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Enabling Climate Science Use to Better Support Resilience and Adaptation Practice

Rapid Evidence Assessment for the CLARE programme

6 March 2020

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Executive Summary

The Department for International Development (DFID) commissioned a review of climate science use in adaptation and resilience practice, to inform the development of their new climate and resilience research framework programme (CLARE). This programme, in partnership with the International Development Research Centre (IDRC), will provide evidence and innovation needed to climate-inform DFID and other UK Government investments threatened by climate change, particularly in Africa.

LTS International (LTS) were commissioned to undertake an initial scoping study, with reference to the following question: "*Within the process of enabling climate science to better support resilience and adaptation practice and achieve internationally agreed commitments, what is working and what is missing in its use, and which people and institutions are key contributors in this field?"*

The LTS team, which comprises both climate resilience and adaptation experts and climate scientists, conducted this scoping study using a light touch Rapid Evidence Assessment (REA) supported by expert consultation and key informant interviews (KIIs). The LTS team reviewed both relevant academic and grey literature, and interviewed climate scientists and development practitioners. The work focused on Africa with a light touch approach applied to South Asia and the Pacific.

The assessment examined current research activities and priorities in the science to application chain. As a stark finding early on in the process, it was clear that in practice the reality of this chain is questionable. As a consequence, the assignment focused more strongly on the use of climate science in adaptation and resilience practice. A detailed assessment of climate science activities and priorities was beyond the scope of this study, however our initial findings, as detailed in this report, may inform future scoping work in this area.

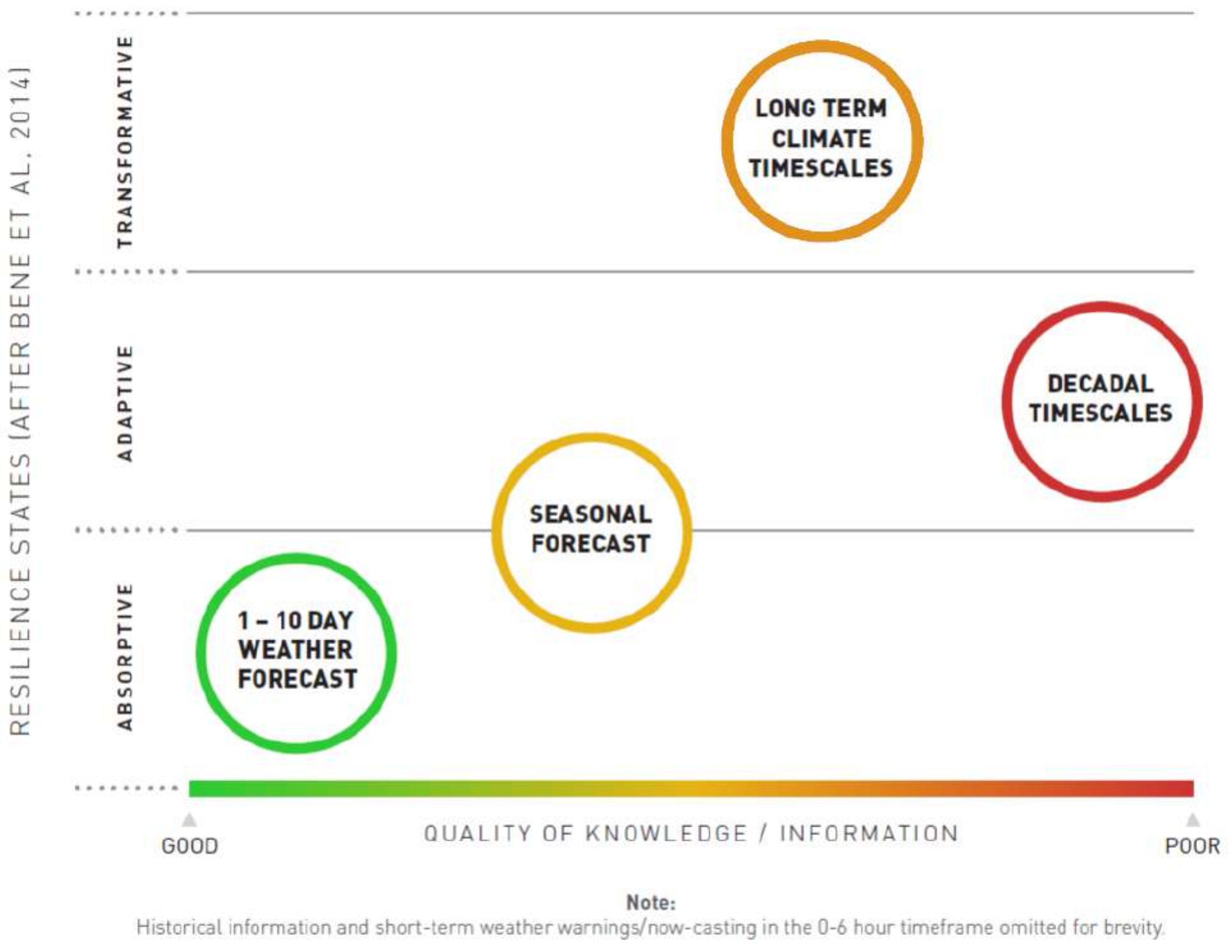
Key Findings

Figure 1 is an illustrative schematic which summarises our key findings on the assessment of the quality and application of climate science to adaptation and resilience practice. It considers four forecasting periods: 1-10 day; seasonal; decadal; and long-term climate timescales. The x-axis represents the relative quality of the application of climate science knowledge. Good quality, for example, is representative of a state where the data used to produce the climate science information is accurate and of high resolution. In addition, the information produced is in a form which is usable and applicable. Information is adjudged to be of poor quality where there is limited accurate information available, for example, due to a lack of quality data or limited level of accuracy within the science. Poor quality data also exists where there is limited supply or usability of information/knowledge for a particular forecasting period.

The y-axis shows where the forecasting periods are best suited to an absorptive, adaptive, or transformative resilience context[1]. The resilient states included in Figure 1, are taken from Bene et al, 2014[1]. Absorptive refers to the various coping strategies by which "individuals and/or households moderate or buffer impacts of shocks on their livelihoods and basic needs". Adaptive refers to the "ability of a system to adjust to climate change, both variability and extremes, to moderate potential damages, take advantage of opportunities or cope with the consequence". Transformative refers to the "capacity to create a fundamentally new system when ecological, economic or social structures make the existing system untenable"[1].

[1] Bene et al, (2012). Resilience: New Utopia or New Tyranny? Reflection about the potentials and limits of the concept of resilience in relation to vulnerability reduction programmes. (**405)** 06. CSP Working Paper. DOI: 10.1111/j.2040-0209.2012.00405.x

Figure 1 Assessment of the Quality and Application of Weather and Climate Information for Adaptation



Key:

- Colouring in the axis indicates the quality of knowledge/information; and
- Colouring of the circles indicates the quality of use of the knowledge/information type.

Our findings are based on expert-informed analysis from the LTS team and key informants from academia and practice. The expert informed analysis is consistent with findings from the review of grey and academic literature on climate science and climate services supporting adaptation and resilience:

- The climate science information for 1-10-day forecasting is good in many places, in that it is produced to a level of accuracy which is useful for some groups of users. Its uptake by users is also good in some places and applicable in an absorptive context within the resilience states. Nonetheless, many people who require short term weather information are not able to obtain it, if it is not provided through accessible, trusted channels. Even if information can be accessed it may not be provided in a format that is understandable and relevant for specific decision-making processes, at a relevant geographic scale and with guidance for users lives and livelihoods;

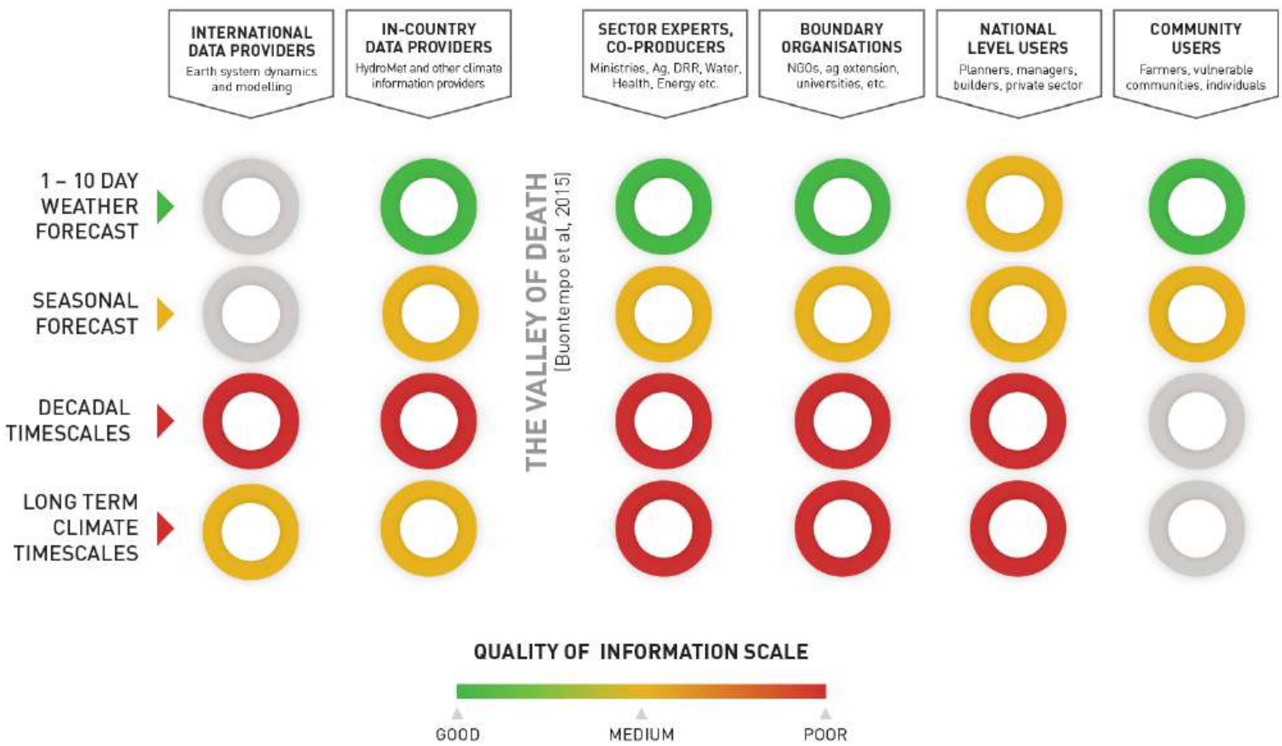
- The science behind seasonal forecasting is fair to good for some seasons and some areas. However, the use of seasonal forecasting is often poor. Findings suggest this is in part because information provision is heavily influenced by the suppliers of information without sufficient consultation of users. Users may not know information exists; they may be unable to understand or have limited trust or confidence in how to appropriately use the information; or they may not have access to sufficiently detailed information (such as livelihood-specific advisories). They may also lack the resources they require to act on the information. Seasonal forecasts have proven more useful in absorptive and adaptive contexts;

- Decadal information is urgently needed by the adaptation and resilience community in adaptive contexts, yet this is where climate science is least able to contribute a supply of information that meets demand. This finding was highlighted in the majority of the KIIs conducted with practitioners involved in resilience and adaptation programming;

- Long-term climate timescales and projections provide useful information on climate trends, particularly with regard to temperature, yet have significant areas of uncertainty with regard to key metrics, including precipitation. Their use is critical in addressing the transformative steps humankind needs to take to become resilient to mitigating the greatest impacts of a rapidly changing climate. Yet a number of key informants also noted the misuse of long-term climate information within development agencies to compensate for a lack of decadal information. This is in part due to the data being misunderstood and may be driven by the response to the demands from government or donor funders, to state what is being adapted to, in adaptation and resilience programming. There are also some climate service providers who seek financial gain by exploiting this lack of understanding, possibly contributing to future maladaptation.

Figure 2 summarises our expertly informed analysis and key findings from grey and academic literature review. It summarises the general quality of information provision (left of the figure), through understanding and use (right of the figure). The gulf, or "Valley of Death", that exists between providers and users of information is a key focus of this report. The circles lacking in colour indicate where there is either limited use or engagement among actors. For example, international data/information providers have key roles in providing the science used to develop 1-10-day and seasonal forecasts, however they are not intended as key access points for in-country end users. Similarly, community users either do not efficiently use or cannot access the type of information relevant to them, for decadal and long-term climate timescales.

Figure 2 Climate Science to Application Information Flow



Literature Review

The review of academic and grey literature yielded limited evidence of academic work where climate science has effectively supported adaptation and resilience building, i.e. where climate science has been commissioned in consultation with the intended users and in consideration of their needs. Where projects are currently enabling climate science to be used for adaptation, the evidence of this taking place is highly informal. It appears that projects which began by listening to and considering user needs and then designing the climate science research on that basis, show potential strong uptake of climate science for adaptation. Where this is not the case, adaptation projects tend to say, “projections show it will be warmer which is why this adaptation action is required”, yet that is the extent of the engagement of climate science.

Active engagement with the climate science needed to enable adaptive management to the risks posed by climate change remains limited. Projections are often used superficially to justify the existence of decisions without effectively informing those decisions.

Among the projects where there is good use of climate information, two classes emerge. The first are projects that are adaptation/resilience focused and have identified a specific need for climate information. In these cases, there is concrete evidence of uptake and impact as well as lessons on inclusion and other elements of good development practice. Examples include agriculture projects using seasonal forecasts to better inform decision-making around investments, as detailed in Hansen et al. 2019[2]; Gbetibouo et al. 2017a[3]). Technologies supporting analysis and dissemination of information are improving. The second class is represented by climate services projects that are supply driven and are serious about listening to users or coproduction. For example, as part of the Global Commission on Adaptation’s Year of Action, the Food Security and Agriculture action track is looking to further promote these through climate-informed digital advisories presenting the greatest potential to bridge information gaps and support transformational adaptation of food systems at scale. In addition, FRACTAL and AMMA 2050 are two projects which use specific methods including learning labs and embedded researchers.

Approaches that have proved effective in mainstreaming climate information into local social, political, and institutional contexts to support complex decision-making have employed a range of methodologies, such as narrative approaches and desktop scenarios. For example, the US Army Corps of Engineers has employed such methodologies while working with urban governments on water management and climate change in Thailand. These facilitate the convening of knowledge from across disciplines, sectors and decision-making levels. Efforts to integrate climate information within decision making have also highlighted the need to remain sufficiently flexible to engage with evolving opportunities and new partnerships.

The review found evidence of the incorrect, or ill-informed, use of long-term climate projection data to fill climate science evidence gaps applicable for decadal decision making in climate adaptation implementation projects. This was in some cases due to perceived requirements in tenders from governments and donors. This has potential for causing maladaptation and reduced value for money outcomes. Where long-term climate information is being used successfully, it is largely among pilot programmes to guide early stages of vulnerability assessments and to mainstream climate change awareness in planning, budgeting and other aspects of governance.

Practitioners with better knowledge of the limitations of long-term projections are using this information to mainstream climate awareness into local governance contexts, and as the basis for vulnerability assessments. Some are changing institutional language from “climate adaptation programming” to climate-informed” programming. This reflects the fact that in the absence of decadal information, users do not know what they should be adapting to. A climate-informed, or climate-aware framing, allows the implementation of “no-regrets” interventions able to tolerate the vagaries of an uncertain future. The language of “inclusive resilience” then describes interventions that focus on issues including pro-poor outcomes in sectoral areas of choice or necessity, that can be climate-informed to the greatest degree possible.

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[2]Hansen, J. W., C. Vaughan, D. M. Kagabo, T. Dinku, E. R. Carr, J. Körner and R. B. Zougmoré (2019). Climate Services Can Support African Farmers' Context-Specific Adaptation Needs at Scale. Frontiers in Sustainable Food Systems, Frontiers Media SA. 3

[3]Gbetibouo, G. Obuya, G. , Mills A, Snyman, D., Huyser O., Hill, C. (2017a) Impact assessment on climate information services for community-based adaptation to climate change Kenya Country Report, CARE International

Team reflections and key informant interviews

There was strong agreement between findings from KIIs, team reflections, and those gathered from academic and grey literature searches. The interviews provided more nuanced insights that in turn guided recommendations for future development of the CLARE programme.

When assessing findings within the context of the current use of climate science, a key finding among the KIIs is that adaptation and resilience practitioners are less concerned about increasing the provision of climate science and more interested in bridging existing constraints to the effective use of climate information that exist amongst a plethora of users in numerous and diverse contexts across sectors, geographies, and governance systems at multiple scales. Resilience-strengthening and adaptation action in practice are also not always informed by the most recent science. There is a requirement to build decision makers' and other users understanding and knowledge of the climate science relevant to their needs. Following this, consideration must be given to how their lives, livelihoods and priorities are impacted by what is known about current and future climate-related risks. This approach will mitigate the risk of falling into the trap of assuming a science-first approach: "if we just have better climate science information then it will be used". As a related point, more emphasis is needed on creating "discerning users" of information and sharing practical, resource-un-intensive tools for supporting decision making under uncertainty. These tools should enable robust decision-making approaches that are adaptable to worst-case climate change outcomes, as opposed to trying to optimise outcomes, which is more difficult in the absence of reliably predictive information.

Among KIIs, there was consensus on the need to make climate information understandable to users, in the context of geography, sector, audience, and decision-making governance structures. This relates to calls for projects to be designed by combining the skills of meteorologists and climate scientists with sector-specific modelers, social scientists, technical advisors and extension services, and decision makers across levels and sectors. A fundamental gap concerning this issue is the need for data translators i.e., staff who understand user needs and the science and tools able to meet them. The ability to work across institutional siloes to connect, at a systems level, requires appropriate skill sets to address multisectoral and other complex problems like to be affected by climate change impact. Consensus was also strong on the need for capacity building and training to strengthen understanding and the appropriate use of climate research in the Global South. This includes enhancing South-South networks within countries and across regions within Africa and between Africa-Asia. Making climate information understandable across diverse contexts is a distributed task and not something where a UK based research institute can effectively lead. Adaptation and resilience actions need to be locally determined given the highly localised impacts of climate change. CLARE has the opportunity to emphasise that trans/multi-disciplinary teams are required for this.

There are gaps in science needed for adaptation and resilience from the meteorology and climate modelling community. There is also critical need for the collection and management of climate-related data and information. Focused procurement of climate science, data collection, and translation into usable form by decision-makers, is urgent. Procurement needs to be impact-led to have value in current decision making. Addressing the challenge of integrating and applying use of climate science with other disciplines, particularly social sciences, to support decision making towards climate resilience and adaptation is imperative. Climate models already provide actionable information across certain timescales, particularly, long term, transformative and end of century predictions. They contribute to short term forecasting yet lack decisive application in decadal timeframes. Given that the most robust approach to climate resilience and adaptation is to strengthen decision-making under uncertainty, clarifying the range of uncertainty relevant to a specific decision-making process, rather than relying on developing the ability to make forecasts and projections with 'low' levels of uncertainty, is key. There are some specific areas where additional climate science over both short and longer timeframes is needed, where the direction of forced change in many impact-relevant variables is uncertain. For example, there is still significant uncertainty over the direction and magnitude of precipitation change in several regions of the world, such as East and West Africa. Further scientific gaps include the cumulative effect of multiple stresses and risks, impacts of temporarily overshooting temperature targets, and critical thresholds for extreme events. Additionally, in each of the terrestrial, freshwater, ocean and human systems specific gaps in scientific understanding remain for impacts under 1.5 ºc or 2 ºc of warming. Those gaps in understanding related to carbon cycle feedbacks may be critical as they have the potential to enhance warming through positive feedback.

More generally, there is a need to characterise risks and opportunities in terms relevant to local stakeholders, to support policy-relevant risk assessment. This includes developing ways of establishing relevant and plausible climate scenarios and assessment frameworks. For example, local-scale studies incorporating high-resolution (differentiated) information on climate information to map on to high-resolution, differentiated information on vulnerability and exposure to assess likely impacts and consequences at a scale relevant to decision makers.

Recommendations for CLARE

This study has identified a number of key recommendations of relevance to the design and development of the CLARE research programme to support adaptation and resilience action.

Structure

- Reflect a user-driven structure in CLARE rather than leading through the production of more climate science, taking into account demand-and-decision-driven relationships contextualised to the geography, sectors, and timescale of need;
- The CLARE initiative is encouraged to promote better linkage between research and development programmes with integrated measures of success. CLARE has an opportunity to build demand-supply bridges while addressing different and complex adaptation pathways. Promote trans/multi-disciplinary knowledge integration processes (co-exploration and co-production);
- Future investments need to be focused on timescales relevant to decision-makers use of weather and climate information. Decadal information remains a massive yet unmet demand among adaptation and resilience practitioners. Assistance is needed to communicate best and legitimate use of long-term climate models in 5 -20-year planning decisions;
- Align assessment of scientific excellence with development impact to recognise and make explicit clear links through climate science provision and user uptake in co-production processes.

Procurement

- The mechanism in which CLARE-related work is contracted will impact types of consortia that will be applying and set the foundation for its rollout. This must be thought through carefully in the next phase of CLARE structuring to support sustainability through inclusion of existing expertise and capacities within countries and regions.

Consultation

- Ensure provision is made to support and develop sustainable organising /convening/facilitating roles between climate science providers and user groups to bridge the gulf that is currently common between them. Facilitating roles could take place simultaneously at multiple levels including development of consortia for individual projects, cross-learning visits between programmes, and international conferences. The visibility and skill of the intermediary or connecting role / function that works across the climate services knowledge system and creates a whole working service - and embeds it in a broader goal or system or sector or project – is essential, yet its role is rarely recognised as it falls outside 'core functions' of project and or value chains. Currently, where the connecting role is recognised, support and capacities are often focused on enabling specific projects rather than enabling sustainable systems for co-producing climate services. For example, MEL is often contracted to project leads and external agencies rather than capacities being developed within climate information providers or key user government services or user groups;

- CLARE should take advice from the climate researcher community to establish their research priorities. However, CLARE should establish what the value of this research is, in terms of need and use, in resilience and adaptation practice, ensuring there is obvious value for money and impact.

