity is strongly skewed in favour of countries in the global North (Haunschild et al. 2016). Infrastructure and capacity gaps and lack of funding are known to be important for many National Meteorological and Hydrological Services (NMHS), and while recent extensive funding and initiatives are going some way to address these concerns, political and economic considerations require careful attention (Harvey et al. 2019). These issues feed into broader research on the political dimensions of adaptation through which ideas, power and resources are determined by different groups across scales ranging from the global North and South to between and within communities (Tanner and Allouche 2011; Eriksen et al. 2015). Other concerns include debates about the role of different actors in the process. For example, some warn that commercialised models of climate service provision might exacerbate the challenge of using information from climate science to inform adaptation by gatekeeping access on the basis of ability to pay, which is particularly an issue in Africa (Webber and Donner 2017).

To achieve salience, there is a need to translate model results into user-relevant information that is contextualised to suit the specific needs of agencies, communities and individuals. This often requires a role for intermediaries (Dilling and Lemos 2011). Limits to the spatial detail of GCM projections and a common focus on timescales far into the future are significant challenges to this goal. A prerequisite is to understand decision-making contexts and information needs for potential "users" of such climate information (Carr et al. 2020; Harvey et al. 2019). Bringing together the "producers" and "users" of climate information can help promote the dialogue required for each to understand the other's perspectives, abilities and needs, bearing in mind that limited resources and skillsets may be important barriers (e.g. Chap. 3). These various actors working together in a process of co-production can improve the likelihood that credible, legitimate and salient information is produced, which increases the likelihood of application (Carter et al. 2019). However, thus far co-production of climate services is still in its infancy, especially in Africa, and there is a need for more rigorous evaluation of its utility (Wall et al. 2017).

Conclusion and Outline of Following Chapters

The need to adapt and build resilience is clear. The demand for information and guidance to support this process is continuing to grow, and is highlighting the need for new types and formats of information, and more innovative interactions with users to increase usability and use (Vincent et al. 2020). Progress towards effective linkage between top-down, supply-side approaches that aim to address the availability of information with bottom-up, demand-side approaches where information is defined by decision contexts has been slow. This book addresses this gap through real-world examples that apply novel approaches to knowledge creation.

The following chapters provide an expanded context, informed by practice, to climate research in Africa, recognising the important relevance of shorter timescales but focusing on longer term (roughly 5–40 years) timescales for adaptation. In Chap. 2, Jack et al. introduce the concept of distillation and its relationship with climate information and definitions of reliability and robustness. They describe an example of information distillation using complementary approaches to GCM projections based on narratives. In Chap. 3, Vincent et al. reflect on the role of process—how activities are designed and undertaken—what principles should be considered (e.g. salience, credibility and legitimacy) and who is or should be involved. They consider what we are learning about a role for co-production from practical attempts to employ it. In Chap. 4, Audia et al. argue for the need to add *equity* to the principles of *flexibility*, *robustness* and *low economic regrets* (FREE) that already characterise DMUU.

Chapters 5–8 then present case studies from Malawi, Tanzania, Zambia and Uganda—four countries where the FCFA programme has supported adaptation and resilience building through improving the provision of climate information that is useful and usable to decision-makers. In Chap. 5, Tembo-Nhlema et al. illustrate how Participatory Scenario Planning (PSP) has been used on seasonal forecasts in Malawi to generate useful and usable information for farmers. In Chap. 6, Siderius et al. present an approach for reducing uncertainty in GCM projections to inform decisions around water, energy and the environment in the Rufiji River basin of Tanzania and how such approaches benefit from user-defined performance indicators. In Chap. 7, Taylor et al. illustrate the process through which various sources of climate information were integrated into Lusaka's Strategic Plan for 2017–2021. In Chap. 8, Cornforth et al. reflect on ways to evaluate the impact that climate information has on decision-making through quantitatively assessing the status of livelihoods under different climate scenarios.

The case study chapters are guided by a series of questions designed to reflect the multidimensional nature of adaptation and some of the issues often encountered in practice:

- What are the characteristics of the decision problem and how are they defined and by whom?
- What kinds of interactions occur and who is involved in them?
- What are the key contextual factors, including the significance of historical climate risks and the role of institutions and governance?
- How are climate risks characterised and communicated, and over which timescales?
- To what extent does uncertainty about climate feature in the case study?
- To what extent are non-climate considerations important and how they are addressed?
- What are the reflections—what works well and why?

In Chap. 9, we reflect on the experiences outlined in the book noting that at their core are attempts to initiate and inform conversations about climate risk and the need for adaptation and resilience building. We consider these conversations and what they mean for the growing adaptation agenda. Africa is urbanising rapidly and is in the midst of major infrastructure expansion which is changing exposure and sensitivity to extremes, and generating new hazard combinations. The research presented in this book recognises that climate plays a dynamic role within complex environment-society processes. This requires adaptation researchers to engage with other sectors and actors to make the agenda relevant and tractable across policy and practice arenas.

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CHAPTER 2

Climate Information: Towards Transparent Distillation

Christopher D. Jack, John Marsham, David P. Rowell, and Richard G. Jones

Abstract Constructing climate information to inform climate change risk-related decision-making is challenging and requires a rigorous interrogation and understanding of multiple lines of evidence and an assessment of the values, limits and uncertainties involved. Critically, there is no definitive approach agreed on by all climate scientists. Rather, a range of approaches and assumptions are used, with implications for robustness,

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reliability and uncertainty. Often these choices and assumptions are informed by the values and objectives of climate science rather than the decision context. We propose an approach, information distillation, that makes explicit and open for deliberation many of the implicit decisions and value judgements that occur throughout the process of constructing information. We argue that this approach must engage substantively with the decision context and open up choices and assumptions in a transparent manner to deliberation across climate scientists and context experts. This should ensure relevance and usability, and build understanding and trust to form an important basis for effective uptake of information. Two case studies are described demonstrating the effectiveness of these approaches and illustrating several important principles for transparent information distillation.

Keywords Information distillation • FRACTAL • HyCRISTAL • Co-production • Uncertainty

Introduction

Responding effectively to the complex challenge of climate change requires well-informed decision-making. Climate science is crucial to the process, for describing and understanding past changes and projecting possible changes in the future, under different greenhouse gas emission scenarios. However, climate science involves many value judgements and choices, with consequences for the resultant information, decision-makers and stakeholders. Therefore, robust decision-making in the face of uncertainties requires transparent interrogation and deliberation of values and choices in order to distil reliable information and manage risk.

Scientific understanding of climate change globally and for Africa has progressed significantly over recent decades. Two key drivers of progress have been improvements in observations and modelling. First, new observational platforms, primarily satellite based, have generated an unprecedented volume of data on atmospheric, land surface and ocean variables. Regrettably, however, the availability of primary surface observations from weather stations is declining in many countries, particularly in Africa. Satellite observations are not enough on their own—they generally require cross-checking (calibration) against surface observations and for some variables such as near surface air temperature, obtaining accurate satellite estimates is challenging (Hooker et al. 2018).

Second, climate model complexity has advanced with the inclusion of a greater number and more realistic representations of climate processes. Global Climate Models (GCMs) included in the first Coupled Model Intercomparison Project (CMIP) that provided key evidence in the Intergovernmental Panel on Climate Change (IPCC) First Assessment Report (1990) were far simpler than the GCMs contributing to CMIP6 and the ongoing IPCC Sixth Assessment Report. For example, the GCMs participating in CMIP6 are predominantly Earth Systems Models (ESMs) which include coupling of models of the atmosphere and its chemistry, the oceans and their biology, sea-ice, and the land surface vegetation, with grid spacings generally in the range of 100–200 km (Eyring et al. 2016). Moreover, advances in computational capacity and scientific understanding have enabled the latest limited area Regional Climate Models (RCMs) to run with grid spacings of 4 km or less, allowing them to resolve features at spatial scales of around 25 km, and explicitly capture deep convection—a key feature of climate in Africa. Such models can reproduce realistic convection, one of the long-standing challenges of climate modelling (Stratton et al. 2018; Kendon et al. 2019; Jackson et al. 2020).

These major advances in climate science through observations and modelling provide increasingly robust evidence that the climate is changing and that mitigation is crucial for constraining the extent of future climate change and associated impacts. However, there remain significant barriers to providing climate information in the format and level of accuracy often desired to support local-scale adaptation decision-making. Indeed, participants at the 1st African Climate Risks Conference (ACRC 2019) emphasised the need to better integrate climate science research into decision-making, while noting the ongoing challenge that uncertainty in climate projections represents to this goal.

This challenge is being approached from two related perspectives: Vincent et al. (Chap. 3) adopt the perspective of integrating climate information more effectively into decision-making through co-production, while this chapter considers the potential for climate science and modelling to provide more considered and defensible information. In the next section, we describe the basis for constructing climate information, highlighting the important concepts of robustness and reliability and the associated assumptions. In particular, we consider the role of value judgements in characterising and reducing uncertainty, and how trade-offs between different types of error arise. This leads into the following section where the concept of *climate information distillation* is introduced. Climate information distillation strives to facilitate greater transparency and inclusion of decision-makers and stakeholders in the value judgements and trade-offs that are generally only considered within the climate science. This is followed by two case studies of climate science information development designed to aid decision-making, supported through the Future Climate for Africa (FCFA) programme. We end with brief conclusions.

Constructing Robust and Reliable Climate Information

One of the most common requests from climate risk management and adaptation exercises is for *robust* and *reliable* climate information with low *uncertainty*. It is worthwhile to step back and consider these terms, how we understand them, and how they are crucial to support the improved use of climate information in decision-making. First, we will consider robustness, or the strength of the evidence behind the information. For climate projections, this relates to climate models and their complexity and realism, and how we evaluate their realism. We then consider the closely related concepts of reliability and uncertainty which relate to the possibility of error—understandably a key concern for decision-making.

Robust Information

The IPCC Fifth Assessment Report guidance note on uncertainties (Mastrandrea et al. 2011) describes *robust* messages as those supported by multiple, consistent and independent lines of high-quality evidence. High-quality evidence rests on strong and well-tested assumptions, rigorous analysis and statistical testing, and validation against observations. However, different lines of high-quality evidence can and do result in different conclusions. Evaluation of multiple lines of independently produced evidence and their agreement or disagreement provides a strong basis for establishing robustness.

Mastrandrea et al. (2011) also note that evaluation of the degree of robustness involves expert judgement. For example, assessment of historical trends of extreme rainfall events over Africa are often reliant on spatially and temporally sparse weather station data with uncertain quality control. Even where multiple independent analyses exist and are consistent (e.g. from different gridded datasets of temperature and rainfall in Africa), they might all assume that the underlying primary data are reliable enough to draw conclusions. Whether this is indeed the case can often not be objectively determined but requires a level of expert judgement which is subjective and may vary from one climate scientist to another.

Establishing robustness of information based on future climate projections is particularly challenging to determine because, as we will discuss later, we cannot verify projections of the future. In this case, robustness rests on three bases:

1. *Comprehensive representation of physical process understanding in models*: Current understanding of climate system dynamics and feedbacks is both informed by and informs model development. We know that models must realistically represent the fundamental dynamics as well as important physical processes such as convection, land surface, ice-albedo and cloud feedbacks.
2. *Ability to reproduce relevant aspects of historical climate variability*: We cannot validate model simulations of future climate change, instead we validate their simulations of past climate modes of variability or trends that are deemed relevant to future projected changes.
3. *Multi-model ensemble agreement*: In line with the IPCC guidelines, if multiple models simulate the same future changes, then this provides multiple lines of evidence in support of a message. If multiple models diverge, they provide less support for any particular message. However, as will be discussed in the subsequent section on uncertainty, models are not completely independent and multi-model agreement is not a sufficient basis for robustness.

These three bases of robustness are closely interrelated. As models are developed in order to represent more processes, or improve their realism, model evaluations tell us how these developments affect the model's simulation of observed climate variability.

Model Realism

Model realism is advancing through two main avenues: improved realism of model components and parameterisations; and increased spatial resolution. The latter allows for more realistic representation of the land surface, including the crucial roles of topography, oceans and atmospheric convection. Until recently, higher resolution climate information has been restricted to RCMs or statistical downscaling (SD) to generate more local detail from coarser GCM grids. However, RCMs and SD are dependent on the realism of the driving GCM and it is not always clear under what conditions RCMs improve the realism of the climate simulation (Dosio et al. 2019). Among other limitations, SD methods also assume that observed climatological relationships will hold in the future warming world (statistical stationarity) which is not necessarily the case (Jack and Katragkou 2019). The added value or realism of regional modelling and SD is another area where multiple viewpoints are held, and expert judgement is deployed.

Computational capacity has now reached the point of enabling convection-permitting resolutions in atmospheric models—a major advance—because climate models generally use convection parameterisations that, while based on physical principles, are significant simplifications of reality and are a cause of much model disagreement or uncertainty (Sherwood et al. 2014). Explicitly permitting convection is an important advance in model realism and initial experiments have demonstrated significant improvements, particularly in the simulation of tropical convective rainfall characteristics over Africa (Stratton et al. 2018).

Model Evaluation

Guiding and understanding advances in climate model realism rests strongly on approaches to model evaluation. At the global scale, we have high confidence in the ability of contemporary climate models to reproduce observed global aggregate trends such as global mean near-surface air temperatures. Most models also realistically simulate responses to climate events such as large volcanic eruptions. Such comparisons have proven a mainstay for defending climate model realism.

At the regional to local scale, in the context of constructing information to inform decision-making, a key element of model evaluation is determining which climate features are relevant to robust future climate change projections. While there has been a call for greater focus on model evaluation in Africa and other regions (James et al. 2018), care must be taken to ensure that models are evaluated with respect to features across multiple scales that are likely to be relevant to future climate changes rather than just contemporary climate means and variability. Importantly, there has been a strong drive towards *process-based* evaluations which focus on key regional processes such as regional moisture transport dynamics, rather than surface variables (diagnostics) such as rainfall amounts. One framing developed under the Future Resilience for African Cities and Lands (FRACTAL) project is that of *process chains* which recognises and helps characterise the many interlinked processes that are relevant to climate change in a region (Daron et al. 2019). Another, used in the Integrating Hydro-Climate Science into Policy Decisions for Climate-Resilient Infrastructure and Livelihoods in East Africa (HyCRISTAL) project, is a 'future-centric' approach to constraining the spread amongst model projections (Rowell 2019, and reference therein).

Advances in model complexity coupled to ongoing and more sophisticated process-based evaluations of model realism are critical foundations for the construction of robust climate information. However, even as the realism and performance of models have improved, the spread (or divergence) of projected changes from different models (referred to as multi-model ensembles) has often not reduced (Knutti and Sedláček 2013). Model advances, thus far, are not producing clear multi-model convergence in future projections, particularly of rainfall and for large parts of sub-Saharan Africa (see Chap. 1). Analysis of multi-model ensembles and characterization of uncertainty therefore remain critically important in constructing reliable messages about future climate change.

Reliable Information and Reducing Uncertainty

Unlike robustness, which relates to the characteristics of the evidence, reliability relates to the probability of error—a challenging concept for future climate projections. More formally, in weather and seasonal forecasts, reliability is one important measure of the track record of a forecast system over multiple forecasts. Reliability refers to the ability of the forecast system, over multiple forecasts, to reproduce the probabilities of climate variations. For example, forecasts of a 60% chance of dry conditions should, if perfectly reliable, be matched by actual dry conditions 60% of the time (Wilks 2011). Reliability of weather and seasonal forecasts can be evaluated retrospectively, but we do not have that luxury for climate change projections and therefore must rely on less empirical measures of reliability. In practice, decision-makers interpret reliability to mean that the information should not turn out to be wrong.

There are fundamentally two ways that climate information can be wrong; we can fail to identify a climate future that does occur and so risk not planning adequately, or we can identify a future that does not occur and plan unnecessarily. It is conceptually simple to avoid the first type of error. We can present a very wide range of future changes and be highly confident that reality will lie somewhere inside the range. However, we then cannot avoid the second type of error as we are almost certainly identifying future climates that will not occur. This approach can force decision-making towards no-regrets approaches that while robust under any plausible future climate, can be very expensive (requiring finance to cover conditions that are never reached) and have other undesirable consequences. There is therefore a strong argument for and motivation to constrain the uncertainty range associated with multiple climate model projections and reduce the risk of identifying futures that are not going to occur (e.g. Chap. 6). This requires drawing on elements of robustness described previously to provide a basis for excluding some futures. However, first we need to understand and characterise different sources of uncertainty and the scope for reducing uncertainty.

Sources of Uncertainty

Any model, regardless of its complexity and resolution, or even its ability to reproduce past climate features, remains a simplified and imperfect representation of the real climate and so there is inherent uncertainty about any simulation of future climate. To characterise this uncertainty, ensembles of semi-independent models (Knutti et al. 2013) are used to construct a range of possible future changes. Models are only semi-independent because many models share core components and parameterisation schemes. The assumption being that a sufficiently large set of independent models will produce a range of future projected changes that approximates the actual uncertainty due to model weaknesses. The extent to which this is true is unclear and there are several associated concerns regarding model independence and their coverage of different processes that generate uncertainty (Parker 2013). Furthermore, where processes relevant to a particular regional climate change response, such as aerosol feedbacks, are inadequately represented in all models from an ensemble, it is possible that the ensemble range does not even include the real future (Rowell et al. 2015).

Additionally, the climate system has an inherent stochastic component that we call *natural* variability. This means that any particular year, or decade, or even multiple decades can be warmer or cooler, wetter or drier, for no other reason than the interacting internal processes that generate semi-stochastic (or randomly determined) variability. Two to three decades into the future, natural variability is typically the largest source of uncertainty because other drivers, such as greenhouse gas concentrations, will be relatively small and difficult to distinguish from natural variability. Beyond one- or two-decades, changes in greenhouse gas concentrations relative to the present become much larger, depending on mitigation progress, and models project larger changes. Beyond around 50 years into the future, the proportion of uncertainty arising from unknown future greenhouse gas concentrations increases substantially (Hawkins and Sutton 2011).

Reducing Uncertainty

The uncertainty associated with natural variability is essentially irreducible. Uncertainty in emissions scenarios is not reducible through climate science; however, when constructing information to inform decisions, it should either be clear why particular emissions scenarios have been selected, or stakeholders should be involved in the selection. These choices often represent the value judgements of climate scientists rather than decision-makers.

A common approach to reducing model derived uncertainty is to decide which simulated futures are less plausible. Simple approaches to this involve discarding the most extreme changes by, for example, only presenting the 25th to 75th percentile range (e.g. as done in the IPCC AR5 Atlas, Van Oldenborgh et al. 2013) under the assumption that more extreme changes are less plausible. However, there is very little basis for this and more defensible approaches involve evaluating model realism under historical climate conditions, with respect to variables or regional climate features of relevance to future regional climate change (e.g. McSweeney et al. 2012). Here, *process-based model evaluation*, described earlier, can play an important role. For example, Rowell (2019) evaluates the realism of models in the CMIP5 ensemble with respect to observed important linkages between clouds and ocean temperatures in the southern Indian Ocean and regional rainfall. This observational constraint provides a basis for excluding one particular model and reducing the spread of projections by one third.

Models that fail to meet some subjective threshold of realism could be excluded from the ensemble. In some cases, these models turn out to be those projecting changes at the extremes of the multi-model range and their removal reduces the range. In southern Africa, for example, research shows models that simulate far too much rainfall in the current period project more drying (Munday and Washington 2019). If it is assumed that the error in current climate generates the high climate change, those models can be removed. In other cases, the excluded models are not outliers, and removing them does not greatly reduce the ensemble range (Rowell et al. 2016; Chap. 6).

It is important to note that there is no strong agreement about if and how model evaluation and exclusion is done. This is another area of expert judgement and diverse perspectives and values. There is some progress in identifying evaluation metrics that capture key features of climate in Africa (James et al. 2018) but approaches to model selection (and their effects on the model range) are still being explored, partly because the process involves numerous value judgements. We argue that the consequences of these choices can have significant implications and stakeholders and their values and expertise should be involved in making them. The next section describes emerging approaches to address this challenge.

Climate Information Distillation

Given the challenges and the advances described earlier, how do we make progress in constructing climate information to support decision-making? One framing of this construction process is increasingly called *distillation*. Though the interpretation of this phrase is varied, essentially the focus is on constructing information that is usable, robust, and reliable for decision-making (e.g. Giorgi 2020). Distillation involves identifying the value in or establishing the meaning of evidence. Because value and meaning are inherently contextual, distillation is necessarily deeply rooted in context. For example, the meaning of an ensemble of climate simulations may be very different for an urban planner and a climate modeller.

Co-production approaches (see Chap. 3) can be very effective in identifying the information needs of decision-makers and translating science into understandable and relevant information. However, within any information construction processes, whether through co-production or not, many decisions and value judgements are made related to realism, robustness, uncertainty, and the risk of making errors. In many cases, these decisions and judgements are made out of context, or with little consideration of context. For example, climate scientists frequently decide that reducing uncertainty is more valuable than the associated risk of failing to identify the real future climate. These critical value judgements are rarely made collaboratively with those managing the risks of error. The implications are seldom understood by either scientists or decision-makers.

We propose an approach to distillation that makes explicit and open for deliberation many of the implicit decisions and value judgements that occur throughout the process of constructing information. We argue that opening up these judgements and decisions through transparency and deliberation builds the critical trust and common understanding of the value (and the limits to value) climate science brings to a decision. Emerging learning (see Chaps. 3 and 7) suggests that these principles may be as important and potentially more valuable for integrating robust climate information into decision-making than efforts to simplify and communicate climate science outputs (Harold et al. 2019; multiple chapters in this volume)—that is, the process of engagement is as important as the climate information itself.

In the next section, we present examples of constructing climate information to support decision-making through the lenses of distillation, before we conclude with some principles and guidelines for distillation itself.

Case Studies

FRACTAL

The Future Resilience for African Cities and Lands (FRACTAL) project aimed to inform climate resilient decision-making in large capital cities in southern Africa. The project chose to adopt a strongly context-led approach to the development of climate information—one that incorporated and refined ideas about information distillation.

The context-led approach was integrated into the research design through pre-proposal consultation and motivated by prior experience in such projects. This was subsequently initiated by supporting city participants ranging from city councillors, urban planners, local academics, representatives of water utilities, power utilities, and civil society organisations (in particular informal settlement representatives) to collectively agree on a suite of "burning issues"—areas of significant common concern across all participants. In most cases, these emerged as insecure water supply, flooding, and sanitation, with a strong focus on peri-urban or informal housing areas. The burning issues were then unpacked progressively through a series of Learning Labs (McClure 2020), based on strong transdisciplinary principles, and are described more fully in Chaps. 3 and 7.

Of importance was the mode of introducing climate information in Learning Labs. In most of the formal interactions climate information was either not introduced in the first workshop activity, or if it was, it was only as a very small component. The objective was to avoid climate science (and climate scientists) strongly defining and framing the values and collaborative learning process.

When climate science information was introduced into the Learning Lab process, it was done through Climate Risk Narratives (Jack et al. 2020). These are descriptions of the city under different plausible (supported by scientific evidence) future climate conditions. In most cases, the initial narratives were informed by three plausible climate futures based on conventional analysis and interpretation of multi-model ensemble projections of climate variables and statistics perceived as relevant for the context.

Climate Risk Narratives became an iterative engagement device through subsequent Learning Lab workshops. Participants were involved in developing descriptions of the socio-economic elements of each narrative, which involved extensive deliberation over what the consequences of different climate futures would be, for whom and what responses were relevant. This prompted and allowed for a diversity of perspectives and values to be expressed. For example, in Windhoek, representatives from a youth organisation wanted the described futures to be optimistic and to reflect their aspirations for the successful implementation of the city's adaptation plans, rather than just negative challenging impacts.

Overall, distilling climate information that effectively engages with decisions is a process that involves building trust, agreeing on common values and priorities, integrating a diversity of experience, evidence, and expertise, and collaboratively managing risk and uncertainty. Reflecting on the process, three important aspects of climate risk narratives are particularly relevant to climate information distillation:

1. The first was the adoption of a risk framing. In Lusaka, the climate projections include large uncertainty about changes in rainfall, with

projections spanning increasing and decreasing rainfall. However, discussions revealed that primary concerns were the impacts of rapidly increasing population and water demand, and reduced total rainfall but more intense rainfall events. Increases in total rainfall did not emerge as a concern. The narratives for Lusaka therefore do not represent a future with increasing rainfall—its exclusion was a collective decision made with consideration and understanding of the climate evidence—a value judgement that reflects the values and priorities of those making decisions or experiencing their consequences.

2. Secondly, very little time was spent on visualization, tailoring, or simplification of climate science evidence. Rather, climate scientists openly engaged with each other and with participants as decisions such as excluding particular futures were made. Building mutual understanding and trust in distillation decisions was prioritised over one-way modes of communication that may pre-emptively close down debate. This is not to devalue approaches to communication, which still have significant value and importance, but rather it is an argument for building trust in order to support legitimacy and collective ownership in the process (Harold et al. 2019).
3. Finally, the perceived barrier of model-related uncertainty rapidly diminished in most cases. Once participants were able to engage with and build common understanding across the range of plausible futures, effective and priority interventions emerged, many of which were common across all plausible futures. In many cases, these interventions were based on good development and urban planning that would also be effective adaptation measures. While efforts to reduce model uncertainty are certainly valuable and climate science should and will continue to strive towards this, the perceived barrier of uncertainty is not always insurmountable, particularly where climate information is constructed through open, transparent, and collaborative distillation.

HyCRISTAL

The Integrating Hydro-Climate Science into Policy Decisions for Climate-Resilient Infrastructure and Livelihoods in East Africa (HyCRISTAL) consortium, also part of the FCFA programme, focused on climate risk and advancing climate science in East Africa (Finney et al. 2019).

Discussions with regional authorities and other stakeholders identified urban water sanitation and hygiene, and rural livelihoods as two important concerns for climate change–informed decision-making. These formed the subjects of pilot studies of decision-making within the project, alongside research on tea production, Lake Victoria water levels and water management.

HyCRISTAL's climate science addressed understanding of specific aspects of climate relevant to the aforementioned concerns, such as rainfall accumulations, extreme rainfall and rainy season onset. Drawing on this research, the wider literature, and discussions with stakeholders, HyCRISTAL also constructed Climate Risk Narratives (e.g. Burgin et al. 2019), with three possible futures spanning much of the plausible range in key variables of model projections, with the underpinning evidence provided in a technical appendix. This enabled HyCRISTAL to use the Climate Risk Narratives for engagement with decision-makers and planners, without conversations becoming too distracted or deterred by the scientific evidence. Moreover, the underpinning evidence was available for transparency, and for legacy so that the Climate Risk Narratives can easily be modified as the evidence base changes.