- Build, or strengthen existing, collaboration/networks between policy makers, local providers and users to open policy spaces on climate-risk governance. Programmes such as WISER, SHEAR and ACCCRN are examples of where externally driven initiatives foster greater collaboration within countries and regions;

- All core elements and functions are equally important for achieving climate resilience impacts but likely to be led by different actors. Efforts should be focused on establishing and strengthening sustainable functions for co-productions, embedded across key actors for co-producing services;

- Recognise that the drive behind co-producing climate services can come from any one of the above elements / processes, not only from the science providers. Therefore, future CLARE research calls should not be limited to climate service providers and this should be made clear in programme outreach;

- As CLARE progresses, develop directories of people and institutions working in different partnerships, programmes, and institutions as a network that can become a resource for both climate science providers and users. Key individuals should be convened to start to identify, in real time, current needs for available climate science and gaps for applied and bespoke research.

Next steps

As an initial step, it is suggested that DFID and IDRC convene representatives from relevant development programmes and key actors in the adaptation/resilience space, along with current climate science information providers. This may include representation from the people and programmes highlighted in the "Expert Reflection" section of this report. It should also include people from the user needs scoping study that was conducted for the CLARE programme and other key experts who have been involved in the preparatory work to support the design of DIFD's CLARE programme.

These convenings will help to identify research gaps, aligned to the needs appropriate for sectors, geographies, and populations, relevant to DFID priorities. Alongside this, the identification of research gaps should be produced in recognition of obstacles in the research applicability, and therefore identifying approaches to overcoming them. This will ensure mainstreaming of the use of climate science through adaptation and resilience practice. Without these, demonstrating value for money through evidence for influence of effective climate adaptive decision-making among multiple levels and contexts of governance and investment may prove elusive.

The outcome will be a guiding process for the next stage of CLAREs development, and a sense of involvement and investment from potential partners. Most importantly, it would begin to bridge the "Valley of Death"[1] representing the gulf encountered between climate information providers and users among the adaptation and resilience communities. By closing the gap CLARE has the opportunity to develop functioning networks within and between countries and continents, and better ensure Value for Money justifying the investment.

Acronyms

Acronym	Meaning
ACCCRN	Asian Cities Climate Change Resilience Network
ACPC	African Climate Policy Centre
AGHRYMET	The CILSS Agro-Hydro-Meteorological Centre
ANACIM	l'Agence Nationale de l'Aviation Civile et de la Météorologie
BACS	Bangladesh Academy for Climate Services
CCA	Climate Change Adaptation
CCI	Centre for Community Initiatives
CMDS	Country Direct Meteorological Service
CEH	Centre for Ecology & Hydrology
CIRAD	Centre de Coopération Internationale en Recherche Agronomique pour le Développement
CNRS-GAME	CNRS-Groupe d'étude de l'Atmosphère Météorologique
CPC	Climate Planning Committee
CSE	Centre du Suivi Ecologique
ECMWF	European Centre for Medium-range Weather Forecasts
FCFA	Future Climate for Africa
FONGS	Fédération des Organisations Non Gouvernementales du Sénégal
FRACTAL	Future Resilience for African CiTies and Lands
FUTA	The Department of Meteorology and Climate Science at the Federal University of Technology, Akure
GCF	Green Climate Fund
GMet	The Department of Meteorology at the University of Nairobi Ghana Meteorological Agency
IARP	Innovative Approaches to Response Preparedness
ICPAC	IGAD Climate Predictions and Applications Centre
ICCCAD	International Centre for Climate Change and Development
IPCC	Intergovernmental Panel on Climate Change

IPSL-LOCEAN	Institut Pierre Simon Laplace - Laboratoire d'océanographie et du climat
IRD-DIADE	Institute de recherche pour le development-DIversité - Adaptation - Développement des plantes
IRD-LTHE	Institut de recherche pour le développement- Laboratoire d'étude des Transferts en Hydrologie et Environnement
ISRA	Institut Sénégalaise de Recherches Agricoles
JKUAT	Jomo Kenyatta University of Agriculture and Technology
KDI	Kounkey Design Initiative
KEMFRI	Kenya Marine and Fisheries Research Institute
KMD	Kenya Meteorological Department
KNUST	Kwame Nkrumah University of Science and Technology
MEL	Monitoring Evaluation and Learning
MO	Met Office UK
NECJOGHA	Network of Climate Journalists for the Greater Horn of Africa
NiMet	Nigerian Meteorological Agency
NMHS	National Meteorological and Hydrological Services
PSP	Participatory Scenario Planning
REA	Rapid Evidence Assessment
REF	Research Excellence Framework
RISA	Regional Integrated Sciences and Assessments
ROPPA	Network of Farmers Organizations and Agricultural Producers of West Africa
SCIPEA	Strengthening Climate Information Partnerships – East Africa
SHEAR	Science for Humanitarian Emergencies and Resilience
UCAD	Cheikh Anta Diop University
UCAD-ESP	Université Cheikh Anta DIOP de Dakar -Ecole Supérieure Polytechnique
UCC	University of Cape Coast
UFHB	Université Félix Houphouet Boigny
UoL	University of Leeds
WASCAL	West African Science Service Centre for Climate Change and Adapted Land Use
WISER	Weather and Climate Information Services for Africa

Table of Contents

1 Introduction

The Department for International Development (DFID) commissioned a review of climate science use in adaptation and resilience practice to inform the development of a new climate and resilience research framework programme (CLARE). This programme, in partnership with IDRC, will provide evidence and innovation needed to climate-inform DFID and HMG investments threatened by climate change, particularly in Africa.

LTS International was commissioned to undertake a scoping is take an initial, light touch, review of the question "*Within the process of enabling climate science to better support resilience and adaptation practice and achieve internationally agreed commitments, what is working and what is missing in its use, and which people and institutions are key contributors in this field?*"

The LTS team, which comprises both climate resilience and adaptation experts and climate scientists, conducted this scoping study using a light touch Rapid Evidence Assessment (REA) supported by expert consultation and key informant interviews (KIIs). The LTS team reviewed relevant academic and grey literature, interviewed climate scientists and development practitioners. The work focused on Africa with a light touch approach applied to South Asia and the Pacific.

The assessment examined current research activities and priorities in the science to application chain. As a stark finding early on in the process, it was clear that in practice the reality of this chain is questionable. As a consequence, the assignment focused more strongly on the use of climate science in adaptation and resilience practice. A detailed assessment of climate science activities and priorities was beyond the scope of this study, however our initial findings, as detailed in this report, may inform future scoping work in this area.

The purpose of this report is to provide both DFID and IDRC with a comprehensive overview of the initial findings from the light touch REA. The report covers keys areas of concern in addition to providing expert informed recommendations to inform the focus if and next steps for CLARE. The report is structured as follows:

- Section 2 describes the methodology applied for the REA, and presents summary data on literature reviewed;
- Section 3 presents the main findings from the literature review and website review of institutions and programmes;
- Section 4 is a detailed summary of key points raised during KIIs with climate scientists, academics, donors, practitioners and consultants.

1.1 Limitations

Given the significant quantity of available information of relevance to this study, and the limited time allocated to the assignment, this assignment relied heavily upon the experience and expertise of the team members. The concordance of findings across academic and grey literature, KIIs and team discussions, give confidence in the integrity of the findings of this work. However, there are a number of limitations to this study, that should be taken into account:

- This study was undertaken by a team of 7 experts, with their colleagues' support, over 6 weeks. Given this short timeframe for completion it was agreed with DFID that a light review would be based on the experience and knowledge of team members. It is important to recognise, therefore, that the expertise, knowledge and experience of the team has influenced the findings and recommendations for the next phase of CLARE design;
- The review of grey literature undertaken as part of this study focused largely on the institutions identified by the team as being active in relation to the climate science and resilience landscape. Given the significant African focus within the team, team members drew on the wealth of information they had and their existing networks to conduct KIIs with key stakeholders. Similarly, the Asia and

Pacific focused work relied on team knowledge to identify a limited number of Key Informants for interviews, all of whom were known to be active for or within those geographies;

- This assignment also had limitations in relation to sectoral scope, with some sectors, such as health, barely touched upon. Further exploration to examine these sectors in detail would be valuable, and also to assess the interplay between sectors and levels of decision-making at multiple levels of governance across diverse contexts. Gaps in science at multiple timescales from now-casting to long-term projections would be also better identified with more time; and

- The gaps in user demand identified in this study are likely small in relation to global demand as a whole. In developing this report there was realisation that a full answer to the question driving effort can only be achieved through reiterative consultation and reflection. Guiding principles have been described to generate a process for bringing together climate science information providers and users. The next phase of CLARE design is well positioned to take this forward.

Literature searches encountered three additional limitations:

1. Websites proved difficult to search in many cases. Systematic search functions and metadata were lacking so it is possible that some evidence has been missed despite best attempts;

2. The academic search focused on sources team members knew of and therefore includes a degree of subjectivity. Standard reviews using engines including WoS and SCOPUS are far less subjective yet presented challenges in terms of the sheer volume of information they brought forward;

3. The limited time for this review limited the ability of the team to search and review systematically, resulting in the agreement with DFID to adopt a more practical 'REA lite' approach.

2 Methodology

This section describes the research protocol that this REA adopted. It outlines the literature review process, inclusion and exclusion criteria, quality assessment procedure, and key informant interview (KII) process.

2.1 Research Question

The study addressed the following research question:

Box 1: Research Question

Within the process of enabling climate science to better support resilience and adaptation practice and achieve internationally agreed commitments, what is working and what is missing in its use, and which people and institutions are key contributors in this field?

The question was addressed by gathering evidence from both primary and secondary sources, through a focused light-touch literature review exercise, and a series of key informant interviews.

2.1.1 Literature review

The literature review assessment adhered to the process of searching, assessment, and analysis, outlined in the DFID (2014) *How to do a REA Note* guidance. The key steps outlined in this document are as follows:

- Evidence search;
- Application of inclusion and assessing of evidence quality;
- Analysis and synthesis, as detailed in the next section.

The literature review emphasised transparency in the search process through precise specification of key inclusion criteria, search strings (detailed in full in Annex 3), and sources of literature. Clearly detailing these elements of the literature review process will allow future research to be built upon this initial light touch study, without duplicating efforts.

The team focused the literature search on two complementary strands, one on academic sources and climate science publications, and the other on grey literature. The academic literature searches were conducted using databases including SCOPUS and Google Scholar, to identify journal articles dedicated to climate change using relevant search strings as referenced in Annex 3.

The results returned from applying the search strings were extensive. Therefore, to help prioritise the huge volume of material identified, and to source grey literature, the team focused subsequent literature searches on relevant institutional websites. The identification of priority websites was guided by discussions with key informants and by the team's existing knowledge and expertise. In addition, the team reviewed other relevant databases including Climate Resilience Networks and Research for Development (R4D). In total 112 Institutional websites and related databases were identified and reviewed, the full list of which is included as Annex 5 to this report.

2.1.2 REA matrix

In order to organise the literature reviewed, an excel file was used to develop the REA matrix. This matrix captures relevant information such as:

- Type of evidence (academic journal, evaluation paper etc);
- Author, institution, publication;
- Geography (country and region);

- Language;
- Quality assessment criteria (transparency, credibility)
- Research type;
- Sector focus (disaster risk reduction, water management, infrastructure etc);
- Conceptualised or operationalised service;
- Climate science timescale;
- Type of information providers, including details co-producers;
- Type of service including communication type (of climate information);
- Relevance to user of climate information;
- Monitoring, Evaluation and Learning; and
- Key take-aways from our analysis.

In order to store metadata related to both academic and grey literature, all literature included in our analysis is stored in Mendeley, which provides further information on the extensive list of journals consulted and sources of literature identified. The structure of the Mendeley database mirrors that of the REA matrix. Documents were only included if they met our defined relevance and quality criteria (discussed below). Access to our Mendeley database can be provided upon request.

Assessment of Inclusion/Exclusion

In line with the TOR for this assignment, the study focused on Sub-Saharan Africa, South Asia and Pacific Islands and reviewed literature published over the past decade in English and French. The quantity of available relevant French literature was considerably less than that published in English.

Table 1 Inclusion/Exclusion Criteria

	Inclusion	Exclusion
Geographical location	Sub Saharan Africa, South Asia, Pacific	Europe, LAC
Language	English, French	Any other language
Publication date	From 2009 to 2019	Before 2009

Quality assessment criteria

Specific criteria were used to evaluate the quality of each piece of research, and its positioning for use and impact. The quality assessment criteria applied in this assignment were guided by the criteria presented in DFID Note Assessing the Strength of Evidence[4]. These criteria are described in Table 2.

[4] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/291982/HTN-strength-evidence-march2014.pdf

Table 2 Quality Assessment Criteria

Criteria	Description
Transparency The evidence is transparent about the context of the study	Does the study present or link to the data and science used? Does the study declare sources of support/funding? Does the study acknowledge existing research?
Credibility The climate services are sound and use science	Does the study present results that effectively and meaningfully measure effects and accurately describes these relationships? Does the study employ a rigorous scientific method resulting in high-quality data?

2.1.3 Key Informant Interviews

Key Informant Interviews (KIIs) were conducted in conjunction with the literature review process. Interviews were augmented by analysis and reflections from the study team. They were used both to inform further institutional website searches, and to answer various questions which emerged from the literature assessment. Through a snowballing process, information about other partner programmes and institutions highlighted through KIIs was gathered and included in the REA matrix.

Detailed information on the informants and their institutions are included in Annex 6. The interviews were key in facilitating discussion on observations including trends, research gaps and reasons for them, and for providing more context on contentious issues. Key informants included staff from international institutions, academics, climate scientists, and Southern-based climate services experts, with a combination of supply and demand-side actors consulted. In addition, the LTS team were involved with an internal focus group discussion, which was facilitated to capture team expertise in a systematic manner. The detail of these findings are included in Section 5 of this report.

Initial analysis of the conclusions from each study included in the REA matrix guided discussion through the following three points:

- Where are the good practices?
- What makes them good practices?
- Where are the gaps?

Team reflections and internal consultation, combined with findings from the literature review, informed the overall synthesis of information presented in Section 5 of this report.

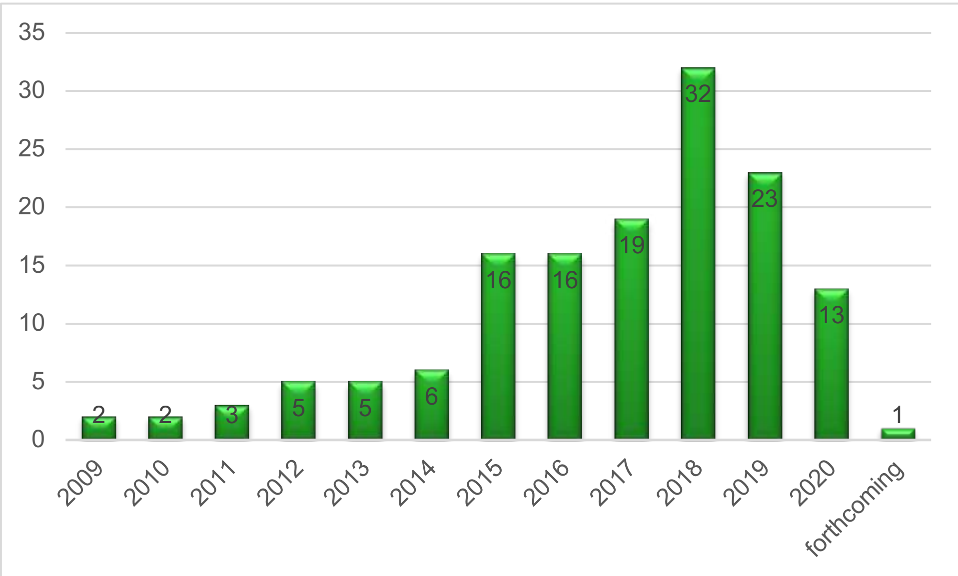
3 Evidence analysis

A total of 143 documents from academic and grey literature were eventually included in the REA matrix and their key conclusions were considered as part of the analysis. The combined evidence from the literature review and the interviews allowed the team to identify the geographical spread and the sectors where climate science is being used to enable adaptation and resilience building.

Timeline of evidence

While considering evidence published over the past decades, climate services has emerged as a theme of focus only in recent years, with more than 60% published over the past three years, as detailed in Figure 1.

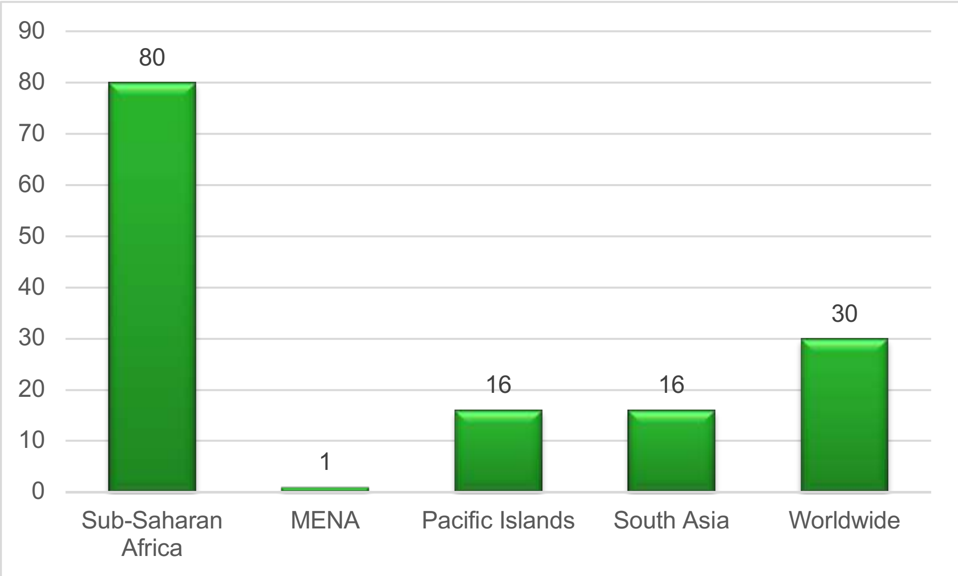
Figure 3 Timeline of Evidence



Geographical spread

While several geographic regions were considered in the study and evidence was gathered following the same protocol, more than half of the evidence gathered during this exercise was focused on Sub-Saharan Africa (56%). The “Worldwide” category includes evidence focused on more than one of the regions considered in the study, or which considers climate services at a global level. This geographical spread is detailed in Figure 4.

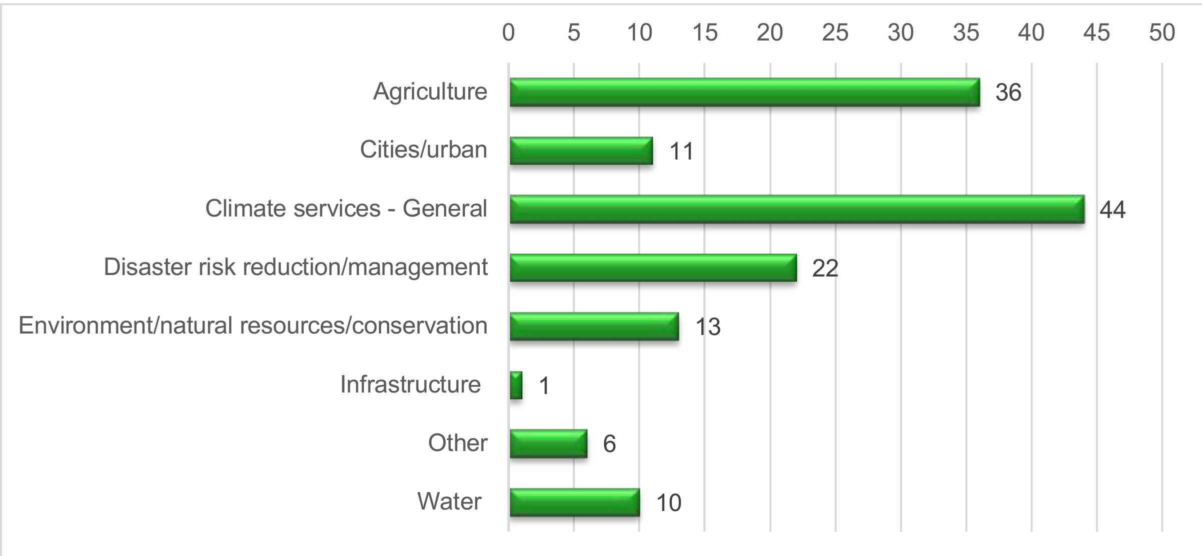
Figure 4 Geographic Spread



Sectors of focus

Evidence and reflections on climate services, without a specific sector focus, represent the main category among the evidence gathered (44%). With a focus on farmers, crops and farming, a quarter of the evidence gathered is dedicated to agriculture-focused services. With discussions including building resilience, linking humanitarian challenges with development and climate change through dedicated services, disaster risk management and reduction was the focus of 22% of the evidence gathered for this study. This is detailed in Figure 5.

Figure 5 Sector Focus



Our findings, presented in the following sections were also compared and contrasted with the findings of major global assessments including the IPCC Special Report: Global Warming of 1.5°C and synthesis reports provided by GCA, Adaptation Gap Report[5].

[5] Olhoff, A., Dickson, B., Puid, D. et al (2016). The Adaptation Finance Gap Report. *United Nations Environment Programme.*

4 Literature Review

Key Summary Points

- The review found limited evidence of academic work where climate science is used for adaptation and resilience building;
- Experience of other programmes shows that reflecting a user-driven structure in the development of CLARE is important, rather than focusing on the production of more climate science;
- Projects that consult on user needs and then designing the climate science research on that basis show strong uptake of climate science for adaptation;
- Transdisciplinary approaches can significantly improve the communication between users and producers and make the quality and type of climate information provided by producers for users both useful and usable;
- Narrative approaches can be used to ground climate information in the local social, political, institutional context and also take into account the complexity of the decision-space;
- Institutional capacity building on adaptation and the use of climate services is important for responding to the scale of climate change challenges for governments at all levels, utilities, and businesses;
- Building leadership, coherence, and understanding between multiple actors who may be more used to working separately, is key to ensuring climate science use in adaptation and resilience practice, and ultimately in decision making across multiple timescales;
- A major barrier to the use of climate science in adaptation and resilience is that even where information is available for climate change and adaptation, there is need for better-filtered, synthesised and accessible formats;
- There is a critical need to produce more locally accurate and relevant forecasts and to provide adequate support to forecast users in each specific climate zone;
- There is a clear need for local and indigenous knowledge to be engaged in the co-production of climate services;
- Projects may support the delivery of services that meet user needs yet lack the business models and capacity strengthening required to ensure continuity of services; and
- Some climate models are already good enough to provide actionable information. There is a need to better use the information available to promote robust decision-making, whilst being mindful and transparent about its limitations.

4.1 General Findings

The review found limited evidence of academic work where climate science is used for adaptation and resilience building. Significant academic literature exists on the barriers to use of climate science (or climate services) for adaptation activities, and many climate science-related grants, programmes and project websites talk about the importance of ensuring the science is communicated to, and used by, decision-makers and communities. Yet there is a distinct lack of published or publicly available evidence of the climate science being used directly.

There may be many reasons for this, including the fact that many projects in this area are in the early stages of progression and therefore outputs have not been finalised for publication. From experience, even where projects are currently enabling climate science to be used for adaptation, the evidence of this taking place is highly informal and may only be available as a news story on a project website, for example, rather than published in a peer-reviewed journal or within formal reporting[6]. Yet such informal evidence might be frowned upon by some authors/reviewers as being too 'anecdotal' for publication. Given the short time frame of many climate-resilience building projects and that engagement with stakeholders has been a priority, a number of projects have prioritised sharing learning through policy briefs as more accessible to non-technical target stakeholders than academic articles. The limited availability of peer-reviewed literature on use of climate information is also skewed by donor and research institution contracting. Some climate research and resilience building programmes have prioritised evidence of scientific excellence, through agreed numbers of articles in peer-reviewed journals, while engagement of decision-makers is measured through different types of indicators, including evidence of changes in policy and numbers participating in workshops.

Therefore, the REA methodology employed for this review of academic and grey literature is unlikely to capture these instances of climate science being used for adaptation. Indeed, without prior inside knowledge of these projects, it is unlikely that this evidence will be found at all using systematic or directed searches.

However, across academic projects where evidence of climate science used for adaptation has been found, there are several themes that emerge, which could provide useful lessons for research going forward.

4.2 Design of CLARE

Experience of other programmes shows that reflecting a user-driven structure in the development of CLARE is important, rather than focusing on the production of more climate science. It is important not to assume that more climate information alone will necessarily lead to better decision-making. The processes and practices by which climate considerations and climate information are included in decision-making are manifold: seeking wider transdisciplinary expertise across different scientific disciplines (including social sciences) is likely to generate innovative project design and consortia. Clearly, climate science needs to be at the centre of CLARE, yet to be effective there is a need for an adjustment in the way in which climate science is procured, to take into consideration user needs and transdisciplinary knowledge co-production processes. As recommended elsewhere in this report, during CLARE inception a convening role is recommended to bring together climate science and development communities to form consortia and co-design interventions. A starting place may be development programmes currently in place or planned that will require climate information for specific needs. Further inception or development periods within the project development process, enabling support for consortia to develop and co-explore research project focus, would be particularly welcome. Ultimately, project teams might include both climate scientists and applied researchers to achieve the same aims; having a way of informing climate scientists of the needs of decision-makers.

4.3 Good practices – 'what works'

4.3.1 Co-design of climate services. A demand-and-decision-driven relationship

Projects that begin by listening to and considering user needs and then designing the climate science research on that basis show strong uptake of climate science for adaptation[7]. For example, the Rainwatch[8] [9] and NIMFRU projects[10]. A collaborative demand-and-decision-driven relationship is needed[11]. Research

[6] Rau, H., Goggins, G. & Fahy, F. (2018) From invisibility to impact: Recognising the scientific and societal relevance of interdisciplinary sustainability research. Res. Policy 47, 266–276.
[7] Tsey, K. et al. Evaluating Research Impact: The Development of a Research for Impact Tool. Front. Public Heal. 4, 160 (2016).
[8] Boyd, E. et al. Building resilience to face recurring environmental crisis in African Sahel. Nat. Clim. Chang. 3, 631–637 (2013).
[9] http://www.rainwatch-africa.org
[10] https://nimfruproject.wordpress.com/project-overview-2/
[11] Daniels, E., Bharwani, S., Butterfield, R. (2019). The Tandem Framework: A Holistic Approach to Co-Designing Climate Services. SEI Discussion Brief. Stockholm Environment Institute.

shows that, with some caveats, co-design (using transdisciplinary approaches, see below) creates knowledge that is more relevant for users[12][13][14] and, thus, is more likely to be used.

Participatory Scenario Planning (PSP) has transformed climate and weather information services in Kenya to be more responsive to user needs[15], leading to more confidence in the advisories, in their decision-making, and ownership of the process. PSP has been used elsewhere (by CARE and others): in Ethiopia, PSP proved to be one of the most effective and empowering ways to promote access to localised early warning and seasonal forecast information to communities, local planners and decision-makers[16] and permits shifts in focus to planning and decision-making in the local context.

4.3.2 Integrating different scientific disciplines for impact

Transdisciplinary approaches can significantly improve the communication between users and producers and make the quality and type of climate information provided by producers for users both useful and usable. This involves the expertise of researchers and scientists, together with decision-makers and practitioners recognizing and exploring their different knowledge types to reach a common understanding of needs, and how those needs could be met in a scientifically feasible and defensible way. The FRACTAL project illustrated this through empirically grounded insights of how the participatory co-design and co-production process creates an understanding of user needs and challenges, and how this process adjusts to the local context to create relevant and actionable knowledge that informs decision-making and planning [17][18]. This transdisciplinary approach is also used in the earlier Regional Integrated Sciences and Assessments (RISA) programmes which exist to produce quality climate information for decision support in North America and the Pacific[19]. Their findings reflect many of those from the FRACTAL project.

A variety of experiential and performative practice approaches have been found to be an effective way to build on transdisciplinary information - for example, Forum theatre (used in FCFA AMMA2050) can engage different stakeholders and support a science-policy-society dialogue on key issues – including inclusive discussion on the cultural and socio-economic and political issues that need to be addressed in reaching consensus on climate adaptation approaches. It is also a way to communicate climate information meaningfully. Another tested approach to knowledge integration that helps to build trust, familiarity and understanding is the use of embedded researchers, deployed to work (part of their time) within a host organisation, as was done in 5 cities in Southern Africa. One FCFA extension projects is undertaking double and triple loop learning on co-production to tease out exactly in what circumstances is better translation of business as usual acceptable, compared to what circumstances actually require co-production as a transdisciplinary method. These approaches contribute to sharing ideas and ways of working between research, policy and practice communities as highlighted in Section 5 Team Reflections and KIIs.

[12] Bremer, S., Meisch, S., 2017. Co-production in climate change research: reviewing different perspectives: Coproduction in climate change research. Wiley Interdisciplinary Reviews: Climate Change 8, e482. https://doi.org/10.1002/wcc.482

[13] Meadow, A.M., Ferguson, D.B., Guido, Z., Horangic, A., Owen, G., Wall, T., 2015. Moving toward the Deliberate Coproduction of Climate Science Knowledge. Weather, Climate, and Society 7, 179–191. https://doi.org/10.1175/WCAS-D-14-00050.1

[14] Taylor, A., Scott, D., Steynor, A., McClure, A., 2017. Transdisciplinarity, co-production, and co-exploration: integrating knowledge across science, policy and practice in FRACTAL (FRACTAL working paper No. 3).

[15] Gbetibouo, G. Obuya, G. , Mills A, Snyman, D., Huyser O., Hill, C. (2017a) Impact assessment on climate information services for community-based adaptation to climate change Kenya Country Report, CARE International

[16] Gbetibouo, G., Lika T., Mills A, Snyman, D., Huyser O., Hill, C. (2017b) Impact assessment on climate information services for community-based adaptation to climate change Ethiopia Country Report, CARE International

[17] Scott, D., Lipinge, K., Mfune, J. et al. (2017) The story of water in windhoek: A narrative approach to interpreting a transdisciplinary process, Water (Switzerland). 10(10)

[18] Steynor, A., Padgham, J., Jack, C. et al. (2016). Co-exploratory climate risk workshops: experiences from urban Africa. *Climate Risk Management.* (13) 95-102

[19] McNie, E. C. (2013). Delivering climate services: Organizational strategies and approaches for producing useful climate-science information. Weather, Climate, and Society. 5: 14-26.

4.3.3 New approaches to communicating climate knowledge and uncertainties

This review identifies that the approaches and channels for communicating climate information vary with the intended audience or decision makers of focus and the timescale of information being discussed. A narrative approach can be used to put climate information into local social, political, institutional context and also take into account the complexity of the decision-space[20][21]. Narratives have been developed as communication devices in response to the frustration that the climate scientists felt after many years of using classic ways of communicating climate science; through maps and other complicated visualisations, which require technical capacity for interpretation. Furthermore, these methods of communication struggle to facilitate adequate engagement on topics related to uncertainty and this approach may be more acceptable to users than long term projections[22].

Other examples show that effective communication can occur via community radio, through engagement with community-based radio stations by national meteorological services in Senegal and through agricultural extension officers in Rwanda to reach farmers[23]. Use of climate information can also be scaled up through training of trainers, also involving government staff, farming extension officers and promoters in Rwanda[21]. In the 2014 Adaptation Gap Report (see Annex 2)[24] use of appropriate mode/style of participation of local users was noted to be an important success factor and lesson for 'what works'[25]. Participatory role-playing games have been used in many situations (in particular by the Red Cross/Red Crescent Climate Centre) and have proved effective at promoting discussions and learning.

4.3.4 Building capacity for climate challenges

Institutional capacity building on adaptation and use of climate services are important for responding to the scale of climate change challenges for governments at all levels, utilities, and businesses. There remains extensive need to strengthen users' understanding of key climate concepts, together with sharing and strengthening tools and approaches enabling appropriate use of climate information. From experience in FCFA FRACTAL project in southern Africa, learning labs proved effective in promoting mutual learning, receptivity to information, and to build the confidence of participants such as city planners[26]. Moreover, there was evidence that stakeholders moved away from traditional 'value-chain' roles1627. Key to this shift is the valuing and exploration of different knowledge types - the climate services value chain and the use of these labels was recognized as limiting. Capacity development tools like PICSA and Climate Capacity Diagnosis & Development (CADD) have been widely used to support stakeholder engagement, training and (in the case of CADD) adaptation planning. Equity considerations are important – for example in the case of the 'ultra-poor'[28], socioeconomic status in the community affects how much information is available and whether it is

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[20] Scott, D., K. N. Iipinge, J. K. E. Mfune, D. Muchadenyika, O. V. Makuti and G. Ziervogel (2018). The story of water in windhoek: A narrative approach to interpreting a transdisciplinary process. Water (Switzerland), MDPI AG. 10.

[21] UNEP. (2016). The Adaptation Gap Report 2016: The Adaptation Finance Gap. United Nations Environment Programme. Nairobi: Kenya

[22] Mcclure, A. (2018). Climate narratives. FRACTAL Briefing note; Coventry et al (2019) on communicating climatic uncertainties.

[23] Hansen, J. W., Vaughan, C., Kagabo, D. M., Dinku, T., Carr, E. R., Körner, J., & Zougmoré, R. B. (2019). Climate Services Can Support African Farmers' Context-Specific Adaptation Needs at Scale. Frontiers in Sustainable Food Systems, 3(21), 1-16.

[24] UNEP (2014) 'The Adaptation Gap Report – A Preliminary Assessment'. United Nations Environment Programme. Nairobi: Kenya

[25] Roncoli, C., Orlove, B. S., Kabugo, M. R., and Waiswa, M. M. (2010). Cultural styles of participation in farmers' discussions of seasonal climate forecasts in Uganda. Agric. Hum. Values 28, 123–138. doi: 10.1007/s10460-010-9257-y

[26] Scott, D. and Taylor, A. (2019). Receptivity and judgement: expanding ways of knowing the climate to strengthen the resilience of cities. (FRACTAL working paper No. 7

[27] Steynor, A., Padgham, J., Jack, C., Hewitson, B. and Lennard, C. (2016). Co-exploratory climate risk workshops: Experiences from urban Africa. Climate Risk Management, 13. 95–102. DOI:10.1016/j.crm.2016.03.001.

[28] Apgar, M., Kniveton, D., Naess, L., Orindi, V., Abuya, N., and Bonaya, M. (2017) Improving the Impact of Climate Information Services in Kenya's Arid and Semi-Arid Lands. IDS Policy Briefing

useful. Adaptation and resilience programmes should not divorce transdisciplinary approaches to knowledge generation from capacity building – such approaches have to include an element of capacity building.

In collaboration with the BRACED project, Harvey al., (2019)[29] investigated national trends in climate services, looking in detail at Burkina Faso and Ethiopia. They identified a trend in bilateral and multilateral donors funding programmes led by non-state actors which have yielded benefits for under-resourced NMHSs[30]. Through collaboration in an ever-growing number of initiatives led by NGOs, universities and further climate, humanitarian, and development agencies, NMHSs have secured investments into monitoring infrastructure, training and education opportunities for staff and funding to cover salaries and expenses for field-based personnel. Despite the concrete benefits offered to national services, the rise of investment and partnerships has also raised concerns—namely around alignment, coordination and coverage of investments and services within the value chain. First, activities funded through bilateral and multilateral agencies may speak to national priorities but are rarely fully aligned with them, reflecting a combination of funder preferences, implementing agency interests and contextual considerations alongside these priorities. This can result in resources being allocated to areas that are not aligned with national priorities or create gaps in areas of investment that are less appealing to funders, such as infrastructure maintenance costs. The authors asked whether NGOs, local consultants and research institutes are active in providing climate services as facilitators and intermediaries. Do they provide the "missing middle" of activities in the value chain where they could play important roles in two-way brokering, interpretation and translation of climate information and knowledge brokering at all scales of climate information[31][32], and what capacity building is required for these intermediary providers to avoid the risk of developing parallel processes and are the way the intermediary roles are currently envisaged and being supported sustainable post external support.

In addition, capacity development needs are not only for traditional "users" but also for "providers". There remains extensive need to strengthen the capacities of "providers" in both scientific areas and engagement and communication with user groups, alongside strengthening users' understanding of key climate concepts and terms and appropriate use of climate information. Notably, GCFS have introduced initiatives to increase capacities for providing (and finding ways of improving) climate services for their effective use in sectors in Southern African Development Community (SADC) states[27], to build the capacity of Meteorological Services and develop evaluation frameworks in support of this.

4.3.5 Building collaboration/networks between policymakers, local providers and users to open policy space

Key to ensuring climate science use in adaptation and resilience practice, and ultimately in decision making across multiple timescales, is building leadership, coherence, and understanding between people, programs, programs, department and institutions that may be more used to working separately.

In some examples, community groups have been formed to strengthen their voice with researchers, producers of climate services, local decision-makers, and utility companies. A 'Climate Planning Committee' (CPC) was elected in an informal settlement in Maputo, Mozambique,[33]. In Rwanda, stakeholders were involved in the use of climate projections (2020-49 and 2079-99) to inform tea and coffee in an agricultural sector plan[34] including Ministry of Agriculture and other relevant agencies, including local planning units, district planners, and development partners. This included the identification of policy 'entry points' at all

[29] Harvey, B., L. Cochrane and M. Van Epp (2019). Charting knowledge co-production pathways in climate and development. Environmental Policy and Governance, John Wiley and Sons Ltd. 29: 107-117.

[30] Dinku, T., Thomson, M. C., Cousin, R., del Corral, J., Ceccato, P., Hansen, J. and Connor, S. J. (2018). Enhancing National Climate Services (ENACTS) for development in Africa. Climate and Development, 10(7). 664–72. DOI:10.1080/17565529.2017.1405784.

[31] Venkateswaran, K., Macclune, K., Tincani, L. et al. (2018). Using climate information for Climate-Resilient Water Management: Moving from science to action. 31.

[32] Harvey, B., Jones, L., Logan, C., Roop, S. (2019). The evolving landscape of climate services in sub-Saharan Africa: what roles have NGSs played? *Climate Change*. (2019) 157;81-98

[33] Broto, V., Ensor, J., Boyd, E., Allen, C., Seventine, C., & Macucule, D. (2015). Participatory Planning for Climate Compatible Development in Maputo, Mozambique. London: UCL Press.

[34] Butterfield, R. and Osano, P. (2020). Using an agricultural sector lens to test and refine the Tandem framework for co-designing climate services – a case study from Edem Ani, Enugu State, Nigeria. SEI Discussion Brief. Stockholm Environment Institute, Stockholm, Sweden.

levels, starting with the national medium-term development plan. In another study in Nigeria, stakeholder network activities looked at building the constituency and relationships for delivering climate action[35] through defining and prioritising the adaptation challenge and defining climate services.

The above good practices have been established in the reviewed projects through some specific approaches and processes that were applied - and found to be successful, in the context of each project. The specific ways they have been applied can differ considerably. More information about each of these approaches is provided in Table 4.

Table 3 CCA approach, action or process

CCA approach/ action/ process	Example(s) and participants/context	Impacts/outcome	Timeframe(s)	Evidence
Training of trainers (using PICSA) for delivery of rural climate services	Farmers and extension officers in Rwanda	Scaling up and developing capacity for CS - 1612 Gov. Staff and promoters trained, 105,000 farmers trained and new information products by NMS	Seasonal	Hansen et al, 2019 p7
Community radio	CB radio stations, CCAFS and the NMS in Senegal, Agricultural extension and CB radio in Rwanda	Radio and SMS reached 740,000 households in Senegal. In Rwanda, 5,000 farmers were involved in the pilot.	Seasonal	Hansen et al, 2019 p8 (mentions that a survey is underway)
Learning Labs to foster dialogue and co-explore burning issues needing to have climate-sensitive decision-making	City planners in Lusaka, Zambia. Flooding, water supply, polluted water, and over-extraction of water from aquifers (FRACTAL)	A process for building confidence and capacity. The inclusion of climate change implications in the policies provides evidence of expanded ways of knowing the climate and increased receptivity to a climate-resilient city.	Projections to 2040	In FRACTAL: Receptivity working paper and Tandem paper (submitted)
Climate risk narratives to communicate different city futures serving as conversation starters	Various examples mainly in EAC and Southern Africa (FRACTAL)		Projections to 2040	McClure, 2018; Scott et al, 2018; Burgin et al, 2019 and UCT 'data distillation' paper (in prep)

[35] K. Venkateswaran, K. Macclune, L. Tincani et al. (2018). Using climate information for Climate-Resilient Water Management: Moving from science to action. 31.

Participatory Scenario Planning (PSP) focusing on integrating CSA practices and DRR strategies within existing farming practices	Smallholder farmers, local and national government ministries, INGOs (e.g. CARE) in Malawi, Ghana, Ethiopia, Kenya, Niger, (ALP, WISER)	Sectoral advisories generated through PSP providing a tangible starting point for communities to identify solutions to their own challenges. PSP generated demand for other CI services (e.g. Esoko private sector providers) and has improved communications with NMS, increased uptake of CSPs	Daily, monthly, seasonal forecasts – with sector-specific advisory	Tembo, 2019; Boardley, 2017; Gbetibouo, 2017; Soeters, 2017
Performative practices/ creative methods including forum theatre, roleplaying and games	Researchers and agricultural stakeholders in FCFA AMMA2050 (Forum Theatre) in Senegal	Discussion and learning among different stakeholder groups	The play is set in 2050	Audia, 2019[36]

4.3.6 Examples of evidence about 'what works' in different time frames

10 day:

- Weather warnings, daily and weekly and 10-day forecasts were part of climate information and CSA activities in Africa. Evidence of use includes: TAMSAT[37] and Red Cross use of flood forecasts

Seasonal

- Integration of traditional local and scientific knowledge for participatory scenario planning (PSP), which can provide seasonal forecasts about the probability of different amounts of rainfall and the timing of onset and cessation of rains[22];
- Use of PICSA in Rwanda to train agricultural extension workers and promoters in the use of seasonal forecasts and application of new information products[38].

Long term

- In many cases downscaled GCM data has been used in making recommendations for sectoral decision-making and planning e.g. in Pakistan and in Afghanistan for recommendations for climate-resilient water strategy [39] (but apparently not taken up);

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[36] Note: FRACTAL is not the only FCFA project to enable take up or co-produced climate information. This would also include AMMA2050

[37] https://www.tamsat.org.uk/

[38] Hansen, J., Vaughan, C., Kagabo, D. et al. (2019). Climate Services Can Support African Farmers' Context – Specific Adaptation Needs at Scale. *Frontiers in Sustainable Food Systems.* **3.**

[39] K. Venkateswaran, K. Macclune, L. Tincani et al. (2018). Using climate information for Climate-Resilient Water Management: Moving from science to action. 31.