Climate Risk Narratives were generated for urban and rural contexts and were widely shared giving indicative impacts of each possible future. At forums such as the GHACOF (Greater Horn of Africa Climate Outlook Forum), they were found useful for engaging individuals in non-climate sectors. For particular decision contexts, HyCRISTAL also generated bespoke projections, for example, of possible changes in flood frequency in key cities, by (i) statistically downscaling CMIP models (unless the models had been shown to be implausible; Rowell 2019); (ii) using changes from state-of-the-art convection-permitting RCM simulations that explicitly model the rain-generating storms, thereby improving the representation of key processes and as a result giving larger changes in extremes than other model types (Kendon et al. 2019; Finney et al. 2020); and (iii) synthesising this new knowledge alongside the full range of changes projected by the CMIP climate models.

The approach of HyCRISTAL was to assume any projection from a globally recognised climate model was plausible until proven otherwise through analysis of the realism of climate change relevant features (see discussion on process-based evaluation above), and to recognise that the actual future could always lie outside the range produced by climate models.

Conclusion

It is clear that with concerted research and funding, supported by advances in computing capacity and observational platforms, our understanding of the climate system and ability to simulate its behaviour is advancing rapidly. This is important and valuable in building confidence in model projections of future change.

However, this chapter and the experiences of many others show that advances in climate science do not effortlessly translate into improved decision-making. The dominant narrative to address this challenge is the need for improved translation, communication and co-production approaches. This speaks to the imperative that climate science is producing information that is relevant to real-world decision contexts—we argue that an effective distillation process that opens up for deliberation with all stakeholders, the wide range of value judgements and choices made within climate science, is also crucial to avoid poor decision-making as well as building trust and ownership of information.

The key principles of climate information distillation we can identify through the experience of the case studies described amongst others can be summarized as follows:

- Develop an understanding of the decision context, not just the general problem area (e.g. water resources), but also the decision space, the options, by whom and how decisions are made. This understanding can strongly inform approaches to constructing climate evidence, characterising uncertainty and avoiding risks of concern.
- Similarly, adopt a contextual risk-framing approach that allows the concerns and risks of the context experts to guide and frame the construction of climate information.
- Understand how uncertainty influences the decision. Through approaches like scenario planning and decision scaling, understand how uncertainty may challenge decision-making.
- Use climate evidence (observations, model projections, downscaling) that clearly adds value to the decision. Simplicity facilitates common understanding and engagement. The added value of the newest models and results takes time to evaluate and should not be assumed.
- If there remains a desire to reduce uncertainty by excluding implausible futures, pursue this transparently and with open deliberation about the potential risks of error.

- Focus on the process and building trust and common understanding across climate and contextual experts. Trust and understanding are important factors behind information uptake and application.

In this chapter, we have tried to push the dominant narrative on information use further back into the climate science process itself and, in so doing, raised important questions about the many assumptions and value judgements that are made within the climate science domain prior to or during the generation of information. These assumptions, many of which are conventionally considered disciplinary and technical, nevertheless have significant implications for the resultant information and risk management decisions. Ultimately, decision-making is a process of risk management and information is used to avoid error. By adopting a more transparent, open, and deliberative distillation process, information can be constructed that integrates the value judgements and understanding of risk and uncertainty of all stakeholders, rather than just climate scientists.

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CHAPTER 3

Co-production: Learning from Contexts

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Abstract Given that climate change is a complex, systemic risk, addressing it requires new knowledge. One way of generating such new knowledge is through co-production, or collaborative development by a range of stakeholders with diverse backgrounds embedded in trans-disciplinary processes. This chapter reflects on emerging experiences of co-producing

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decision-relevant climate information to enable climate-resilient planning and adaptation to climate change in Africa. It outlines principles that have emerged and evolved through experiential learning from a wide range of co-production processes in Africa. It also uses case study experience from various contexts to highlight some of the more contextual challenges to co-production such as trust, power and knowledge systems and institutional factors (mandates, roles and incentives) and illustrates ways that trans-disciplinary co-production has addressed these challenges to mainstream a response to the climate challenge.

Keywords Co-production • Climate services • Adaptation • Climate-resilient development • Trans-disciplinarity

Introduction

Climate change is a complex, systemic risk and addressing it requires new knowledge. Although in recent years there has been a significant increase in the availability of robust climate information, this has not always translated into effective climate-resilient planning and adaptation. This is often because whilst climate information is being produced, it is not actually usable by decision-makers in practice—instead there is a "usability gap" (Lemos et al. 2012). Recognition of the usability gap has called into question the traditional modes of knowledge production. Rather than the dominant supply-driven models, whereby scientists produce information to fill a knowledge deficit, there is a need for producers and users of information to work together through sustained engagement and iteration to co-produce knowledge that is credible, salient and legitimate (Cash et al. 2003).

Co-production is increasingly promoted as a deliberate approach for increasing the usability of climate services by fostering partnership between "producers" and "users" to create a service that is effectively tailored and targeted (Bremer et al. 2019). The history of co-produced climate services is longer in developed countries, and the practice is still in infancy in the developing world (Kruk et al. 2017). Because it involves a range of partners co-producing context-specific information, there is no blueprint for co-production. In this chapter, we outline some principles to inform co-production of climate information. We then illustrate the experiences of three projects within the Future Climate for Africa (FCFA) programme, each co-producing climate information to inform medium term (5–40 years) planning in different contexts: agriculture and cities (African Monsoon Multi-disciplinary Analysis-2050, AMMA-2050), cities (Future Resilience of African Cities and Lands, FRACTAL) and the water-energy-food nexus (Uncertainty Reduction in Models for Understanding Development Applications, UMFULA) (including in partnership with a fourth FCFA project-Integrating Hydro-climate Science into Policy Decisions for Climate-resilience Infrastructure and Livelihoods in East Africa, HyCRISTAL). We end the chapter by discussing some of the more contextual challenges experienced in the three projects, such as trust, power, different knowledge systems and governance factors (mandates, roles and incentives), and how trans-disciplinary co-production has addressed these challenges to mainstream a response to the climate challenge.

Co-production in Climate Services

Whilst co-production is relatively new in the field of climate change, it has a longer history in other fields where producing salient, credible and legitimate information can be improved by the involvement of users in the process. Public service administration, science policy and science and technology studies, and participatory development are all fields in which knowledge co-production has been applied (Miller and Wyborn 2018).

In all cases, co-production blurs the boundary between "producers" and "users" of information that has typically characterised the linear supply chain. It also challenges the dominance of science and the (explicit or implicit) power differences that often result from those involved in the production or use of scientific outputs. This was a particular motivation behind the participatory turn in development that challenged the supremacy of outside technocratic interventions, instead putting beneficiaries—and their priorities and skills—at the centre of the process. Understanding how power is exerted within processes of knowledge-making and use, and with what effects, was also key to the growth of co-production in science and technology studies, where collaborative approaches to problem identification and solution are now a normative goal of much science policy (Wyborn 2015; van Kerkhoff and Lebel 2015).

Co-production can thus broadly be seen as a collaborative and inclusive set of approaches by producers and users to create usable knowledge to address complex issues such as climate change (Vincent et al. 2018). Also in contrast to the typical supply-driven knowledge deficit model, co-production is very much an iterative process, requiring regular engagement and trusted relationships between participating parties to be successful. Bearing this in mind, there is no silver bullet for co-production and it can rather be characterised by a number of principles.

Principles of Co-production

Various authors have proposed principles of co-production (e.g. Vincent et al. 2018; O'Connor et al. 2019; Norström et al. 2020). Here we outline ten principles of co-production for climate services based on the experiences in FCFA and beyond (Carter et al. 2019) (Fig. 3.1). These principles were derived collectively by five authors based on a review of existing academic literature and practical experiences across a variety of climate services contexts from across a range of climate resilience-strengthening programmes across timescales, including FCFA, and are therefore identified based on experience, or ex-post. They are outlined here before the next section illustrates how some of them were applied in FCFA projects.

Tailor to Context and Decision

Not only the process, but also the outputs of co-production should reflect the specific context and needs of the decision-making process being engaged. This means understanding the specific user need and decision-making context, designing engagements to fit within specific cultural contexts, understanding power dynamics and remaining cognisant (and sometimes humble) about the level of contribution that may result from the process.

Deliver a Timely and Sustainable Service

In the co-production of climate services, there may be conflicts in the time frames of interest to the various actors involved. Project managers will be dealing with project-related deadlines for the funders; farmers are concerned with time frames related to planting times and timely purchasing of

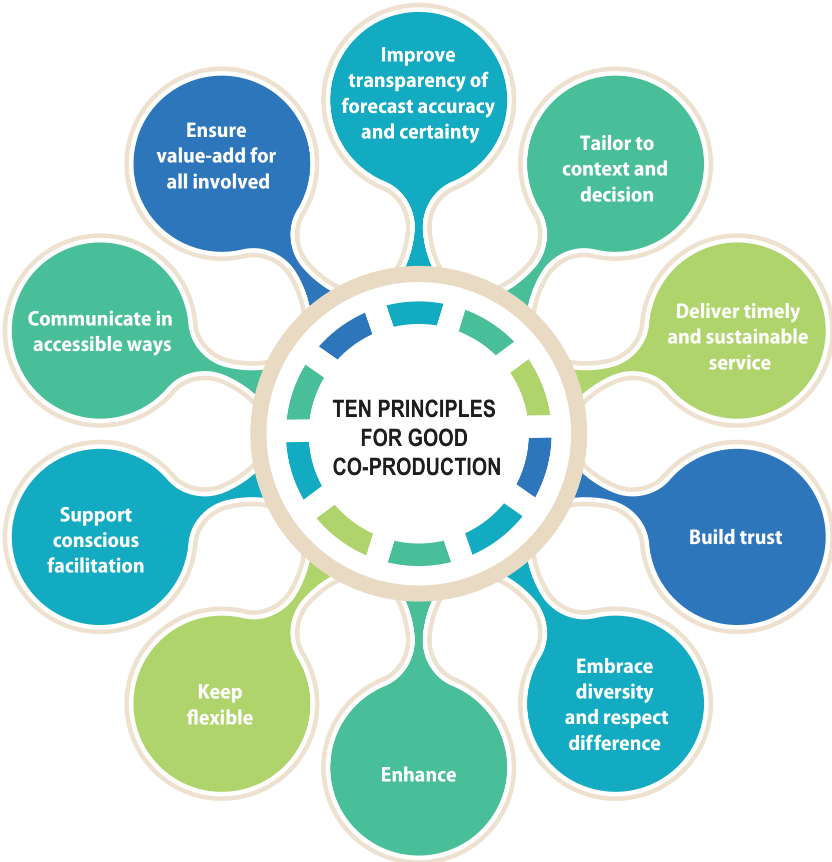

Fig. 3.1 Ten principles for co-production (Carter et al. 2019)

seeds; meteorologists are limited by access to required climate parameters (e.g. sea surface temperature); and policy makers are bound by bureaucratic process and policy development time frames. In order for climate services to be usable, it is also important to align time frames of the forecast to meet the time frames of the decision(s) it is intended to inform. Ensuring timely and sustained availability of funding is necessary to ensure that the process is not linked to a project lifespan.

Build Trust

Trust is the cornerstone to any lasting relationship, and is particularly important in co-producing climate services where a number of parties are coming together who may not normally collaborate. Building trust and equitable relationships takes time and often resources, but the resulting trust allows for an increasingly open sharing of ideas, opinions and knowledge needed to truly understand each other's worldviews, positions, strengths and weaknesses. Open dialogue about the intended process and outcomes of co-production is important to build trust. Without trust between partners, the co-production process is, at best, superficial and, at worst, detrimental to any future engagements and/or use of any products that may result from the process.

Embrace Diversity and Respect Differences

By definition, co-production involves people from different disciplinary and professional backgrounds, each bringing different knowledge and values. Extra effort is required to listen to others and to embrace the skills, ways of working and expertise that others bring to help understand the bigger picture. The benefits of working in a diverse group should be embraced from the beginning and an ethic of respect for differences should be fostered, taking into account that creativity may be required to enable everyone to feel comfortable to share their perspectives. That said, disagreement and debate should be encouraged (in a safe space) because they are often the starting point for new insights.

Enhance Inclusivity

Truly inclusive stakeholder engagement helps all participants of co-production feel valued and safe, regardless of their social characteristics and identities, such as gender, age, ethnicity, sexuality and language. Empathy is important; stakeholders should be encouraged to listen to others and understand their perspectives. This might involve being sensitive to historic privileges, prejudices and biases and doing things differently. For example, ensuring that women can participate might require that the timing, location and activities of meetings account for the social norms that typically restrict women's input. Without explicit consideration of inclusivity, there is a risk of excluding marginalised or less powerful groups. Inadvertent exclusion of certain user groups would likely reinforce inequality and produce information that is not usable in a particular context.

Keep Flexible

Co-production is often a non-linear and "messy" process that requires navigation of unknowns. Employing adaptive management, and having the flexibility to change plans, timelines and priorities along the way is critical for a successful co-production outcome. This is often complicated by the fact that diverse partners have varying other priorities and incentives; and the funding mechanisms that underpin co-production are also unlikely to be accustomed to dealing with the need for flexibility and the emergent nature of outcomes.

Support Conscious Facilitation

Addressing the need to build trust, be inclusive, thorough and flexible requires a process that diffuses power dynamics and hierarchies. It requires recognition of different worldviews and moving beyond the assumed superiority of 'objective' science, to a space where the variety of knowledges and experiences are valued and heard. Ensuring that the co-production team has members with these skills, or is able to bring them onboard as and when required, is essential.

Communicate in Accessible Ways

Establishing a common ground amongst the wide range of actors engaged in co-production requires awareness of the different jargons that each party uses and, in many cases, different languages. Co-developing universally understood terminology is important and requires active effort, for example, on the part of information producers, to communicate rather than simply disseminate their outputs. Communication requires an understanding of the way that people experience and perceive climate-related risks, the sources of information that they use and trust and the formats that are most accessible to them.

Ensure Value-Add for All Involved

Priorities across the wide range of partners that need to be engaged to co-produce weather and climate services may differ greatly. While researchers may prioritise publishing research, government decision-makers may be concerned with upcoming elections, while private sector bodies may be interested in commercial opportunities and those people directly affected have greater concern for meeting more immediate needs. Differing aims are more likely to be met if they surface early and the process manages to ensure that there is a shared prioritisation in meeting them.

Improve Transparency of Forecast Accuracy and Certainty

Many climate services involve forecasts and projections of a future state, and are inherently probabilistic. Clearly communicating the confidence and skill of climate information is essential so that it is credible and legitimate in the eyes of users, and does not raise false expectations. Strengthening decision-makers' understanding of key climate concepts and confidence in using probabilistic forecasts enhances capacities to not only use climate information appropriately, but also, more generally, for decision-making under uncertainty.

Case Studies

Three projects in FCFA employed a range of co-production approaches and we here consider how the approaches embraced the principles that were derived from reflecting on a wider range of projects. Not all of the FCFA projects applied all principles to the same extent—but here we consider how each applied various principles to co-produce climate information to enable adaptation and climate resilient-planning in Africa: in agriculture and cities (AMMA-2050), in cities (FRACTAL) and in the water-energy-food nexus (UMFULA) (including in partnership with a fourth FCFA project, HyCRISTAL).

AMMA-2050

AMMA-2050 aimed to co-produce information relating to the future functioning of the West African monsoon and how this could inform climate-resilient agriculture in Senegal and flood-resilient planning in Ouagadougou, Burkina Faso.

AMMA-2050 employed a suite of methods to support co-production of this climate information. Participatory Impact Pathways Analysis (PIPA) identified the specific problems to be addressed within each pilot, mapping key stakeholders and proposed pathways for addressing these. A serious game known as "Plateau" was used with farmers and farmer networks in Senegal's peanut basin, together with subsequent participatory modelling with (sub-state) regional decision-makers and agricultural researchers to ensure that a bio-economic model appropriately integrated key factors affecting small-holder farmers (Table 3.1). A play was developed encompassing key actors in climate adaptation, including the climate scientist, social scientist, local government, donor, farmer leader and farmers, reflecting key issues identified of concern to the various participants. Performances of the play, known as Theatre Forum and run by a local group, provided platforms for dialogue between key stakeholders in the adaptation process, including climate information producers, agricultural researchers, donors, national and local government and farmer groups (Table 3.1).

Collaboration with another project enabled AMMA-2050 to inform regional and sectoral reviews supporting the development of Senegal's National Adaptation Plan (NAP). Engagement with members of the National Assembly and the *Comité Régionale du Changement Climatique* (COMRECC), through stakeholder fora and Theatre Forum performances, enabled the project to inform review of national and regional development plans. In Burkina Faso, a *café scientifique* and ongoing consultations with Ouagadougou's mayoral offices and the Ministry of Town Planning and Housing enabled the development of Intensity Duration Frequency curves and flood-risk maps to inform city planning and infrastructural investments, with the project's outputs also acting as inputs to supporting Burkina Faso's NAP (Table 3.1).

FRACTAL

FRACTAL aimed to advance scientific knowledge about regional climate responses to human activities and to co-produce knowledge with relevant stakeholders to support resilient development pathways in southern African cities. FRACTAL aimed to do things differently from the start, focusing first on understanding the decision context and allowing climate

Table 3.1 Selected methods and techniques employed in FCFA projects to enable collaboration

Method	*Brief description*	*Project*
Participatory Impact Pathways Analysis (PIPA)	Comprising a series of tools, including problem tree analysis, network mapping, visioning and outcome logic models, PIPA is an adaptable approach through which partners jointly develop pathways to achieve agreed project aims	AMMA-2050
Games (including Plateau)	Serious games provide a space for experiential learning that contribute to unpacking relevant issues, grappling with different perspectives, understanding complex phenomena, as well as comparing terminology and concepts in a collegial environment. In the Plateau game, each plateau—or board—represents the fields of several farmers. Farmers choose their activities and allocate their resources, with output dependent on both their decisions and the 'climate card', giving rain distribution across the boards. Participants propose options on how to meet needs, including collaboration and potential policy interventions	AMMA 2050, FRACTAL
Participatory modelling	An exploratory space for decision-makers to test the impacts of different policies and actions and researchers to better appreciate decision-making contexts and learn about issues that needed to be considered in modelling	AMMA-2050
Theatre Forum	A performance is characterised by three main stages: (1) Actors play a story inspired by real facts and existing tensions between actors. (2) A moderator then invites debate to bring out feelings, interpretations and proposals to resolve tensions. (3) Spectators then come to replace one or more of the characters to test possible solutions and collectively discuss them. The other actors remain in character, improvising their responses	AMMA-2050
café scientifique	A world café, where researchers host a series of small-group discussion tables, each focused on sharing a specific decision-making tool or research output, while small groups of decision-makers move between the tables to discuss and provide feedback on each product	AMMA-2050

(*continued*)

Table 3.1 (continued)

Method	*Brief description*	*Project*
City learning labs	Facilitated events that bring together a broad range of stakeholders to constructively engage with complex 'burning issues' (Arrighi et al. 2016). Different knowledge types, experiences, emotions, identities and values of people from various backgrounds are equally valued in the learning labs. Facilitators include a variety of methods to support sharing of voices from as many stakeholder groups as possible	FRACTAL
High level breakfasts	Semi-formal events that aimed to share 'snapshots' from city learning processes (e.g. from the learning labs) with high-level decision-makers so that they have the opportunity to learn about and shape these processes	FRACTAL
Collaborative learning fora	Dedicated spaces in which researchers and stakeholders could come together to brainstorm and iterate emerging ideas on the form of the model	UMFULA

information needs to emerge over time. Co-production methods, implemented over three years, included exploratory city learning labs, field trips, games, roleplays, social evenings, training events, high-level breakfasts and very honest discussions about knowledge generation, evidence and assumptions (Table 3.1 (Arrighi et al. 2016). These methods supported a climate information distillation process described in Chap. 2. Together these activities enabled a space to co-define each city's unique issues, co-explore climate change risks and co-identify opportunities for resilience. Methods used in the co-production process included some that are less frequently used.

Stakeholders from local and national government, NGOs, research organisations and civil society groups generated knowledge on climate risks in the local development context of southern African cities through these trans-disciplinary co-production activities. This knowledge has variously been used in the cities. Lusaka's updated Strategic Plan (2017–2021), for example, integrates climate change considerations with explicit mention of FRACTAL in the acknowledgements from the Town Clerk (Chap. 7). Maputo Municipality is establishing an urban resilience hub and has requested specific support from their local university partner in the FRACTAL project. The City of Windhoek led the development of an Integrated Climate Change Strategy and Action Plan (ICCSAP) and, acknowledging the benefits of the integrated approach, decision-makers in Windhoek are hoping to institutionalise collaborative, co-learning platforms to continue exploring climate risks and solutions with a wide variety of stakeholders.

UMFULA

UMFULA aimed to address the "usability gap" between climate science producers and users to provide more useful and usable climate information to inform medium-term (5–40 year time frame) decision-making in the water-energy-food nexus in Malawi (and Tanzania), and medium- to long-term decision-making in the tea sector in Malawi (and Kenya with HyCRISTAL). The motivation for co-production came from consultation among producers and users in Malawi (Vincent et al. 2014). Government technical staff in the water sector (e.g. in the Ministry of Agriculture, Irrigation and Water Development) reported that they did not know how to use outputs from Global Climate Models, despite being motivated to act on climate change (Pardoe et al. 2018). The Department of Climate Change and Meteorological Services (DCCMS) also identified challenges they face in being able to meet increasing demands for information from government departments with a very slim organisational structure and significant pressure on staff resources.

Members of the UMFULA team worked with different stakeholders to co-produce three main outputs. Together with the DCCMS they developed future climate scenarios, the content and presentation of which was informed by users' needs (Mittal et al. 2017). Together with the Ministry of Agriculture, Irrigation and Water Development, and other stakeholders concerned with water availability, they co-produced an open access Water Evaluation And Planning system (WEAP) model that projects future water availability under a range of socio-economic and climate scenarios (Bhave et al. 2019). This partly took place through collaborative learning fora (Table 3.1). They also co-produced tailored information for the tea sector in Malawi and Kenya, focusing on crop- and location-specific climate metrics of interest, namely the future risk of heat stress (defined as five consecutive days exceeding 35 °C in Malawi, and exceeding 27 °C in Kenya) (FCFA 2019).

Identifying and Overcoming Challenges

Although each project worked in different contexts, co-producing climate information using different methods, reflection by the authors as participant observers in the co-production processes, together with more formal evaluation of the tools, showed that they all encountered a number of similar issues. These included trust; power and the challenge of representing different forms of knowledge; and institutional factors: roles, mandates and incentives.

Trust

Building trust is a critical component of co-production, as outlined earlier, yet has its challenges. Trust was built in various ways by the three projects presented here. Since the co-production process is time- and labour-intensive, to a certain extent trust accrues passively throughout the time of repeated engagements and as interpersonal relationships are built. In UMFULA, for example, one of the criticisms that arose early on was that representatives of many scientific research projects would appear at the start of their time frame and then not be heard from again until the end of the project. To avoid this, the team undertook an early process of stakeholder mapping which not only included identifying who had an interest in the climate information and the nature of their interest, but also how they would like to be kept engaged over the four-year duration. One-page updates were produced every six months and distributed as per stakeholder preferences (e.g. electronic or hard copy) and team members made a concerted effort to keep in touch with those people that had stated preference for face-to-face contact. Interpersonal relationships are a prerequisite for trust, and a key component of the credibility of a process, but co-producing climate information also requires building of trust in the generation and use of the information itself.

Trust in the legitimacy of information is particularly important, given the scientific complexity of climate information and the uncertainty that is embodied in generating future projections. This requires meaningful and relevant communication of the uncertainties within climate information, and evaluating levels of understanding to assess the effectiveness of communication approaches employed (Harold et al. 2019). Having identified low levels of confidence in the ability of key stakeholders to understand climate projections led UMFULA to produce a series of short briefs directly addressing challenges identified by users, for example, "Climate models: what they show us and how they can be used in planning" (FCFA 2016) and "How to understand and interpret global climate model results" (Conway et al. 2017). These increased the confidence of the stakeholders to engage in further discussions around climate information. In contrast to UMFULA, AMMA-2050 and FRACTAL have employed different methods to strengthen decision-makers' understanding concerning key climate concepts. AMMA-2050 supported direct dialogue between climate information producers and decision-makers. This included a workshop on climate information held in Burkina Faso in partnership with another resilience-building programme to support local government planning and a meeting with Mayors and Ministry representatives. FRACTAL conducted learning labs and placed embedded researchers in each city's planning department, enabling ongoing dialogue, including capacity to answer questions relating to the generation, use and limitations of climate information (Chap. 7).

Successfully building trust through interpersonal relationships and credibility of information was not without challenges. Turnover of staff in planning positions in government (sectoral ministries or city administrations) is relatively rapid. Confronting fluidity of participants within the co-production process meant that progress was not always linear. It was also time- and resource-intensive to develop and maintain the trust required for effective co-production.

Power and Respecting Different Forms of Knowledge

For co-production to be successful, the process needs to recognise and embrace different forms of knowledge (e.g. scientific, indigenous and experiential) and flatten the power hierarchies that usually accord relatively different levels of value to those different knowledge systems. What makes these power differences particularly difficult is that the values and (mis)perceptions come from all parties. In our cases, by virtue of being interested in co-producing climate information, there was typically an awareness and openness on the part of the "producers" of climate information to other forms of knowledge. However, having seen the greater value placed by society on scientific knowledge, the "users" may inadvertently also assume superiority of those knowledge systems, even if those engaged in that system did not perpetuate it. Sometimes this results in a co-production process having to address the expectation from users that producers uniquely have the answers to solve their problems. In short, all parties need to be aware of different ways of knowing and being in the world, and be willing to question the dominant modes to actively co-produce knowledge together.

Different ways of engaging can help to address these power imbalances, with the innovation of the engagement forum signalling a change from the norm in knowledge systems. If a meeting room is set up with a projector and producers talking to users, for example, it can reiterate the superiority of science (as well as being insensitive to the cultural specificity of participation, e.g. Roncoli et al. 2011). All three FCFA projects tried to create these new spaces to sidestep existing (mis)perceptions of power dynamics, by emphasising the importance of collective learning in spaces where equality and inclusion of opinions was promoted, with UMFULA holding collaborative learning fora and FRACTAL holding learning labs. AMMA-2050 employed PIPA and Theatre Forum to support a level platform for dialogue between different stakeholders. Performances of the play with different audiences—including members of the National Assembly, the *Institut Sénégalais de Recherches Agricoles* (ISRA), with (sub-state) regional decision-makers and farmers' networks—provided opportunities to identify and explore different perceptions, priorities and potential solutions.

Knowledge systems are one element of power, but the experience of co-producing climate information identified other elements of relational power that are socially constructed and culturally specific. Attempting to flatten power hierarchies in knowledge systems is embedded within relational power systems in which that knowledge plays out. Hierarchies are often very important in governments in sub-Saharan Africa (e.g. Pardoe et al. 2018). FRACTAL experienced some tensions during engagements when attempts at levelling the playing field led to researchers using language to address government participants in the room that was sometimes too familiar or casual and disrespectful of their status. In UMFULA, the team adopted multiple layers of engagement: in addition to regular technical discussions, senior researchers would liaise with directors to maintain high level strategic links (and the required support for the continued success of the technical links).

In short, dealing with power issues, whether they be related to knowledge types, work or cultural norms, gender or historic oppression, might require uncomfortable conversations and careful facilitation. These should be seen as part of the co-production process, and a critical prerequisite for co-production to proceed effectively.

Institutional Factors: Roles, Mandates and Incentives

Co-production requires a different way of operating, which does not always sit easily with existing institutional mandates and incentive structures. The process is so critical to the product (in the form of usable climate information) but is very time-consuming and labour-intensive. This creates demands on both the side of the user and the producer. For the user, co-production creates significant demands on already-pressured staff resources in public sector environments; whilst for the producer, the incentive structures and recognition (for promotion and professional development) do not yet provide sufficient recognition of knowledge exchange activities (Dilling and Lemos 2011; Norström et al. 2020).

In UMFULA, commitment to the co-production process was shown by the nomination of a formal desk officer within the DCCMS in Malawi, which played a key role in ensuring partnership with the national meteorological and hydrological service, and also signalled government commitment to other departments who were variously involved in co-producing climate information (e.g. various departments in the Ministry of Agriculture, Irrigation and Water Development). However, significant pressure on limited resources within the DCCMS meant that the nominated desk officer was not always available. FRACTAL experienced a similar issue with their learning labs where, at least in the early days before the utility was proven, there was inconsistent participation which impeded their effectiveness (due to the need to retrace steps). In addition to pressure on limited resources, the key tasks and performance indicators for government staff also meant that attending engagements took time away from their core roles and, in the case of emergency situations (e.g. being summoned by a minister), that would take priority over their participation in co-production. To a certain extent, building trust and ensuring the multiple levels of engagement (including senior researchers with directors) acted to mediate this risk by increasing support and ensuring consistency of participation in engagement processes. In AMMA-2050, two partnering research institutions, ISRA and the West African Science Service Centre on Climate Change and Adapted Land Use (WASCAL), recognised the need to ensure dedicated institutional capacity for science-policy and for researchers to have the tools and training to effectively engage with decision-makers.

Conclusion

Co-production requires a new way of operating that challenges norms of knowledge production and the dominance of scientific knowledge systems, instead recognising that user involvement to co-produce knowledge is essential for addressing the climate change challenge. AMMA-2050, FRACTAL and UMFULA all aimed to co-produce climate information for different sectors in different contexts with the aim of improving usability. Illustrating the principles for co-production outlined here, each project applied various methods and techniques which led to increased demand for, and discerning use of, climate information for decision-making.

The process of co-production, and the application of the principles, creates a number of challenges. The experience of three FCFA projects highlighted priority challenges in terms of trust, power and respecting different forms of knowledge, and the role of governance factors—roles, mandates and incentives. Building trust, addressing power and respecting different forms of knowledge require individual commitments to do things differently. But more than individual commitments, institutional change is required to create a conducive environment for co-production to take place (Turnhout et al. 2020).

Research institutions currently insufficiently recognise investments in supporting the understanding and appropriate use of climate products and services through co-production. While this is changing, for example, through the UK Research Excellence Framework and donors' requirements for climate resilience consortia to demonstrate the socio-economic value of research investments, there remains a need to review the way in which their impacts in strengthening climate resilience are monitored and evaluated. To justify investment, it is important to monitor impacts across the co-production process, as opposed to solely the final project output. This monitoring should consider impacts that are often intangible, such as strengthening of personal and professional relationships leading to ongoing collaborations, creating an open flow of information between producers and users of climate information, awareness raising, fostering ownership of climate services products by their users and behavioural change with regard to the use of climate services (Carter et al. 2019). These "soft" changes may lead to more tangible outcomes such as increased institutional investment in science-policy and stakeholder engagement, as well as job promotion for researchers championing co-production efforts (Visman 2019).

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CHAPTER 4

Decision-Making Heuristics for Managing Climate-Related Risks: Introducing Equity to the FREE Framework

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Abstract Managing climate-related risks is clouded in differing levels of uncertainty that are magnified when trying to understand their potential impacts on socio-ecological systems. The 'cascade of uncertainty' is

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particularly apparent in Africa where socio-ecological data are sparse, and the development and validation of impact models are at varying stages. In this context, using heuristics may serve as an effective way for policy makers to incorporate climate change knowledge into decision-making. Previous scholarship has identified the principles of Flexibility, Robustness and Economic low/no regrets in decision-making under uncertainty. In this chapter, we first make the case for adding Equity to these heuristics, where equity involves ensuring that reducing the climate change risk for one cohort of society does not result in its increase for another. Second, we describe how these principles have been applied under two DFID/NERC funded projects: ForPAc and AMMA-2050 through the use of Participatory Impact Pathways Analysis tools.

Keywords Climate change • Heuristics • Uncertainty • Equity • Decision-making

Introduction

Attempts to reduce climate risks on society need to consider the issue of uncertainty. Weather and climate[1] information has the potential to inform climate-risk management efforts drawing from historical observations, model ensembles of current climate, through short-term weather forecasts to seasonal forecasts and future climate scenarios. Different climate information has different degrees and sources of uncertainty. For example, short-term (e.g. daily to weekly) forecasts are inherently probabilistic due to the atmosphere's chaotic nature, while uncertainty at climate change timescales arises from model uncertainty, emission uncertainty and natural climate variability (Stainforth et al. 2007; Chap. 2). This uncertainty not only varies with the lead-time of the forecast or projection but the parameter of interest, region and the spatial and temporal scale of forecasting product.

The different uncertainty levels in forecasts and scenarios of future weather and climate magnify when trying to understand the impact these changes will have on socio-ecological systems (Daron et al. 2015). The

[1] Hereinafter weather and climate will be referred to simply as 'climate'.

compounded effects of uncertainty on efforts to identify risk and adaptation options are often referred to as the 'cascade of uncertainty' (Wilby and Dessai 2010). The cascade of uncertainty is particularly apparent in West and East Africa where socio-ecological data are relatively sparse and development and validation of impact models are at varying stages. This uncertainty often results in the view that resolving climate-related risk is a complex and even wicked problem where the solutions are not easily, if at all, solved analytically. In the context of such complex problems, decision-making using heuristics (approximate guidelines based on experience) use climate science to bound rather than optimise decisions. Using heuristics to inform decisions often serves as the most effective and sometimes only way for policy and decision-makers to incorporate climate information and knowledge into their thinking and action.

Previous scholarship has identified the principles of Flexibility, Robustness and Economic low-regrets when making decisions within the context of uncertainty (Wilby and Dessai 2010; Ranger et al. 2013; Maier et al. 2016). Accordingly, the principle of *Flexibility* involves making decisions that can be changed as new climate information evolves; *Robustness* involves decisions that may lead to positive outcomes across a range of scenarios and forecasts; and *Economic low regrets* decisions are ones that attempt to negate the possibility of minimal or zero returns in the future at the expense of investment in other priorities in the present (Ranger et al. 2013).

Here we firstly make the case for adding *Equity* to these principles to make the mnemonic FREE (Flexible, Robust, Economic no/low Regrets, Equitable) to guide decision-making around climate risk. We focus on equity both in ensuring that reducing the weather and climate change risk for one cohort of society or one element of the ecosystem does not result in transferring or increasing risks to another and in its role and value in inclusive decision-making. The second part of the chapter describes Participatory Impact Pathways Analysis (PIPA) and considers the extent to which this approach has been able to support application of the FREE principles, leading to more equitable and inclusive decision-making across timeframes, within two research projects: Towards Forecast-Based Preparedness Action (ForPAc, https://www.forpac.org/) and African Monsoon Multidisciplinary Analysis-2050 (AMMA-2050, https://www.amma2050.org/).

The FREE Framework of Heuristic Decision-Making

The Intergovernmental Panel on Climate Change (IPCC) states in its Fifth Assessment Report (WGII AR5) that in Africa 'Climate change [will be] a multiplier of existing health vulnerabilities (high confidence), including insufficient access to safe water and improved sanitation, food insecurity, and limited access to health care and education' (Niang et al. 2014, p. 1202). The IPCC places Climate Risk Management at the centre of attempts to adapt to climate change impacts such as these. Integrated in the concept of 'risk' is the acknowledgement that future climate change is uncertain. Uncertainty in planning for climate change arises not only from our incomplete knowledge of climate processes and the inability to model them but also from unknowns as to which pathways society will choose in terms of the emissions of greenhouse gases. Uncertainty also arises in how climate-related stresses and shocks will impact socio-ecological systems and how these will respond to, reduce, or magnify risk.

A variety of strategies are being used in African countries to manage the impacts of climate-related hazards at the household, community, national and regional levels. These include early warning systems, risk transfer schemes, social safety nets, disaster risk contingency funds and budgeting, livelihood diversification and migration (Niang et al. 2014; UNISDR 2011). Climate science offers both short-term forecasts and mid- and long-term scenarios of climate hazards to help inform these strategies. However, even in cases where the climate science is relatively advanced and the frequency and intensity of climate hazards are quantifiable (e.g. short-lead weather forecasts), climate science is unable to eliminate all the uncertainty. For example, there is still uncertainty associated with quantifying the climate hazard impact on socio-ecological systems. Furthermore, it is recognised that many of the impacts of climate variability and change are indirect, interconnected and poorly quantified. In this context, a set of common assumptions may help, and heuristic reasoning can be employed (Preston et al. 2015).

Heuristics are commonly used in decision-making when the problem is complex and does not lend itself to linear analytical approaches that attempt to calculate the optimal and most economically efficient solution to a problem. Instead, heuristic-based decision-making aims to support practical operationalisation and effectiveness. Commonly, decision-making heuristics, or rules of thumb, are developed individually, based on actors' framings, experience and knowledge (including scientific knowledge), but are also discussed collectively and can evolve through social learning (Agrawal et al. 2009). While rules of thumb are usually based on experience and strongly influenced by scientific evidence, they are also formalised and critiqued in grey literature such as practitioners' guides, policy documents and in peer-review articles (Lorenzoni et al. 2000; Preston et al. 2015). The following section outlines four principles for framing heuristic-based decision-making to reduce climate-related risks.

Flexible, Robust, Economic No/Low Regrets and Equitable (FREE)

A key aspect of heuristic-based decision-making for climate risks is the ability to link short-term actions to longer-term pathways, which is at the core of sustainable climate-resilient planning. Policy makers and governments tend to have more political will to act when faced with a disaster, and that is no different in climate-related emergencies. However, governments are often faced with longer-term planning decisions, including infrastructure and spatial planning. In such contexts, flexibility is strengthened through engaging with diverse stakeholders across scales and managing time-sensitive decisions in ways that, at the same time, support sustainable adaptation plans. Yet this is constrained by uncertainty regarding the scale and direction of future climatic changes and variabilities (Pielke et al. 2012). This uncertainty leads to multiple and diverse possible consequences on complex socio-ecological systems (Daron et al. 2015). Ranger et al. (2013) suggest that adaptation pathways should be able to cope with climate risks in uncertain future scenarios by building flexibility to change over time as more is learned or conditions change.

Recognising the deep uncertainty entailed in managing climate-related risks also underscores the importance of robust reasoning in decision-making. The principle of 'Robustness' requires that risk management strategies should perform well against most sets of future conditions and ideally include options for several contexts (Ranger et al. 2013). Decisions may need to account for a range of forecasted conditions that span an important threshold. In West Africa, scenarios of future rainfall change span both an increase and a decrease in rainfall. However, while at first sight this might seem to present too wide a range of possible futures for planning, research by AMMA-2050 has shown that due to the unidirectional increase in temperatures with climate change, irrespective of the sign of rainfall change, crop yields will likely decrease with climate change

(Roudier et al. 2011; Sultan et al. 2019). Despite this seeming certainty, the magnitude of future change is still highly uncertain.

Heuristics for managing climate-related risks also need to consider the degree to which proposed action supports no or low regrets (collectively termed ‘Economic low regrets’), addressing both current and future risks or providing co-benefits for other issues of concern. The IPCC defines no-regrets options as plans or policies that can generate socio-economic benefits whether forecasted climate changes occur or not. For the purpose of this chapter, economic low and no regrets options focus on actions that acknowledge current economic limitations while offering opportunities to build future resilience (Watkiss et al. 2015). For example, natural ecosystem-based flood control exemplifies a low or no regrets options where there are immediate environmental benefits irrespective of future climate change. However, other actions may entail significant trade-offs between objectives and sectors, such as conflicting demands between environmental protection and the need for new housing or economic development. Ranger et al. (2013) suggest that a holistic approach, whereby adaptation planning is mainstreamed into decision-making across different levels and sectors of the government, is a way forward. It is also important that adaptation is not seen in isolation but as part of sustainable development, where potential synergies and trade-offs are considered across a broad range of risks, opportunities, objectives, measures, and timeframes. Consideration of low and no regrets actions across timeframes enables short-term actions to be considered as part of a longer-term preparedness and sustainable adaptation planning processes.

Robust, flexible, and economically low and no regrets decision-making heuristics provide the basis for a comprehensive approach to address the complexity of climate change adaptation planning. These approaches have largely been framed within the context of economic capacity. However, it is unlikely that economic investments or interventions will effectively address climate risk management unless they can characterise how direct and indirect risks, costs and benefits are distributed within a society and across an ecosystem. It is widely acknowledged that economic analyses of the costs and benefits of potential interventions need to be combined with social analyses to understand the potential and sometimes unexpected impacts of planned activities. In making explicit the trade-offs between sectors, timeframes and social groups, heuristics to support climate risk management must also include the principle of equity. Recognising the importance of inclusivity, the equity heuristic ensures that climate risks are not simply passed onto more marginalised members of society, displaced to other components of the social-ecological system, or indeed transferred from current to future generations.

Inequities are exacerbated by climate extremes. The literature on disasters and development recommends that factors such as gender, age, race, and ethnicity as well as socio-economic status and social capital are key to individual and collective vulnerability to disasters (Shreve 2016). Such factors, in turn, influence the ability to benefit from interventions and ultimately the capacity to be resilient in the face of climate change. Successful and sustainable climate risk management will ultimately depend on how different institutions address equity, considering social and cultural contexts, representing all at-risk groups, and recognising the diverse ways in which people may be affected by climate-related risks and adaptation interventions. The next section explores how FREE factors have been used in different projects to support sharing climate information between science and policy actors.

Communicating Climate Information Across Science and Policy and FREE

It is widely recognised that climate information uptake is limited in many developing countries. The lack of uptake has previously been attributed to the 'usability gap' (Lemos et al. 2012). A variety of reasons for the usability gap have been put forward (see also Chaps. 1–3), including

- a lack of credibility, salience, and legitimacy of climate information and climate information producers (Cash et al. 2003);
- a lack of capacity, institutional arrangements and resources amongst users to capitalise on this information (Lorenz et al. 2017);
- mismatched terminology used by scientists and decision-makers to describe the types of information that are available and needed for problem solving (Daly and Dilling 2019);
- unrealistic expectations regarding the development of climate information products for problem solving (Briley et al. 2015); and
- non-conducive organisational culture and individual reward structures to using climate information (Dilling and Lemos 2011).

Equally a number of facilitating processes, structures and actors to improve the use of climate information have been described, including co-development, co-production, knowledge networks, social learning, and communities of practice (Chap. 3; Lemos et al. 2012; Leitch et al. 2019); as well as information brokers, boundary organisations and chains, embedded capacity and collaborative group processes (Dilling and Lemos 2011; Kirchhoff et al. 2015). Scholars have discussed barriers and opportunities to close the usability gap and increasing attention has been paid to describing the steps needed to help facilitate the use of climate information and knowledge (Singh et al. 2018; Carter et al. 2019), including addressing inequities in the partnerships and processes employed (Daly and Dilling 2019; Vincent et al. 2018; Turnhout et al. 2020). This section considers the application of FREE heuristics in enabling emerging climate science to strengthen climate-resilient decision-making using PIPA, as illustrated within the two projects, ForPAc and AMMA-2050.

Participatory Impact Pathways Analysis (PIPA)

Designed to enhance a project's developmental impact through better impact assessment,[2] PIPA is a project management tool that enables stakeholders affected by research to jointly identify a shared vision of the impact of the research and co-develop pathways to achieving it. As a first step, it aims to understand the determinant causes of a research problem from multiple perspectives with participants from a range of stakeholders developing problem trees of the issue(s) in focus. The incorporation of a diversity of stakeholders is key to attempts to incorporate equity into the research. By including marginalised groups, the issue of how negative outcomes can be transferred from one group to another can be explored, and hence the issue of equity raised. Participants subsequently undertake a visioning exercise, designed to agree on an overarching aim of continued engagement. The stakeholders then develop network maps, firstly depicting existing relationships between multiple stakeholder types, before creating 'future' network maps, identifying additional actors and stakeholder linkages required to achieve the shared project vision. The process makes explicit the project's impact pathways, developing an Outcome Logic Model identifying the changes in practice, knowledge, attitudes and skills

[2] Link to the PIPA wiki page: http://pipamethodology.pbworks.com/w/page/70283575/Home%20Page

required to achieve the shared project aim. The PIPA process offers a vital opportunity for joint reflection between researchers and societal partners on how to scale co-production products and processes out across relevant institutions and up, supporting transformative changes through social learning, advocacy and policy change.

PIPA is well-suited to supporting inclusive approaches to strengthening climate resilience. The approach (1) recognises the need to listen to people's different framings of the risks that climate poses; (2) encourages inclusive participation in decision-making; and (3) co-develops pathways to achieve strengthened climate-resilience (Fox and Kniveton 2018). The approach is sufficiently flexible to be adapted with additional and complementary methodologies and can be modified according to the goals at a certain point of a project. This allows for several iterations of PIPA over the course of the project, each creating spaces for formal and informal discussions that lead to collective and transactional decision-making. The following sections explore how PIPA has supported flexible, robust, economic (no and low regrets) and equitable climate-resilient decision-making in projects focused on differing timescales in both urban and rural contexts in Kenya and Burkina Faso.

Towards Forecast-Based Preparedness and Action

Guided by the Sendai Framework for Disaster Risk Reduction, humanitarian organisations are increasingly seeking to enhance mitigation and preparedness for climate-related risks. Forecast-based Action (FbA) is a set of loosely associated approaches to support the use of forecasts in undertaking relevant early actions for at-risk communities in resource-constrained contexts. They are similar in design to early warning systems in terms of forecasting and communication of possible threats but place more emphasis on protocols, so actors know what to do based on a range of forecasts (Wilkinson et al. 2018). Recognising the inherent uncertainty in forecasting potential disasters, FbA approaches attempt to help decision-makers take into account the costs and benefits of anticipatory actions and forecast-driven false alarms. While FbA approaches attempt in theory to provide an economically defensible rationale to making a decision on whether to invest in preparedness or mitigation actions based on a forecast, in practice they are often difficult to implement because disasters tend to be unique and the losses, including the quantification of cascading risks, difficult to determine.

Funded by the Science for Humanitarian Emergencies and Resilience (SHEAR) Research Programme, ForPAc seeks to improve forecasts at different lead times and strengthen forecast-based action for flood and drought hazards in Kenya. It seeks to support anticipatory decision-making in three case studies: (i) the Drought Early Warning System (DEWS) in Kitui County, (ii) urban flooding in Nairobi and (iii) the flood early warning system in the Nzoia river basin. In a series of workshops, PIPA was employed to consider how climate forecasts can better support existing drought preparedness decision-making for Kitui County. This follows the national DEWS process but is managed by a County Steering Group (CSG), comprising the National Drought Management Authority (NDMA), key ministries of the Kitui County government, humanitarian and development partners and the Kenya Meteorological Department County Director of Meteorological Services.

Alongside problem tree analysis, visioning and stakeholder mapping to strengthen researchers' understanding of the decision-making context, PIPA and a subsequent climate information training workshop included exercises to strengthen decision-makers' understanding of key climate concepts, including forecast uncertainty, as well as their confidence in using probabilistic forecasts within drought decision-making. Drawing on Participatory Integrated Climate Services for Agriculture (PICSA) (Dayamba et al. 2018) and the principle of Economic no/low regrets, the project also integrated within PIPA a tailored preparedness options matrix. Mapping initial phases of drought and forecast timeframes with preparedness actions and levels of investment to identify the forecast probability thresholds required to activate actions (see Table 4.1) highlighted the potential for triggering low-cost preparedness actions (e.g. awareness-raising, advocacy and prepositioning of stocks) at longer lead times. Discussion on the completed matrices made clear that marginal mixed farming in arid areas experiences water scarcity even in seasons of 'normal' rains, requiring minimal probabilities of below normal forecasted rainfall to justify investment in preparedness.

PIPA employed a tailored version of stakeholder mapping, with participants identifying the key steps in the drought decision-making process, the actors engaged, and climate information being employed at each step in the process. This mapping made clear that the climate information is not currently informing several key steps within the DEWS process, including drought contingency planning, monthly bulletins and seasonal assessments. Operationalising the principles of flexibility and robustness,

Table 4.1 Preparedness options matrix combining initial drought phase classification, preparedness actions at three- and one-month lead times, required forecast probability, level of investments, institutional leads and funding sources, as well as challenges

Drought phase	*Preparedness action three months onset*	*Preparedness actions one month onset*	*Probability threshold (Level of forecast probability of below normal rains required to take preparedness action)*	*Required level of investment*	*Organisational leads*	*Sources of financing*	*Risks and challenges*
Normal	• Assess the condition and service boreholes • Water trucks and stock piling of parts • Post-harvest management capacity building • Soil and water conservation • Roof catchment • Road runoff • Pasture conservation awareness • Drought tolerant crop awareness • Water, Sanitation and Hygiene (WASH) awareness	• Service strategic borehole and water trucks • Raise awareness on drought tolerant crops to agro-dealers to stock • Procure and distribute drought tolerant seeds for most needy cases • Livestock disease surveillance • Destocking (Voluntary) • Prepositioning of hay • procure and distribute water treatment chemicals • Land preparation • Advocate early planting • Human Disease Surveillance of vulnerable groups	• Marginal mixed farming: 30% • Mixed farming: >50% Kitui County has two principal livelihood groups: marginal mixed farming in arid area and mixed farming in semi-arid zones	Low to Medium	NDMA and County government of Kitui	• County government • Development partners • NDMA (Normal Operations)	• Bureaucracy • Political goodwill • Timely action • Institutional co-ordination

(*continued*)

Table 4.1 (continued)

Drought phase	*Preparedness action three months onset*	*Preparedness actions one month onset*	*Probability threshold (Level of forecast probability of below normal rains required to take preparedness action)*	*Required level of investment*	*Organisational leads*	*Sources of financing*	*Risks and challenges*
Alert	• Servicing strategic boreholes • Raise Drought Tolerant Crops (DTC) awareness • Human and livestock disease surveillance • Destocking (Voluntary) • Prepositioning of hay • Prepare Advisories (All sectors) • Roof catchment • Procure and distribute water treatment chemicals	• Preposition spare parts for boreholes and water trucking • Procure and distribute DTCs to most needy • Intensify disease surveillance • Conflict awareness • Enhance school feeding programmes	• Marginal mixed farming: 30% • Mixed farming: 30%	Medium	NDMA and County government of Kitui	• County government • Development partners • NDMA (Normal Operations)	• Political goodwill • Timely action • Institutional co-ordination

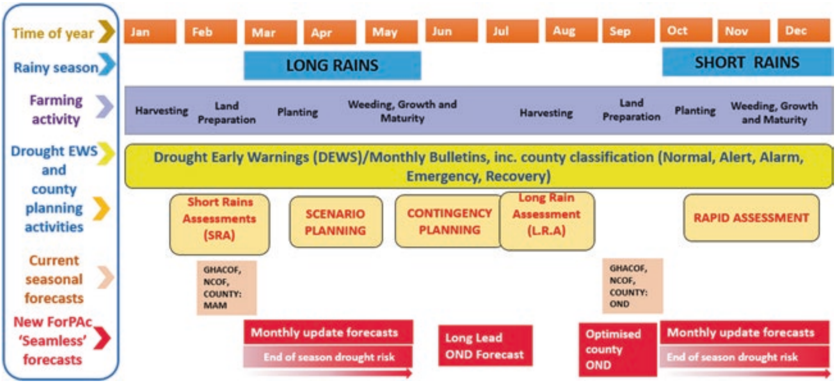

Fig. 4.1 Schematic showing seasonal: rains, farming activities, drought management activities, provision of climate information and key entry points where ForPAc seamless prototype forecast products could strengthen drought management and preparedness

PIPA analysis identified windows of opportunity for providing enhanced forecasts that could activate earlier drought mitigation and preparedness actions (see Fig. 4.1), and how climate information could better support each step within the DEWS process.

Working with the Kitui CSG, the project co-produced a suite of prototype products, including a long-lead seasonal forecast, an optimised seasonal and monthly forecast and a Standard Precipitation Index (SPI). These prototype forecast products were piloted for the 2019 October, November and December rains with decision-makers to consider what different preparedness actions could be applied recognising the probability and skill of the forecasts. Preparedness actions that aligned with the FREE principles, for forecasts, in this instance, indicating a 45–60% probability of above average seasonal rains, included: planting more maize than usual, vaccinating livestock against Rift Valley Fever, WASH sensitization, and desilting of water pans. ForPAc products were prototypes, and not yet official Kenya Meteorological Department products; because government ministries require official forecasts to justify action, some of the actions were taken and some remained proposed. While an effective framework for supporting elements of FREE, consideration of equity within PIPA could have been strengthened through participation from those people whose lives and livelihoods are directly affected by climate-related risks, thus enabling identification of innovative preparedness measures beyond those included within the County's existing Contingency Plan.

Strengthening Flood-Resilient Urban Planning in Ouagadougou, Burkina Faso (AMMA-2050)

Focused on enhancing understanding about High Impact Weather events to inform medium-term (5–50 years) decision-making in West Africa, the AMMA-2050 project has undertaken two pilot studies (in Burkina Faso and Senegal) to examine how tailored climate information can better support specific climate-sensitive decision-making processes. In Burkina Faso, partners have sought to strengthen flood-resilient urban planning for the capital, Ouagadougou, particularly within planning for the city's development, 'the Grand Ouaga plan,' in which participatory consultation has been limited.