- In a few cases, sectoral policy or plans have actually been determined based on long-term climate projections, e.g.:
    - A study in Rwanda used climate projections (2020-49 and 2079-99) to inform tea and coffee plantation placement in an agricultural sector plan [40];
    - A study in Burkina Faso on possible futures and adaptation options for groundwater under a changing climate[41];
    - Through the PAS/PNA project, AMMA-2050 climate findings have supported sectoral planning to contribute to development of Senegal's National Adaptation Plans and highlighted to National Assembly members the need to review national agricultural policies[42].

4.4 Barriers to the use of climate science in adaptation and resilience

The literature review also surfaced consideration of barriers. An impression is made that framing climate science research from a user-needs perspective is unusual given the current funding structures for science which typically place the users and "impact" of the work at the end of the process. Starting from the user perspective may challenge climate science researchers to work beyond the confines of the discipline and engage in issues of local capacity, governance and technology to address barriers to the use of the science. These elements play a vital role in creating the enabling conditions for science to be used effectively within development projects but are often not considered. Encouraging climate research with this approach would support increased use of climate science for adaptation and resilience building.

4.4.1 Unsuitable climate information formats and products

A major barrier commented upon, is that even where information is available for climate change and adaptation, there is need for better-filtered, synthesised and accessible formats (Adaptation Gap Report, 2014). More emphasis is needed on strengthening understanding [43] of the complexity of the decision space, and on the requirements of decision-makers. The report notes that "climate data is largely being fed into this decision-making space through a supply-driven process" and that "users lack the capacity to evaluate whether the climate data can be appropriately applied to decision making". There are multiple uses, and potential user groups for climate information. To support adaptation, there remains unmet needs for sector-specific and city-level information at longer timeframes. Equally at shorter timeframes, there remains a need to strengthen the scale and livelihood relevance of forecasts. The simple issuance of a seasonal forecast from a NHMS, for example, may not be directly usable by a farmer who needs to decide which variety of millet they should plant, and whether or not they need to store water. The most commonly made decisions, made by the most vulnerable decision makers, are best served with contextualised information about the weather and the seasonal climate addressing their needs. Service Development Teams developed within SCIPEA and continued within WISER enabled climate producers to address timing constraints, providing seasonal forecasts that could better support farmers' decision making (see case study in Carter et al, 2019)[44]. By contrast, the report notes the "co-exploration" approach to using climate data, which entails

[40] P. Watkiss et al. (2015) Mainstreaming Climate Information into Sector Development Plans: the case of Rwanda's tea and coffee sectors. 2nd Edition. *Future Climate for Africa.*
[41] H. Young, R. Cornforth, A. Gaye et al (2019), Event Attribution Science in Adaptation Decision-Making in the Context of Extreme Rainfall in Urban Senegal. *Climate and Development*. 11(9). 812-824
[42] E. Visman, F. Tazen. (2019). Assessing the Impact of AMMA-2050 through Key Informant Interviews with Partnering Decision-Makers and Scientists.
[43] Jones, R. N., Patwardhan, A., Cohen, S., Dessai, S., Lammel, A., Lempert, R. J., Mirza, M. M. Q. and Von Storch, H. (2014). Foundations for decision making. In Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. 195–228.
[44] Carter, S., Steynor, A., Vincent, K., Visman, E., and Waagsaether, K. A manual for co-production in African weather and climate services: Home. 2019.

engaging a full complement of user groups (from modellers to policymakers) in defining the decision-making space into which climate model data is required[45][46].

4.4.2 Inadequate and/or uneven funding for adaptation

Another reason for the lack of examples of uptake of climate information is the general lack of funding for adaptation action. The 2016 Adaptation Finance Gap Report[47] provided a further assessment of adaptation needs and costs, and the difference between the costs and the finance available to meet those needs, in a developing country context. It notes that sub-Saharan Africa and South Asia have been the main recipients of funding for adaptation from dedicated climate funds, but that the distribution of flows is uneven.

4.4.3 The dominance of a 'science-first' (impact-led) approach

Projects are still often conceived and designed in a "science-first" (impacts-led) approach where the assumption is that filling an information deficit will unproblematically lead to a change in behaviour (and greater use). An example of such a "science first" the Greater Horn of Africa[48] reported low uptake of seasonal forecasts in the context of disaster risk reduction where the production of outlooks is led only by climate experts. The limited role for non-climate experts spread a general feeling of exclusion in decision-making in pilot projects.

4.4.4 Local information

A critical need is to produce more locally accurate and relevant forecasts and to provide adequate support for forecast's users in each specific climate zone (see an example from GHA[43]). To fine-tune climate forecasts linked to the needs of local decision makers, the establishment of local climate centres is important. In addition, DRR activities are needed in areas at highest risk.

4.4.5 Engaging with local and indigenous knowledge in developing climate services

Gaps exist where local and indigenous knowledge needs to be engaged within co-production of climate services. As previously effective traditional knowledge systems for decision making around climate have been increasingly challenged as climate changes, NGO and government efforts to promote "Western" forms of climate science and forecasting have frequently failed to meaningfully account for or engage with this existing knowledge base and its associated practices—a factor that is seen to partly explain the limited adoption of early climate service initiatives'.

4.4.6 Lack of business models to ensure sustainability

Projects may support the delivery of services that meet user needs yet lack the business models and strengthening of capacities required to ensure continuity of services. There is a recognised need to co-develop from inception business models that can enable continuity. Demonstrating the effectiveness of services can encourage government willingness to prioritise climate services that are useful for local livelihoods, highlighting the need to ensure monitoring and evaluation – together with key participation of key users - of climate services.

4.5 Outstanding climate science gaps

Our analysis has less of an emphasis on the current climate science gaps, however we have reviewed the existing use of science to adaptation evidence. The Intergovernmental Panel on Climate Change (IPCC) produce regular syntheses of the state of knowledge on climate science and its implications for adaptation

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[45] Steynor, A., Padgham, J., Jack, C., Hewitson, B. and Lennard, C. (2016). Co-exploratory climate risk workshops: Experiences from urban Africa. Climate Risk Management, 13. 95–102. DOI:10.1016/j.crm.2016.03.001.
[46] A. Steynor, J. Padgham, C. Jack et al. (2016). Co-exploratory climate risk workshops: experiences from urban Africa. 13, 95-102.
[47] UNEP. (2016). The Adaptation Gap Report 2016: The Adaptation Finance Gap. United Nations Environment Programme. Nairobi: Kenya
[48] Baudoin, M., Wolde-Georgis, T. (2015) Disaster Risk Reduction Efforts in the Greater Horn of Africa. Int J Disaster Risk Sci 6, 49–61. https://doi.org/10.1007/s13753-015-0041-x

and mitigation actions. The latest synthesis report from the IPCC entitled Special Report: Global Warming of 1.5 ºc highlights outstanding knowledge gaps both in the underlying science on climate change impacts[49] and our understanding of the pathways to action[50]**.** There are gaps in science needed for adaptation and resilience from the meteorology and climate modelling community. There is also critical need for the collection and management of climate-related data and information. Focused procurement of climate science, data collection, and translation into usable form by decision-makers, is urgent. Procurement needs to be impact-led to have value in current decision making. Addressing the challenge of integrating and applying use of climate science with other disciplines, particularly social sciences, to support decision making towards climate resilience and adaptation is imperative.. Some climate models are already good enough to support some types of actionable information, given that the most robust approach to adaptation and resilience in the face of uncertainty is not to take projections too literally and not to rely on a developing ability to make projections with a 'low' level of uncertainty. There needs to be better use of the information available, within its limitations, to promote robust decision-making.

However, there are some specific areas where additional climate science is needed where the direction of forced change in many impact-relevant variables is uncertain. For example, there is still significant uncertainty over the direction and magnitude of precipitation change in several regions of the world, such as East and West Africa. Further scientific gaps include the cumulative effect of multiple stresses and risks, impacts of temporarily overshooting temperature targets, and critical thresholds for extreme events. Additionally, in each of the terrestrial, freshwater, ocean and human systems specific gaps in scientific understanding remain for impacts under 1.5 ºc or 2 ºc of warming (Table 5)[27]. Those gaps in understanding related to carbon cycle feedbacks may be critical as they have the potential to enhance warming through positive feedback.

Annex 7 presents a brief list of some science gaps identified during this review. It is illustrative and by no means exhaustive. The CLARE development process is recommended to convene climate science providers with adaptation and resilience communities in geographies of interest to DFID to co-identify what science gaps exist, and which should be prioritised for support.

4.6 Observations from website review of institutions and programmes

The literature search did not find much evidence on the direct use of climate knowledge in decision making/planning, and this appears mainly due to the low uptake of climate data (especially at medium and longer time frames) in practice, and few examples recorded by academics in particular. There are various reasons and factors at play. It is also a function of the way the evidence/examples are presented on publicly accessible websites, where it is often hard to find details. In view of this effort was made to record why outputs could not be included and why the type of evidence we are seeking was not forthcoming on particular websites during the search. In doing so, different factors emerged that could be in play for each type of website searched.

For these reasons, the overall confidence that we have encountered most of the key evidence is low. Yet use of mixed-method analyses, a wide net and iterative process provides reasonable confidence in general conclusions. The review includes actors mentioned by DFID and KIIs. In addition to the evidence built up through consulting and searching, particular focus was directed to institutions known to be doing relevant work.

To search further DFID is recommended to:

- Focus on searching for information on programmes that have started recently, which are now gearing up to produce outputs: Recent programmes such as WISER and SHEAR have been set up with the specific aim to include users, including regional planners and agriculture advisors. A full assessment of these should provide further examples than we were able to summarise in the time given. On the other hand, several programmes had not yet produced outputs and so proved fruitless.

[49] Hoegh-Guldberg et al., (2018) "Chapter 3 - Impacts of 1.5°C of Global Warming on Natural and Human Systems," in IPCC Special Report: Global Warming of 1.5 ºC, V.
[50] Coninck, H. et al., (2018) "Chapter 4 - Strengthening and Implementing the Global Response," in IPCC Special Report: Global Warming of 1.5 ºC.

Other programmes were less about users' uptake of information than its production and these did not provide examples of co-production. In some cases, outputs are driven by climate science producer perspectives and sometimes focus more on planning and strategies, frameworks etc. Some examples point to access to, and use of, climate knowledge particularly in evaluations but are usually in the grey literature and rarely provide specific examples;

- Further search funders/donor sites –including project evaluation information that the team did not have time to cover: There is a proliferation of networks/web platforms where climate change information can be found and which report climate action. We have low confidence that most of the networks have been covered in this review given the enormous volume of them (however they include some important ones like weADAPT, CDKN). However, from team and KII experience, those currently active in linking climate research and the adaptation and resilience communities have been covered. Many old sites that ended activity at the end of project funding are a gap. Several reports commissioned by USAID, ADB, WB had been found in institutional website, so less time was spent cross-checking donor websites. Some of them contain vast amounts of resources. Reports tend to be quite technical, concentrating on what the donor is doing, but lack detailed evidence of clear outcomes concerning how climate data were used and with what impact;

- Use more general search terms and browsing publications lists where appropriate (also see the paper on mapping the landscape of climate services: Most reviewed examples in the REA matrix came from institutions. It was surprising that not many examples were found on the individual institutions' own websites. Frequently it took a long time and significant searching to find relevant information – examples were not easy to find in many cases; tagging/metadata could be improved. It is possible that institutions' outputs are reported elsewhere and/or that website/branding has a lower priority in some cases. Institutional-level searches concentrated on African and South Asian Institutions (e.g. UCT). Some European institutions and EU funded programmes do lead and include African and Asia cases (e.g. GERICS) and several were found to bridge the academic and grey literature (e.g. SEI Climate Services). Indeed, there remains a need to identify where best to collate learning on climate services. While WISER invested in strengthening the Africa Climate Policy Centre (ACPC), emerging learning remains scattered and not readily accessible unless through informal networks;

- Refrain from searching the main academic literature sites as this might not be efficient – our initial search string returned thousands of results: Searching further is unlikely to uncover much more evidence/examples of the use of climate information. A database of 117 entries, including both academic and grey sources, has been constructed where, in addition to recording where good examples were found, there is also documentation of when websites lacked relevant papers and why this was the case. In some cases, outputs were driven by climate science producer perspectives and sometimes focus more on planning, strategies, and frameworks. Yet this situation may change due to the introduction of newer programmes. Some examples point to use of, and access to, climate knowledge particularly in evaluations but these are usually in the grey literature. Institutionally, many European, African and Asian institutions were covered, and considerable time was spent looking for cases and partners, yet few direct examples of climate data being used in adaptation and resilience planning were found. Some allude to the climate challenges/stresses of specific locations and to adaptation plans, yet whether climate information is used inform the other is not clear – again this would need to be checked with the researchers involved. In general, it was not required to search using search terms as most websites usually have a simple list of publications that had to be scanned. Terms including climate, data, knowledge, information, climate forecasts, evaluation, decision making, adaptation planning, are better ways to find relevant papers than 'climate services' which tend to return review papers on the barriers to use of services and development of climate service products.

5 Expert Reflection, provided by LTS Team and Key Informant Interviews

Key Summary Points

- The CLARE design process has the opportunity to fund science more appropriately for adaptation and resilience needs, moving away from the current top-down science-based approach toward joining up with multiple forms of decision-led needs. The design process also needs to be co-produced, to ensure user-friendly information;
- Capacity building is essential to influence adaptive and resilience decision making through various governance pathways. Capacity building should include training on 'stakeholder engagement' as a core part of meteorological or climate science training. Currently there are no incentives or structures to prioritise this. This should also include training on communication for non-technical audiences. Capacity building should particularly be emphasised at national levels and address the relative neglect at the sub-national level where most users exist;
- There is a vital need to invest in both strengthening decision-makers' understanding about weather and climate information, and climate information producers' risk communication capacities and understanding of the decision-making contexts which climate information is to support;
- Resources are needed to support all the core elements/functions of a climate service – i.e., production, interpretation for use, communication, decisions and use, learning and feedback, and enabling the multi-actor connections between all these;
- CLARE support should not be limited to climate service providers; there is ample potential to add science value within adaptation planning, adaptation finance proposals / projects, climate smart agriculture, and other sectors, where use and impact is the primary concern;
- A shift is needed to focus on integrated climate service chains with clear communication of information that meets user demands in contrast to funding climate science without a value chain linkage to well-defined end-use;
- Attention must be applied to ensuring knowledge brokers are involved within the decision making process. We encourage donor consortia fund to concentrate on >10 year programmes. These should complement North to South capacity building with more robust South to South linkages. In addition, knowledge management functions are best situated within the region of focus and/or at a country level;
- The greatest demand for information rests at the decadal level, where there is currently a paucity of information. The lack of information on decadal gaps, and lack of knowledge that science cannot fill this hole, must be explicitly addressed to avoid maladaptation.

5.1 General Findings

Modalities of funding for climate research supporting adaptation and resilience programming have to date demonstrate limited sustained impact. Findings from the literature survey confirm issues recognised through the experience of the LTS team and key informants. Co-design of programmes linking climate science and users through well-defined knowledge exchange frameworks and processes is relatively uncommon. Much support of climate science appears to have been deployed toward an increased generation of information, paying too little attention to its use and thereby failing to address the gulf between actors involved in the supply and demand for information.

There are many reasons for this disconnect, or "valley of death" separating the generation of information and its accessibility and use. The problem is not intractable if CLARE is reframed to reflect a user-driven structure rather than the production of more climate science without clear justification. Key issues identified by the LTS team through internal consultation and KIIs highlighted the following pathways for enabling address of existing constraints to uptake and use of climate science.

5.2 Supply-led programme design

With few exceptions, use of climate science research in programming intended for use by the adaptation and resilience community is usually planned without sufficient consultation with intended users. Sustainability of investments is sometimes hampered by donor requirements to deploy Northern scientific capacities, rather than engaging and strengthening those within region.

Box 1. John Furlow, Deputy Director for Humanitarian and International Development, Columbia University's International Institute for Climate and Society (IRI).

The type of information used in adaptation decision support should be determined by the decisions that are actually being made. Long-term climate data does not fit with decision timeframes for governments. Individuals such as farmers are far more likely to need information at weather and seasonal timescales than decadal or end-of-century. When used by the adaptation community, they are at risk of working without useful application climate information. A critical need is to bump up investment in climate services in countries themselves and develop capacity among their institutions; this will raise the potential to pay attention to risk. To be successful data "translators" are needed to make information understandable.

A disconnect between information supply and uptake is driven in part by differences in impact metrics between the research and development funders, as was pointed out by KIs involved closely with UK academia. The performance of UK-based academic researchers was noted upon as largely measured by the production and citation of peer review articles as required by the Research Excellence Framework (REF) rather than metrics found in development practice and addressing SDGs and related targets.

Donors can support the operationalisation of underpinning principles for co-production within the prioritisation of research, supporting equality of partnerships and monitoring of achievements. Current assessment of scientific excellence, for example through the REF process, needs to be better aligned with development impact evaluation measures to address differing values and incentive systems.

The CLARE design process has the opportunity to fund science more appropriately for adaptation and resilience needs, moving away from the current top-down science-based approach toward joining up with multiple forms of decision-led needs.

DFID is therefore encouraged to promote better linkage between research and development programmes with integrated measures of success[51]; systems-based innovations connecting multiple levels of decision making, addressing continental to community-based need. In doing so CLARE has an opportunity to build demand-supply bridges while addressing different and complex adaptation pathways.

Future investments should focus on decision-making perspectives enabling integrated approaches to using weather and climate information across short and long-term timescales, promoting a provider-user co-design and strengthening resilience to address risks from climate variability, extremes and change. KIs implementing adaptation and resilience programmes suggest this would mitigates further risk of overlooking decision-making constraints, thereby leading to poor (if any) uptake of relevant information from a climate science perspective.

[51] Buontempo, C., Hewitt, C. D., Doblas-Reyes, F. J. and Dessai, S. (2014). Climate service development, delivery and use in Europe at monthly to inter-annual timescales, *Climate Risk Management, 6,* 1–5. https://doi.org/10.1016/j.crm.2014.10.002.

KIs with donor backgrounds highlighted that mechanisms through which CLARE-related work is contracted will impact types of consortia that will be applying and set the foundation for its rollout (2 KI). CLARE's development is encouraged to consider this carefully in the next phase of its structuring.

5.3 Co-design of projects and climate services

Box 2. Jeremy Stone, Asia Regional Resilience Advisor, Mercy Corps.

Design projects that combine specialist technical skills of forecasters and modellers with social scientists and community mobilisers. The most up to date technical information is useless if it can't be interpreted. Find ways to engage national universities where possible and jointly design services and outreach.

Most KIs expressed opinion that while there is a need for climate research to support adaptation and resilience there is not enough uptake of information that is already available. There is often an assumption among the research community that if data is available, it will be used. This is perceived as incorrect and strongly influences the gulf between climate science supply and use.

Co-design of development programming and co-production of user-relevant information is overwhelmingly recommended, along with the capacity building necessary to influence adaptive and resilient decision-making through many different governance pathways. Convening and managing the partnerships to accomplish this will require transdisciplinary skills, teams, and consortia.

There have been a considerable number of initiatives to identify, agree and share principles underpinning co-production of climate services[52]. However, the values, approaches and priorities of established development monitoring, evaluation, accountability and learning differ from those employed in frameworks focused on assessing scientific excellence. There remains a need to align indicators for measuring scientific and development 'success' to ensure all partners, and particularly those people who are the focus of intended impact, benefit from efforts that seek to strength resilience to climate-related risks.

A key recommendation for the CLARE development process is that resources are needed to support all the core elements/functions of a climate service – i.e., production, ensuring foundational understanding of key climate concepts and confidence in interpretation an use, communication, application within decision-making, learning and feedback, and enabling the multi-actor connections between all these. These are equally important to achieving climate resilience impacts yet likely to be led by different actors.

There is a need to recognise that the drive behind coproducing climate services can come from any one of these elements / processes, not only from the science providers. CLARE support should not be limited to climate service providers; there is ample potential to add scientific value within adaptation planning, adaptation finance proposals / projects, climate smart agriculture, and other sectors, where use and impact is the primary concern.

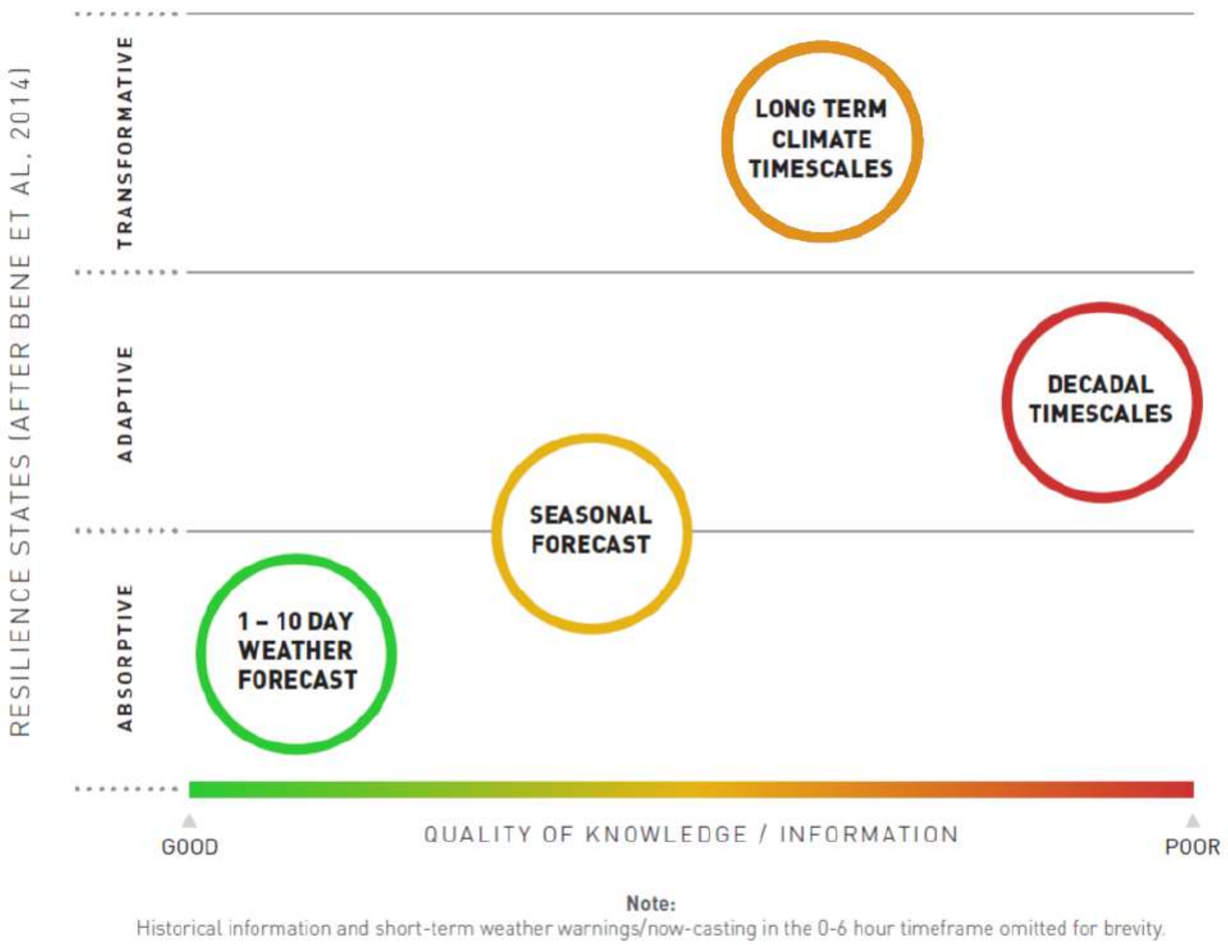
In the complex collaborations and consortia required to co-produce climate services able to build the resilience of the people whose lives and livelihoods which are most directly impacted, there is a need to identify and consider benefits for all stakeholders involved in programme co-design and implementation.

[52] Adams, P., Eitland, E, Hewitson, B, Vaughan, C. Wilby, R., Zebiak, A. (2015) Toward an ethical framework for climate services A White Paper of the Climate Services Partnership Working Group on Climate Services Ethics; Steynor et al, 2016, Taylor, A, Scott, D., Steynor, A. and McClure, A. (2017) Transdisciplinarity, co-production and co-exploration: integrating knowledge across science, policy and practice in FRACTAL, FRACTAL working paper #3.

5.4 Capacity to understand climate information

Figure 6 is an illustrative schematic, which summarises expertly informed discussions on the assessment of the quality and application of climate science for adaptation and resilience practice. These discussions were held among the LTS expert team and with key informants. Our analysis reflects findings from the grey and academic literature reviewed. It considers four forecasting periods – 1-10 – day, seasonal, decadal, and long-term climate timescales and plots them on two axes. The x-axis represents relative quality of climate science knowledge, and the y-axis whether best suited to an absorptive, adaptive, or transformative resilience context[53].

Figure 6 Assessment of the Quality of Weather and Climate Information for Adaptation



Key:

- Colouring in the axis indicates the quality of knowledge/information; and
- Colouring of the circles indicates the quality of use of the knowledge/information type.

[53] Bene et al, (2012). Resilience: New Utopia or New Tyranny? Reflection about the potentials and limits of the concept of resilience in relation to vulnerability reduction programmes. (**405)** 06. CSP Working Paper. DOI: 10.1111/j.2040-0209.2012.00405.x

Key findings relating to climate science and climate services supporting adaptation and resilience:

- The climate science information for 1-10-day forecasting is good in many places, in that it is produced to a level of accuracy which is useful for some groups of users. Its uptake by users is also good in some places and applicable in an absorptive context within the resilience states. Nonetheless, many people who require short term weather information are not able to obtain it, if, it is not provided through accessible, trusted channels. Even if information can be accessed it may not be provided in a format that is understandable and relevant for specific decision-making processes, at a relevant geographic scale and with guidance for users lives and livelihoods;

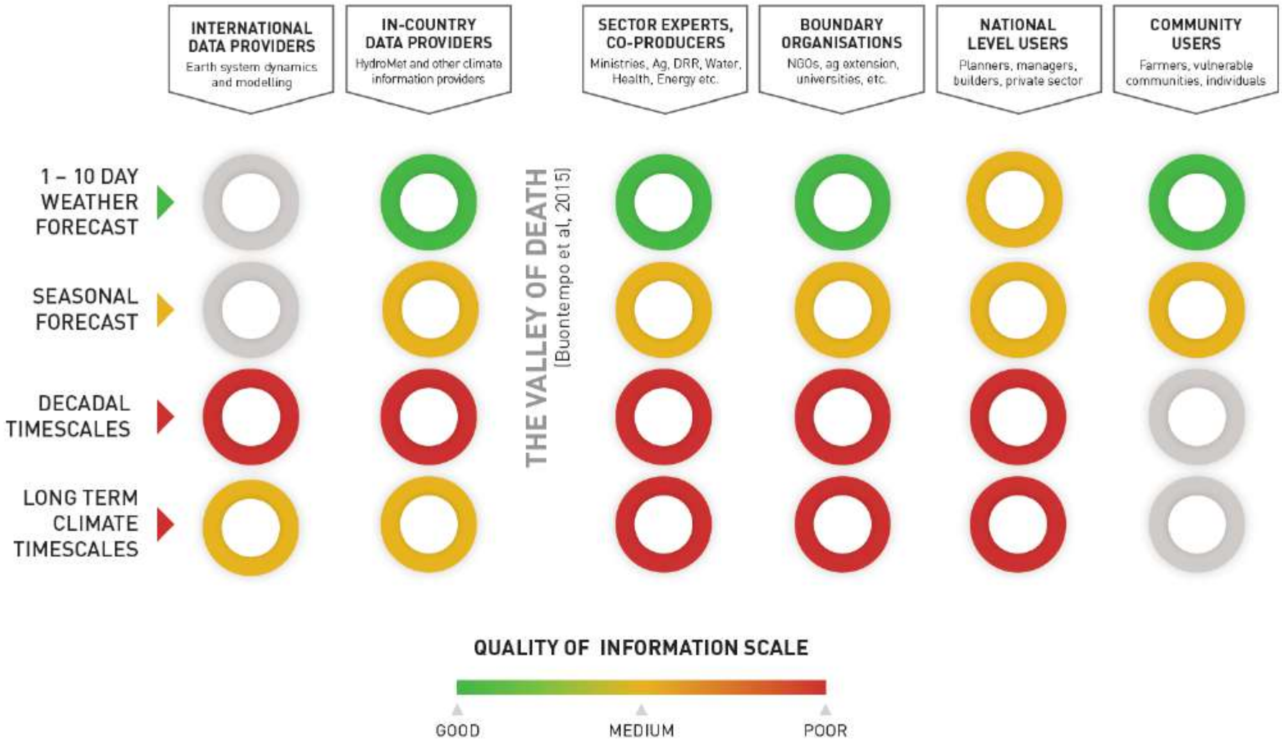
- The science behind seasonal forecasting is fair to good for some seasons and some areas. However, the use of seasonal forecasting is often poor. Findings suggest this is in part because information provision is heavily influenced by the suppliers of information without sufficient consultation of users. Users may not know information exists; they may be unable to understand or have limited trust or confidence in how to appropriately use the information; or they may not have access to sufficiently detailed information (such as livelihood-specific advisories). They may also lack the resources they require to act on the information. Seasonal forecasts have proven more useful in absorptive and adaptive contexts;

- Decadal information is urgently needed by the adaptation and resilience community in adaptive contexts, yet this is where climate science is least able to contribute a supply of information that meets demand. This finding was highlighted in the majority of the KIIs conducted with practitioners who work resilience and adaptation programming;

- Long-term climate timescales and projections provide useful information on climate trends, particularly with regard to temperature, yet have significant areas of uncertainty with regard to key metrics, including precipitation. Their use is critical in addressing the transformative steps humankind needs to take to become resilient to mitigating the greatest impacts of a rapidly changing climate. Yet a number of key informants also noted the misuse of long-term climate information within development agencies to compensate for a lack of decadal information. This is in part due to the data being misunderstood and may be driven by the response to the demands from government or donor funders, to state what is being adapted to, in adaptation and resilience programming. There are also some climate service providers who seek financial gain by exploiting this lack of understanding, possibly contributing to future maladaptation.

Figure 7 is also an illustrative schematic, derived as was Figure 1, showing the general quality of information provision (left of the figure), through understanding and use (right of the figure). The gulf, or “Valley of Death”, that exists between providers and users of information is a key focus of this report. The circles lacking in colour indicate where there is either limited use or engagement among actors. For example, international data/information providers have key roles in providing the science used to develop 1-10-day and seasonal forecasts, however they are not intended as key access points for in-country end users. Similarly, community users either do not efficiently use or cannot access the type of information relevant to them, for decadal and long-term climate timescales.

Figure 7 Climate Science to Application Information Flow



There are a wide range of reasons for the constraints in enabling effective use of climate information. Some stem from the meteorological services' historical focus on aviation, others from weak science-policy-practice dialogue and non-inclusive risk governance across a wide range of areas including and beyond weather and climate. In terms of supporting research and development for climate-resilience building and adaptation, there is a general impression that gulf represented by the "Valley of Death" to some extent derives from the structure of programme funding (Jones et al, 2018)[54]. Emerging programmes like the ARRCC, ACToday, Knowledge Brokering for Pacific Climate Futures from the Australia-Pacific Climate Partnership, are focusing on integrated climate service chains and clear communication of information meeting user demands in contrast to funding climate science without a value chain linkage to well-defined users. Likewise, adaptation and resilience programmes are designed without clear links to climate science providers. However, there are some examples of projects which do support these linkages, although there are difficulties in these linkages being understood. This includes misunderstanding of what roles and activities are required, and how to ensure these are sustained post-project. For example, FCFA, WISER, and SHEAR required partners to specify intended stakeholders and decision-making processes of focus. However, there was less clarity on how knowledge exchange activities were to be undertaken and the resources and capacities required to support these processes. .

Training on 'stakeholder engagement' is not yet a core part of meteorological or climate science training, nor is there an incentive structure that prioritises this routinely[55]. African SWIFT, Met Office with KMD, and other internationally funded efforts are seeking or have sought to develop modules and training for meteorologists that includes user engagement. KMD has integrated engaging with decision-making processes as a core

[54] Jones, R. N., A. Patwardhan, S. J. Cohen, S. U. Dessai, A. Lammel, R. J. Lempert, M. Monirul Qader Mirza Bangladesh, H. von Storch, W. Krauss, J. Wolf Germany, C. Young, R. Bierbaum, N. King, P. Kumar India, V. Barros, D. Dokken, K. Mach, T. Bilir, M. Chatterjee, K. Ebi, Y. Estrada, R. Genova, B. Girma, E. Kissel and A. Levy 2 Foundations for Decision Making Coordinating Lead Authors: Lead Authors: Contributing Authors: Review Editors.

[55] Visman, E., Audia, C., Crowley, F., Pelling, M., Seigneret, A., Bogosyan, T. (2018) Underpinning principles and ways of working that enable co-production: Reviewing the role of research, KCL/BRACED Learning Paper #7,

responsibility of the devolved County Directors of Meteorological Services (CDMS)[56]. Internationally, including within developed countries, there is a need to recognise user engagement and risk communication as foundational, core elements of co-developing and co-delivering meteorological and climate science training and services.

Co-production of information requires strengthening capacity-building efforts for a wide range of users with different understandings of the role of climate science in their decision processes, and the uncertainty it brings. CLARE development should heed over-emphasis on capacity building at national levels and relative neglect of at sub-national levels where more users exist[57].

Box 3. Rob Wilby, Professor of Hydroclimatic Modelling, Loughborough University

The priority for DFID should not be on spending money on new climate research except on understudied sectors and places. The greater need is for science translation into practice, as well as for capacity building and training. Why not sponsor students to come to the UK to do MScs or, better still, support curriculum development in vulnerable countries? In an ideal world, users would know what to ask of climate science, but currently, this is rare. Climate model information is often being used inappropriately.

There is a vital need to invest in both strengthening decision-makers' understanding about weather and climate information, and climate information producers' risk communication capacities and understanding of the decision-making contexts which climate information is to support. To effectively use climate information, decision-makers' need to appreciate the probabilistic nature of the information, which is a trained skill. This also requires that climate information producers transparently communicate the probabilities in each forecast and the confidence or skill in the models and statistics that underpin the forecast. Meteorological and climate science training needs to ensure risk communication for non-technical audiences across decision-making levels (from the local, city, to national and regional), employing a variety of approaches that support experiential learning, including scenarios and practical decision support tools. Much work on this has already been done, and there is a need to collate, review and consolidate approaches that have proved effective within different contexts to fast-track learning[58].

In some adaptation programs Key Informants know of unintentional misuse of climate information because they confuse good long-term projections with data-poor decadal projections. Proposals to donors may include the climate challenges that are intended to be adapted to via development interventions. IPCC, SERVIR and other sources are quoted with limited, if any, understanding of the time frame of the intended work, and that decadal projections are different from long-term projections. This has the potential to cause maladaptation, although in most cases funded work moves on with development activity without further consideration of climate.

There are practitioners encouraging their agencies to move away from reference to "climate adaptation" programming to "climate-informed". For example, in the design of programmes teams will start by reviewing existing reports and data which usually involves NAPA's/NAPs, climate strategies, data from national meteorology hydrology departments and services. A review of climate/risk assessments produced by other agencies is undertaken. At the design stage it is usually sufficient to understand the key shocks and stresses with which to define higher level interventions. A more detailed localised resilience assessment is then undertaken to define site specific interventions following start-up of programmes.

The Asian Cities Climate Change Resilience Network (ACCCRN) programme (now closed) published a series of papers on activities in over 10 cities in S and SE Asia. Climate models were used to inform initial vulnerability assessments leading to support of reprioritised city government work as a way of mainstreaming

[56] Visman, E., Shaka, A., Wachana, C., and Githungo, W. (KMD) (2018) Guide: Developing a County Climate Information Services Plan, WISER

[57] Harvey, B., Jones, L., Cochrane, L. et al. The evolving landscape of climate services in sub-Saharan Africa: What roles have NGOs played? Climatic Change 157, 81–98 (2019). https://doi.org/10.1007/s10584-019-02410-z

[58] Carter, K., Steynor, A., Vincent, K., Visman, E., Waagsaether, K. (2019). A manual for co-production in African weather and climate services.

climate awareness into city planning and budgeting[59,60]. Shared learning between cities around the diverse activities undertaken through the programme allowed interventions to become resilience experiments allowing comparison of how successful interventions were in raising awareness of climate risks in diverse governance contexts[61].

The Global Commission on Adaptation[62] "Scaling Climate Services to Enable Effective Adaptation Action noted that infrastructure is the adaptation context most closely associated with long-term planning at the time scale of climate-change projections, and notes that timescales of information need to be tailored to the varying time horizons of decisions. Design decisions have relatively long-time horizons. Once the infrastructure is built, decisions around operations and maintenance become dominant.

Recent climate-science focused programmes, including SHEAR and FCFA, have focused on research with limited resources for investing in strengthening decision-makers' understanding of key climate concepts and practical guidance on how to use probabilistic information. The number of proposals for training amongst the final year cross-SHEAR integration projects highlights shared recognition amongst researchers and operational partners of the need for increased investment in this area. This is not just training users in climate science, but training them in the use of climate information and how to be "discerning consumers" of information, and training for climate scientists on understanding decision-contexts.

Box 4. Marta Bruno Soares, ARRCC PI, and Natalie Suckall, Research Fellow Leeds University.

We need extra effort going into training and ongoing support on how to use climate data and identifying how different governance and sectorial contexts can uptake and use climate information on the ground. For that, we need to allow the social sciences to have a more prominent role in the development of weather/climate services. We cannot just spend money on models and computers. There is information; the question is how to use it.

The International Research Institute for Climate and Society (IRI) has established an Adapting Agriculture to Climate Today for Tomorrow (ACToday) initiative that aims to combat hunger by increasing climate knowledge in six countries that are particularly dependent on agriculture and vulnerable to the effects of climate variability and change: Bangladesh; Colombia; Ethiopia; Guatemala; Senegal; and Vietnam. In Bangladesh, the International Centre for Climate Change and Development (ICCCAD) is working with ACToday to broker a capacity building role around multi-stakeholder groups. This complements other workstreams initiating a Bangladesh Academy for Climate Services (BACS) bringing climate information providers and potential users together to better understand each other's needs and limitations. Without such information brokerage between potential users and providers, the sector is supplier driven with little utility of the information supplied.

The Australia Pacific Climate Partnership has a A$75 million investment over four years (2018-2022). Through the Partnership, the Australian Government partners with Pacific Island countries and regional organisations in alignment with the Framework for Resilient Development in the Pacific (FRDP) to integrate climate and disaster resilience and low carbon growth across sectors. The Partnership includes four components to address critical gaps in climate information services, governance, gender and social inclusion, and to boost technical capacity in Australian aid investment sectors." One project, 'Knowledge brokering for Pacific climate futures' is addressing the problem that while the climate science is excellent, it is not being integrated into decision-making about development. It therefore co-designs appropriate tools and processes for different kinds of development decision-making (initially agribusiness, tourism and community development). Essentially it is trying to build skills among partners to become knowledge brokers themselves and evaluate what works and what does not in terms of their brokering and brokering tools/processes.

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[59] Friend, R., Jarvie, J., Reed, S. et al. (2014) Mainstreaming Urban Climate Resilience into Policy and Planning; reflections from Asia.
60 Jarvie, J., Sutarto, R., Syam, D. et al. (2015) Lessons for Africa from Urban Climate Change Resilience Building in Indonesia. Current Opinion in Environmental Sustainability. 13, 19-24
[61] Reed, S., Friend, R., Jarvie, J. et al. (2015) Resilience Projects as Experiments: implementing climate change resilience in Asian cities. *Climate and Development.* 7 (5) 469-480
[62] Hansen, J., Furlow, J., Goddard, L. et al. (2019) Scaling Climate Services to Enable Effective Adaptation Action.

Overall, there is a lack of international standards on how climate data use is applied. There is confusion about the potential for climatology to be a useful climate service that could perhaps be explored further. With particular reference to climate service providers working from long-term projections, there are concerns that unintended and intended misuse of information by certain service providers for financial gain may be causing maladaptation.

Efforts can be strengthened in this area to encourage uptake of useful information that is being ignored, and also to prevent further intentional and unintentional misuse of climate science.

5.5 Regional and national institutional support for climate science uptake

Sustainable systems and services supporting mainstreaming of climate information into national and sub-national decision making are hampered by project-based approaches. As is best possible, the length of projects needs to reflect the cross-sectoral, cross-disciplinary collaboration required to support co-production and effective use of climate services[63]. Whereas mainstreaming to date has largely resulted from donor-supported projects, greater attention must be applied to:

- Finding long-term solutions enabling knowledge exchange to support specific decision-making processes;
- Encouraging donor consortia to fund >10-year programs to maximise sustainable impact;
- Complementing North to South capacity building with more robust South-South linkages. Scientific capacities need to be strengthened within countries and regions along with knowledge broker roles that, up until now, have tended to be situated and invested in donor countries and not regionally/continentally based. Similarly, efforts need to be made to strengthen linkages between more operationally focused national meteorological and hydrological agencies and climate science research institutions to best meet decision-makers' needs for climate information at different timescales;
- Understanding of decision-making processes and pathways; projects should better understand governance systems and frameworks that science can feed into;
- Advocacy for climate information mainstreaming to be made at sub-national levels.

Box 5. Dr Saleem Huq, Director, Director of the International Centre for Climate Change & Development (ICCCAD).

We need modelling ability at national level in universities. This is where the capacity building must be based. Global modelling centres doing 100-year scale need to invest in downscaling geographically and decadal. The place for this is not the Met department - go to universities. Modelling is science - it needs universities that also train new climate workers and can convene government and courses. Universities are legacy partners - projects do not have legacies.

Weakness around these issues is demonstrated by the number of pilot projects that have been at least partially effective in enabling climate services at seasonal or sub-seasonal timeframes, and longer, for specific user groups. These have frequently discontinued following the end of project stages, due to lack of integration within NMHS core services or unsustainable approaches employed, for example, reliance on SMS when no business model or government commitment to the continuation of the project or programme.

Institutional sustainability needs to be embedded into criteria for assessing investment in climate services and the development of continuity business models, as a core element from the outset of investment. Investment has frequently been to external intermediaries at the expense of investing in NMHS capacities for

[63] Visman, E., Audia, C., Crowley, F., Pelling, M., Seigneret, A., Bogosyan, T. (2018) Underpinning principles and ways of working that enable co-production: Reviewing the role of research, KCL/BRACED Learning Paper #7,

user engagement[64]. Resources, priorities and capacities for engaging with users have rarely been integrated into the core business of NMHS. Resources can be effectively invested in supporting NMHS in the user engagement to enable operationalising national frameworks for climate services, and support investments in building sustained capacities where NMHS demonstrate the commitment to prioritising this area.