PIPA was employed in both pilots to enable exploration of the views of different stakeholders, identification of additional partners who could support the aims of the project, and development of 'road maps' supporting a range of co-production processes led by different AMMA-2050 partners (Carter et al. 2019; see Chap. 3). In Burkina Faso, PIPA was used at different points of the project, to ensure different actors had spaces to discuss the FREE heuristics in relation to potential actions and outputs of the project. At the beginning of the project, in 2017, AMMA-2050 organised a joint workshop with the Building Resilience and Adaptation to Climate Extremes and Disasters (BRACED) Zaman Lebidi project, funded by the UK Department for International Development. The workshop focussed on how weather and climate information could support local government decision-making.

Prior to the PIPA problem tree process and visioning and stakeholder mapping exercises, the workshop promoted the equity principle through establishing a common ground amongst participating local government representatives, development actors, the national meteorological agency and partnering researchers. In this process, the local government decision-making context for mayors in rural and urban contexts was outlined, before providing an overview of key climate concepts and existing climate information services. Following this, participants engaged in a scenario exercise designed to strengthen decision-makers' confidence in using a range of climate products and support dialogue between decision-makers and technical experts. Simulating the difficulties of making appropriate use of climate information within commune-level decision-making processes, the exercise exemplified constraints in operationalising the heuristics of flexibility and robustness. In the final session of the workshop, AMMA-2050 and BRACED partners outlined how their projects could respectively strengthen effective use of climate information within local government decision-making. From this basis, AMMA-2050 then developed an Outcome Logic Model to guide the project's pilot in Ouagadougou. Most immediately, the PIPA Stakeholder mapping highlighted to AMMA-2050 partners the value of ensuring sustained engagement with local and national decision-makers. This resulted in the appointment of a dedicated focal point to ensure a channel for ongoing interaction with key stakeholders. While AMMA-2050 was focused on strengthening medium-term decision-making, stakeholders highlighted the need to also address more immediate climate-related risks. Consequently, partners developed an awareness raising pamphlet with advice on flood-preparedness and response, simultaneous with developing technical briefs on tools for supporting longer-term planning.

PIPA was also employed at the end of the project, in a very similar format. Participants coming from various branches of local and national government were asked to reflect on the impacts of AMMA-2050 on relevant policies and activities, focusing specifically on how project outputs could have contributed to reducing the usability gap in climate information. The stakeholder mapping highlighted complexities in hierarchies and scale that were acknowledged over the course of the project but never made explicit and discussed potential strategies for addressing those in a future, advocacy-focussed part of AMMA-2050. Flexibility and robustness of approaches was put forward as a key element of successful outputs; equity was mentioned especially in ensuring that approaches would not benefit a part of society while increasing risks for another. This workshop resulted in discussions among the societal partners focussing on the issue of bottom-up and top-down interventions, the potential of citizen-led action combined with project- or government-led ones, as well as the possibility of linking some more immediate flood awareness-raising initiatives to long-term national adaptation policies.

The participatory approaches employed by AMMA-2050 have offered spaces and illustrated ways of supporting more inclusive planning, including within the development of the Grand Ouaga plan, and the importance of recognising risks across decision-making levels and timeframes.

The use of PIPA in AMMA-2050 provided a shared learning experience for researchers and decision-makers to explore together how weather and climate information can better support local government decision-making. In doing so, it was an opportunity to practice the FREE heuristics and draw expertise for more integrated approaches to strengthening climate resilience. For participating early career climate scientists, the workshop provided a first experience to consider how their research could practically support decision-makers' concerns.

Discussion of FREE as Framework to Support Climate-Resilient Decision-Making

The underlying premise of using heuristics to support climate risk management is that the prediction and projection of the impacts of both short-term high-impact weather events and longer-term climate changes are characterised by uncertainty. Within this context of uncertainty, the FREE framework provides guiding principles to help decision-makers derive mitigation, preparedness and adaptation actions that consider current knowledge of weather and climate change impacts. FREE provides a framework to support consideration of climate-related risks across timeframes, decision-making processes, sectors and social groups, while profiling the importance of equity considerations.

It is vital that decision-makers ensure flexibility to be able to take appropriate anticipatory and adaptation actions dependent on current and emerging scientific understanding of climate-related risks across timeframes. Given the inherent uncertainty of climate information, decisions need to be robust to the evolving 'envelope of uncertainty.' Actions taken in resource-constrained environments need to ensure economic no/low regrets and consider how measures to support mitigation and preparedness for immediate climate-related risks contribute to longer term climate-resilient, sustainable development. The experience outlined earlier highlights the need to ensure that addressing climate-related risks is equitable, and that this is made explicit and includes inclusive decision-making in deciding the trade-offs across timeframes, sectors and social groups.

PIPA has supported inclusive and transparent dialogue in planning for climate-related risks across urban and rural contexts and across timeframes. In both AMMA-2050 in Burkina Faso and ForPAc in Kenya, the PIPA methodology has enabled research to be better aligned with immediate and longer-term societal concerns and decision-makers' priorities. The use of PIPA in these research projects has demonstrated that the approach offers opportunities for supporting flexible, robust, low-regrets and equitable decision-making. It supported inclusive and participatory dialogue across researchers and decision-makers and helped to recognise trade-offs between short- and long-term objectives and between different elements of the FREE framework.

While providing a useful approach for considering the underpinning FREE principles, PIPA is shaped by pre-existing partnerships and networks, as much as it also offers opportunities for reshaping these. More widely the FREE framework provides a useful reference for assessing the extent to which approaches employed within climate-resilience strengthening initiatives have been able to operationalise its four guiding principles. As such, the FREE framework may be reviewed and further developed as a foundational tool for strengthening climate risk management.

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CHAPTER 5

Creating Useful and Usable Weather and Climate Information: Insights from Participatory Scenario Planning in Malawi

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Abstract For climate information to be used at the grassroots level, it needs to be understood, collectively interpreted and effectively communicated. Participatory Scenario Planning (PSP) is one method of co-producing useful and usable sectoral and livelihood advisories for decision-makers, based on locally downscaled weather (typically seasonal

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forecasts). The chapter outlines an initial investigation into the history and application of PSP in Malawi, finding that it can generate useful and usable information that is deemed credible, legitimate and salient by its intended users. Its usability is reinforced through the demonstration effect which leads to even sceptical farmers adopting it after they have witnessed proof of its effectiveness from early adopters. In Malawi, the sustainability of PSP is threatened due to limited integration in planning frameworks and reliance on projects, hence need for a mechanism to ensure its regular occurrence and embeddedness in formal governance structures.

Keywords Climate services • Seasonal forecasts • Co-production • Knowledge brokering • Agro-meteorology

Introduction

In order to adapt and make decisions that reduce the adverse impacts of climate variability and change, it is necessary to have climate information about the future conditions. Future climate information can be provided on different timescales, from short-term, such as seasonal forecasts, to longer-term climate projections. Like many other countries, Malawi's availability of information has increased over time; however, it has not necessarily led to effective adaptation to climate change. This is because the nature of information available does not necessarily meet decision-making needs, and the presentation means it is not always well understood by users in the agricultural sector. The field of climate services has arisen to meet this need "to provide climate information in a way that assists decision-making by individuals and organisations," as defined by the World Meteorological Organization (WMO) Global Framework for Climate Services (Hewitt et al. 2020).

Participatory Scenario Planning (PSP) is one technique within the field of climate services that aims to generate useful and usable information and, following successful use in other African countries, it has been applied in Malawi. PSP is an integrated community-based approach aimed at strengthening adaptive capacity and supporting planning and implementation of Disaster Risk Reduction and climate-resilient development, informed by knowledge of climate information and risks. It allows for collective interpretation of seasonal forecasts by involving producers, users and intermediaries in co-generating meaningful impact-based scenarios based on each of the probabilistic terciles of a seasonal forecast (i.e. below normal, normal and above-normal). It also allows for blending of indigenous and scientific knowledge in climate information.

In this chapter, we provide an overview of PSP and how it has been applied in the Malawian context since its introduction in the 2014–15 season, highlighting the parties involved in the process of generating the advisories, and the ways in which they have been used by the target audience, particularly farmers. The overall aim is to assess the extent to which PSP has been able to generate useful and usable information for decision-making to reduce climate risk.

Climate Services, Co-production and Participatory Scenario Planning

Despite the significant efforts and resources that have been targeted at generating better information on a range of timescales, from short-term weather to seasonal forecasts to long-term climate projections, there remain barriers to its use (Lemos et al. 2012). Various studies have highlighted that the information produced does not necessarily meet users' needs, for example, in terms of time frame, spatial scale and applicability (e.g. Singh et al. 2017; Vincent et al. 2017). Improved information alone is not adequate—it needs to be useful and usable to decision-makers, which typically requires that information is targeted and tailored to the different needs of users (Sivakumar 2006; Dilling and Lemos 2011; Vaughan and Dessai 2014).

Creating targeted and tailored information requires closer collaboration between producers and users (Hewitt et al. 2017). Co-producing such information has the benefit of ensuring that there is both scientific credibility, legitimacy and salience to users, defined as the three key criteria for knowledge systems (Cash et al. 2003). However, producing new knowledge in this way requires new ways of working and, crucially, involves partnership of producers and users (e.g. Chap. 3). As recently as 2014 this was still a novel approach. Scientists are not always the best at understanding user needs or communicating, which is required for such co-production partnership (Porter and Dessai 2017). The capacity limitations of National Meteorological and Hydrological Services in Africa mean that adding the role of understanding user needs can create unrealistic burdens on them (Ziervogel and Zermoglio 2009). Instead of expecting this from the climate information producers, there may be a role for boundary agents or knowledge brokers who can bridge the divide (Cvitanovic et al. 2015). NGOs are increasingly playing this intermediary role as they have links with both producers and users (Harvey et al. 2019).

One of the ways that climate information can be made more useful to users is to generate scenarios. Scenarios can link socioeconomic and climate trends to provide plausible, alternative futures and thus are useful for planning (Tschakert and Dietrich 2010). PSP involves climate information producers and users to generate scenarios that are useful and usable for them in decision-making (Kok et al. 2007). PSP for adaptation planning has been used in many different contexts around the world and has well-documented benefits, in terms of increasing legitimacy, utility and building capacity and shared understanding within the process of development (e.g. Bizikova et al. 2014; Flynn et al. 2018).

Evolution of PSP in Malawi

The concept of PSP for climate services was first raised in Malawi by the Civil Society Network on Climate Change (CISONECC) in 2013, following its positive use in Kenya (Carter et al. 2019). When the idea was enthusiastically received, CISONECC arranged for the NGO, CARE, to provide training for several Malawian NGOs and government departments and ministries, including the Department of Climate Change and Meteorological Services (DCCMS), Department of Disaster Management Affairs (DoDMA), and the Ministry of Agriculture, Irrigation and Water Development (MoAIWD) in April 2014. At the same time, other resilience-building programmes in the country were independently experimenting with improving communication of weather forecast information and farmer-focused advisories in Chichewa, and thus were keen to join the emerging group of parties involved in the PSP exploration. Malawi representatives later attended a regional training event organised by CARE in 2015, after which they presented the concept to various stakeholders in Malawi. A National Core Team was constituted, comprising a range of stakeholders (Table 5.1).

PSP was first formally implemented as a multi-stakeholder process in Malawi at the national level in the 2015–16 season. In the meeting, the National Core Team was presented with the seasonal forecast by DCCMS, and then divided into sector-related groups to provide interpretation and

Table 5.1 Composition of the multi-stakeholder PSP National Core Team

Government departments	*NGOs*	*Multilateral institutions*	*Media*
DoDMA, Environmental Affairs Department, MoAIWD, Ministry of Health, Ministry of Education, and DCCMS	Red Cross, Catholic Development Commission (CADECOM) Oxfam, ActionAid, CARE, Christian Aid, Centre for Environmental Policy and Advocacy (CEPA), Total Land Care, Churches Action in Relief and Development (CARD), Evangelical Association of Malawi (EAM), Leadership in Environment and Development for Southern and Eastern Africa (LEAD SEA), National Association of Smallholder Farmers of Malawi, and Green Belt Initiative	UNDP WHO	Various individuals

develop messages. The meeting was held in October 2015 after the Government of Malawi approved the national seasonal forecast.

The stakeholders discussed the presented three scenarios of the seasons and shared potential impacts, opportunities and advisories. Table 5.2 provides an example of the 2015/16 PSP outcome for the below normal rainfall scenario for the national level (where a large part of the country shows 35% likelihood of above normal rainfall, 40% likelihood of normal rainfall, and 25% likelihood of below normal rainfall)—highlighting possible hazards, risks, opportunities and advisory messages. The compiled messages were validated by DoDMA and MoAIWD and then disseminated through various channels, including resilience programmes. The national-level process works on the national-level seasonal forecast, which is fairly coarse spatial resolution and not ideal for district-level use. Resources permitting, therefore, ideally downscaled district forecasts can follow a similar process to generate district-level scenarios and advisories. Production of downscaled district forecasts by DCCMS currently occurs when funded by organisations that conduct PSP workshops in the districts.

The PSP core team introduced PSP at the district level, especially in areas where project partners expressed interest and could collaborate and assist with logistics of ensuring all relevant parties could participate, including staff from DCCMS. At district level, the actual PSP workshops took place as soon as the downscaled seasonal forecast was available. They were attended by various parties who have knowledge about, or whose activities are affected by, weather conditions. They included DCCMS, DoDMA and the implementing NGO(s), along with local government departments including disaster management, agriculture, health, forest, water and energy, as well as the relevant Civil Protection Committees—which are governance structures for disaster risk reduction at the District (DCPC), Area (ACPC) and Village levels (VCPC) and community members (including farmers). Relevant community institutions and community members participate in order to assist in interpreting the seasonal forecasts during the workshops and to contextualise the forecast information and potential impacts through sharing the past experiences and local indicators related to weather and climate.

Each district PSP process uses the forecast for the coming season to generate scenarios that include potential hazards, risks, opportunities and impacts for each of the terciles within the forecast. The outcome of the workshops is advisories based on the tercile probabilities of the forecast that enable effective community-level adaptation decision-making (see Table 5.2 for an example), and a communication plan for further disseminating the information through relevant communities, for example, by word of mouth, radio and phones. Participants leave with knowledge of the forecast, skills in interpreting early warning information, and

Table 5.2 Snippet of the PSP-derived messages for the 2015–16 national forecast

Below normal rainfall in agriculture sector (erratic rains)			
Impact	*Advisories for agropastoralists*	*Opportunities*	*Lead Dept.*
Crop failure	Preserve harvest from previous year	High demand for commodities e.g. maize	Min. Agric.
	Increase area under irrigation	Increased demand for short duration crop varieties	Min. Agric.
	Grow drought-tolerant crops		Min. Agric.
	Plant early maturing varieties		Min. Agric.
	Crop diversification		Min. Agric.
	Adopt conservation agriculture technologies		Min. Agric.
Fodder scarcity	Preserving animal feed e.g. hay		Min. Agric.

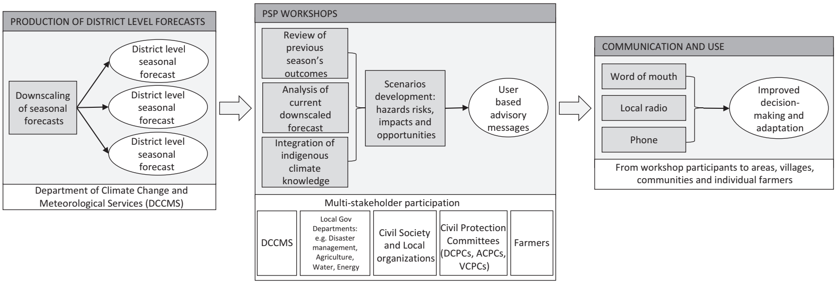

Fig. 5.1 Schematic representation of the PSP process and actors involved

awareness of their own capacities and vulnerabilities and ways of taking adaptive decisions in line with the forecast. The process is then progressively taken to areas and villages through the ACPC and VCPC members that have attended the district-level workshops, where the overall advisory is further contextualised and communicated with community members through word of mouth (villages tend to be small). Figure 5.1 provides a schematic representation of the PSP process and actors involved at various stages.

Experiences of PSP in the Districts of Karonga and Mulanje

In Malawi, 18 districts had experiences of PSP between 2015–16 and 2018–19, funded through various initiatives and resilience programmes. Two districts that have successive years of experience with the process are Karonga and Mulanje. Since Karonga is in the Northern Region and Mulanje is in the Southern Region, the forecasts were different, and thus were selected for an investigation of the process and analysis of the extent to which PSP was successful in generating useful and usable information. In order to do this, interviews and focus group discussions were held with PSP participants at national and district levels, including NGOs, a government department (DCCMS), DCPC, ACPC and VCPC (Fig. 5.2), and three men and two women farmers who had been involved in the process.

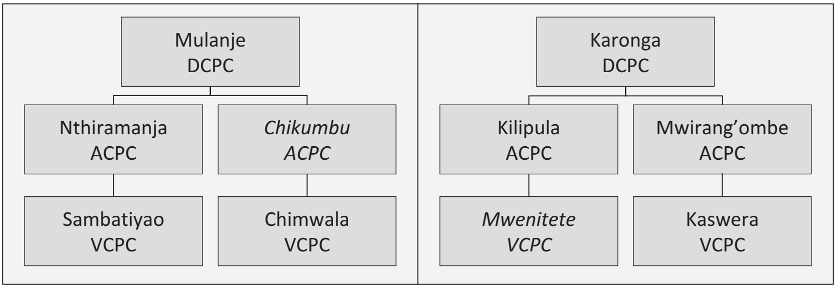

Fig. 5.2 Civil Protection Committees at the District (DCPC), Area (ACPC) and Village level (VCPC) in Mulanje and Karonga districts that were part of the research (* note Chikumbu ACPC and Mwenitete VCPC were unavailable to be interviewed during fieldwork but still shown here to complete the hierarchy of governance)

How Have Farmers Used PSP Information in Previous Seasons?

Farmers showed good understanding of the PSP advisory messages and many also changed their activities in response to the advice that was generated. Farmer 3 (male) from Sambatiyao, Mulanje, explained: "*From the forecast, we were informed that the season for 2015–16, especially Southern Region, will have limited rainfall compared to Central and Northern Region. Considering that this was October, I quickly changed the decision to plant maize on a bigger plot to spread the risk by growing hybrid maize, sweet potatoes, cassava and vegetables.*" In the north of the country, which can experience flooding, the forecast in that season was for wet conditions. Farmer 1 (female) from Kaswera, Karonga explained: "*During the workshop, technical experts from DCCMS explained that the season had the potential of heavy rains, and messages were developed on avoiding flood risk areas and growing crops that require more water such as rice and maize.*"

The nature of the seasonal forecast, and thus the messaging associated with the interpreted advisory, changed the next season. Farmer 4 (female) from Chimwala, Mulanje, stated that "*we were informed that the 2016–17 season had a higher probability of wet season, especially the first three months of the season. We developed and followed messages on growing crops that require more water like maize, cassava and bananas. Furthermore, we were encouraged to reduce mulching on our fields, unless they are in slope areas, to avoid standing water and saturating the soils. We were also informed to be* *alert to the weather messages through radios to enhance our decisions.*" Farmer 5 (male), also from Chimwala, Mulanje, concurred, explaining "*2016–17, the forecast was interpreted in October 2016, and because of the season outlook, that the season will have heavy rainfall, I and my fellow villagers grew crops that require more water such as maize. We were also informed that we should avoid places which could flood, like growing crops in river banks and living in swampy areas and shaky houses.*"

To What Extent Is the Information Credible, Salient and Legitimate?

Credibility of the messages was higher amongst the PSP workshop participants who had been directly involved in the scenario generation process compared to those that just heard the finalised advisory. Farmer 2 (male) from Kaswera, Karonga, indicated that he faced challenges when sharing PSP outputs because some members of the community expressed dissatisfaction on the messages and forecasting because they believe that God only can predict the season, highlighting the role of cultural beliefs. The representative from Chimwala VCPC also highlighted that when he shared outputs from the 2015–16 and 2016–17 processes, there were some community members that never showed interest in the messages and needed to be convinced. NGO representatives also acknowledged some problems with trust in the information but said that the integration of local knowledge into the PSP discussion was important as it validated local weather and climate indicators, and improved legitimacy. Only one of the farmers interviewed said that he did not believe in local indicators, with the majority trusting them. Having trusted messengers also aids credibility by increasing legitimacy: one farmer (5, male) who was the Group Village Headman in Chimwala indicated that he did not face any challenges in disseminating the PSP output because of his leadership position and he felt that people's trust in him extended to trust in the message he was sending.

Credibility in the forecast grows when the seasonal conditions unfold as predicted. However, given the probabilistic nature of seasonal forecasts, and the limits to skill, this is not always the case. Farmer 2 (male) from Karonga stated that he went against the advice for the 2015–16 condition, deciding to grow drought-resistant crops even though the forecast showed above normal rainfall. He said that heavy rains did come in the second half of the season, but that "*some farmers within my area had to* *plant maize two times because of dry spells. Farmers now have a habit of planting drought resistant crops such as cassava, banana, sweet potatoes, and hybrid maize because the weather has really changed, and local maize is not an option*." However, one village in Karonga was subject to flash floods in 2018 and those farmers that had not accessed the forecast or participated in the workshop were the ones who were most adversely affected. The representative from Churches Action in Relief and Development (CARD) highlighted that the planning for three possible scenarios marked a difference in farmer approaches, which was reiterated by the representative from Centre for Environmental Policy and Advocacy (CEPA) who highlighted that "*there can be a lack of planning culture among farmers in Malawi*." Demonstrated utility of information goes a long way to build credibility and PSP was able to continue in Karonga in 2017–18 under a different project.

Growing credibility through demonstrated utility was also reported by farmers in Chimwala in Mulanje district. Farmer 4 (female) from Chimwala indicated that she and her community members could appreciate the value of the PSP messages more in the second year (2016–17) of PSP compared to the first year (2015–16), because initially the farmers were still not sure if the messages should be trusted. However, when the first season did have lower than average rainfall, participating farmers were still able to harvest good yields despite the poor conditions. Farmer 3 (male) from Sambatiyao, Mulanje, said that the season for 2015–16 was dry with irregular rains as forecasted and because he was well informed of the season, managed to harvest tangible yields from the crops he grew except maize. Similarly, credibility increased when initial PSP messages coincided with local indicators of forthcoming weather conditions. In Karonga a local indicator of a dry season is Nkhokoko flies flying upwards. These were observed around September 2016. The PSP workshop for 2016–17 had highlighted dry conditions in the Northern Region, local indicators thus corroborated this. Confidence then increased, with farmers largely trusting and implementing the advisories developed during the workshops. This was reiterated by the Mulanje DCPC who stated that, although it is difficult to quantify achievements from PSP since data has not been gathered on yields, it was his perception that farmers who participated in the PSP process and implemented the messages harvested better yields compared to other farmers in the area, especially in the dry 2015–16 farming season.

The utility of information is also linked to the salience of the presentation—that is, how well it meets farmers' needs. Previously, weather forecasts or warnings were disseminated without advisories or messages. As such, it was difficult for farmers to interpret the meaning and decide on their actions. The messages were delivered in English and expressed in technical jargon, irrespective of the variety of knowledge, understanding and needs of the receivers. Instead, the PSP process has led to increased appreciation of the value of the information, with many farmers also stating that the knowledge they gained on interpreting seasonal forecasts was also very valuable to enable them to make informed choices. Farmer 5 (male) in Chimwala, Mulanje, indicated that he has "*begun to appreciate making informed decision in line with the seasonal forecast. I no longer practice agriculture the traditional way, because each season is unique.*" This is a significant change in understanding, as traditionally the annual calendar and farming practices have been very static. Farmers now embrace crop diversification because of the messages that they get from PSP workshops to ensure that they still harvest even during bad rainfall years. Community members have appreciated that seasons will always be different, as such it is important to depend upon the seasonal forecasts for decision-making.

The salience of information is also related to the timing with which it is received. Interviews with key informants showed that most PSP workshops at area and village level were undertaken between October and December of the season, once the seasonal forecast had been released in September or October and had cascaded through national and district level PSP processes. The information is legitimate because it has its origins in the annual Southern African Development Community (SADC) Regional Climate Outlook Forum, after which the consensus message is localised into a national seasonal forecast for Malawi by DCCMS. However, whilst the source of information is legitimate, salience is linked to the timing of the message, which is often impeded by delays in the chain of communication.

The chain of communication from regional to approved, localised seasonal forecast has several stages and delay at one stage cascades through the chain to delay the ultimate release of the information. Once the regional message has been localised for Malawi, it goes through a government approval process. If resources for PSP workshops have not been prearranged, that can be an additional source of delays. PSP workshops are undertaken immediately after the seasonal forecasts are made available—however, if this is November or December, it is too late for optimal decision-making since the rainy season starts in October. Farmer 5 (male) from Chimwala, Mulanje, said that the first year of PSP was initially not that useful as the workshop was very late, taking place midway through the season, but that "*it helped me to prioritize winter cropping where I grew* *vegetables, hybrid maize and vegetables to supplement the season.*" The CISONECC representative stated that an expedited approval process is key to their advocacy agenda to reduce these timing issues.

The experiences of PSP to date, and the growing appreciation of the need for dynamic approaches to farming, have stimulated an increase in demand for climate information from the grassroots level, as well as among district-level government and NGOs. This suggests that the information is deemed to be legitimate. Farmers interviewed reported that they pay greater attention to the standard daily, five-day and ten-day forecasts that are issued by DCCMS and transmitted via local radio and print media. This is partly because they have greater understanding of weather forecasts from the PSP process. This is particularly important for the seasonal forecasts, where the probabilistic nature is very different to understand from the deterministic nature of short-term forecasts. Farmer 1 (female) from Kaswera, Karonga, explained: "*I have learnt that the forecast are probabilities.*" In combination with their more dynamic approach to farming, greater ability to comprehend climate information means they are able to use emerging short-term forecasts as the season unfolds to modify their plans and take precautionary measures. DCCMS has been able to improve production and dissemination of short-term weather bulletins, such that the bulletins are released consistently, use both local and formal language as well, and are accompanied by advisories. Farmers are also to take advantage of changing conditions, rather than fear them. For instance, farmer 3 (male) from Sambatiyao, Mulanje, indicated that with advisory provided by PSP, one could take dry spells as an opportunity for business in cases where supply was otherwise reduced. A representative of the Karonga DCPC reported, "*We have seen an increased interest and numbers of farmers and CPCs approaching us for an interpretation of weather information they have heard or read to ensure that any action taken is information based.*" Representatives of the Kaswera VCPC indicated that through the two sessions of PSP, members of the community have begun to appreciate that climate change is real, and decisions should be informed by weather and climate information such as seasonal forecasts.