5.6 Knowledge Management

In many donor-funded projects the knowledge management function has been overly centralised and situated internationally. This has constrained building capacity within regions and countries where work is being conducted. It has prioritised international exchange at the expense of exchange of learning between and within regions of programme focus[65]. Beyond knowledge management is the need for resources, skills and expertise in knowledge brokering. This is a precondition for any information service to work, so it does happen, but is generally invisible and unconscious. The focus on coproduction is beginning to make it more visible – but also much more important that it is skilled.

Knowledge management functions are best situated within the region of focus and/or at a country level. Ideally these would be networked to promote cross-learning and other synergy. This would enable knowledge management to benefit and strengthen existing networks of practice. It would also facilitate cross-learning across countries and regions, for example between East and West Africa.

Box 6. Amir Bazaz, Senior Lead - Practice, Indian Institute for Human Settlements

A problem is who is benefitting and who is not. Who has power and who does not, so who benefits? Effectiveness of the use of climate data is mediated by power, agency and more often is biased in favour of those who have power, agency, resources. Front line institutions are trying to mitigate this problem.

5.7 Inclusive access to climate information

Inclusion and diversity within climate services investment are not sufficiently addressed at present. For example, consideration of gender and inclusion were not initially prioritised within the establishment of the FCFA programme[66]. Integration and monitoring of gender and inclusion were similarly found to be insufficiently addressed within BRACED-funded projects[67]. The vital importance of affording voice to the marginalised within climate adaptation discussions, as well as prioritisation of services and research, is increasingly recognised.

CLARE planning should ensure consideration of gender and inclusion within criteria for investment as well as within ongoing monitoring. Supported work needs to explicitly recognise and clarify how it will support participatory discussion on the necessary trade-offs in adaptation and resilience-building, including the displacement of risks and changing opportunities. Promotion of transparency toward inclusive resilience building with pro-poor outcomes will guide programming toward SDG and other goals and mitigate risk of resilience dividends being biased toward the more powerful in society.

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[64] Harvey, B., Jones, L., Cochrane, L. et al. The evolving landscape of climate services in sub-Saharan Africa: What roles have NGOs played? Climatic Change 157, 81–98 (2019). https://doi.org/10.1007/s10584-019-02410-z

[65] Visman, E., Pelling, M., Audia, C., Rigg, S., Crowley, F., and Ferdinand, T. (2016) Learning to support co-production Approaches for practical collaboration and learning between at risk groups, humanitarian and development practitioners, policymakers, scientists and academics, KCL/BRACED Learning

[66] Visman, E., Bologo/Traoré, M., Jankowski, F., Affholder, F., Gérard, F., Barnaud, A., Audia, C., and Ngom Basal, Y. (2019) Technical Report No. 7: Considering how Gender and Inclusion have been addressed within AMMA-2050

[67] Leavy, J., Boydell, E., McDowell, S., and Sladkova, B. (2018) RESILIENCE RESULTS BRACED FINAL EVALUATION, p7

5.8 Cost/Benefit justification for climate services

Rigorous but inexpensive cost/benefit tools are required that recognise both social and qualitative as well as economic and quantitative costs/benefits, which accurately reflect the full range of costs involved across the whole process of co-producing climate services, inclusive of strengthening decision-makers' understanding of climate information and its appropriate application.

There remains a need to demonstrate the value of climate services and integrate monitoring and evaluation capacities within NMHS and climate centres. To support uptake, there remains a need for transparent assessment of the cost/benefits of employing probabilistic climate information, with varying levels of skill. This is currently only done infrequently and employing resource-intensive approaches. The benefits of development and research investment in climate science, and climate-science based approaches including forecast-based action, need to be compared with investments in other sectors. There is a need for more objective, external evaluation of the degree to which projects, programmes and investments are 'climate-proofed' i.e., informed by and accurately seeking to address potential climate risks. Alongside technical evaluation of forecast skill, there is a need to ensure non-technical users can assess perceived skill and relevance. Some projects, for example, Rain Watch, African SWIFT and WISER Highways are piloting ways of supporting forecast verification and evaluation by 'users', to improve observations and modelling as well as to build trust and uptake.

The CLARE development team should also be aware that in parallel, as part of the Global Commission on Adaptation Year of Action, the Food Security and Agriculture action track will include a component focusing on mobilising funding for climate-informed digital advisory services. A budgeted investment blueprint for these services will be generated in order to inform how much investment is needed and where. To create a well-informed investment blueprint, work is proceeding on what the current investment landscape is and what gaps may remain. Through a series of literature reviews, consultations, collaborative events, a survey and an online mapping exercise, the action track team aims to provide a robust landscape of climate-informed digital advisory services that will help generate an actionable investment blueprint. A final draft for review will be presented early/mid-September to allow sufficient time for final revision and to have the Blueprint finalised and presented at the Global Action Summit in the Netherlands October 22nd 2020 and /or at COP-26 in Glasgow, Scotland. The Global Action Summit will also provide an opportunity for donors, countries, and organisations to make commitments towards the Blueprint and the identified priorities.

5.9 Current demand

There is great demand for climate information at the decadal level, where there is currently a paucity of information. There are many cases where this has led to inappropriate use of long-term projections either because of demand from governments and donors, insufficient understanding of the limits of use for long-term projections, and sometimes dubious selling of climate services. This demand for decadal information does not take away from the point that many users still want short term (1-10 day and seasonal) forecasts that are relevant to them at the right geographic scale, sector specific and with advisories.

Box 7. Paul Jeffery, Chief of Party, APIK/USAID Climate Adaptation Program, Indonesia.

Climate science and data do not directly drive the adaptation action - the adaptation action is determined locally through consultations with gov, communities etc and understanding local needs and priorities - generally, a menu of options is produced. Science can then be applied in helping determine which adaptation options should be prioritized first. So, it is a case of marrying/bridging the top-down science with real ground-driven priorities. But if you don't have the ground-driven priorities produced through a consultative process it doesn't work.

The lack of information on decadal trends, and lack of knowledge that science cannot fill this gap, must be explicitly addressed to avoid maladaptation. In parallel, there is a need to integrate models into forecasts and more generally a need to strengthen decision makers' understanding about the extent of current climate science capacities. Climate producers need to transparently communicate and ensure users appropriately appreciate the skill of the currently available services across temporal and geographic scales.

The Green Climate Fund (GCF) is driving further demand for actionable information and methodologies for use among many different parties. There is an increasing demand for knowledge brokering skills from expert perspective, application, and results. There are often assumptions that these can be provided by scientists and MET offices, yet there is a need for more understanding of the capacities needed to enhance the ability to bring different actors together. National institutions, particularly universities, may play a critical role here, both as locations for climate information outreach and development of cadres, particularly at the M.Sc. level, able to play brokering roles.

A parallel requirement is to employ a systems-based approach to develop, contextualise and operationalise national and regional frameworks for climate services. Within each country and region, it will be important to identify the range of organisations that need to be in the mix. Attention should be placed on assessing the most appropriate location and function for structuring ongoing dialogue across sectors, disciplines and decision-making levels.

6 Conclusions and Recommendations

This study was commissioned by DFID to review and assess evidence against the following key question:

Within the process of enabling climate science research to better support resilience and adaptation and achieve internationally agreed commitments, what is working and what is missing, and which people and institutions are key contributors in this field?

This review has found limited evidence from academic or grey literature where climate science is used to inform adaptation and resilience building in practice. KII with a range of relevant stakeholders supported this finding and provided valuable contextual analysis to inform future DFID climate change programming. Searches of institutional and programme websites proved more challenging as systematic search functions and metadata are generally lacking. It is therefore possible that evidence has been missed despite best attempts; the overall confidence that we have encountered all of the key evidence is low. However, the use of mixed-methods analyses, a wide net and the iterative process employed provides reasonable confidence in the conclusions of this study.

From the literature review, a range of attributes that enable climate science research to better support good resilience and adaption practice emerged:

- **Co-design of climate services – a demand-and-decision-driven relationship**. A collaborative demand-and-decision-driven relationship was found to create knowledge that is more relevant for users and, thus, is more likely to be used;
- **Transdisciplinary knowledge integration processes**. These improve the communication between users and producers resulting in co-produced information that is both useful and usable;
- **Narrative and experiential learning approaches and frameworks to support cross-sectoral, cross-disciplinary dialogue**. Such approaches can support mainstreaming climate information into local social, political, and institutional contexts and also take into account the complexity of the decision-space;
- **Building and embedding local institutional capacity to address climate challenges**. This is needed in the countries where adaptation and resilience building are taking place and is important for responding to the scale of climate change challenges for governments at all levels, as well as utilities, and businesses. Equity considerations are also important and affect how much information is available and whether it is useful;
- **Building collaboration/networks between policymakers, local providers and users to open policy space**. The evidence reviewed demonstrates that this strengthens community voice with researchers, producers of climate services, local decision-makers, and utility companies. Building leadership and coherence between programs and divisions that work separately was found to be key to network development.

Concomitant with these lessons are barriers to the use of climate science in adaptation and resilience. Prominent among these are:

- **Unsuitable climate information formats and products.** A major barrier to the application of climate science is not the lack of information on climate change and adaptation, but a lack of information products that meet user needs in a format that is accessible and easily translated into contextualised decision-making processes;
- **Inadequate and/or uneven funding for adaptation**. Across sub-Saharan Africa and South Asia, the main recipients of funding for adaptation from dedicated climate funds, and the distribution of funding flows is uneven;

- **The dominance of a "science-first" (impacts-led) approach.** The design and production of climate information products is generally led only by climate experts. The limited role for non-climate experts to date, has been shown to cause user exclusion from decision-making in pilot projects;

- **Availability of localised information**. There is a critical need for better provision of locally accurate forecasts and for increased support for forecast users in specific areas. Climate/weather information in accessible formats to support DRR activities in areas at highest risk are also needed;

- **Lack of engagement with local and indigenous knowledge in developing climate services.** NGO and government efforts to promote "Western" forms of climate science and forecasting have frequently failed to engage with indigenous knowledge bases and associated practices.

The expert reflection and KIIs confirmed findings from academic and grey literature. More importantly, these provided nuance from the most recent, and ongoing, work applying climate science to adaptation and resilience. The major barriers identified to the use of climate information identified through this study, outlined below, guide the recommendations for the next phase of CLARE design:

- **Supply-led programme design.** With few exceptions, the use of climate science programming for adaptation and resilience is planned without sufficient consultation of intended users. The disconnect between information supply and uptake is driven in part by differences in impact metrics between the research and development funders;

- **Lack of co-design of projects and climate services.** Whereas there is a need for climate research to support adaptation and resilience there is not enough uptake of information that is already available. There is often an assumption among the research community that if research information is available, it will be used;

- **Capacity to understand climate information.** Training on 'stakeholder engagement' is not yet a core part of meteorological or climate science training, nor is there an incentive structure that prioritises this routinely. Co-production of information needs to be matched with capacity-building efforts for a wide range of users with different understandings of the role of climate science in their decision processes, and the uncertainty it brings;

- **Regional and national institutional support for climate science uptake.** Sustainable systems and services supporting mainstreaming of climate information into national and sub-national decision making are hampered by project-based approaches. The length of projects needs to reflect the cross-sectoral, cross-disciplinary collaboration required to support co-production and effective use of climate services and complementing North-South capacity building with more robust South-South linkages. These could be better situated within the region of focus and/or at a country level. Universities could play a critical role as both research centres and builders of national self-reliance in climate information development and dissemination;

- **Inclusive access to climate information.** The importance of affording voice to the marginalised within climate adaptation discussions, as well as prioritisation of services and research, in insufficiently recognised at present;

- **Cost/Benefit justification for climate services.** To support mainstreaming of climate information into decision-making pathways, transparent assessments of the cost/benefits of employing probabilistic climate information, with varying levels of skill, is needed;

Most of the 'science' needed for adaptation and resilience is not 'climate science' i.e. meteorology and climate modelling. The main challenge is in the integration and application of existing climate science with other discipline-based knowledge to support climate adaptation and resilience.

Recommendations for CLARE

This study has identified a number of key recommendations of relevance to the design and development of the CLARE research programme to support adaptation and resilience action.

Structure

- Reflect a user-driven structure in CLARE rather than leading through the production of more climate science, taking into account demand-and-decision-driven relationships contextualised to the geography, sectors, and timescale of need;
- The CLARE initiative is encouraged to promote better linkage between research and development programmes with integrated measures of success. CLARE has an opportunity to build demand-supply bridges while addressing different and complex adaptation pathways. Promote trans/multi-disciplinary knowledge integration processes (co-exploration and co-production);
- Future investments need to be focused on timescales relevant to decision-makers use of weather and climate information. Decadal information remains a massive yet unmet demand among adaptation and resilience practitioners. Assistance is needed to communicate best and legitimate use of long-term climate models in 5 -20-year planning decisions;
- Align assessment of scientific excellence with development impact to recognise and make explicit clear links through climate science provision and user uptake in co-production processes.

Procurement

- The mechanism in which CLARE-related work is contracted will impact types of consortia that will be applying and set the foundation for its rollout. This must be thought through carefully in the next phase of CLARE structuring to support sustainability through inclusion of existing expertise and capacities within countries and regions.

Consultation

- Ensure provision is made to support and develop sustainable organising /convening/facilitating roles between climate science providers and user groups to bridge the gulf that is currently common between them. Facilitating roles could take place simultaneously at multiple levels including development of consortia for individual projects, cross-learning visits between programmes, and international conferences. The visibility and skill of the intermediary or connecting role / function that works across the climate services knowledge system and creates a whole working service - and embeds it in a broader goal or system or sector or project – is essential, yet its role is rarely recognised as it falls outside ‘core functions’ of project and or value chains. Currently, where the connecting role is recognised, support and capacities are often focused on enabling specific projects rather than enabling sustainable systems for co-producing climate services. For example, MEL is often contracted to project leads and external agencies rather than capacities being developed within climate information providers or key user government services or user groups;

- CLARE should take advice from the climate researcher community to establish their research priorities. However, CLARE should establish what the value of this research is, in terms of need and use, in resilience and adaptation practice, ensuring there is obvious value for money and impact.

- Build, or strengthen existing, collaboration/networks between policy makers, local providers and users to open policy spaces on climate-risk governance. Programmes such as WISER, SHEAR and ACCCRN are examples of where externally driven initiatives foster greater collaboration within countries and regions;

- All core elements and functions are equally important for achieving climate resilience impacts but likely to be led by different actors. Efforts should be focused on establishing and strengthening sustainable functions for co-productions, embedded across key actors for co-producing services;

- Recognise that the drive behind co-producing climate services can come from any one of the above elements / processes, not only from the science providers. Therefore, future CLARE research calls should not be limited to climate service providers and this should be made clear in programme outreach;

- As CLARE progresses, develop directories of people and institutions working in different partnerships, programmes, and institutions as a network that can become a resource for both climate science providers and users. Key individuals should be convened to start to identify, in real time, current needs for available climate science and gaps for applied and bespoke research.

Next steps

As an initial step, it is suggested that DFID and IDRC convene representatives from relevant development programmes and key actors in the adaptation/resilience space, along with current climate science information providers. This may include representation from the people and programmes highlighted in the "Expert Reflection" section of this report. It should also include people from the user needs scoping study that was conducted for the CLARE programme and other key experts who have been involved in the preparatory work to support the design of DIFD's CLARE programme.

These convenings will help to identify research gaps, aligned to the needs appropriate for sectors, geographies, and populations, relevant to DFID priorities. Alongside this, the identification of research gaps should be produced in recognition of obstacles in the research applicability, and therefore identifying approaches to overcoming them. This will ensure mainstreaming of the use of climate science through adaptation and resilience practice. Without these, demonstrating value for money through evidence for influence of effective climate adaptive decision-making among multiple levels and contexts of governance and investment may prove elusive.

The outcome will be a guiding process for the next stage of CLAREs development, and a sense of involvement and investment from potential partners. Most importantly, it would begin to bridge the "Valley of Death"[1] representing the gulf encountered between climate information providers and users among the adaptation and resilience communities. By closing the gap CLARE has the opportunity to develop functioning networks within and between countries and continents, and better ensure Value for Money justifying the investment.

Annex 1 Terms of Reference

Call down support

Climate Science research for resilience and adaptation - Evidence Map

Information and Analysis to Support Programme Design Scoping of Climate and Resilience Framework Programme (CLARE)

Introduction

The Department for International Development (DFID) is committed to commissioning world-class research that directly improves people's lives. To meet the demand for development of capability along the climate science to services value chain DFID RED's Climate Energy and Water (CEW) Team is leading the development of a new climate and resilience research framework programme (CLARE), in partnership with IDRC. The programme will provide the evidence and innovation needed to help climate-proof DFID and HMG investments that are threatened by climate change, particularly in Africa.

To support this investment in climate science to services DFID wishes to commission a climate science landscape review and gap analysis. The aim this work is to take an initial, light touch, view of research activity and priorities across the whole science to application value chain, to inform the design and development of the CLARE research programme to support adaptation and resilience action.

The science to application value chain covers the underpinning research on climate, from model development and ground-breaking new climate science, to applied climate research and the development of services to support climate change adaptation and resilience development activity. It also includes research on a range of timeframes, from observations, current and near-term climate and the long-term climate change trend.

While climate services are, in general, at a more mature stage of development for weather and seasonal timescales, research to support adaptation to long term climate change are also important to this scoping study. This includes both incremental and transformational adaptation, the different challenges that the provision of adaptation services raises, and the stakeholders involved. Of particular interest is research in the application of the climate science in trans-disciplinary research into the challenges for development in the context of complex human-environment systems in a changing climate.

Climate change will affect all aspects of development planning and programming, and in the long term represents a serious threat to the achievement of the Sustainable Development Goals. The impacts of climate variability and change will not occur in isolation of other drivers of change. As such services to support climate resilience and adaptation for development need to be informed by an understanding of Earth Systems dynamics, and critically, the interaction of these dynamics, principally through weather and climate conditions and events, with development outcomes (e.g. achieving the Sustainable Development Goals). The aim of this science to services landscape review and gap analysis is to gain a top-level view of research and development activity in this area, to inform the development of the CLARE research programme. The audience for this work will be the CLARE programme team.

In its entirety the full review will be undertaken in two parts. The first stage will be a desk-based study, designed to informing the business case for the development of CLARE, and these ToRs relate to this first stage. It is anticipated that this desk-based study will be followed by a later second stage to undertake a more active engagement with a range of researchers and institutions to challenge and augment the findings of this first stage.

The desk-based review will focus on three key aspects of climate science to services research activity.

1. **Where are we with the science to support adaptation?** State of the science summary and literature review of research activities and findings that support climate resilience and adaptation. While the application of the science is critical, it is also important that the upstream, underpinning climate science research necessary to develop a range of climate services over all timescales, is not overlooked in this review.

2. **What gaps in science evidence can be identified?** Summary of research evidence gaps identified in the literature (e.g. 1.5 °C report), and from the research mapping process for question 1.

3. **Who is working in this space?** Stakeholder mapping of leading actors in climate science to services research globally. This will include underpinning climate science, applied climate science, interdisciplinary research on climate change impacts and human-environment system responses and the pull-through of this science to services for resilience and long-term adaptation.

The following terms of reference will outline the expectations, timeliness and desired outputs.

2. OBJECTIVE

To provide a light-touch overview mapping and assessment of the state of climate science research to support adaptation and resilience action, from the core, underpinning research, through to application and services, across timescales from early warning and disaster risk reduction, through to adaptation to long term climate change. The core objectives underpinning this overarching aim is to:

1. Systematically identify and collate the available evidence on the state of climate science to services, including underpinning earth system dynamic science and modelling through to impacts, applied science tackling transdisciplinary research on the development challenges of climate variability and long-term change, and climate services and adaptation;

2. Identify the key research gaps and recommendations for future research available from the literature;

3. Map main research institutions and scientists leading on the research and service development identified in 1 (this will also inform later consultation);

4. Summarise the evidence base in a manner which is useful to inform engaged discussion with the institutions and scientists identified in 3.

Recipient

The recipient of the work will be DFID's Climate, Energy and Water Team. Primarily for internal use in support of the business case and planning for CLARE. Subject to quality approval, the final product will be available to the general public on request.

Scope of work

The supplier may propose their own approach to identifying and processing the evidence base on climate science research informing adaptation and the achievement of the SDGs.

The evidence map must include:

1. Evidence on latest climate science developments and research gaps.

2. Evidence on development of applications of climate science and integration of this information in transdisciplinary research. This will include research in key sectors within CLARE such as food systems, built environment, Conflict & security, Health and Humanitarian. Other sectors could include water and energy systems, ecosystems services and urban-environment systems.

3. Evidence on developments in climate services to support resilience and adaptation action over a range of timescales, and how this relates (or does not relate) to the underpinning and applied climate research.

4. Stakeholder mapping the institutions and scientists undertaking the research in 1 & 2.

The final outputs can be categorised in a way that emerges from analysis of the evidence but should include research along the science to services value chain. It can be organised around the key sectors within CLARE, or by the position along the science to services value chain. Of particular interest is transdisciplinary, systems-based research that characterises climate impacts in a systems context, not just isolating climate impacts from other drivers of development outcomes.

The supplier may choose how to present the data though they must keep in consideration that the final product should be useful to support the second stage of scoping which will actively engage with a range of climate research stakeholders to challenge and refine these findings.

Methodology

Preparation of the evidence maps, databases and descriptive reports should include the following steps:

<u>Scoping exercise</u>

- Initial scoping activity will take place at the outset of the project in order to:
- Clarify the research question, including working definitions of key concepts
- Refine the scope and methodology for the literature search
- Agree the framework for the quality appraisal of literature
- An inception meeting will be held with DFID to discuss the detail of the proposal and the planned approach to be taken. Given the wide scope of the request, and the need for a light touch approach, this meeting with be an important milestone in developing a mutual understanding of the ambition of the output.