Summary of PSP Benefits and Barriers

The success of PSP as a method to disseminate climate information to users in Malawi has been summarised in Table 5.3. The acceleration of requests for training and implementation shows that PSP still has potential to reach even more districts, areas and villages.

Table 5.3 Summary of benefits of the PSP process

- Collectively defined interpretation and advisories are more usable than the seasonal forecast alone
- Bridges the divide between science and society—providing an opportunity for communities to understand scientific information and technical experts to understand local knowledge and weather information needs and uses
- Inclusive and accessible—the participatory nature of the workshops puts everyone on the same level, regardless of literacy and scientific background, and increases legitimacy
- Enables women and the elderly, who otherwise struggle to access climate information, to make use of seasonal forecast in their decision-making
- Through a PSP workshop, harmonised messages reach more users within a short time through multiple communication media

Despite the seeming success of PSP in Malawi to date in generating credible, legitimate and salient information for farmers for selected districts since its introduction in 2015-16, there are several challenges that have impeded it being scaled out throughout the country. This research suggests that the scaling out and sustainability of PSP has been challenged by various institutional and policy barriers. These barriers are technical and financial, and reinforced by the lack of a policy framework, including limited profiling of PSP in the 2019 National Meteorological Policy (Malawi Government 2019) and the fact that a National Framework for Climate Services has not yet been developed. The limited support of PSP from national frameworks has resulted in "projectizing" PSP initiatives which raise concerns over sustainability (Harvey et al. 2019).

Conclusion

An investigation of the experience of PSP in Malawi with implementers at national, district and sub-district level, and farmers who are targeted with the interpreted advisories, highlights that there is scope for PSP as a method to produce useful and usable climate information for decision-making. Farmers who have used PSP-issued advisories have been able to maintain production even when weather conditions have been suboptimal, and evidence of this has converted others to embracing the process. PSP has helped farmers at district/community level to determine when to plant when effective rains start, determine the type of seeds based on the length of the growing season forecast, identify farming practices to be done during the months of prolonged dry spells and decide on appropriate pest management practices, particularly during prolonged dry spells such as when pests like fall armyworms become more active. Thus PSP offers great promise for promoting seasonal adaptation decision-making that reduces the risk of weather conditions on livelihoods.

Whilst this case study addresses a gap in critical evaluation of PSP and complements findings from a CARE evaluation of the 2016–17 season (CARE 2017), it must be viewed within limitations. As PSP continues, there is need for further evaluation in several dimensions (Wall et al. 2017). First, there is need for more spatially extensive analysis, recognising the wide variety of different actors (in terms of NGO partners) that are involved in different districts, since this study only sampled 2 of the 18 districts that have undergone PSP to date. Second, there is also more room for a comprehensive overall evaluation. This could involve a larger sample size, with more attention paid to the extent to which design of the process takes place with a gender lens, considering different needs of men and women for information, other social denominators such as age and level of education, as well as different preferences in communication, and greater interrogation of the role of indigenous knowledge so as to better be able to validate seasonal forecasts. Third, as PSP continues and the evidence base expands, there is also need for in-depth longitudinal evaluation, in particular as discussion is still underway on appropriate metrics for co-produced climate services, which should consider both producers and users and process and outcome.

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CHAPTER 6

High Stakes Decisions Under Uncertainty: Dams, Development and Climate Change in the Rufiji River Basin

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Abstract The need to stress test designs and decisions about major infrastructure under climate change conditions is increasingly being recognised. This chapter explores new ways to understand and—if possible—reduce the uncertainty in climate information to enable its use in assessing decisions that have consequences across the water, energy, food and environment sectors. It outlines an approach, applied in the Rufiji River Basin in Tanzania, that addresses uncertainty in climate model

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projections by weighting them according to different skill metrics; how well the models simulate important climate features. The impact of different weighting approaches on two river basin performance indicators (hydropower generation and environmental flows) is assessed, providing an indication of the reliability of infrastructure investments, including a major proposed dam under different climate model projections. The chapter ends with a reflection on the operational context for applying such approaches and some of the steps taken to address challenges and to engage stakeholders.

Keywords Tanzania • Infrastructure • Model evaluation • Hydropower

Adaptation Decision-Making in Tanzania's Rufiji River Basin

Major investment decisions about infrastructure have long-term consequences that require anticipation of the future socio-economic and climate conditions under which they will function (Hallegatte et al. 2012). While there is evidence for cost-effectiveness of making infrastructure investments climate resilient, many decisions still fail to consider climate risk sufficiently, if at all (Global Commission on Adaptation 2019).

Large water-related investment decisions are currently under consideration in the Rufiji River Basin to support Tanzania's ambition of establishing itself as a middle income, more industrialised country. The massive Julius Nyerere Hydropower Project (JNHPP, Fig. 6.1)—long planned and with the potential to double the country's electricity production—was approved in 2018 and preparations such as land clearing, river diversion

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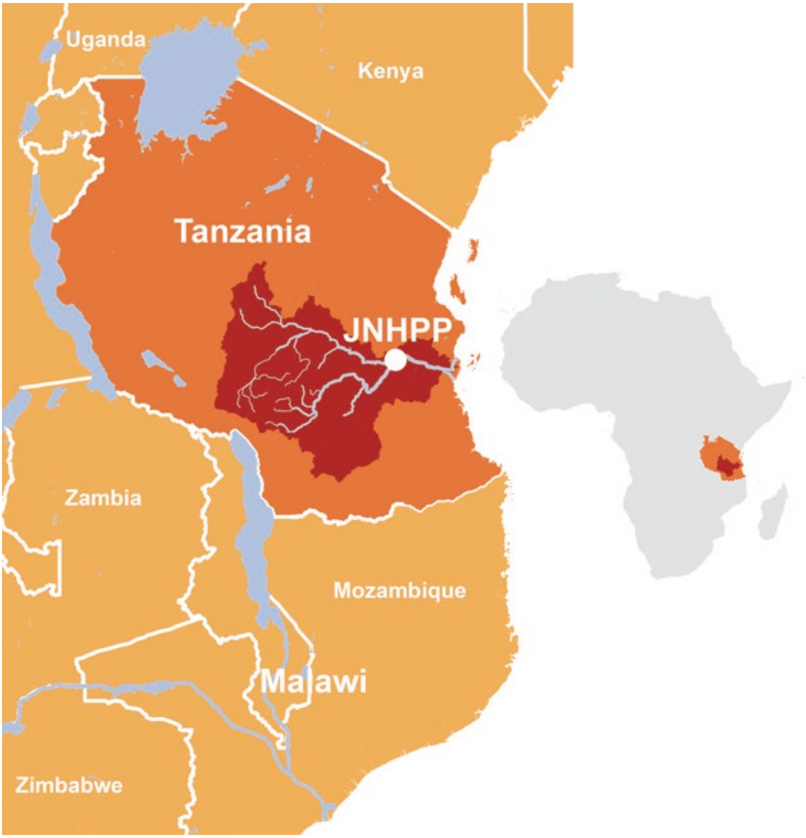

Fig. 6.1 The Rufiji River Basin in Tanzania, with the Julius Nyerere Hydropower Project (JNHPP)

tunnels and road infrastructure are in progress. When finished, this will be the second-largest dam by size in Africa. To boost agricultural production, Tanzania's new National Irrigation Master Plan (NIMP) and the Southern Agricultural Growth Corridor of Tanzania (SAGCOT) initiative identify massive scope for further irrigation expansion. To achieve this large investments are required, among many other things (the irrigation targets are very optimistic), in what are highly climate-sensitive sectors; the cost of constructing the JNHPP, excluding socio-environmental mitigation, is estimated at 4.7 billion US dollars against 2016 prices (Tanzania

Government 2016). Moreover, such infrastructure has long lifetimes, with profound implications for future economic and social development trajectories, and as such can be considered to be 'high stakes' decisions. The Rufiji River Basin is the largest and most economically important river basin in Tanzania, producing half of Tanzania's river flow, supplying water for 4.5 million people and for irrigation and livestock, generating roughly 80% of the country's hydropower and supporting environmental flows in several major wildlife parks (Siderius et al. 2018). Alongside climate risk, there are important trade-offs between the effects of these developments across the water, energy, food and environment sectors (Duvail et al. 2014; Geressu et al. 2020; WWF International 2017) which require consideration given the challenge of achieving sustainable development in the basin.

Climate change in Tanzania and more widely in south-east Africa is characterised by large uncertainty, with climate models projecting wetter and drier conditions (Kolusu et al. 2021; UMFULA 2019). High levels of observed inter-annual and multi-annual rainfall variability dominate the historical record in the Rufiji River Basin. Rainfall records show a severe multi-year drought at the beginning of the twentieth century (Siderius et al. 2020). In recent years, droughts of shorter duration have, alongside management issues, exposed the vulnerability of existing hydropower in the basin. Occasional floods have further highlighted the management challenges of climate variability in this part of Africa (Siderius et al. 2020; UMFULA 2019). Experience in climate risk assessment has revealed a need to a focus on decision-relevant timescales, and to give greater attention to climate model evaluation (and the decisions therein—see Chaps. 1 and 2) and consideration of climate variability, within climate change analyses to help model projections become more useful in guiding local, practical adaptation (Conway and Schipper 2011; Nissan et al. 2019; Ray and Brown 2015).

Uncertainty about the future climate is compounded by the ad hoc nature of information provision and advice about climate change risks, leading to low consistency and confusion about the reliability and legitimacy of information—a concern that is echoed by several stakeholders in the Rufiji River Basin. Indeed, during consultations in the basin, stakeholders expressed a strong desire for more clarity, not only on the changes expected, but also on the differences between the myriad of climate model outcomes, their relevance to operational practice and preferably more specific information on the direction of change (for rainfall) and changes in extremes. The last two demands will remain difficult to meet as reduction in uncertainty of rainfall and the behaviour of extremes has proven elusive (Kolusu et al. 2021; Rowell et al. 2016). However, there is potential to portray a risk profile that includes uncertainty to aid the decision process surrounding major infrastructure such as the JNHPP.

UMFULA, a four-year research project under the Future Climate for Africa (FCFA) programme, tried to address these challenges by bringing together climate and impact scientists focussing on approaches to reduce uncertainty associated with differences between model projections. Infrastructure and basin management plans that work acceptably well under diverse sets of future conditions (robust solutions, or Decision-Making Under Uncertainty—DMUU) are generally preferred over those that perform best under just one or a few climate projections. Major development agencies and donors are placing renewed emphasis on 'stress testing' infrastructure investments against multiple likely futures (Lempert and Schlesinger 2000; Ray and Brown 2015) but progress towards developing methods and for operationalising them has been slow. Large ensembles of climate models are readily available. At the same time, there is the understanding that climate models are not equally good nor are they truly independent of each other (Chap. 2; Knutti et al. 2010; Sanderson et al. 2017). In this chapter, we evaluate a specific DMUU approach applied in a developing country context that addresses the issue of uncertainty and climate model weighting in a stress testing exercise. Our aims are to (i) explore ways of constraining climate projection uncertainty through weighting and (ii) assess the impact of model weighting on infrastructure performance indicators.

Approach

We use the Rufiji River Basin in Tanzania as an example and illustrate the technical and practical implications of constraining and assessing the effects of uncertainty due to differences between climate model results. Though our study was performed without feeding into formal decision-making processes, our example design was informed by extensive consultation about the current decision context in the basin. We use climate impact simulation models developed and validated with local observations following discussion with agencies such as the Rufiji Basin Water Board and the Ministry of Water and Irrigation (Fig. 6.2,

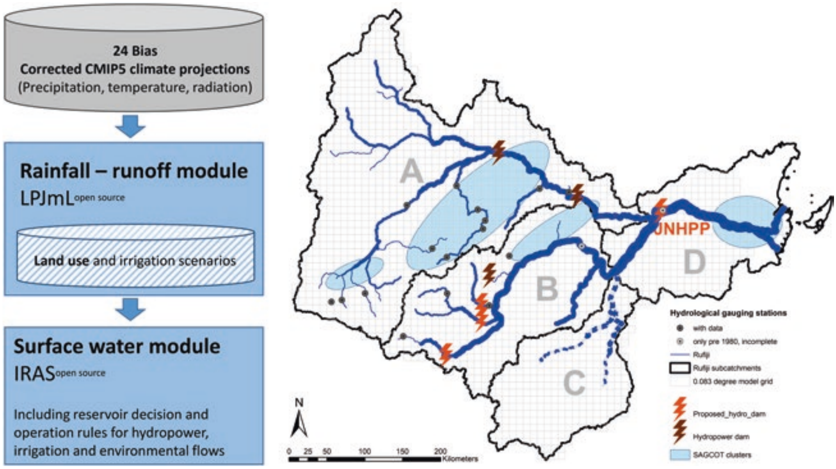

Fig. 6.2 System model schematic and basin map with main proposed dams and the SAGCOT clusters. Rufiji and main subcatchments: (**a**) Great Ruaha; (**b**) Kilombero; (**c**) Luwegu; (**d**) Lower Rufiji

Geressu et al. 2020; Siderius et al. 2018). The infrastructure development plans are adapted from the present river basin development plan (WREM International 2015).

Results presented in this chapter are based on an integrated suite of models consisting of a crop-hydrology model modified to local conditions, in combination with a water resources system model and a multi-objective search algorithm to evaluate development interventions in the basin (Geressu et al. 2020; Siderius et al. 2018). We consider a river basin design where all the proposed dams and potential irrigation sites are implemented, with operating rules of the dams set to maximise the minimum average annual energy generation in any one of the climate projections. We analysed a set of 24 climate models from the Coupled Model Intercomparison Project (CMIP5) that supported the Intergovernmental Panel on Climate Change (IPCC)'s Fifth Assessment Report. The model results were those available from a bias-correction exercise to allow for the difference between observations and model results over recent decades (Famien et al. 2018).

We use simulations of the historical period and the period 2021–2050 using the Representative Concentration Pathway (RCP) 8.5 forcing scenario (high rates of greenhouse gas emissions). Model weighting is derived via comparison of climate model simulations of past conditions (control climate, not yet corrected for bias) with historical observations based on the Global Precipitation Climatology Centre (GPCC) monthly rainfall version 7 (Schneider et al. 2017); and Climatic Research Unit (CRU) Temperature (Harris et al. 2014). The ability to simulate observed mean state, variability, drivers of variability such as the El Niño-Southern Oscillation and recent trend was evaluated, using a 'present-centric' approach (Chap. 2; Rowell 2019). In addition, we apply one 'future-specific' approach, whereby we try to understand the causes of climate projection spread among models and then relate this to how they simulate the present climate. We rule out projections according to several criteria. Specific detail on the weighting methods can be found in Kolusu et al. (2021).

Multiple stakeholder consultations were used to establish the river basin development alternatives and identify and prioritise important river basin performance metrics. These involved government staff (primarily in the Rufiji Basin Water Board and the Ministry of Water and Irrigation), hydrological and environmental researchers from universities and several locally active NGOs working on sustainability and development issues. Consultations took the form of small workshops (8–20 participants) held in March 2017, March and November 2018 and July 2019, complemented by informal discussions with many individuals between January 2016 and July 2019.

An initial longlist of performance indicators was narrowed down to seven after discussion with stakeholders, given their usefulness and major constraints due to very limited data availability in large parts of the basin. The seven indicators were: energy from hydropower, annual total, firm (reliable) annual and firm monthly; irrigation; total irrigated area, irrigation water demand deficit; environment; area flooded by the JNHPP and river flow disruption downstream in the lower Rufiji, which supports an important delta lake ecosystem, fisheries and flood recession irrigation. Here, we focus on indicators for two sectors that showed the strongest trade-offs: energy generation, both average annual and firm, and the impact on environmental flows in the Lower Rufiji (Table 6.1). We restrict our analysis of environmental flows to one indicator, disruption to the observed seasonal flow regime (which features a marked contrast between wet and dry season flows), noting that environmental flows are a

Table 6.1 Final selection of decision relevant performance metrics for the water, energy and environment sectors in the Rufiji River Basin

Category	*Performance metrics*	*Rationale*
Energy	Total average annual energy from all dams in giga watt hour per year (Gwh/year)	Indicates potential energy generated from existing and new reservoirs in a typical year
	Firm monthly energy (Gwh/month)	The monthly energy that is exceeded 99% of the time. It is a metric of how the energy generation is distributed seasonally and the reliability of energy supply
Environmental flows	Extent to which the observed seasonal flow regime is preserved (unit less metric)	Indicates a change in flow variability just downstream of the JNHPP due to upstream regulation. Maintaining present-day high seasonal flow variability will benefit the Selous lake ecosystem, flood recession agriculture and ecosystem and fisheries in the Rufiji River delta

multi-faceted concept that include other aspects such as (peak) flow volumes and water quality.

From Climate Uncertainty to Performance of Specific Sector Metrics

In our bias-corrected climate model sample, most (19 out of 24) models project a modest to high increase in annual rainfall; the rainfall change for 2021–2050 compared to the near-present day (or baseline) period of 1980–2010 ranges between -10% and +30% (Fig. 6.3a). Note that in the larger set of available, non-bias corrected CMIP5 models, the distribution of rainfall change is more equally balanced between wetter and drier projections (not shown). This climate uncertainty is then both amplified and modified by hydrology (compare Fig. 6.3a, b); the largest changes in runoff are more pronounced, ranging from approximately -30% to over +60%, and while the majority of models project an increase in rainfall, the impacts on runoff are more evenly distributed between drier and wetter futures. Increased transpiration by plants and crops due to higher temperatures can offset a projected increase in rainfall in some cases. An additional factor is the change in the distribution of rainfall over the season and between years. A relatively small redistribution in rainfall towards the

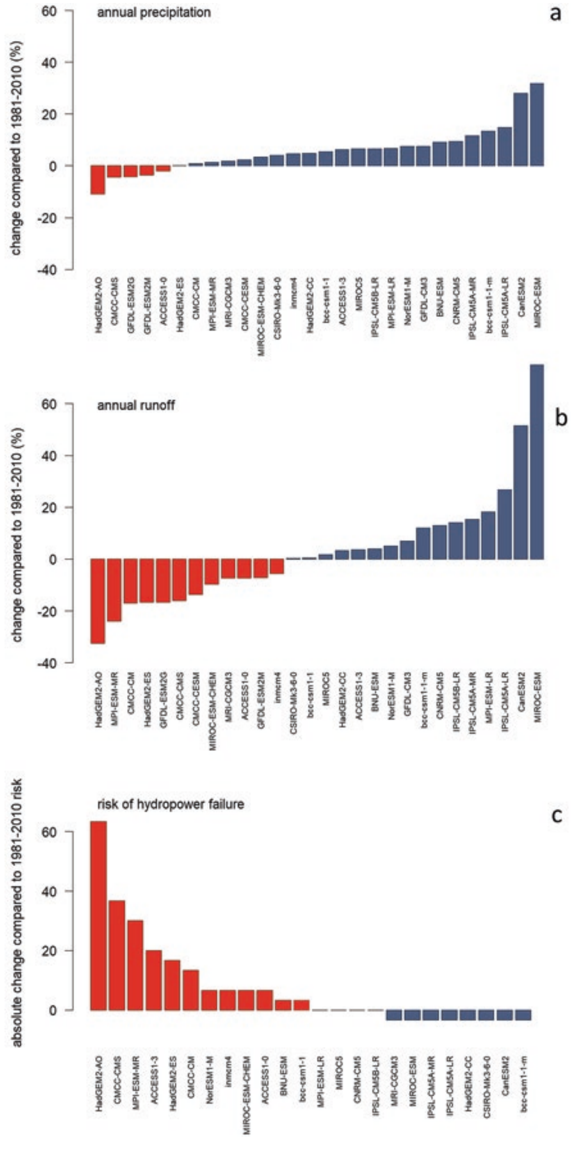

Fig. 6.3 (**a**) Projected change in rainfall, (**b**) river basin runoff at the JNHPP site near the outlet, and (**c**) the risk of a year with at least one month below a firm energy threshold in the JNHPP, comparing 2021–2050 to the baseline period 1981–2000, with model projections ranked from driest (in red) to wettest (in blue). Baseline hydropower risk is low, at 3.3%. Results shown for a set of 24 bias-corrected climate models

onset period of the rainy season, with more isolated high-intensity rainfall events in October, November or December, and towards the months after the rainy season, in June and July, increases the fraction of rainfall that is absorbed by the soil and subsequently transpires through vegetation.

The range of uncertainty is further transformed when translated into impacts on specific water, energy and environment sector performance indicators. Figure 6.3c shows the change in future hydropower performance, expressed as the annual likelihood (in per cent) of failing to meet target monthly firm energy generation by the JNHPP. Under recent (1981–2010) climate conditions, according to our simulations, that likelihood would be once in 30 years (3.3%). This likelihood is further reduced in the wetter projections, but it increases in the driest projection to over 60%, that is, representing a failure to meet the target more than once in every two years. While the distribution in positive and negative impacts between projections is largely similar to the runoff change, non-linear relationships between rainfall, runoff and hydropower generation mean the increase in likelihood of failure is amplified in the driest climate model projections.

Many of the projected increases or decreases in runoff are non-trivial; if the drier future becomes reality, this would constrain ambitions to become energy secure through the construction of the JNHPP because the expected firm energy would be greatly reduced. Further expansion of other forms of energy, such as solar and wind, might be considered to buffer energy supply in times of shortage. In cases of much wetter future conditions (e.g. some with up to 60% more runoff through the Rufiji River), major floods would likely become a much more regular occurrence. The scheme's flood release design might require re-evaluation under such extreme circumstances. While we have only focussed on one performance indicator for one sector, other sectors such as agriculture and the functioning of river dependent ecosystems also show highly contrasting impacts under this broad range of climate model results. We now consider if it is possible to reduce this uncertainty, by assessing the ability of models to realistically simulate past climate and exclude those that perform poorly.

Can We Reduce Uncertainty by Excluding Climate Model Projections?

There is no established method for deciding upon which climate models to use for impact and risk assessment, although it is widely agreed that using only one model (or the average of many) and ignoring the range suggested by other available models is poor practice. Generally the 'go-to' source is the CMIP5 ensemble of models compiled for the IPCC Fifth Assessment. While there are many options available for selecting models, there is limited guidance and many questions arise, for example, should we use: All available models? Early versions and later versions of models? Exclude some models deemed to be poor performers or weight them less—but which reasons to use for excluding or weighting models? Moreover, how important are other practical considerations (time, expertise, cost) in decisions about model selection? Such issues are even more daunting if one considers using the regional climate model simulations available from the Coordinated Regional Climate Downscaling (CORDEX) programme, for example (Giorgi et al. 2009).

We explore these questions about model exclusion and weighting in the next section and examine the extent to which they have a bearing on end-point decisions about adaptation. In particular, we focus on climate model realism (or skill) in simulating key features of African climate and use this to rank or weight (give different levels of influence to models with differing levels of skill) model selections (sub-samples) from a sample of 24 from CMIP5. We compare three methods of model weighting, noting that others could be used.

Figure 6.3 shows rainfall change for the Rufiji River Basin and impacts on runoff using an equal weighting of 24 climate models available from CMIP5, and Fig. 6.4 illustrates the effects of three different methods of weighting climate models on the range of impacts on runoff.

1. *Binary inclusion/exclusion by rank based on skill.* Models are assigned a weighting of either one or zero depending on their skill rank. Models are ranked from (1–24) according to a number of skill metrics, selected as key metrics of climate processes important to the region. The average rank across multiple metrics is derived and once ranked, the top 50% of the 24 models are selected and assigned a weight of one (Fig. 6.4a). All other models deemed 'unacceptable' are weighted zero (left blank). This is similar, for example, to the

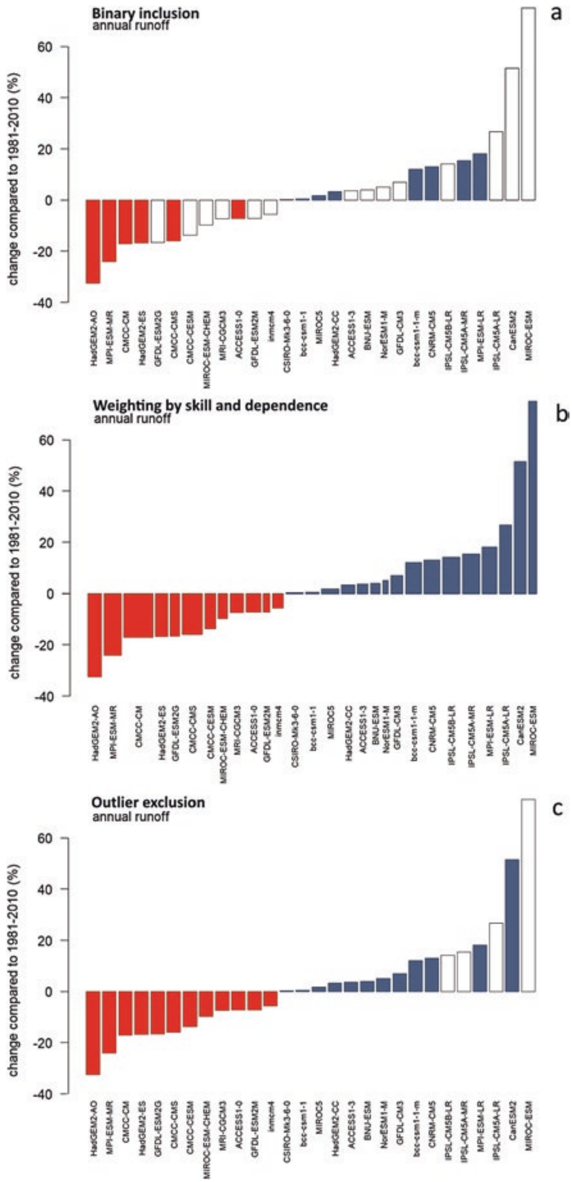

Fig. 6.4 Reducing uncertainty in projected annual runoff; (**a**) model ranking and binary inclusion (here selecting the top half best models), (**b**) a weighting approach (with the width of the bars representing the weight), and (**c**) a process based outlier detection approach. Model projections are ranked from the largest reduction in runoff (drier projections in red) to the largest increase in runoff (wetter projections in blue). Excluded models are shown in white

ensemble subsetting approach developed by Rowell et al. (2016). As can be seen in Fig. 6.4a, the distribution of excluded models is similar between those that project a decrease and those that project an increase in runoff. However, the excluded models include the most extreme wet ones, which alters the profile of results, suggesting an overall more modest range of impacts.

2. *Model weighting by skill and independence.* Using the approach of Sanderson et al. (2017) from the US fourth National Climate Assessment, each model is assigned a weight which is the sum of a 'skill' weight (i.e. the model performance with respect to observations) and a model independence weight (i.e. the model performance with respect to all other models, such that models whose performance is similar to each other have reduced weighting). Figure 6.4b shows that while it gives more weight to some models over others, the overall profile of impacts itself does not change. No model scores very well on all metrics, and similarly, no model scores badly on all metrics; it is a mixed bag with only some performing slightly better/worse than the majority, which means that the average scores are not that distinctive. That said, the highest score is a dry projection (CMCC-CM) while the lowest score is a wet projection (MIROC-ESM).
3. *Model outlier weighting.* In this approach, the 'outlier' models are identified, that is, those models whose climate change impacts are most extreme and hence likely to be associated with the highest costs of adaptation, something we wish to avoid if the models are low reliability. The models are then assessed in terms of how well they simulate extreme impacts, guided by our understanding of these mechanisms in present and future conditions. A weighting of zero is applied to models which are deemed unacceptable. The underpinning rationale is that adaptation decisions based on either a multi-model mean of climate projections or including the full ensemble are likely to be heavily influenced by any outlier models. Adaptation that is robust to climate change uncertainty may be more expensive if the uncertainty is skewed by outliers. It is therefore reasonable to assess whether such outliers are credible. Here, climate scientists of the UMFULA project identified several models that showed unrealistic behaviour over the historic measurement period in south-east Africa. In the subset of bias corrected models, these tend to be wetter [IPSL and MIROC models—see also Rowell (2019) for an evaluation of bias in the IPSL model] and their

exclusion shifts the impact profile a little. However, we note that analysis using the larger CMIP5 set of 32 models found various drier projections were also deemed implausible (Kolusu et al. 2021).

All three methods reduce the dominance of projections of increased runoff but this effect is only small with the weighting approach (Fig. 6.4b). The effect of the ranking method is larger, but the decision about how many models to exclude is rather arbitrary and could be tested for significance against random exclusion of models (Fig. 6.4a). A process based approach with expert judgement (Fig. 6.4c) helps understanding of scientific reasons for the model range, but is much more time consuming and requires value judgements about which models are examined, how and the exclusion criteria.

Performance Indicators Informed by Model Weighting

Analysing the impact of different climate projections on outcomes of interest to decision-makers, such as firm or total energy production in the Rufiji River Basin, can highlight the sensitivity of decisions to uncertainty in climate projections. It can also help identify climate models with lower skill for a particular region and hence less credibility for use in actual decisions.

We apply this approach to the case of the Rufiji River Basin, using two performance indicators: total average annual energy generation and the impact on the seasonal variability of downstream flows (Table 6.1; Fig. 6.5). For this example, the Rufiji system is simulated assuming all proposed dams and potential irrigation sites are implemented. The operating rules of the dams are set to maximise the minimum average annual energy generation in any one of the climate projections; that is, reservoir operating rules of all dams, including the JNHPP, are optimised to operate at their best even under the most challenging projection (i.e. with low and variable inflows) for energy generation. This constitutes a form of robust decision-making as we do not know yet how the future climate will unfold. An alternative would be to try to assess the trajectory of climate change in the coming years and optimise operating rules accordingly, using those projections that seem to match this trajectory (adaptive management). However, especially in regions with strong inter- and multi-annual climate variability, such as in south-east Africa, reliably describing the trajectory of change will remain difficult.

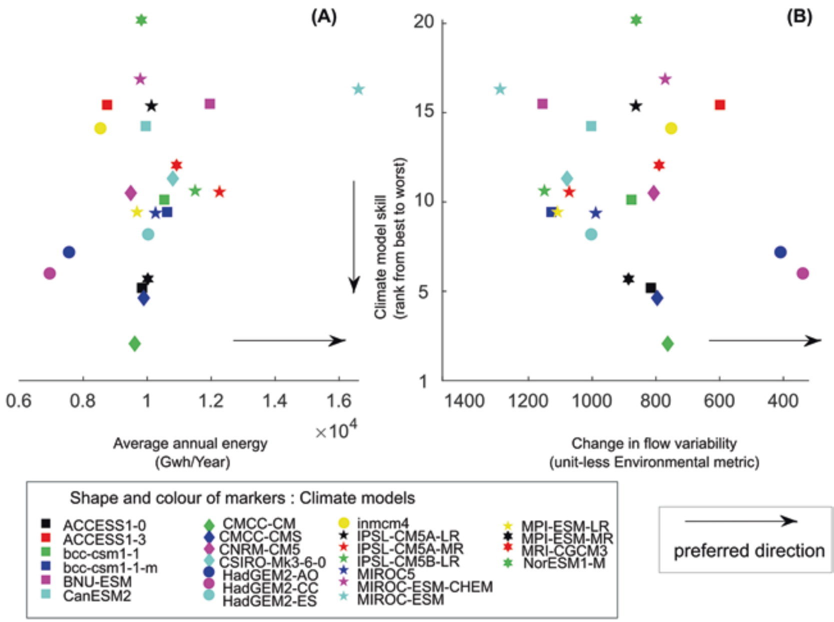

Fig. 6.5 (**a**) Total average energy performance and (**b**) change in seasonal flow variability as an indicator of impact on environmental flows, for all climate projections (ranked by skill on the y-axis, from 1 [best] to 24 [worst]) for the Rufiji River Basin where all development options are implemented and the reservoir release rules are set to maximise the minimum performance in any one of the climate projections

Figure 6.5a shows that total average energy generation for the Rufiji system reservoirs varies considerably between the climate model projections but without any apparent association with climate model skill (assessed using Method 2, 'model weighting by skill and dependence'). The majority of projections for the hydropower performance are close to that obtained for the best-ranked model, a power generation of around 10,000 Gwh/year for the Rufiji. Taking into account the skill of climate models can help us understand and communicate to decision-makers the plausibility of the range in outcomes. The model that predicts the highest annual energy generation (MIROC-ESM) is an outlier; it also has low climate model skill and could be a case for exclusion. If we give credence to climate model skill, it would suggest the hydropower potential of the Rufiji River Basin is more likely to be at or below 10,000 Gwh/year, than above this level (Fig. 6.5a). Such information could be useful in planning for future energy availability, for example, to design plans for additional energy sources as a contingency for less productive projections becoming reality.

Projections of environmental performance show a wide spread with a slight pattern for greater negative impacts on seasonal flow variability, especially for lower ranked climate models (Fig. 6.5b). The higher ranked HadGEM2-CC and HadGEM2-AO projections score relatively well for flow variability even though their total energy generation is the lowest of all.

For this dam and irrigation expansion development combination in the Rufiji, the assessment of climate model skill does not give a consistent result in terms of the impacts on hydropower or environmental flow performance. For both the energy generation and environmental metrics, the Rufiji performs at a similar level under the projections by the best ranked (CMCC-CM) and worst ranked (NorESM1-M) climate model.

Discussion and Recommendations

Weighting of climate model projections gives some insight into the range of uncertainty, but for this region and set of models, it does not produce a consistent relationship between model realism in simulating regional climate and the direction and magnitude of its rainfall projection and how this translates into key impacts in the basin. Low- and high-performing models project both wetter and drier conditions. Even when excluding the most extreme projections, considerable uncertainty remains. Process-based weighting (Method 3 here) gives most insight into reasons for model divergence and allows for some model exclusion, but the method requires considerable resources, scientific expertise and value judgements such that standardising it would be very difficult.

The Rufiji River Basin is located in south-east Africa, a climate system transition zone, where complex responses to global and regional teleconnections result in high rainfall variability and lack of model consensus about future rainfall change (Siderius et al. 2020). This complicates model evaluation and limits the value of model weighting to uncertainty reduction—we therefore caution against extrapolating our findings. In other regions, model weighting might provide a more distinctive split between 'good' and 'bad' models, though others (Rowell et al. 2016; Sanderson et al. 2017) have found similar inconclusive results to ours.

The translation of climate change into runoff through the use of hydrological models enhances the range of uncertainty. While rainfall projections suggest a higher likelihood of wetter conditions over the Rufiji River Basin, when taking into account increased temperatures and the likelihood of changing seasonality in rainfall, the split in terms of impacts on runoff between wet and dry projections is similar. The range of uncertainty is further modified when climate or hydrological indicators are translated into specific sector performance indicators such as failure to provide monthly firm energy production. We could not address two other important technical sources of uncertainty in this chapter: poorly understood hydrology of large ungauged tributaries which limits the reliability of the crop-hydrology and water resources models (Siderius et al. 2018); and while we use only one impact model, others have shown that different impact models have different climate sensitivities.

Management and governance also play a crucial role in determining which options are selected and the extent to which policies are implemented. For example, our basin development scenario is highly ambitious in terms of irrigation expansion, and optimisation of dam releases assumes coordination of existing and planned reservoirs, something that is not guaranteed. Cross-sectoral coordination between line ministries such as water, energy and agriculture has been limited in practice (Pardoe et al. 2018a).

Climate change projections are not routinely integrated into planning and decision-making in Tanzania. While Tanzania's Meteorological Agency recognises the increasing importance of climate change, their focus is primarily on providing daily, ten-day and seasonal forecasts. With limited funding, they tend to prioritise model resolution over model inclusion (e.g. Luhunga et al. 2018). Our results indicate the importance of including information from a range of models, rather than the use of just one or an average of many.

Our findings are part of a four-year scientific research project involving several research groups and over 15 senior scientists, postdocs and Ph.D. students. Given operational realities, especially in low-income countries, where climate research has to compete with a multitude of other development priorities, this level of analysis (in terms of capacity and finance) is unlikely to be available. However, in terms of specific cost, the budget required to undertake a Rufiji climate risk assessment is small compared to the cost of major infrastructure such as the JNHPP and the potential costs of future underperformance.

In this study, international academics collaborated with academics in Tanzania. In the Rufiji River Basin, the Rufiji Basin Water Board and the Ministry of Water and Irrigation are responsible for monitoring and managing water resources, with some external financial and technical support from various international research and development projects, and consultancies, often on an ad hoc basis with limited coordination. Daily operations (e.g. monitoring and permit processing) absorb most staff duties, time and resources. Both organisations have limited capacity to keep up with the evolving knowledge on climate projections and the complexity of methods and range of uncertainties, alongside rapid innovation in DMUU approaches. We saw that regular interactions with local academics acting as consultants, hosting students for research dissertations and often subsequently employing them means that strong links exist between research and practice. However, constraints on teaching and research in many universities and parallel issues in line ministries limit the degree to which new insights can be adopted. To improve capacity and embed and operationalise DMUU approaches such as those presented here will require continued funding and collaboration, including scholarships to train early career researchers in the latest techniques, and to create a stimulating work environment with competitive salaries to retain staff (Pardoe et al. 2018b). While this project did not have a formal agreement to feed into actual decisions in the basin, the regular interactions with formal institutions raises awareness about climate risk, and the strengths and weaknesses of tools and approaches for DMUU.

In conclusion, we find that in this example, the model weighting approaches do not greatly reduce the inter-model uncertainty, but it can be better understood. Planning decisions would still need to consider performance under multiple plausible futures (robustness), and decisions about infrastructure should prioritise cases with more easily reversible options (or delay major irreversible decisions) and greater flexibility such as in the design of reservoir operating rules and regular review of contingency plans. While significant hydropower capacity will be added to the Tanzanian grid by the JNHPP, the reservoir and other interventions need to be able to cope with changes in hydro-climatic variability. Adaptive management will be required to secure reliable energy supply and mitigate the impact of the JNHPP reservoir on the Rufiji's downstream delta ecosystem.

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CHAPTER 7

Integrating Climate Risks into Strategic Urban Planning in Lusaka, Zambia

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Abstract This chapter explores opportunities provided by strategic urban planning to mainstream climate risk considerations into the development decisions of city governments. It does so by describing the ways in which the climate-related information co-produced within the Future Resilience of African Cities and Lands (FRACTAL) project was integrated into the preparation of the Lusaka City Council Strategic Plan 2017–21. The chapter concludes by presenting four lessons emerging from the efforts at integrating climate information into the strategic planning process in Lusaka, Zambia: Lesson (1) Trust and relationships are key to sharing data and information needed to build a compelling case for managing climate risks; Lesson (2) Enable a variety of stakeholders to engage with climate

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information; Lesson (3) There needs to be an enabling legal, policy and financing framework; Lesson (4) Prepare to meet resistance; skilled intermediaries and city exchange visits help.

Keywords Zambia • Strategic planning • Urban development • Cities • FRACTAL

Introduction

Reducing the climate risks facing cities is now firmly on the international policy agenda. The specifics of how to do so have to be worked out for each city, both in terms of assessing the climate risks and building contextually suitable responses into urban strategies, plans, budgets and programmes of work. This is no easy task. Cities around the world are grappling with the complexities of how to shift from piecemeal sectoral and project specific assessments and interventions to integrated city-wide, and ultimately city-regional, climate resilient urban development strategies and programmes (UN-Habitat 2015; Lomba-Fernández et al. 2019).

One vehicle for integrating climate considerations into high-level city planning is the strategic urban development plan many city governments produce and revise every four or five years. These are plans that set the priorities for directing public spending and the work of public officials and administrators tasked with delivering on the promises made by local and national politicians (Gore 2015). The process of developing, reviewing and revising such plans is a complex combination of politics, technical inputs and engagements with communities of residents and other key city stakeholder groups. There are growing efforts to ensure that these urban planning processes integrate the best available scientific climate information in order to align them with international and national climate agendas to deliver on low carbon and climate resilience targets (Giordano et al. 2020).

This chapter presents the case of developing the 2017–21 Strategic Plan for the city of Lusaka in Zambia. It explores how climate risks are characterised and prioritised in the plan (as compared with the 2010–15 Strategic Plan) and unpacks the processes by which various sources and types of climate information were integrated into the development of the Lusaka Strategic Plan, partly supported by efforts at co-exploring, co-producing and distilling relevant climate information within the Future Resilience of African Cities and Lands (FRACTAL) project (Chap. 2). The chapter offers a set of reflections on how climate information and climate risk considerations, including a range of future projections, can be progressively brought into such strategic urban planning processes, across the technical, political and stakeholder engagement aspects, all of which are required to achieve real traction.

Climate Vulnerabilities in Lusaka

Lusaka, the capital city of Zambia, has an estimated population of 2.5 million. With an annual population growth rate of 4.8% (2000–18), it is projected to grow to 4.3 million by 2030 (UN DESA 2018). Climate variability and change is partly contributing to Lusaka's rapid growth, as poor agricultural productivity in Zambia's rural areas is leading to rising urban migration (Thurlow et al. 2012).

Lusaka is characterised by dramatic contrasts between modernist formal areas and impoverished informal parts of the city, which are home to over half of Lusaka's population (Chitonge and Mfune 2015). However, climate impacts experienced in Lusaka cut across this formal-informal divide, in the form of water shortages, power outages, flooding and disease outbreaks, especially cholera triggered by flooding and poor sanitation.

Most of Lusaka's electricity comes from hydropower generation. Roughly 40% of the water supplied to Lusaka by the Lusaka Water and Sewerage Company (LWSC) is sourced from the Kafue River, some 50 kilometres from the city, and the remaining 60% is extracted from groundwater (Simukonda et al. 2018). However, the LWSC is only able to supply roughly 52% of the water demand from Lusaka's rapidly growing population and industry. The remaining 48% is drawn directly from groundwater by private individuals and companies (FRACTAL 2019).

For those living and working in formal areas, periods of drought pose the risk of both severe water shortages and power outages. Low river flows result in the hydropower supply being interrupted, which in turn means that groundwater cannot be pumped from boreholes, and surface water from the Kafue River cannot be pumped to the city. Water and electricity shortages and rationing disrupt enterprise activity in Lusaka across multiple sectors, forcing businesses to reduce production, representing major economic losses (Mwila et al. 2017; Gannon et al. 2018). During prolonged dry periods, water kiosks (i.e. standpipes where water is sold to those without connections) and shallow wells run dry, forcing many in informal areas to travel far in search of alternative sources, often associated with very poor-quality water, in turn, presenting serious health risks (FRACTAL 2017).

Flooding is a regular occurrence across many parts of the city, due to a combination of intense rainfall, poor drainage and blockages in the drainage network from a lack of waste management (FRACTAL 2017). Many of Lusaka's informal settlements experience floods on an annual basis, causing destruction of property and water borne diseases. Frequent cholera outbreaks are strongly associated with the quantity of rainfall. It is estimated that 60% of Lusaka's urban areas have no adequate sanitation (FRACTAL 2017). Owing to lack of sewer lines, pit latrines are the most common sanitation facilities in informal settlements. In 2017, a cholera outbreak initially controlled by aggressive interventions, including hyperchlorination and oral vaccine distribution, resurged after heavy rains followed by widespread water shortages, resulting in many deaths in Lusaka (Sinyange et al. 2018). In areas of poor sanitation, flooding acts as an outbreak trigger and the risk spreads across the city.

Climate projections for the Lusaka region suggest that all parts of Lusaka and surrounding regions will become warmer than they used to be, posing risks to health, agriculture and water supply (FRACTAL 2018). By the 2040s, temperatures may become up to 3 °C higher on average than current conditions, with extremely hot days and widespread heat waves becoming much more frequent (*Ibid*). Long-term rainfall trends for the Lusaka city region could entail drier rainfall seasons becoming much more common, with a tendency towards more prolonged drought conditions. However, Lusaka will continue to experience wet rainfall seasons with the associated risk of large-scale flooding. Some projections suggest that localised heavy rainfall events might become more frequent and intense (Jack et al. 2020).

Strategic Urban Planning as a Means of Mainstreaming Climate Action in Cities

Internationally, strategic urban planning emerged within the public sector in the 1970s and 1980s in the US and Europe, aimed at creating a framework to guide decisions and the allocation of resources based on the relative strengths of a city and emerging national and international opportunities and threats (Bryson and Roering 1987). Strategic urban planning takes a broader view than traditional master planning with its focus on land use regulation and infrastructure requirements. The use of strategic planning in cities is expanding with the hope of guiding not only the decisions across all functions and levels of city government, but also seeks to shape the mission, priorities and practices of other organisations operating in and shaping the city. Newer versions of strategic urban planning place emphasis on inclusion, participation and collaboration as a means of growing consensus and support for change towards future visions of the city (Albrechts et al. 2017).

Within African cities, the uptake of strategic urban planning has been recent and is not yet widespread. The rise of strategic urban planning marks a shift in urban poverty and development interventions from the microscale of locations (i.e. site specific slum upgrading projects) to policy interventions aimed at the city-wide scale, based on a recognition that the need is to connect people to jobs and services wherever they are located (Robinson 2008). There is a difficult balancing act undertaken in these exercises between pushing economic growth imperatives and basic service delivery imperatives, particularly in cities where high levels of unemployment persist and many residents live in hazardous, informal conditions of settlement.

Tackling climate change at the city scale is being added to the sustainability imperative within the design and development of strategic urban plans (UN-Habitat 2015). Adapting cities to changing climate conditions requires prioritising interventions across the spatial extent of the city region and the full range of climate risks and vulnerabilities. Several scholars argue that urban planning is a key field for tackling climate change in cities because it is a domain that draws in and effects many actors shaping the city space, it deals with numerous types of critical infrastructures and it is inherently forward looking (Parnell 2015; Lomba-Fernández et al. 2019). The challenge is that urban development decisions are inherently political in nature, as land and space have contested value and competing uses. Early evidence highlights the limitations and constraints of planning as a vehicle for city-wide climate adaptation, partly because planners within local authorities are constrained in the extent to which they can coordinate between sectors and have limited expertise in dealing with climate data and information (Carter et al. 2015).

De Satgé and Watson (2018) argue that planning in cities of the Global South operates in contexts characterised by conflicting rationalities between states and markets driven by the logic of modernisation, control and profit, and poorer communities driven by the logic of survival. Strategic planning is only as effective as the convening power and authority of the city government to regulate land use, direct investments and monitor activities to enforce compliance. In African cities, like Lusaka, this convening power and authority is weak, hence the very high levels of informality. Planning in the context of African cities is a discipline and a profession plagued by a poor reputation, limited legitimacy and severe capacity constraints, but planning cannot be bypassed if climate change is to be systematically addressed in cities (Parnell 2015). To explore this further, we now turn to the case of strategic urban planning in Lusaka to investigate what it reveals about the potential value and limitations for integrating climate risk information and furthering urban climate adaptation.

Integrating Climate Information into the Strategic Planning Process in Lusaka

Lusaka still displays the colonial legacy of modernist planning inherited from the British town and country planning tradition; a functionalist, physical planning approach based on the zoning of physical space. This manifests as spatial segregation and the ongoing growth of informal settlements on the city's periphery without adequate access to basic public services (Mulenga 2013). The Zambian government passed the Urban and Regional Planning Act in 2015 to reform the planning system towards being more inclusive and responsive to local development contexts. The Act requires all city planning authorities to produce strategic urban plans in the form of Integrated Development Plans. Prior to the passing of the Act, Lusaka City Council (LCC), with the support of various international donors, had already begun developing strategic plans with the first Strategic Plan for Lusaka City 1999–2004. This was replaced by the 2010–15 Strategic Plan. In 2016, this plan was reviewed and, in line with the decentralisation policy promoted by national government, a process of widespread community and stakeholder engagement was initiated to formulate a 2017–21 Strategic Plan for Lusaka. The review of the 2010–15 plan highlighted the importance of getting wide ownership of the Strategic Plan, from political and administrative leadership in local government, as well as public and private sector actors, to ensure implementation and measurable improvement in delivering public services to all communities.

The process of developing the new Strategic Plan coincided with the initiation of the FRACTAL programme, which had the aim of advancing the integration of scientific knowledge about regional climate patterns into city-regional decision-making to contribute towards resilient development pathways (see also http://www.fractal.org.za/lusaka/ and Chap.

2). The intersection of these two processes created opportunities for exploring climate-sensitive development issues facing Lusaka and how climate information might inform decisions being made about strategic priorities for local development. Table 7.1 provides a chronological account of the activities involved in integrating climate information into the development of Lusaka's 2017–21 Strategic Plan.

The series of FRACTAL Learning Labs, City Dialogues, city exchange visits and training events described in Table 7.1 created engaging, collaborative spaces in which various stakeholders from government, civil society (including NGOs and community representatives) and the private sector came together with scientists to share knowledge and perspectives on urban development challenges and explore how some of these intersected with patterns of climate variability and change (Jack et al. 2020). A FRACTAL embedded researcher was employed for the duration of the project to work in two spaces, the University of Zambia (UNZA) and the LCC, to ensure continued interaction between researchers and city officials. The embedded researcher played a key role in brokering the multi-stakeholder engagements and in sustaining interest and continued action on mainstreaming climate information in the Strategic Plan. Senior management staff and Councillors from LCC participated in city exchange visits to Durban and Windhoek to learn about how peer cities in the region are mainstreaming climate change in municipal policies and plans (Ndebele-Murisa et al. 2020). This was influential in mobilising high-level support for the integration of climate change concerns into Lusaka's Strategic Plan.

Issues of water scarcity, groundwater exploitation, declining water quality linked to the lack of sanitation services and regular flooding became focal points for deliberation and knowledge co-production that fed into the Strategic Plan in several ways. Through the series of FRACTAL engagements, community representatives became confident in articulating the connections between the everyday challenges they were experiencing in their local area and broader processes of environmental and climate change playing out at the city-regional, national and global scales. Similarly, City Councillors deepened their understanding of the linkages between local livelihoods, health and safety concerns and environmental issues.

Through iterative FRACTAL-led efforts at unpacking and expanding a set of Climate Risk Narratives and developing thematic policy briefs[1]

[1] The Climate Risk Narratives and the set of policy briefs can be accessed via: http://www.fractal.org.za/lusaka/

Table 7.1 Chronology of activities contributing to the integration of climate risks in the Lusaka Strategic Plan (2018–21)

Date	*Activities*
2015	2010–15 strategic plan expires; Lusaka City Council (LCC) formed two Strategic Planning committees and a Technical Working Group to prepare a new plan
Early 2016	Review of 2010–15 plan through consultative meetings; FRACTAL project leader in Lusaka identifies opportunity to support Strategic Planning process
Aug-16	FRACTAL appoints an LCC urban planner working on urban resilience and disaster risk reduction as the Lusaka-embedded researcher to work between University of Zambia (UNZA) and LCC on integrating climate information into decision-making
Sep-16	FRACTAL hosts Inception Workshop and first Lusaka Learning Lab exploring climate sensitive urban development issues; water security, flooding and informal peri-urban areas came out as key; many involved in the Strategic Planning process participated in these events
Jan-17	FRACTAL convenes training for City Councillors on climate issues; Councillors discussed connections between climate and complaints they received about water points running dry and areas getting flooded; talked about mainstreaming climate risk management into the Lusaka Strategic Plan through collecting information on climate risks and impacts at the ward level
Jan-17	FRACTAL hosts Lusaka City Dialogue on Water Resources and Climate Change delving further into understanding connections between climate patterns and water security, which contributed to stakeholders identifying these as key issues in the consultation meetings for the Strategic Plan
Mar-17	Thirty-three wards engaged through community meetings to create ward profiles identifying local risks, needs and priorities; due to FRACTAL involvement, the tool used to guide ward engagement included a section asking about weather and climate events, local impacts and responses
Jun-17	FRACTAL convenes second Lusaka Learning lab where participants undertook a visioning and backcasting exercise to identify pathways to safe and affordable water for all; a method for stress testing Lusaka's water system under various scenarios was discussed; four thematic groups were established to identify knowledge gaps relating to flooding, unregulated groundwater abstraction, low water supply and poor water quality
Sep-17	Inputs from wards and stakeholder consultations used to formulate 5 thematic areas for the Strategic Plan, with water and climate issues featuring strongly in the Public Health and Environment theme; thematic working groups formed to draft text for the Strategic Plan based on inputs from consultative meetings; the Public Health and Environment thematic group was led by the FRACTAL embedded researcher and many members participated in the FRACTAL Learning Labs, dialogues and training events and thereby recognised important linkages between water and climate issues

(*continued*)

Table 7.1 (continued)

Date	*Activities*
Nov-17	Five representatives from LCC and UNZA undertake city exchange visit to Windhoek to explore shared issues of climate risks to water security; FRACTAL convenes third Lusaka Learning Lab with four thematic groups mapping issues and drafting policy briefs on flooding, unregulated groundwater abstraction, low water supply and poor water quality; Climate Risk Narratives presented describing three future scenarios under different climate conditions and groups worked on updating the narratives with impacts and responses
Feb-18	Five representatives from LCC, UNZA and the National Water and Sanitation Council undertake city exchange visit to Durban to share knowledge on city projects to reduce climate vulnerability for residents in informal settlements and to sign the Durban Adaptation Charter
Mar-18	FRACTAL convenes the fourth Lusaka Learning Lab where presentations and group discussions deepen understanding of water management challenges and efforts, groundwater regulations and flood risk reduction
Apr-18	FRACTAL convenes climate training session on the Climate Risk Narratives for Lusaka and the scientific evidence underpinning the narratives
May-18	Death of Lusaka Mayor postpones completion and adoption of new Strategic Plan
Jul-18	Internal working group set up, and included the FRACTAL embedded researcher, to complete the Strategic Plan
Aug-18	FRACTAL convenes a Lusaka City Governance Dialogue and Talanoa Dialogue exploring findings on the actors, discourses, frameworks and physical realities shaping water, energy and climate decisions affecting Lusaka
Sep-18	Comments on draft plan from Councillors and stakeholders
Oct-18	Strategic Plan finalised with water and climate concerns identified as priorities and approved through full Council
Nov-18	Fifth Lusaka Learning Lab finalised policy briefs and presented to high-level panel including ministerial representatives

dealing with various water issues, community representatives, government decision-makers, planners and technical staff were arriving at new insights into the climate drivers and impacts of local development issues that they incorporated into their respective roles in contributing to the Strategic Plan. This is evidenced by the attention given to gathering information on weather and climate events, impacts and responses through community consultations in all 33 wards of Lusaka, and the inclusion of a climate change adaptation and mitigation strategy and program within the strategic priorities for the city, which was absent in the previous Strategic Plan.