<u>Literature search</u>

The literature review should include as rigorous and systematic a search of evidence as is feasible within the time constraints imposed. Ideally this would **follow the process of a Rapid Evidence Assessment** (REA), and so similar in nature to a systematic review but it is accepted that methodological concessions are likely to be required to ensure the report can be produced in a timely fashion.

The search should target published literature but not focus only on academic journals and databases. It is likely that much of the relevant literature will come from less formal published sources (e.g. evaluations of donor-led interventions). As such, the literature search should include targeted searching on an agreed set of relevant websites including, for example, R4D, Gov.uk, and World Bank.

The literature search need not be fully exhaustive, but the steps followed should be transparent and include a description of any possible biases that result from not having undertaken a fully comprehensive search of available literature.

Output format

The scoping, stakeholder mapping and research gaps analysis should be presented in a way that will best facilitate evidence an understanding of the research landscape and further engagement with identified stakeholders. A proposal for the structure of the output should be developed as part of the scoping stage and reflected in discussions in the inception meeting.

Reference material

A record of all reference material included in the scoping work should be provided in a format that makes interrogation straightforward.

Quality assurance

The review approach should be fully documented to ensure

Deliverables and Reporting

Four formal outputs will be submitted to DFID during the process:

1. Inception Presentation
2. First draft of scoping report, stakeholder map and research gaps and recommendations
3. Final version of outputs
4. Presentation of findings

The team of consultants will submit a first draft of the final report and presentation of initial findings to DFID. The scoping and final reports will be no longer than 30 pages, excluding annexes. A clear and succinct executive summary is required (focusing on findings rather than process employed).

Annex 2 Adaptation Gap Report Review

UNEP's Adaptation Gap Reports

This series of reports (2014, 2016, 2017, 2018) looks at the gap between implemented adaptation and the needs for adaptation – as defined by adaptation targets, plans, preferences and capacities in response to current climate change and future evolution. Adaptation Gap reports were reviewed in order to improve our understanding from the user needs side. We reviewed where the reports mention climate information/data and gaps in knowledge evidence of the use of data. The reports are more overview information (not really detailed) but include some potentially useful examples.

The first Adaptation Gap report in 2014 focused on methodological issues for measuring adaptation and on and financing requirements. It also considered knowledge gaps and lessons, for example in communicating climate information (see section 5.4) use of appropriate mode/style of participation of local users was noted to be an important success factor and lesson for 'what works' (Roncoli et al. 2010). Another important area discussed is the integration of traditional local and scientific knowledge for participatory scenario planning (PSP), which can provide seasonal forecasts about the probability of different amounts of rainfall and the timing of onset and cessation of rains. Forecast information is used to provide adaptation options tailored to different livelihoods for use in decision making.

However, a major barrier is not the lack of information on climate change and adaptation, but the need for better-filtered synthesized and accessible information. More emphasis is needed on knowledge transfer and communication (Jones et al. 2014), on the complexity of the decision space, and on the requirements of decision-makers. The report notes that "climate data is largely being fed into this decision-making space through a supply-driven process" and that "users lack the capacity to evaluate whether the climate data can be appropriately applied to decision making". By contrast, it notes the "co-exploration" approach to using climate data, which entails engaging a full complement of user groups (from modellers to policymakers) in defining the decision-making space into which climate model data is required (UCL 2014, Steynor et al. 2016).

The 2016 Adaptation Finance Gap Report provided a further assessment of adaptation needs and costs, and the difference between the costs and the finance available to meet those needs, in a developing country context. It notes that sub-Saharan African and South Asia have been the main recipients of funding for adaptation from dedicated climate funds, but that the distribution of flows is uneven.

The 2017 report focuses on assessing progress towards the global goal on adaptation (SDG13). On the national scale, climate information (status of production, access, and use of climate change information) was determined to be one of the most prominent indicators to measure progress in the goal in any of the proposed monitoring frameworks. However, the report included very limited information on adaptation at the sub-national scale.

The 2018 report focused further on gaps in country-level adaptation laws and policies, added new information on adaptation finance gaps, and on countries' progress in adaptive capacity. In addition, part II looked at the adaptation gap in the health sector - comparing current climate-related health outcomes with those that would occur under desirable levels of health adaptation efforts. It concludes that one aspect of this gap is that more detailed health data/projections are needed. The report (section 8.3) discusses the need for strengthening the knowledge base, information sharing and its use. A key barrier to climate risk information uptake is its unsuitability to inform public health decision-making - the 'mismatch' with user needs is an ongoing challenge in public health decision-making (Singh et al., 2018). Even national public-health planners struggle to use decadal and multi-decadal climate projections sufficiently (Shaw et al., 2009; Singh et al., 2018). This finding relates to the usefulness of timescales of information – it begs the question of whether seasonal and short-term information might have greater uptake than long-term climate projections in health sector decision-making.

Annex 3 Search Strings

If appropriate, general search:

“Climate” AND “services” “Climate” AND “Information” “Weather” AND “Services” “Weather” AND “Information”

More specific search strings:

“climate” AND “services” AND “mitigation”	“climate” AND “ services” AND “ecosystem”
“climate” AND “ services” AND “Resilience”	“climate” AND “ services” AND “Natural resource”
“climate” AND “ services” AND “disaster”	
“climate” AND “ services” AND “Risk”	“climate” AND “ services” AND “Flood”
“climate” AND “ services” AND “agricultur*”	“climate” AND “ services” AND “Drought”
“climate” AND “ services” AND “RURAL”	“climate” AND “ services” AND “Forest”
“climate” AND “ services” AND “CROP”	
“climate” AND “ services” AND “product*”	“climate” AND “ services” AND “water”
“climate” AND “ services” and “farm”	
“climate” AND “ services” AND “conflict”	“climate” AND “ services” AND “Desertification”
“climate” AND “ services” AND “WAR”	“climate” AND “ services” AND “food”
“climate” AND “ services” AND “Insurgenc*”	“climate” AND “ services” AND “famine”
“climate” AND “ services” AND “Terrorism”	“climate” AND “ services” AND “starv*”
“climate” AND “ services” AND “Weather”	“climate” AND “ services” AND “Hunger”
“climate” AND “ services” AND “security”	“climate” AND “ services” AND “green growth”
	“climate” AND “ services” AND “Renewables”
“climate” AND “ services” AND “Urban”	“climate” AND “ services” AND “Equitable growth”
“Climate” AND “ services” and “cit*”	
“climate” AND “ services” AND “Built environment”	“climate” AND “ services” AND “Sustainable growth”
“climate” AND “ services” AND “Infrastructure”	“climate” AND “ services” AND “Economic development”
“climate” AND “ services” AND “Peri-urban”	
“climate” AND “ services” AND “Health”	“climate” AND “ services” AND “Epidemic”
“climate” AND “ services” AND “Disease”	“climate” AND “ services” AND “Nutrition”
“climate” AND “ services” AND “Vector”	“climate” AND “ services” AND “Mortality”

“climate” AND “ Information” AND “mitigation”	“climate” AND “ Information” AND “ecosystem”
“climate” AND “ Information” AND “Resilience”	“climate” AND “ Information” AND “Natural resource”
“climate” AND “ Information” AND “disaster”	“climate” AND “ Information” AND “Sustainable resource”
“climate” AND “ Information” AND “Risk”	“climate” AND “ Information” AND “Flood”
“CLIMATE” AND “ SERVICES” AND “HAZARD”	
“climate” AND “ Information” AND “agriculture”	“climate” AND “ Information” AND “Drought”
“climate” AND “ Information” AND “RURAL”	“climate” AND “ Information” AND “Forest”
“climate” AND “ Information” AND “CROPS”	“climate” AND “ Information” AND “Regulating services”
“climate” AND “ Information” AND “Livestock”	
“climate” AND “ Information” AND “production”	“climate” AND “ Information” AND “water”
“climate” AND “ Information” AND “conflict”	“climate” AND “ Information” AND “Desertification”
“climate” AND “ Information” AND “WAR”	“climate” AND “ Information” AND “food”
“climate” AND “ Information” AND “Insurgenc*”	“climate” AND “ Information” AND “famine”
“climate” AND “ Information” AND “Terrorism”	“climate” AND “ Information” AND “starvation”

"climate" AND " Information" AND "Weather"	"climate" AND " Information" AND "Hunger"
"climate" AND " Information" AND "security" "climate" AND " Information" AND "hazards"	"climate" AND " Information" AND "green growth" "climate" AND " Information" AND "Renewables"
"climate" AND " Information" AND "Urban"	"climate" AND " Information" AND "Equitable growth"
"climate" AND " Information" AND "Built environment"	"climate" AND " Information" AND "Sustainable growth"
"climate" AND " services" AND "Infrastructure"	"climate" AND " services" AND "Economic development"
"climate" AND " services" AND "Peri-urban"	"climate services" AND "Migration" "climate services" AND "Displacement"
"climate" AND " services" AND "Health"	"climate" AND " services" AND "Epidemic"
"climate" AND " services" AND "Disease"	"climate" AND " services" AND "Nutrition"
"climate" AND " services" AND "Vectors"	"climate" AND " services" AND "Mortality"

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Annex 5 Website Survey

ACPC and CR4D	Cities for Climate Protection Australia Adaptation Initiative	Global Project Climate Services for Infrastructure Investments	Pacific Meteorological Desk & Partnership
Adaptation and Mitigation Interaction Assessment Tool (AMIA)	Climate Change, Agriculture and Food Security	Green Climate Fund	RAINWATCH
AdaptWater	Climate Resilience and Food Security: CRISTAL Food Security Tool	HyCRISTAL: Integrating Hydro-Climate Science into Policy Decisions for Climate-Resilient Infrastructure and Livelihoods in East Africa	Red Cross IARP and other initiatives via Red Cross Red Crescent Climate Centre
ADB	Climate Services Partnership	ICCIP	Satellite data for Weather Index Insurance-AgricuLtural EaRly warning system (SatWIN-ALERT)
AFDB	Climate-kic Research innovation	ICIMOD	Science for Humanitarian Emergencies and Resilience main projects and catalysts
Afrialliance	ClimDev Africa	IFAD ASAP programme	SDG Climate Action Nexus tool (SCAN-tool)
Africa Adaptation Initiative	CoastAdapt	IIED	Secretariat of the Pacific Regional Environment Programme (SPREP)
Africa Climate and Development Initiative (ACDI)	Coastal Resilience to flooding Impact through relocatable Storm surge forecasting Capability for developing nations (C-RISC)	Improving the Role of Information Systems in Anticipatory Disaster Risk Reduction (IRIS)	SEI Climate services
Africa Climate Change Research Alliance (ACCRA)	Conservation International	Integrated Risk Governance project (part of FutureEarth)	Southern Africa Development Community
African Academy of Sciences	CSAG University of Cape Town	International Climate Change Information and Research Programme ICCIRP	Southern Africa Research Universities Association
African Ministerial Conference on Meteorology (AMCOMET) and the Integrated African Strategy on Meteorology Weather and Climate Services	CSIRO	International Union for Conservation of Nature (IUCN)	Taru
African Research Universities Association	DANIDA	International: TAMSAT-AgricuLtural EaRly warning sysTem (TAMSAT-ALERT) platform	The Green Book online tool supports municipal planning with the development of climate resilient settlements
African Risk Capacity	DECCMA	IPCC	The Nature Conservancy
African SWIFT	DFID	JPI Climate - Coordination and Support Action (CSA) SINCERE	UN Environment
AMMA-2050	DRISL	Met Office UK	UNDP
Asia Disaster Preparedness Centre	Enhancing National Climate Services (ENACTS) for Africa	Ministry of Environment New Zeland	UNDP Africa Adaptation Initiative, Africa Adaptation Programme
Asia Regional Resilience to a Changing Climate (ARRCC)	Enhancing Resilience to Agricultural Drought in Africa through Improved Communication of Seasonal Forecasts (ERADACS)	Mitigating basis risk in weather index-based crop insurance: harnessing models and big data to enable climate-resilient agriculture in India	UNDP Climate Information for Resilient Development in Africa
ASSAR	FAO	NAP Global Network	Urban Africa Risk Knowledge (ARK)

Australian Bureau of Meteorology	Farmax	NARCliM	Urban Disaster Risk Hubs
AUSTRALIAN CLIMATE FUTURES	FES	National Research Foundations	Urban-know Knowledge in Action for Urban Equality
Australian Gov. Dep. of the env. and Energy	Forecast-based Preparedness Action: Probabilistic Forecast Information for Defensible Preparedness Decision-Making and Action (ForPAc) in Kenya	NCCARF	USAID
BRACED	Forecasts for AnTicipatory HUManitarian action (FATHUM) in Uganda and Mozambique	NFLICS in Dakar, Senegal	WASP - World Adaptation Science Programme
Building resilience and inclusion in Sub-Saharan Africa through social learning around climate risks	Future Climate For Africa	NICRA_ICAR	WCRP – World Climate Research Programme
Building understanding of climate variability into planning of groundwater supplies from low storage aquifers in Africa (BRAVE)	Future Earth	NIMFRU: NATIONAL-SCALE IMPACT BASED FORECASTING OF FLOOD RISK IN UGANDA	WeADAPT platform
CarbonFarmingGroup, funded by Tindall Foundation	Future Resilience for African CiTies And Lands (FRACTAL)	NIWA, the National Institute of Water and Atmospheric Research	WISER
CARE Adaptation Learning Programme	GCRF and UKRI	OverSeer	WMO through GFCS
Care India - Building-resilience	GERICS	Pacific Climate Change Portal	World Bank
CDKN	Global Challenge Resilience Fund	Pacific Islands Climate Change Cooperative	WOTR

Annex 6 KII Table

This table describes the key informants contacted in the course of developing the Expert Reflections section of the report.

Table 4 KII Table

Institution	Name	Title
CDKN	Lisa McNamara	Knowledge Management and Partnership Coordinator, Africa

Lisa oversees CDKN Africa's Knowledge Management Programme which supports knowledge sharing on climate-compatible development in Africa and captures and shares lessons emerging from CDKN programmes.

Lisa's work involves knowledge brokering and building learning dialogue processes that better mainstreams climate knowledge into decision making across multiple contexts.

Institution	Name	Title
CSIRO	James Butler	Sustainability Pathways Program CSIRO Land and Water

James directs a project in support of the Australian Government's Australia Pacific Climate Partnership which has this summary:

"The Australia Pacific Climate Partnership is a A$75 million investment over four years (2018-2022). Through the Partnership, the Australian Government will partner with Pacific Island countries and regional organisations in alignment with the Framework for Resilient Development in the Pacific (FRDP) to integrate climate and disaster resilience and low carbon growth across sectors. The Partnership includes four components to address critical gaps in climate information services, governance, gender and social inclusion, and to boost technical capacity in Australian aid investment sectors."

His project, 'Knowledge brokering for Pacific climate futures' is addressing the problem that while the climate science is excellent, it is not being integrated into decision-making about development. The project task is to find out why, and then co-design appropriate tools and processes for different kinds of development decision-making (initially agribusiness, tourism and community development). Essentially it is trying to build skills among partners to become knowledge brokers themselves and evaluate what works and what does not in terms of their brokering and brokering tools/processes. It links with CDKN to design an evaluation process for past knowledge brokering activities across their joint spheres of interest.

Institution	Name	Title
DAI US	Paul Jeffery	COP - APIK/USAID

The APIK (Adaptasi Perubahan Iklim dan Ketangguhan) program funded by USAID is a five-year initiative focused on climate change adaptation and disaster risk management in Indonesia. The Chief of Party leads the implementation of this program and is responsible for overall technical and operational management of APIK to ensure targets and outcomes are achieved. APIK has 5 main components: 1) strengthen Government of Indonesia capacity at the national, provincial and local levels in order to integrate climate change adaptation and disaster risk reduction into decision-making; 2) community based climate change adaptation and disaster risk management activities; 3) improving climate information systems and how the information is used; 4) engaging private sector in climate change adaptation and disaster risk reduction; 5) knowledge management and collaboration.

Paul's programme benefitted from direct input from Caspar Ammann of NCAR, also included in this table.

Farm Africa	Yvan Biot	Science advisor

Yvan was a DFID senior scientist working on climate change and environment. He know works with Farm Africa building its technical expertise in soils and climate, assist the programmes team with design and delivery and provide strategic advice to senior management, as required.

ICCCAD (and IIED)	Saleem Huq	Director

Dr Saleemul Huq is the Director of the International Centre for Climate Change & Development (ICCCAD) since 2009. Dr Huq is also a Senior Fellow at the International Institute for Environment & Development (IIED), where he is involved in building negotiating capacity and supporting the engagement of the Least Developed Countries (LDCs) in UNFCCC including negotiator training workshops for LDCs, policy briefings and support for the Adaptation Fund Board, as well as research into vulnerability and adaptation to climate change in the least developed countries.

Saleem’s team has initiated a Bangladesh Academy for Climate Services (BACS) to bring climate information providers and potential users together to better understand each other’s needs and limitations. They feel that without such information brokerage between potential users and providers the sector is just supplier driven with little utility of the information supplied.

IIED	Clare Shakya	Director - Climate Change

Clare is the director of IIED’s Climate Change research group. She has over 25 years of experience in development, in climate, energy and natural resources. Previously she spent 15 years with DFID, leading the integration of climate change thinking and finance into DFID's development interventions in Asia and Africa Divisions. She is interested in politically astute, agile processes that learn iteratively about how to support a just transformation to a climate positive future.

IIHS	Aromar Revi	Director IIHS

Aromar Revi is the founding Director of the Indian Institute for Human Settlements (IIHS) India’s prospective interdisciplinary national University and Institution of Eminence, focused on urbanisation. Over a decade, he has built IIHS into one of the world’s leading education, research, training, advisory and implementation- support institution, focusing on the multi-dimensional challenges and opportunities of sustainable urbanisation. He is one of the world’s leading experts on global environmental change, especially climate change. He is a Coordinating Lead Author (CLA) of the 2018 IPCC Special Report on Global Warming of 1.5 °C (SR15). He has worked extensively to bring the global urban and climate agendas together, including as a coordinating lead author of the SR1.5 Summary for Urban Policymakers, released at CoP24 in Poland in 2018.

IIHS	Amir Baza	CARIAA-ASSAR research consortium

Amir Bashir Bazaz is Lead-Practice at IIHS. He holds a PhD in Management from the Indian Institute of Management Ahmedabad, with a specialisation in Public Systems. He works on issues at the intersection of economics, climate change mitigation, and adaptation and sustainable development. He has substantial experience in working with various integrated assessment frameworks and modelling arrangements. His current research interests are low carbon societies/infrastructure, climate change adaptation and mitigation (across scales), with specific focus on urban-climate change linkages and climate, energy and environment policy. At IIHS, Amir is the Regional Research Lead for a multi-partner, multi-year climate adaptation research project – Adaptation at Scale in Semi-Arid Regions (ASSAR). This project is a part of an IDRC/DfID funded global climate adaptation research program – Collaborative Adaptation Research Initiative in Africa and Asia (CARIAA), operational across the regions of West, South and East Africa as well as South Asia.

ISET	Karen McClune	Executive Director

Karen has worked at ISET-International since 2008 on projects around the world, most recently in Vietnam, Peru, Nepal, and the United States. In this work, Dr MacClune has conducted post-flood forensic analyses, served as scientific advisor for flood and water operations modelling, built and run hydrologic models, developed training materials for and facilitated resilience building projects, and built capacity of decision-makers and practitioners on how to design their communities for a future of uncertainty. An ongoing theme throughout her work is the combination of technical analysis with stakeholder outreach, discussion and process facilitation in support of planning and policies for climate change adaptation.

ISET works closely with NCAR, referred to in this table, and has worked with TARU and the Army Corps of Engineers.

IRI - Colombia University	John Furlow	Deputy Director for Humanitarian and International Development

John Furlow joined Columbia University's International Institute for Climate and Society (IRI) in May 2017. As Deputy Director for Humanitarian Assistance and International Development, John works with IRI's scientists to help apply their research and expertise to decision making in public health, agriculture, infrastructure planning and other vital sectors. Prior to coming to IRI, John designed and led the Climate Change Adaptation Program in USAID's climate change office. He advised the government of Jamaica in the development of its national climate change policy and its climate smart agriculture sector plan. John is involved in the ACToday programme (Adapting Agriculture to Climate Today, for Tomorrow), which aims to combat hunger by increasing climate knowledge in six countries that are particularly dependent on agriculture and vulnerable to the effects of climate change and fluctuations: Bangladesh, Colombia, Ethiopia, Guatemala, Senegal and Vietnam.

ACToday in involved in supporting Saleem Huq's BACS network referred to in this table and overlaps with Cristina Rumbaitis del Rio's climate informed digital farmer advisory services work

Leeds University	Natalie Suckall	Research Fellow

Natalie is an environmental social scientist who examines the social dimensions of climate change in low- and middle-income counties, especially in South Asia and Sub-Saharan Africa. Her research has included: exploring if droughts and floods in Malawi lead to urbanisation as subsistence farmers migrate to town; examining the synergies and trade-offs that occur between climate mitigation and human development as fishing communities in Zanzibar respond to environmental stresses; and, understanding how some of the poorest households in deltas in Bangladesh, India and Ghana cope with frequent cyclones and coastal erosion. Natalie has also worked in the UK where she has explored transformative approaches to coastal management in the face of sea level rise. Natalie re-joined the Sustainability Research Institute in 2019 to work on the Asia Regional Resilience to a Changing Climate (ARRCC) programme. The ARRCC programme aims to strengthen weather forecasting systems across Asia. It targets the most vulnerable countries in the region, primarily Bangladesh, Pakistan, Nepal and Afghanistan.