Further, the City formulated 12 local area plans for 12 wards to coordinate water security investments with a focus on informal settlements. These local area plans included explicit consideration of climate change implications for water security.

While the inclusion of climate adaptation and mitigation as a strategic priority marks an important step forward in Lusaka's urban planning, the depth of integration and emphasis on managing climate risks should not be overestimated. Within the plan, there are signs of inconsistency and lingering confusion as to how identified climate risks translate into priority actions and relevant outcomes to be monitored. For example, the single indicator assigned to the climate change adaptation and mitigation programme is the number of trees planted. This does not tie into the water quality, quantity and equity concerns raised in relation to changing climate risks in the situational analysis section of the plan. But it marks the beginning of positioning climate change within the purview of urban development actors in Zambia, from the community level up to the Mayor. This work is continuing and being further deepened and expanded through the Lusaka Water Security Initiative (LuWSI), which as of 2019 is coordinated by the former FRACTAL embedded researcher, as well as the ongoing efforts of the wider FRACTAL network.

Lessons on Integrating Climate Risk into Urban Planning in African Cities

Based on the experience of working to integrate climate risk information into the Lusaka Strategic Plan 2017–21, four key lessons emerged that may be of use to planners, decision-makers and researchers in other cities grappling with how to mainstream climate into urban development strategies.

Lesson 1: Trust and Relationships Are Key to Sharing Data and Information Needed to Build a Compelling Case for Managing Climate Risks

Integrating climate risks and climate adaptation measures in urban planning requires having adequate data that show the costs of maintaining the status quo, as well as having data that show the benefits of planning for climate adaptation. Currently the data that exist are held by different agencies and departments in an uncoordinated and inaccessible manner, making integrated planning very difficult. The partnership between UNZA and LCC and the ways in which the FRACTAL Learning Labs and dialogues were convened and facilitated managed to overcome institutional barriers and brought relevant climate and development institutions together to share information and resources, and explore ways to build a climate resilient Lusaka. Contacts were exchanged among participants, formally and informally, and experiences shared that enabled increased collaboration on addressing climate change in Lusaka. Through iterative, highly collaborative engagements, stakeholders shared their institutionally held data and information, and this was key for the Strategic Plan formulation by the LCC. The FRACTAL and LuWSI network has continued to have high convening power among climate and development actors in Lusaka, building the relationships and trust needed to collaborate and share data. An information repository has been established with over 150 documents on water research, planning, water quality monitoring, land use and survey diagrams. Work is underway, convened by LuWSI, on a digital atlas and information management system that links different sources of information on climate, water, land use, planning and governance from key stakeholders in the water sector, with the aim of having various sources accessible in one place. However, there is still a long way to go to build a sustained culture of data sharing and collaboration among the local stakeholders.

Lesson 2: Enable a Variety of Stakeholders to Engage with Climate Information

Climate responses require an integrated and bottom up approach and therefore all responders from individuals to collective groups, institutions and other stakeholders need to be well informed and understand the linkages between impacts and climate drivers. Integration of climate risk and adaptation measures in urban planning should be discussed in locally relevant and meaningful terms, easily explained in local languages and in engaging formats, like graphics and stories, as was developed through the Climate Risk Narratives in FRACTAL. Climate risk is amplified by historical land use and planning inefficiencies and can easily be attributed to this. There is therefore a need to continuously disseminate information on climate conditions and potential impacts to various stakeholders and not only to decision-makers at City Council and Provincial government.

Lesson 3: There Needs to Be an Enabling Legal, Policy and Financing Framework

Integrating climate risk into urban planning is dependent on the type of legal and policy instruments available. For instance, the 2010–15 Strategic Plan was based on the Town and Country Planning Act that had very limited multi-stakeholder engagement. The 2017–21 Strategic Plan is guided by the decentralisation policy and the Urban and Regional Planning Act, which require that communities be represented and are involved in identifying risks and priorities, as well as part of the implementation of the plan. In the process of developing the Lusaka Strategic Plan, consultative meetings were held with communities, who proposed the types of solutions they would be able to undertake in response to the identified risks, including climate risks. Climate risk integration needs to align with existing national agendas, for example, the 7th National Development Plan and Zambia's Vision 2030 in the case of Lusaka, as well as global and regional agreements, like the Durban Adaptation Charter. The need to meet certain criteria for funding also plays a key role in whether climate information is integrated or not.

Lesson 4: Prepare to Meet Resistance; Skilled Intermediaries and City Exchange Visits Help

There were some within the LCC, as well as in national government and other agencies, who felt that climate change and the use of climate information is not the mandate of the city government. There are many occasions when it is required to make a compelling and convincing case for why understanding and managing climate risks are integral to achieving the service delivery and urban development goals of the city government. Skilled intermediaries are needed to bring relevant climate research into the purview of planners and managers. These intermediaries not only need to be adequately knowledgeable but should have influence and be able to integrate alternative perspectives and new ideas into high-level decision-making spaces. They need to be able to navigate across the various layers of consultation and decision-making spaces with ease. Appointing someone with both a solid academic background and considerable experience working in government as the FRACTAL embedded researcher to work as an intermediary between the university and the City Council, proved central to the success of mainstreaming climate risks into the Lusaka strategic planning process. As was the diplomacy and strategic vision of the FRACTAL project leader in Lusaka.

It is necessary to get key high-level decision-makers on board and bought into the climate agenda in order to support the process and overcome barriers and stumbling blocks. The FRACTAL city exchange visits that saw senior managers and Councillors visiting other cities in the region that are further ahead in advancing a city climate agenda proved impactful in building high-level support. Ultimately, climate risks and measures to manage them must be identified through a clear and mutually agreed process, with the appropriate figureheads endorsing the approach as well as the resulting priorities, otherwise it will not translate into action.

In conclusion, these lessons will need to be taken forward within Lusaka, where the next challenge is to translate the Strategic Plan into an Integrated Development Plan that provides spatial specificity as to how the ambitions and priorities laid out in the Strategic Plan will be implemented. In parallel, strategies for addressing climate and water risks in high risk settlements are being pursued through the Lusaka Water Security Action and Investment Plan.

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CHAPTER 8

Supporting Climate-Resilient Planning at National and District Levels: A Pathway to Multi-stakeholder Decision-Making in Uganda

Rosalind J. Cornforth, Celia Petty, and Grady Walker

Abstract If rural adaptation is to be effective, then it cannot take the form of prescriptive actions determined by outsiders and subsequently imposed upon rural communities. Our focus in this chapter is to reflect on the effectiveness of rural adaptation in the context of food security and agriculture in Uganda and provide insight into a way forward using learning from the HyCRISTAL project rural pilot. We critically explore the boundaries of 'adaptation' and 'resilience' as policy responses to climate change in poor rural communities through the interdisciplinary use of quantitative and qualitative methodologies, including innovative visual methods and action research. We identify some of the limits to building adaptive communities and explore potential solutions for enabling informed decision-making for rural adaptation that are linked to investment in

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sustainable development. We highlight the importance of multi-stakeholder approaches and the generation of a 'knowledge ecosystem' that combines physical and social science methods and data to generate context-specific information to inform decision-making.

Keywords Climate resilience • Livelihoods • Africa • Climate information • Rural adaptation • Decision-making • Uganda

Introduction

Effective rural adaptation to climate change and variability depends on a multi-stakeholder approach to climate-informed decision-making, contextualised by local circumstances, and supported by new approaches to the generation and synthesis of interdisciplinary knowledge from across the physical and social sciences. Getting the different sectors working together is, however, difficult. As Boyd and Cornforth (2013) observe, 'Climate research is often communicated at global or regional levels, whilst lessons from livelihood projects are often relevant at the national context only' (p. 201). However, such barriers may be overcome when a wide variety of actors, including physical scientists, social scientists and in-country decision-makers—from ministers to smallholder farmers—commit to work together and share their knowledge and experience (e.g. Mitchell and Maxwell 2010; Jarvis et al. 2011).

Climate change issues threaten ongoing development efforts in Uganda, which is already experiencing the negative impacts of climate variability (Markandya et al. 2015). Droughts in 2008, 2010 and 2016–17 caused significant losses. In 2010, the economic losses were approximately US$470 million, equivalent to 16% of the total annual value of crops and livestock. In 2019, significant losses occurred in certain districts due to a combination of floods, landslides, crop pests and diseases and hailstorms (UNOCHA 2019).

Recognising the threat of climate change, the government of Uganda has made commitments to reduce climate risk. The National Vision 2040 and National Development Plan (NDPII) both make provisions for mitigation and adaptation (Uganda Government 2015a). Although there is a climate change policy in place (Uganda Government 2015b), the National Climate Change Bill has not yet been finalised, and pressures on financial resources impede effective implementation and monitoring of activities. Early discussions with the National Early Warning Co-ordination Centre, the Uganda National Meteorological Agency (UNMA) and other stakeholders from national to village level highlighted a knowledge gap in terms of realistic scenarios of the potential impacts of climate change, among other things.

To address this gap, the Integrating Hydro-Climate Science into Policy Decisions for Climate-Resilient Infrastructure and Livelihoods in East Africa (HyCRISTAL) rural pilot described in this chapter maps out a practical pathway to multi-stakeholder decision-making, drawing together knowledge and insight from both the social and physical sciences, to develop realistic scenarios of potential climate change impacts on defined populations and guide policy decisions. The research took place in Mukono District, east of Kampala, Uganda's capital and largest city, bordering the shores of Lake Victoria. We present the structure and form of the pathway to multi-stakeholder decision-making, then outline how this pathway was applied in Mukono, and the outcomes, and, finally, reflect on the utility of this approach in enabling effective adaptation and resilience.

A Pathway to Multi-stakeholder Decision-Making

Developing realistic scenarios required the integration of long-term hydro-climate projections with local context-specific information. We adopted an integrated approach with four key elements, depicted in the outer circle of Fig. 8.1: Research; Technology and Data; Capacity Building; and Governance. Each element then played a contributing part in developing an understanding of context and communication pathways to inform improved decision-making for climate resilience at the national and local levels (Fig. 8.1). The engagement was facilitated by Climate Action Network-Uganda (CAN-U), a locally based climate action advocacy organisation, which established a network of farmer (and fisher) champions to represent local perspectives and subjectivities concerning adaptation strategies.

Interdisciplinary Research involved rural livelihoods modelling—to develop plausible scenarios of the potential impact of climate change on the defined populations, combined with an understanding of the historical drivers of change in the land, natural resources and population dynamics in the Lake Victoria Basin.

Rural livelihoods modelling was informed by the Sustainable Livelihoods Framework and Household Economy Approach (HEA). The idea of sustainable livelihoods recognises that people's livelihoods result from the different types of livelihood assets or 'capitals' (physical, social, financial,

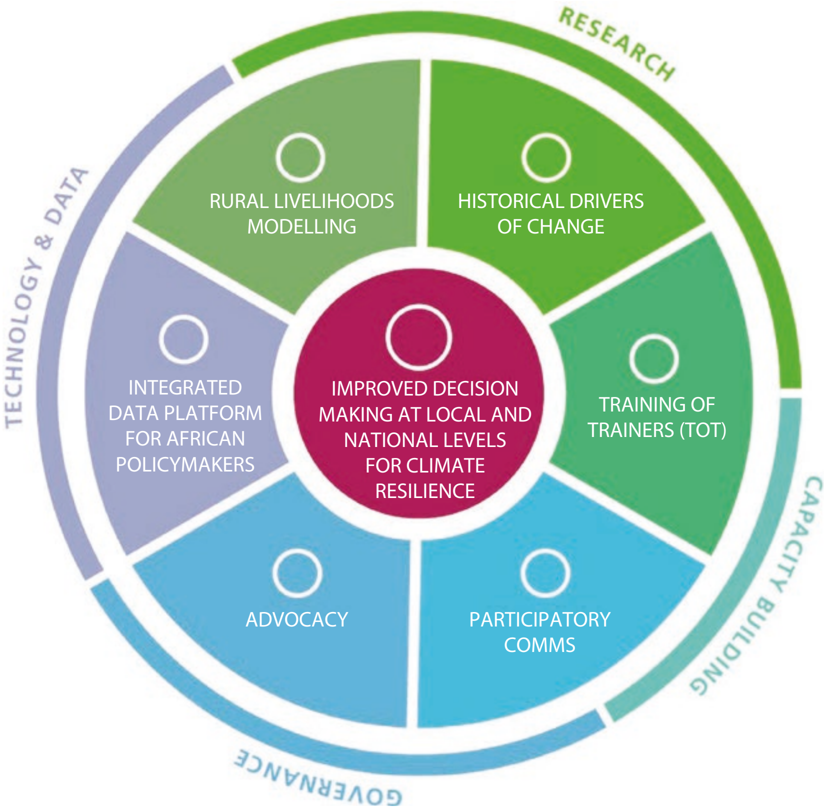

Fig. 8.1 Multi-stakeholder engagement approach and mixed-method research design

natural and human) on which they are able to draw, and that institutions mediate the capacity to convert those capitals into livelihood outcomes (Chambers and Conway 1992; Scoones 1998; Ellis 2000). It thus draws on Sen's Entitlement Theory (Sen 1981). The HEA complements sustainable livelihoods by providing a practical, field-based methodology to quantify income generated by households in 'livelihood zones' based on the assets and opportunities available to them and the ways in which they are used to generate food, food stocks and income (Seaman et al. 2014). The HEA is designed to allow short run predictions of the impact of production, price, and other year-to-year changes in the income and welfare of rural households. A modified version that is based on the same conceptual framework—the Individual Household Method (IHM)—is applied at a finer spatial resolution, namely single study villages rather than livelihood zones, and allows for more detailed analysis of differences within and between households across the wealth distribution.

The **Technology and Data** component involved integration of the different physical and social science data streams (climate, hydrology, agriculture and livelihoods) in HyCRISTAL through the Integrated Database for African Policymakers (IDAPS) platform. Analysis and sharing of local contextualised knowledge on IDAPS enabled decision-makers at the National Planning Authority (NPA) to explore realistic 'what if' scenarios.

Building Capacity occurred through 'Training of Trainers' conducted in partnership with local institutions and partner universities in HEA data collection and IDAPS analysis. This helped to accelerate, grow and sustain IDAPS adoption and ensure local institutions can continue to deliver both HEA and IDAPS training, with a view to post-project sustainability.

Governance involved the use of targeted advocacy and innovative participatory media communications and visual methods and action research approaches to influence relevant national and local decision-making processes. At the national level, processes that were informed include the National Development Plan, the National Environment Management Bill and the Koronivia Joint Work on Agriculture (a process taking place under the United Nations Framework Convention on Climate Change [UNFCCC] to address climate and agriculture issues). At local level, the target audience was district budgetary allocation committees supporting adaptation planning within the communities.

Applying the Pathway to Multi-stakeholder Decision-Making in Mukono: Process and Outcomes

Interdisciplinary Research: Developing Plausible Scenarios of the Potential Impact of Climate Change on Defined Populations

Data for rural livelihoods assessment and climate impact modelling were collected using the HEA. Workshops held in Mukono were used to identify livelihood zones. Livelihood zone data were then collected through interviews conducted in groups at the community level for a defined 'reference year' (in this case May 2015–June 2016). This was the most recent year that community members identified as being neither particularly bad nor particularly good for production. Wealth group interviews yielded data for a household 'typical' of the wealth group and included household asset holdings, a household budget including all sources of income and necessary supporting data such as household membership, market prices, information on additional sources of income that households might exploit under conditions of economic stress, seasonality and the price of food and non-food goods. This dataset could then be used to explore the expected impact of changed hydro-climate conditions on 'typical' household income (Seaman et al. 2014) using the IDAPS platform.

Additional detailed household economy information was collected using the IHM. In addition to the IHM interviews, focus group interviews covering adaptation and historical livelihood change were conducted, disaggregated by age and gender, which provided additional insight into 'adaptive' livelihood responses to climate and non-climate related events (e.g. the collapse in global coffee prices in the late 1990s, coffee wilt disease, banana mosaic disease and reduced maize yields due to changes in seasonal rainfall), and the social and cultural, as well as financial considerations that played a part in shaping these changes. This information provides insights into the extent to which future hydro-climate conditions are likely to be tolerated within existing adaptive capacity, and where further adaptive capacity might need to be strengthened.

Collecting data on household resilience and vulnerability is essential to contextualise modelling data and generate locally appropriate scenarios. In this case, findings of the HEA and IHM analysis on the contribution of specific crops and fishing to household food security across the income distribution provided a quantitative indication of household sensitivity to different climate risk scenarios. This identified that wrong assumptions had been made at the project's design phase (which included local climate scientists and fisheries experts, as well as physical scientists based in the UK) regarding the balance between fishing and agriculture in the rural economy of households living in lakeshore communities and the immediate hinterland which, if they had been used in a single disciplinary manner, could have been misleading.

Feedback sessions and dialogue with local farmers identified potential growth areas for smallholder incomes and barriers, together with possible solutions, to reduce climate risk. Examples included improving market access through investment in rural infrastructure or upgrading rural extension services and improving pest control.

The more detailed IHM studies generated financial analysis of the costs and affordability of various adaptation options available locally, showing that over 50% of the study population had disposable incomes that were well below the level needed to invest in activities that yielded even modest returns. For the poorest 25% of households, 'negative coping' often involving illegal or semi-legal activities, with unavoidable risks to both individuals and the environment, was the only available response to income shocks. Again, a single disciplinary approach would have missed this reality and may have resulted in recommendations for adaptations that would not have been affordable to the majority of the population.

As well as affordability, the qualitative data generated through focus groups highlighted how socially constructed gender roles and responsibilities may also lead to differential access to proposed adaptation strategies by women and men. With the collapse of income sources traditionally managed by men (e.g. coffee, bananas, fish), the lives of a generation of women now in middle age have been profoundly changed. Social conventions that had limited their work to the domestic sphere were dropped as they took up petty trade and small-scale enterprise in order to put food on the table. A short ethnographic study to engage with different people's present-day, lived experiences of these realities enabled understanding of the opportunities and constraints they place on their adaptive practices. This is essential to avoid recommending adaptation strategies that are either not accessible to all, or would act to reinforce existing gender inequalities.

Technology and Data: Preparation for Uncertainty Through Realistic 'What If' Scenarios Using IDAPS

Working with the National Emergency Coordination and Operations Centre (of the Department of Disaster Preparedness and Management) and stakeholders from national to village level, the IDAPS multi-sector data platform was developed (Cornforth et al. 2020). The platform is open data and cloud-based and is intended to be freely accessible to stakeholders at every level. The purpose of the platform is to democratise access to information and allow local decision-makers to create and explore their own scenarios for planning and climate-impact preparedness and adaptation.

Box 8.1 Stepwise Development of IDAPS

The first IDAPS user forum was hosted in 2017 by the Uganda National Council for Science and Technology (UNCST). Key attendees included four Members of Parliament, including Honourable Cecilia Atim Ogwal (Deputy Speaker) and the leader of the Parliamentary Forum on Climate Change; the Assistant Commissioner, Ugandan Ministry for Water and Environment (MWE); Deputy Executive Secretary of UNCST; a senior representative from Uganda's National Emergency Coordination and Operations Centre; representatives of civil society climate change advocacy groups; and senior district level technical officers.

This wide-reaching stakeholder engagement was the first step towards ensuring that the IDAPS platform is accessible and applicable to a diverse group of users, a necessary condition for successful and well-informed decision-making. Subsequent steps have focused collective efforts on co-developing, refining and prioritising Use Cases to include on IDAPS. Here, a Use Case, at the highest level, has the simple formula:

$$\text{As a X}\left(\text{a role}\right)\text{, I need Y}\left(\text{a feature}\right)\text{, to do Z}\left(\text{a benefit}\right)$$

IDAPS then brings together the most relevant data sets from across different disciplines to satisfy a prioritised Use Case (*for a role*). These data are then presented in a way (*the feature*) that is meaningful to the non-specialists enabling them, for the first time, to interact with the data and develop scenarios based on their own perceptions of plausible futures (*the benefit*).

IDAPS brings together data from climate modelling, agronomy and hydrology to model the impact of climate scenarios on people's livelihoods and their ability to access their basic food and non-food needs. The HEA and IHM outlined earlier were used to model the impact of climate and other shocks on rural livelihoods in order to understand who would be affected, and in what ways, by a defined change scenario in a specific livelihood zone. At a national level, by contributing to a deeper understanding of the likely impact of climatic change on people's livelihoods in particular districts throughout Uganda, the possibility of delivering timely national responses (Cornforth et al. 2020) that are tailored for appropriate mitigation and adaptation strategies should be greatly enhanced.

IDAPS visualisations and decision Use Cases have been meaningfully co-produced with government and civil society stakeholders at the national, district and sub-district levels to develop a set of Stakeholder Value Narratives (Fig. 8.2). The first IDAPS module (the HEA) has been successfully used in a pilot project. The second module (IHM) has also been completed, and allows for more detailed analysis, monitoring and evaluations at an individual household level. New modules of IDAPS are in development for use in climate change scenario impact modelling, which integrate hydrological and meteorological data to support policy decisions for the sweet potato market (Young et al. 2020). The first of these has been used to examine the government interventions that might be needed in the context of a wetter and warmer climate, that is to say, 'Future 1' in the HyCRISTAL Climate Narratives (see Burgin et al. 2019).

Capacity Building

For a decision-making tool such as IDAPS to be effective, and for additional modules to be developed for use in other districts, it is necessary to provide training in HEA data collection and IDAPS analysis. Currently, engagement with policymakers and administrator stakeholders in Uganda is deepening with 'Training of Trainers' capacity building work ongoing. The interview frameworks and data analysis methods used in HEA and IHM studies have been designed to be easily taught, and training curricula have been developed with local universities.

Governance and Advocacy: Scaling Up Co-management and Social Learning Through Participatory Communications (Visual Methods Research)

Advocacy and awareness raising activities are proceeding in concert with capacity building. The facilitator of the process, CAN-U, has strong government links and advocacy experience. A high-impact advocacy plan was co-developed, aimed at communicating and influencing decision-making on rural adaptation at the sub-national and national levels in Uganda, guided by the findings from the rural pilot research. Working together with CAN-U, direct proposals were made to the Climate Change Working

Group during the consultative process for the Ugandan National Environment Bill. In making suggested revisions and additions to relevant clauses in the bill, the team were able to signal the need for comprehensive livelihoods zoning and the prerequisite of having a deep, balanced and uniform baseline understanding of livelihoods before any of the impacts of climate change on society and the economy might be fully understood.[1]

Together with CAN-U, a network was also developed of farmer (and fisher) champions who were in a position to represent local perspectives and subjectivities concerning adaptation strategies. Eight community farmer champions based in Mukono were identified and trained in video storytelling and research. The use of video has an established track record in research and development as a participatory communication practice and method that can transcend entrenched barriers to inclusion of marginal voices and perspectives (Walker 2018). It achieves this while also delivering effective horizontal and vertical communication and brokering effective links that otherwise may not exist. In Mukono, rural theme partners used basic video making as a way of overcoming and subverting the traditional one-way knowledge exchange processes sometimes found in rural research and communication. By engaging the farmer champions identified by CAN-U and providing training in visual storytelling, researchers initiated a conversation between farmers and their district government.

The focus of this conversation was on how their agricultural and fishing practices need government support to respond to challenges in the context of an increasingly unpredictable climate. This approach allows farmers to work in their own language, using their own cultural idioms, in a way that enables their own subjectivity to surface. Building this bridge for two-way communication between farmers and their district government initiates a process in our pilot communities that allows farmers to overcome the inclusion hurdle in adaptation planning.

At national level, the advocacy work targets the Parliament of Uganda, the national planning agencies and the departments of agriculture, climate change and finance (see Fig. 8.2). The farmer champions have also met with the NPA and held a dialogue on key planning needs for future adaptation to climate change. These connections were identified through the initial stakeholder mapping activities conducted by CAN-U. These highlighted the decision-making influence points targeted by the

[1] See: http://www.walker.ac.uk/about-walker/news-events/walker-institute-team-contributes-to-ugandan-national-environment-bill/

Fig. 8.2 Schematic showing the development of the multi-level networks under the HyCRISTAL rural pilot. Key: *CCD* Climate Change Department, *COP* Conference of the Parties under the UNFCCC, *EAC* East African Community, *LVBC* Lake Victoria Basin Commission, *MAAIF* Ministry of Agriculture, Animal Industry and Fisheries, *MWE* Ministry of Water and Environment, *NAP* National Adaptation Plan, *NEMA* National Environment Management Authority

integration of participatory communications and the CAN-U advocacy plan and are illustrated in Fig. 8.2.

At district level, the farmer champions have interacted with district leaders, agriculture extension workers and national and sub-national leaders to inform and influence budgeting and planning for rural adaptation and, in particular, increased access to agricultural extension services. The Mukono District local budget is showing signs of response towards financing and supporting climate needs of smallholder farmers with funding for targeted agriculture extension services increasing by 18% in the financial year 2019–20. Further to this, HyCRISTAL smallholder champion farmers have reported increased access to extension services in their communities in the last financial year.

Discussion and Conclusion: The Importance of Multi-stakeholder Approaches for Climate-Informed Rural Decision-Making

Our HyCRISTAL pilot study in Mukono set out to answer the question 'What information do local policymakers need now to reduce vulnerability and enhance resilience?' Our experience highlights the importance of multi-stakeholder approaches and the generation of a 'knowledge ecosystem' that combines physical and social science methods and data to generate context-specific information to inform decision-making. The approach we have described shows how established research tools rooted in both the qualitative and quantitative research traditions can combine to provide a deeper, policy relevant understanding of fundamental questions of climate change, resilience and adaptation. Lessons learned included how communities, sector services and non-governmental organisations (NGOs) might better plan their activities based on likely scenarios that reflect opportunities, risks and outcomes in agriculture, disaster risk reduction, adaptation and resilience.

If rural adaptation is to be effective, then it cannot take the form of prescriptive actions determined by outsiders and subsequently imposed upon rural communities. Even if all the evidence suggests a certain course of action should be taken, without input from the rural communities themselves, there is the danger that adaptation merely expands marginalisation through the reproduction of historical power imbalances resulting from remote decision-making and the elite custodianship of information. For rural adaptation to be effective, it needs to reflect and more critically understand local experience and perspectives, based on knowledge sharing (both information and the skills required to interpret it), to allow for devolved decision-making, and to be as inclusive as possible, given unequal power structures.

To answer our question asked earlier, the convergence of various strands of research and communication in the rural pilot—from local to national to regional—provides policymakers with the types of information they need. This promotes consideration of scenarios and the taking of actions based on a systems-based understanding derived from multiple and diverse sources of knowledge. This is continuing to enable policymakers across all levels to make better informed short- (e.g. revised allocation of district budget to support targeted extension services) and long-term decisions (e.g. adoption of revised clauses in the Uganda National Environment Bill) related to rural adaptation. It also allows specific consideration of the problem of under-investment in the rural economy and rural populations through the evidence provided by the rural pilot.

By understanding adaptation to drivers of change as a political and socio-economic process, and not simply a scientific one, then the notion of science-led solutions fails the fit-for-purpose test. Direct engagement with decision-makers, empowered at all levels with access to relevant information, is imperative, and central to this is a strategy for, and execution of, effective communication.

Finally, our rural pilot study has highlighted the need to critically interrogate and understand the implications of adaptation and resilience as policy responses to climate change in poorer rural communities. Failure to do this runs the risk of promoting solutions that are ineffective or even counter-productive. Active involvement of local populations in the governance process and advocacy through, for example, video storytelling, provides opportunities to surface the needs, education and aspirations of marginalised rural communities, which include growing numbers of largely neglected, 'left behind' youth. This re-framing offers the potential to contribute to and enhance national capabilities for more effective and inclusive climate risk management and provides civil society with new opportunities for policy engagement in sustainable development.

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CHAPTER 9

Conversations About Climate Risk, Adaptation and Resilience in Africa

Declan Conway and Katharine Vincent

Abstract This book contributes to previous and ongoing action to initiate and inform conversations about climate risk and the need for adaptation and resilience building. This involves blending insights from climate science about what the future climate will look like with experiences of the social science of response through adaptation, based on practical applications in a variety of contexts. In this chapter, we reflect on these conversations and what they mean for the growing adaptation agenda. We consider who needs to be involved in conversations about adaptation, how such conversations can be structured and the need to assess their outcomes. We profile important considerations relevant for tailoring climate information to make adaptation decisions and discuss the outcomes of different types of conversations. We conclude by noting the significance of recent major

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climate events and the rapidly evolving risk landscape in sub-Saharan Africa, and arguing that the need for these conversations is ever more evident. The experiences outlined in this book provide a starting point for conversations about adaptation that aim to inform future action.

Keywords Climate risk • Adaptation • Climate information • Co-production

Introduction

Climate change is posing a risk with which we all have to live. As a result, the learning process about climate change adaptation will continue for decades into the future. There are no blueprints for this process: instead we have to learn by trial and improvement.

In Chap. 1, we introduced a series of questions that informed the writing of the subsequent chapters, based on our collective insights about what are important considerations for adaptation and resilience:

- What are the characteristics of the decision problem and how are they defined and by whom?
- What kinds of interactions occur and who is involved?
- What are the key contextual factors including the significance of historical climate risks and role of institutions and governance?
- How are climate risks characterised and communicated, over which timescales?
- To what extent does uncertainty about climate feature in the analysis?
- To what extent are non-climate considerations important and how they are addressed?
- What are the reflections—what works well and why?

Reflecting on the resulting chapters, which address the questions in a variety of ways (and sometimes implicitly), we see their collective contribution as adding to previous and ongoing action to initiate and inform conversations about climate risk and the need for adaptation and resilience building. This involves blending knowledge from climate science that provides insights into what the future climate will look like with experiences of the social science of response through adaptation, based on practical applications in a variety of contexts in sub-Saharan Africa. To do so requires a process of communication. By raising awareness, sharing knowledge between different actors and promoting inclusion, the book aims to 'inform the conversation' that is ongoing in international and national policy arenas, and more broadly in society, to help make more equitable and effective decisions to reduce climate risk. We therefore structure this chapter around the idea of conversations that occur in support of adaptation and resilience in the face of climate risk.

Much of this book deals with underlying principles and different structures designed to facilitate effective conversations along the whole climate services value chain, which includes the robustness of information, approaches to engagement and construction of knowledge. Climate change is defined as a wicked problem—namely one that defies easy resolution due to constantly changing baselines and inherent uncertainty. This means that addressing it requires post-normal science, where science cannot be divorced from the values and norms that give it value and use (Funtowicz and Ravetz 1993). To take those values and norms into account, post-normal science requires active engagement of the non-scientific communities. Participatory engagement and co-production are among the mechanisms through which post-normal science takes place. Equity and inclusion are core principles to be promoted through these approaches, taking into account who is involved and their roles. These structured conversations are also designed to address in various ways factors that are required for succesful information use, including credibility, legitimacy/trust and salience, among others (Cash et al. 2003; and running through Chaps. 1–8).

This chapter reflects on these conversations and what they mean for the growing adaptation agenda. In the next section, we consider who needs to be involved in conversations about adaptation before turning to ways in which such conversations can be structured and the need to assess their outcomes. We then examine what considerations are relevant for tailoring climate information to make adaptation decisions. In the following section, we reflect on the outcomes of those conversations, and we then conclude with a section about focusing conversations on the need for action.

Who Is or Needs to Be in the Conversation?

Conversations about adaptation need to engage widely. Figure 9.1 from the Global Framework for Climate Services (GFCS) shows the range of actors and roles involved along the climate information value chain linking knowledge to action. The climate science community is a crucial part of the process—this is where new understanding is generated that has great potential for application. In much of Africa, National Meteorological and Hydrological Services (NMHS) and regional economic communities and their associated bodies (the African Center of Meteorological Application for Development—ACMAD, the Intergovernmental Authority on Development Climate Prediction and Application Center—ICPAC, and the Southern African Development Community Climate Service Centre—SADC CSC) hold formal mandates for collecting data, issuing forecasts and reporting on climate. This occurs through the mechanisms of, for example, the pan-African inter-governmental bodies such as the African Ministerial Conference on Meteorology (AMCOMET), the African Ministers' Council on Water (AMCOW), the African Ministerial

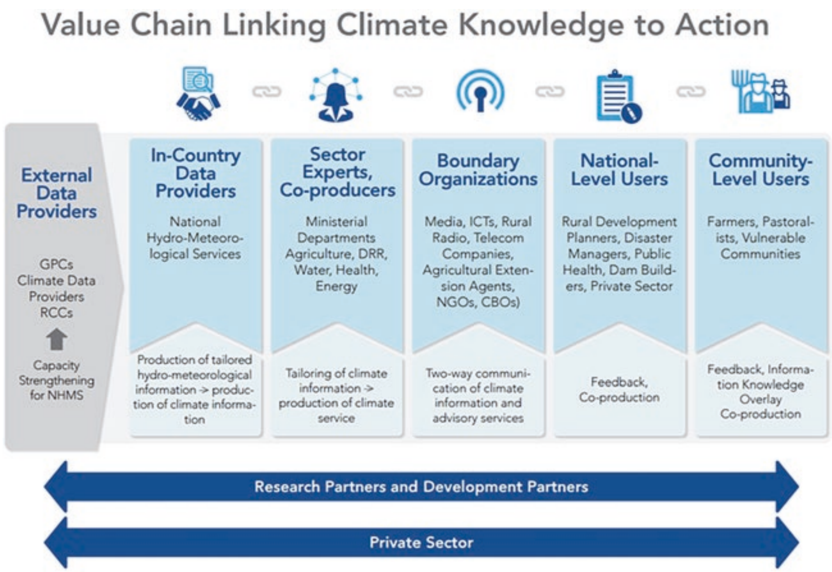

Fig. 9.1 The range of actors and roles involved along the climate services value chain linking knowledge to action. Source: Figure prepared by Winrock International and WMO for the USAID-supported Assessing Sustainability and Effectiveness of Climate Information Services in Africa project. Washington, DC, USA; https://gfcs.wmo.int//saly-coordination-workshop

Conference on the Environment (AMCEN) and Regional Climate Fora, as well as internationally through the United Nations Framework Convention on Climate Change (UNFCCC) and the World Meteorological Organisation (WMO). They are where most of the technical capacity exists, complemented by the university sector where, with some exceptions, capacity is generally more limited than the global North. Many institutions support only a few or just one individual with some experience, although the number is growing. In Future Climate for Africa (FCFA), the consortia integrated some of these organisations either as core partners or through regular engagement.

As this book clearly shows, the conversations necessary for adaptation go way beyond the science. This can create new and far-reaching demands on the traditional science-based organisations and their staff—in terms of remit and skills and financial resources. The gap between core science and application can be vast, and it does not need to engage everyone, indeed for many scientists this is unnecessary. A growing range of boundary organisations are also concerned with adaptation and resilience and have expanding numbers of specialists, and thus play a critical role within the climate services value chain. In some cases, very limited technical information is actually required to achieve confidence in making decisions. In fact, leaving climate information completely out of the conversation initially may be good practice to avoid priming and to openly identify primary concerns (e.g. Chap. 2).

Important questions arise with respect to whether and how the established leading science organisations take on these new roles and to what extent the necessary knowledge and skills are presently being taught. And are they even the right people or organisations to take on these roles? While it is beyond our scope to answer definitively, experience suggests that it is difficult for NMHS to engage without additional funding, broader staff capacity, or changes to their mandate. There is a grey area between official responsibilities as data providers and demands to work with sector experts and users, and roles for intermediaries who require access to data and people's time (providers, sector experts and users). The interfaces or boundary areas between the data providers and sector producers (Fig. 9.1) need more recognition and formal guidance on roles and responsibilities, backed up by allocation of resources and capacity strengthening to deliver results.

University teaching offers the most promise to fill the skills gap over the long-term and could benefit from modifying existing courses/modules and setting-up new interdisciplinary degree programmes. There are well-known drawbacks to short-term training programmes and technical assistance (Mataya et al. 2019). Placements and collaborations through linking student dissertation topics with practitioner organisations offer a route for trans-disciplinary collaboration between researchers and practitioners and the potential for deeper understanding of decision contexts (Chap. 6). The Future Resilience for African Cities and Lands (FRACTAL) programme found very positive experiences through embedded researchers working in host organisations helping to broker multi-stakeholder engagements and sustain momentum (Chap. 7). These efforts are designed to address concerns about externally and technically driven agendas. They aim to support initiatives from the ground up—promoting more endogenously African driven actions (Vogel et al. 2019). This includes working hard to raise the low presence of African-based researchers in academic journals and Intergovernmental Panel on Climate Change (IPCC) reports (Pasgaard et al. 2015) and giving more credence and platforms to alternative ways of sharing insights, recognising different forms of knowledge. Building confidence through long-term commitment will help (Hewitson 2015). Similarly, and crucially, so will strengthening the opportunities for early career researchers as the next generation who can bring their insight and voices to the challenge (Mustelin et al. 2013).

Taking the time to understand contexts at any scale of decision-making highlights that it is never just about the climate. Climate impacts play out against pre-existing exposures and vulnerabilities, reactive or anticipatory responses are conditioned by people's capacity and longer-term planning, both of which reflect the underlying power structures that operate through governance within societies. Such structures play a major role in determining processes in decision-making and reflect and reproduce the underlying socio-political patterns that construct vulnerability, a context that extends far beyond adaptation as narrowly defined by a focus on climate risk (Adger et al. 2009). Careful design and deep engagement that recognises these contexts should underpin approaches to adaptation. Involving national level and community level users is fundamental to this process.

How Have These Conversations Taken Place?

The cases presented in earlier chapters exemplify various ways in which conversations can be inclusive. Co-production is a process that brings together different parties and, as Vincent et al. (Chap. 3) note, is increasingly promoted to enhance the utility and usability of climate information. They proposed ten principles of co-production derived from both academic literature and practical experiences but, crucially, emphasised that there is no blueprint for what is required. Participatory Impact Pathways Analysis (PIPA) comprises problem tree analysis, visioning and stakeholder mapping, and a climate information training workshop, leading to an options matrix that aims to support preparedness (Chaps. 3 and 4). Participatory Scenario Planning (PSP) takes place through consultative dialogue between weather and climate information producers and users who generate sector-specific advisories (Chap. 5). Chapter 7 outlines how multiple fora in the FRACTAL programme served to enhance interaction with stakeholders in urban settings and ensure that the problem context drives the construction of climate information, including learning labs and embedded researchers. These fora helped inform and refine the interactive and inclusive process of information distillation and Climate Risk Narratives outlined in Chap. 2.

Conversations have diverse and often intangible outcomes within and through the climate services value chain. Growing investment in adaptation and a scaling up of the types of approaches presented here underscores the need to define and collect evidence of effective outcomes. Dialogue and co-production are time consuming, they often require physical meetings and involve many people, all of which generate significant costs and are increasingly hampered by issues of fatigue in some frequently targeted user groups. NMHS and national and community level organisations are likely to require extra resources for the new demands on staff time that will arise when tasked with adaptation, many of whom may also need knowledge and skill sharing. However, applications of co-production on climate change timescales in Africa are in their infancy and there is a need for more extensive assessment of their utility and the potential for replication and scaling up (Wall et al. 2017). As well as challenges with evaluating co-production, universal indicators for adaptation are unrealistic given context-dependent risk (Leiter and Pringle 2018) and differences in people's values as they relate to their experience and sense of place that are largely intangible and non-commensurable (Tschakert et al. 2019). Nevertheless, we see a need for more comparative analysis with a focus on locally or self-defined measures of outcomes, cost effectiveness, strengths and weaknesses of approaches, processes and outcomes, and potential for replicability at scale. The rich history of experience in other fields of application in co-production and participatory approaches in development could offer some useful lessons. Evidence is now emerging from Community-Based Adaptation (CBA) projects. For example, an assessment of whether CBA was effectively promoting adaptive capacity in 32 projects across four Pacific Island countries found mixed performance, with positive responses for appropriateness but issues highlighted for sustainability (McNamara et al. 2020).

What Are Conversations Based On?

A major part of FCFA focused on high-level climate science, producing many articles on Africa's climate. These include uncovering positive trends in daily rainfall intensity in West Africa (Taylor et al. 2017), proposing a framework for an African lens in climate model analysis (James et al. 2018), and improvements in simulation of crucial convective-scale processes through high resolution modelling (Kendon et al. 2019) together with the first climate projections at this scale. While this vast body of work builds the science knowledge base that interfaces with applications, the pathways to impact can take many years. The types of climate information used in this book are diverse, representing multiple timescales and in all cases a substantial tailoring of information that addresses to varying degrees its credibility, legitimacy and salience. Chapters 4 and 5 consider seasonal forecasting (Audia et al. and Tembo-Nhlema et al., this volume), two adopt a Climate Risk Narrative approach covering medium term future timescales informed by climate model projections (Chaps. 2 and 7), and two use elements of an impact-led approach by simulating impacts directly with climate model projections and process models (Chaps. 6 and 8). Development of Climate Risk Narratives draws heavily on the science but may result in summaries or infographics (Burgin et al. 2019) that bypass the technical aspects, underscoring a case for involving stakeholders in this translation process (Chap. 2).

Of note is that there is little detail about the climate information itself—the focus is primarily on the process of reaching a point where information becomes usable. Apart from Chap. 2, which actively promotes making the value judgements in the climate science explicit in a consultative process, and Chap. 6, which presents a technically detailed approach to decide on which model projections to use, climate models are barely mentioned. By intent, there is limited description of greenhouse gas emissions scenarios, whether and how to downscale from coarse to fine climate model resolution information, quantification of uncertainty about changes in climate variables, and discussion of how many and which climate models to use. These are all stages in the cascade of uncertainty from global climate projections to local or decision-relevant scales of information that often form core content in climate impact studies (e.g. Wilby and Dessai 2010; Wilby et al. 2009). Moreover, in most of the chapters, there is a strong focus on understanding recent and current experiences of climate risk to make the issue more tangible and relevant to decision-makers. While the chapters address the interface between top-down and bottom-up approaches, they tend to draw more heavily from elements of the latter, avoiding the technical complexity because it may not be of direct value to actual decisions underway (Conway et al. 2019). In short, there are various ways of facilitating conversations that can take place with currently available information to manage climate risk and facilitate adaptation and resilience—as outlined in Chaps. 3–8.

Considerations Relevant for Tailoring Climate Information to Make Adaptation Decisions

Deciding on how to frame the elements of adaptation, particularly the climate information requirements, requires consultation to establish the aim of the exercise, for whom, and what are their main concerns? A key factor in this is the scale of the decision. While adaptation has been widely seen as a local and place-specific process there are many situations where decisions have large areal dimensions with consequences far into the future. There is also growing recognition that climate risks cross boundaries (jurisdictional, political and sectoral) and as such adaptation action can redistribute or transfer climate risks (Benzie and Persson 2019). This raises questions about the scale of the adaptation response space—we aim to be comprehensive, but how to do so without making the decision context too complex and paralysing the process, with too many options and actors?

Many forms of climate information and ways of structuring conversations about climate risk and adaptation are available to suit the scale of the decision situation. Most involve variations of a sequence of actions that include: consulting about the problem and agreeing the aims of the exercise; developing an understanding of the system of interest; identifying what is important for stakeholders, assessing the significance of future climate risks to development plans and identifying options (e.g. Willows et al. 2003). Further stages can include implementing decisions, followed by monitoring, evaluating and adjusting. We stress that simplicity is essential to ensure sustained use. While more sophisticated and ambitious use of climate information, tools and decision support systems are attractive and promoted by researchers, they often fail to meet the realities of operational practice. For example, Clar and Steurer (2018) identified 88 support tools for climate services/adaptation but they had received very limited evaluation. When they examined whether and how the Willows et al. (2003) framework, a tool that had been widely promoted in the UK during the late 1990s and 2000s, was used by local authorities, they found very low levels of awareness and use.

Deciding which approach is most suitable is an important initial part of an adaptation process and requires consultation. Bearing this in mind, Fig. 9.2 shows a continuum ranging from a simple light touch approach suitable for many small and short-lived decisions through to detailed assessments for major long-lived decisions such as large-scale infrastructure and urban planning. For light touch screening approaches such as adjustments to agricultural practices and technology, or selecting small-scale water and sanitation technologies, only limited climate information is required. A summary of recent variability can be extrapolated into the next few years, flagging the need for action where any crucial climate

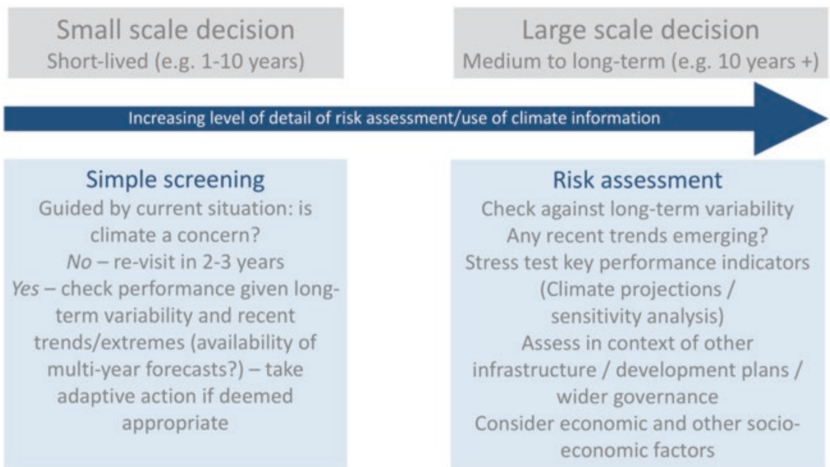

Fig. 9.2 The types of climate information and approach vary with the scale of the decision situation

sensitivities have been experienced, and if not, reviewing the situation every two to three years.

However, major decisions require careful planning and risk assessment should include climate. Where large investments are involved and their planned lifespan is long and decisions may be irreversible, it is crucial to consider future climate risk. While examples are emerging of climate risk assessments, they are still far from routine. Chapter 6 describes part of a detailed climate risk analysis for a major dam project in the Rufiji River Basin in Tanzania that would amount to a considerable budget (many thousands of US dollars), but this is small compared to the cost of the infrastructure and the potential costs of future underperformance. It is on longer-term future timescales that uncertainty about the future climate and other socio-economic factors have more bearing on the risk assessment process. Deriving climate information can easily become bogged down in technical detail, be capacity and resource intensive and lead to confusing messages about uncertainty. Detailed assessments should not be undertaken lightly.

What we can say with high confidence is that warming trends will continue, increasing the frequency and intensity of heatwaves and, other things being equal, enhancing soil moisture deficits. For rainfall, ideas of Robust Decision-Making (RDM) or Decision-Making Under Uncertainty (DMUU), like the principles captured in the Flexible, Robust, Economic no/low Regrets and Equitable framework (FREE, Chap. 4), can help address the uncertainty. Such approaches are designed to identify decisions and adaptation options that work reasonably well across large ranges of uncertain future climatic conditions or that retain flexibility in a cost-effective manner (Groves and Lempert 2007). These principles can be applied at a range of decision scales with limited inputs.

What Have Been the Outcomes of These Conversations?

FCFA was designed out of a realisation that many sub-Saharan African countries do not include climate information in medium- to long-term planning. The programme aims were framed as: achieving better tailoring of information to needs; greater recognition of political factors in decision-making; and more consideration of ethical dimensions of promoting long-term climate risk in situations dominated by pressing developmental priorities and short-term political timeframes (Jones et al. 2015). Despite the commencement of new conversations and application of new tools and decision-making frameworks to increase use of climate information, there remain, to our knowledge, limited instances where direct use of information on medium to long-term future climate change routinely form part of formal decision processes in sub-Saharan Africa.

Most of our examples are discrete, where specific research projects have engaged with formal and informal agencies and their planning processes, which have their own lock in effects and path dependency. In some cases, the influence may be evident. For example, in Chap. 7 the authors were able to work closely with policymakers in preparation of the City Council's Strategic Plan (2017–2021) and through multi-level engagement in Uganda; Chap. 8 fed insights into district level budget decisions and revisions to the National Environment Bill. In many other cases, the influence is less distinct but still present through the sharing of information between those involved in the engagements (many more specific examples can be found at FCFA, https://futureclimateafrica.org/).

Focusing Conversations on the Need for Action

FCFA is one of many programmes that are contributing to an ongoing conversation about climate change, adaptation and resilience building—gradually making society more climate aware, more climate literate, and more climate prepared. And the need for those conversations has become ever more evident in the four years since the start of the FCFA programme. During that time Africa has experienced, alongside many other extremes, one of the strongest El Niño–Southern Oscillation events in over 50 years (in 2015–16) and the strongest Indian Ocean Dipole event in six decades (2019). Both are large-scale modes of global climate variability that influenced conditions over extensive areas of Africa and brought with them wide-ranging impacts. The drought in southern Africa that accompanied the 2015–16 El Niño–Southern Oscillation resulted in an extensive loss of crops and livestock and an increase in food prices, driving an estimated 39 million people into deeper food insecurity (Archer et al. 2017). The Indian Ocean Dipole was associated with high rainfall across large parts of East and the Horn of Africa between October and November in 2019. Heavy rainfall caused landslides and flash floods with millions of people affected. The Day Zero water supply crisis in Cape Town received global media coverage, prompting intense debate over the role of drought and water resource management decisions and infrastructure prior to and during the crisis (e.g. Taing et al. 2019). The event exemplifies how poverty mediates the ways in which exposure translates into impacts, the complex and often contested causal pathways between climate hazards and their human consequences, and the windows of opportunity for learning and policy response that extreme events provide.

Future risk is likely to lie well beyond what has been experienced in the recent past and, however well intentioned, levels of concern and funding for contingency plans fade over time. We are heading for minimum 1.5 °C and quite possibly well above 2 °C of global mean temperature rise this century. The impacts of changing frequency and intensity of extremes along the way could be exacerbated by the potential for exceeding low probability but high-impact tipping points (Lenton et al. 2008). New landscapes of risk are emerging as a result of hazard complexes occurring in rapid succession or in cascades through knock-on effects across sectors. For example, the 2015–16 drought in southern Africa was associated with complex compound features: successive years with low rainfall and extreme temperatures leading to rain-fed crop failure and heat stress on livestock and plants; reduced river flows leading to less irrigation and less hydropower; cascading to further impacts on water pumping for urban and irrigation uses and health/hygiene problems (Chap. 7; Gannon et al. 2018). At the time of writing, the impacts of Covid-19 are playing out against the compound effects of flooding in East Africa in early 2019 and massive locust infestations, both associated with the extreme Indian Ocean Dipole of 2019 (Marsham 2020).

Fortunately, the increasing evidence of climate risk is accompanied by two important and related drivers of growing demand for adaptation measures. The first is greater recognition and experience of the escalating social and economic burden caused by changing frequencies, intensities and combinations of hazards. The second is stronger international and national level policy commitments, such as the Paris Agreement and the Global Goal on Adaptation. There is competition for resources and development priorities and short-term political and planning horizons, but by emphasising the need to embed the climate dimension in a wider context of decision-making we recognise the importance of aligning adaptation and resilience building with other sectors and actors, to make the agenda relevant and tractable for policy and practice. In short, conversations about climate need to be had. Our premise is that the interface between experiential and policy drivers of autonomous and planned adaptation and resilience building stimulates innovation for practice. It is at this interface that the value and use of climate information is raised and tested. And the experiences outlined in this book provide a starting point for such conversations to inform future action.

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