Leeds Uni and Met office	Marta Bruno Soares	Met Office and PI for ARRCC

Dr Marta Bruno Soares is a Met Office University Academic Fellow holding posts at the University of Leeds and the Met Office. Marta is a social scientist and her research revolves around the development of climate services across a range of sectors, organisations and geographical regions with a particular focus on understanding the barriers and enablers to the use of climate information, assessing the value climate information in decision-making processes, enhancing stakeholders' engagement in co-production processes, and the analysis of science-policy interface. Marta is PI for the DFID-funded programme 'Asia: Regional Resilience to a Changing Climate'(ARRCC; 2018-2022; £12M) - leading the VALUE work package on the assessment of the socio-benefits across and within the ARRCC programme

Loughborough Uni	Rob Wilby	Professor of Hydroclimatic Modelling

Rob's research is about the management of freshwater environments under climate variability and change. This includes reconstruction of drought and flood indices to assess the severity of recent extreme events or detailed monitoring of river temperatures for ecological purposes. Time spent in the water industry, government, and consultancy has given Rob a very practical and pragmatic approach to this work. Following secondments to the National Center for Atmospheric Research in Boulder, Colorado he co-developed the Statistical DownScaling Model (SDSM). This freely available climate scenario tool has underpinned many climate change impact assessments including for water supplies, flood risk (fluvial and tidal surge), air quality and urban heat island intensity in countries as varied as Canada, China, Morocco, Tajikistan and Yemen. His latest research is exploring smarter approaches to climate risk assessment and decision making under deep uncertainty about the future climate. This shifts the focus onto better understanding then managing the climate vulnerability of human and natural systems. Ongoing projects include seasonal river flow forecasting for hydropower plants in Central Asia, modelling urban water and sanitation hazards in East Africa, and strategies for keeping rivers cool in the UK.

Rob also advises ADB and other funders of large infrastructure projects on how to use long-term climate projections in the immediate decision-making over investments.

Mercy Corps	Jeremy Stone	Regional Resilience Advisor - Asia

Jeremy is a development and resilience specialist with significant experience in programme management, design, research, and implementation. His work has focused on the challenges of creating sustainable development interventions that complement environmental conservation, development planning and socio-economic change that build resilience to climate change and addresses the complex interactions between sectors, expertise, policy and perspectives. Over the last 10 years his work has covered a broad range of management, research and implementation of projects in the fields of resilience, renewable energy, climate change proofing and adaptation, policy, mitigation, forestry and environmental sustainability.

Met Office - UK	Katy Richardson	Senior Climate Information Scientist (International Development)

Katy works in the Climate Security Team investigating the relationship between climate change and human security. Katy's role as an Applied Climate Scientist is to contribute to government and commercial funded projects assessing the potential impacts of climate change on human systems. This involves analysis of climate data and projections, and interpretation and communication of the data from the perspective of human security.

NCAR	Casper Ammann	Climate modeller

Caspar is a Project Scientist III working in the Climate Science and Applications Program (CSAP) at the National Center for Atmospheric Research in Boulder, Colorado. Ammann has a doctorate in geosciences from the University of Massachusetts, and a master's degree in geography, geology and mineralogy from the University of Bern, Switzerland. He is studying global and regional climate, how and why it varies naturally, and how recent changes in human activity (emissions, land use changes) already have and might further alter the climate across time and space. His efforts support science applications that advance the use of predictions and projections for the provision of useful and usable information through standardize methods and tools.

Caspar consults on adaptation and resilience programs including APIK, mentioned in this table, and collaborates with ISET.

NCAR	MacKenzie Dove	Environmental and Social Scientist

MacKenzie is an interdisciplinary research scientist and international development professional, with experience working across public, private and academic sectors in support of climate change adaptation and resilience efforts. A governance specialist with expertise on market systems and the integration and use of climate-driven risk indices within policy, regulatory standards, legal frameworks, and investment strategies in key sectors: agriculture, environment, finance, health, and disaster risk management. Currently research analyses the effective development, integration and operationalization of risk indices and thresholds. This includes the analysis of societal impact and risk transfer within governance systems, institutional and regulatory structures, commodity markets, and macro-economic trends. MacKenzie has work experience across East, West and Southern Africa, South Asia, North America, and Europe.

ODI	Sarah Opitz Stapleton	Research Associate – Risk and Resilience Programme

Sarah is a Research Associate in the Risk and Resilience programme. She works at the intersection of climate services, social vulnerability and risk analysis for climate adaptation and disaster risk reduction programmes in Asia and Latin America. Sarah has a PhD in Environmental Studies and MS in Hydrology Civil Engineering.

Sarah used to work with ISET, referred to in this table. She is also working on the parallel CLARE study looking at the connection between conflict and climate change.

TARU Leading Edge	Gopalakrishna Bhat	Chairperson

TARU Leading Edge Consulting is a multi-disciplinary consulting firm with strong technical expertise in urban contexts, climate change and disaster mitigation, is active throughout India and works with local, state and national governments, multi-lateral organizations and civil society groups to address development challenges in India. Twenty-five States and 30 major cities of the country have worked with TARU. TARU has developed country strategies for India's largest development partners; design and management of reform initiatives in key sectors; world-class disaster risk assessment and mitigation planning; and, assessments of some of the world's largest public programmes. TARU has worked closely with ISET, referred to in this table.

US Army Corps of Engineers	Guillermo Mendoza	Hydrology Engineer – International Program Manager – Institute for Water Resources.

Guillermo pushes the limits of innovation in water resources management. IWR is a Field Operating Activity for the US Army Corps of Engineers that was designed to analyse and anticipate changing water resources management conditions, and to develop planning methods and analytical tools to address economic, social, institutional, and environmental needs in water resources planning and policy. He has worked close with ISET, referred to in this table, assisting cities in Asia in managing water resources in the face of climate change threat.

WRI	Cristina Rumbaitis del Rio	WorldFish board

Cristina was, until recently, Regional Program Manager for Action on Climate Today, a program supported DFID seeking to mainstream climate change resilience into development planning and budgeting at the national and sub-national level in India, Pakistan, Nepal, Afghanistan and Bangladesh.

She now supports a GCA initiative on developing climate informed digital agricultural services. This links with both ICCCAD and IRI, referred to in this document.

WWF US	Nikhal Advani	Director: Climate, Communities and Wildlife

Nikhil leads WWF's work on climate, communities and wildlife. This includes researching how wildlife and rural communities are being affected by changes in weather and climate and developing and implementing solutions to help them adapt. Nikhil's recent projects include an initiative to crowdsource data and implement climate adaptation projects for rural communities (WWF Climate Crowd), a Wildlife and Climate assessment series to research species vulnerability to climate change, creation of a Wildlife Adaptation Innovation Fund to help at risk species adapt to climate change, and he is a member of the IUCN SSC Climate Change Specialist Group.

WWF US	Shaun Martin	Senior Director, Climate Change Adaptation and Resilience
Shaun helps conservation programs become "climate smart," making sure they are prepared to address the inevitable consequences of climate change — increased drought, more severe storms, melting glaciers, shifting seasons — and their effects on biodiversity, people, and the ecosystems that they rely upon. He spends the majority of his time training WWF field staff on how to adapt their conservation practices to take climatic changes in their region into account. To date he has educated nearly 1,000 WWF staff and partners from dozens of countries across the globe.		

Annex 7 Science Gaps

Overview

For this section of the report, we consider more broadly the emerging science for adaptation and resilience, outline an illustrative number of areas of climate science where outstanding gaps do remain, and briefly discuss the enabling environment for that science to be used, and key institutions and people working to close demand-provider gaps. The main challenge in closing the demand-provider gap remains in the integration and application of existing climate science with other discipline-based knowledge that empowers people to make their own livelihood choices in the face of climate and environmental change. Arguably, most of the 'science' needed for adaptation and resilience is not therefore 'climate science' i.e. meteorology and climate modelling, rather an interdisciplinary approach that brings climate information into the decision context at the relevant decision scale, and takes into account the policy/political successes/failures. This interdisciplinary approach combines the salience of qualitative narrative and historically anchored approaches, with the hard evidence brought by quantitative information: in this case focusing on quantitative climate and livelihoods data. This section was produced in collaboration with key IPCC authors, some of which are included in table 6 below.

Emerging Science for Adaptation and Resilience

Better climate science is not in itself sufficient to reduce climate risk. This is due partly to what Bruce Hewitson refers to as the "Distillation Challenge"[68]**.** But is also due to the fact that policy makers and communities have to adapt to climate change in the face of pre-existing, deep seated development challenges including poverty, lack of investment in agriculture, infrastructure, education and health, limited data to guide policy and target resources, siloed sectors and governance, and a low capacity to prepare for and respond to extreme events. This highlights the need to invest in capacities to deal with current variability and extremes as a way of strengthening capacities for future climate-related risks.

As a result of this development context, as extreme climatic shocks and weather events become more frequent and more intense, the ability of local, national and regional organisations to avoid systemic crisis will be further weakened. Climatic trigger events can be predicted and quantified, albeit with much uncertainty. However, the socio-economic and political context also has a major impact on the outcome of these events, and despite significant investments in early warning systems, progress towards making hazard-prone communities safe has been limited (UN SDG Report, 2017). This is hampered by the inability to act on climate information as is universally acknowledged to be true around the world, both in developed and in developing countries. The gap is therefore less one of climate science knowledge, but of how to get people to take action. These barriers to action are different across developing countries (and even between different countries, most likely), which is why the engagement has to start with what is trusted at the local scale. And the knowledge gap is to find ways to bring climate information into the decision context at the decision scale.

Given this, the complex and non-linear relationship between the initial climate hazard and subsequent risks is thus better answered by not asking what will happen, but what would be the impact of particular interventions under an uncertain climate change. And for that we need to start building quantitative information on vulnerability and exposure, in a way that can connect to storylines of climate variability and change and starting from the local scale understand the specific actions that will have an impact and are implementable. This is the subject of emerging science - a storyline approach — combining the salience of qualitative expert narratives and historical precedent and indicators with the hard evidence provided by quantitative climate and livelihoods data — to provide public and private decisionmakers with actionable insight into complex scenarios & better-informed & more transparent guidance on how to build resilience & livelihood security[69]**.**

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[68] Hewitson, B., Waagsaether, K., Wohland, J., Kloppers, K. and Kara, T. Climate information websites: an evolving landscape. WIREs Clim Change 2017, 8:e470. doi: 10.1002/wcc.470

[69] Young, H. Shepherd, T., Acidri, J., Cornforth, R. J., Petty, C., Seaman, J., Todman, L. (2020). Storylines for decision-making: Climate and food security in Namibia. Climate and Development. (In review)

Beyond the climate science, the key emerging questions for adaptation and resilience building are:

1. What are the institutional, social, economic, cultural and structural barriers to enhancing adaptation and resilience?
2. What does 'good' adaptation and resilience look like?
3. What are the advantages and disadvantages of different ways of enhancing adaptation and resilience, in the local context?
4. What governance mechanisms are needed to enhance adaptation and resilience?

Illustrative Science Gaps to Support Decision Making

Broadly speaking, we already have a lot of knowledge on which to base climate decisions. The climate models have merely confirmed, that what was already in the Charney report[70] in 1979 (the first comprehensive assessment of global climate change due to carbon dioxide) seems to be holding up; in other words, they have shown that the simple physical arguments made there are not overwhelmed or buffered by the nonlinear processes that are in the models i.e. the models are not providing any more robust information that we could not already have derived from physical principles. And the most robust approach to adaptation and resilience in the face of uncertainty is in any case, not to take projections too literally and not to rely on a developing ability to make projections with a 'low' level of uncertainty.

However, there are some specific areas where additional climate science is needed where the direction of forced change in many impact-relevant variables is uncertain. For example, there is still significant uncertainty over the direction and magnitude of precipitation change in several regions of the world, such as East[71] and West Africa. Further scientific gaps are documented in the latest synthesis report from the IPCC[72] which highlights outstanding knowledge gaps both in the underlying science on climate change impacts[73] and our understanding of the pathways to action[74]**.** These include the cumulative effect of multiple stresses and risks, impacts of temporarily overshooting temperature targets, and critical thresholds for extreme events. Additionally, in each of the terrestrial, freshwater, ocean and human systems specific gaps in scientific understanding remain for impacts under 1.5 ºC or 2 ºC of warming (Table 5)[7]. Those gaps in understanding related to carbon cycle feedbacks may be critical as they have the potential to enhance warming through positive feedback.

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70 Charney, J. G. et al. (1979). Carbon Dioxide and Climate: A Scientific Assessment Report of an Ad Hoc Study Group on Carbon Dioxide and Climate. Woods Hole Report. National Academy of Sciences.
71 Dunning, C. et al. (2019). 'Eastern African Paradox' rainfall decline due to shorter not less intense Long Rains. Climate and Atmospheric Sciences 2(1). 1-16.
72 Masson-Delmotte, V. et al. (2018). IPCC Special Report: Global Warming of 1.5 ºC
73 Hoegh-Guldberg et al., (2018) "Chapter 3 - Impacts of 1.5°C of Global Warming on Natural and Human Systems," in IPCC Special Report: Global Warming of 1.5 ºC
74 H. de Coninck et al., (2018) "Chapter 4 - Strengthening and Implementing the Global Response," in IPCC Special Report: Global Warming of 1.5 ºC.

Table 5 Summary of gaps in understanding the current terrestrial, freshwater, ocean and human systems from IPCC Special Report: Global Warming of 1.5 degrees Celsius, Chapter 3.

Earth System	Gaps in Understanding
Terrestrial and freshwater	Vegetation health and carbon storage potential under climatic change
	Risks from species' maladaptation to climatic changes (e.g. spring flowering times)
	Feedbacks and impacts from land use change for mitigation (e.g. bioenergy with carbon capture and storage)
	Dynamics between climatic change, freshwater resources and socio-economic impacts of lower levels of warming i.e. 1.5 °c
Ocean	Deep sea processes and risks to these ecosystems
	Changes in ocean chemistry and circulation, and their impacts on food webs, disease, coastal protection and fisheries
	Links between changes to coastal and ocean resources and human food security
Human	Impacts on and risks to food distribution, health and well-being, poverty and coastal infrastructure, particularly in developing countries and particularly for rural communities, indigenous groups and marginalised peoples
	Micro-climates within cities and associated risks to human systems
	Changing levels of risk of extreme events, and impacts on human displacement and migration

Since the publication of the IPCC Special Report: Global Warming of 1.5 ºC, further gaps that have been identified include:

- The impacts of reduction in aerosol emissions to improve air quality on future precipitation changes[75];
- The contribution of warming tropical wetlands to rising methane emissions;
- Many regional aspects of climate at +1.5 ºc, +3 ºc (where current Nationally Determined Contributions (NDCs) would lead us) are still not assessed properly;
- The feasibility, scientific understanding, impacts and governance of geoengineering solutions to reduce potential overshoots are not well known;
- The warming avoided by mitigating non-CO2 climate forcers (especially methane) is still not well quantified;

More generally, there is a need to characterise risks and opportunities in terms relevant to local stakeholders, to support policy-relevant risk assessment. This includes developing ways of coming up with relevant and plausible climate scenarios and assessment frameworks. For example, local-scale studies incorporating high-resolution (differentiated) information on climate information to map on to high-resolution, differentiated information on vulnerability and exposure (see for example, the Household Economy Approach (HEA) and Individual Household Modelling (IHM)[76] used in the FCFA HyCRISTAL rural pilot and the SHEAR NIMFRU project; www.walker.ac.uk) to assess impacts and consequences at a scale relevant to decision makers (see Section 2).

Interrogating those impacts and consequences on society requires a better understanding and use of complex socio-ecological models with improved projections of risk under combined climate and development pathways[27](Hoegh-Guldberg et al., 2018). Policymakers are increasingly interested in risks under multiple different future emission and development pathways and could therefore be well served by the development of lower-resolution models that can be run with many futures as a decision-making tool, rather than higher-resolution models. Some climate scientists have argued that there is too great a focus on extreme emissions

[75] L. J. Wilcox et al., "Accelerated increases in global and Asian summer monsoon precipitation from future aerosol reductions," Atmos. Chem. Phys. Discuss, no. in review, 2020, doi: https://doi.org/10.5194/acp-2019-1188.

[76] Seaman J., Sawdon, G., Acidri, J., Petty, C. (2014). The household economy approach: Managing the impact of climate change on poverty and food security in developing countries. Climate Risk Management, 4, 59-68.

scenarios (RCP 8.5) in climate modelling, with insufficient attention given to low and medium emissions scenarios consistent with 2 or 3 degrees of warming.

Critically, as noted above, the science needs to be targeted and relevant to the decision space, which could mean focusing more on current risk and the near-term perspective. Chapter 10 within AR6 WG1, points towards a useful future direction to achieve this, by developing regional case studies which attempt to make sense of the observed record in the context of present day climatology, and the multiplicity of evidence brought by GCMs and Regional Climate Models (https://wg1.ipcc.ch/AR6/outline.html). Another important tool to target science towards the decision space is in short-range climate prediction (up to seasonal; there is much less value in decadal for developing countries). As short-range climate prediction is seen as an accepted information source with proven value, it seems better to bring climate information into that information context, rather than working from the climate projections themselves. How to do this, however, remains a critical knowledge gap – a gap that requires an integrated understanding of the relevant decision scale and takes into account the policy/political successes/failures i.e. the Enabling Environment.

Enabling Environment Needed for this Science to be Used

Question 1 highlights the importance of considering the institutional, social, economic, cultural and structural barriers to enhancing adaptation and resilience. This point is clearly illustrated by comparing the scientific gaps identified above to those articulated by users of the climate science for adaptation planning.

The Senior Adaptation Officer from the Climate Change Department of the Ugandan Ministry for Water and Environment identified climate science priorities for adaptation as a need for higher resolution modelling and projections, to aid area-specific adaptation planning, as well as sector and sub-sector vulnerability assessments, climate smart technologies, empowerment of national scientists in the design of adaptation technologies, and technology for dissemination of climate information to various audiences[77]. The contrast between these priorities and the climate science gaps identified demonstrates the importance of considering the context of the environment in which the science needs to be used, to ensure it supports adaptation and resilience building in practice.

As Chapter 4 of the IPCC Special Report: Global Warming of 1.5 ºc highlights, alongside the scientific gaps in our understanding of climate impacts there are also outstanding knowledge gaps in terms of the impacts of adaptation options and conditions for operationalising them[28]. The report identifies key gaps as the lack of literature on the socio-cultural impacts and acceptability of adaption options, and limited evidence on institutional, technological and economic feasibility of options. Furthermore, the report lists gaps in ‘enabling conditions’ for mitigation and adaptation action, including governance, institutions, lifestyle and behavioural change, technological innovation, policy and finance[28]. These ideas have been conceptualised as an ‘Enabling Environment’)[78].

- Governance and law - Legal, policy and budgetary framework; information pathways and response triggers;
- Data and Technology - Infrastructure for data collection, dissemination and assimilation (weather stations; IT network and hardware, market price information, readily available historical datasets recovered from archives etc e.g. RAINWATCH); physical constraints on the free flow, exchange and collation of information;
- Capacity building – Availability of personnel across institutions trained to collect, audit (quality control) analyse and respond to information; human resource constraints on free flow, exchange, collation and analysis of information and practical response; and
- Science - Access to appropriate analytical tools for data integration and presentation/visualisation of climate impacts to decision makers.

[77] Presentation from Mr Semambo Muhammad, Senior Adaptation Officer, Climate Change Department, Ministry of Water and Environment, Republic of Uganda, January 2020 at a DFID UK-Uganda summit.
[78] Cornforth, R. J., Petty, C. P., Plumpton, H. (2020). ‘Filling critical capacity, needs and knowledge gaps through adopting a systems-based approach to adaptation and resilience building: Introducing the Enabling Framework for Action’. (In press)

To effectively address climate risks and support adaptation and resilience building, all four elements need to be considered and barriers or gaps in knowledge assessed from regional through to community levels to understand where research and engagement is needed to enable change[34, 79].

Illustrative list of Key People and Institutions Working in this Space

Below are a number of physical scientists working in the area of climate science and adaptation who largely start from the users of the science and work towards delivering some/all of the elements of the Enabling Environment required to achieve the user's priorities. Links are made to exemplar articles to demonstrate their approaches. Note, the list serves as an illustrative example only based on the knowledge of the team, and accessible within the time constraints of this particular element of the LTS scoping study.

Table 6 Key People/Institutions in the climate science space

People	Institution	Project / Paper Example
Kofi Asare	Ghana Space Science & Technology Institute, Ghana	https://zenodo.org/record/3366368#.XkGrly2cau4
Declan Conway	LSE, UK	https://www.nature.com/articles/s41558-019-0502-0.pdf
Ros Cornforth	Walker Institute, UK	https://www.tandfonline.com/doi/full/10.1080/17565529.2019.1571401, and https://www.nature.com/articles/nclimate1856
Surraje Dessai	University of Leeds	https://agupubs.onlinelibrary.wiley.com/doi/pdf/10.1002/2017WR020970
Barbara Evans	University of Leeds	https://link.springer.com/article/10.1007/s10584-019-02499-2
Bapon SHM Fakhruddin	Tonkin and Taylor International	https://link.springer.com/chapter/10.1007/978-94-017-8598-3_9
Chris Jack	University of Cape Town, SA	https://www.sciencedirect.com/science/article/pii/S221209631630002X?via%3Dihub
Festus Luboyera	Uganda National Meteorological Authority< Uganda	https://www.ugandaradionetwork.net/story/ugandas-historical-climate-data-undergoing-digitization
Suzanne Moser	Research and Consulting, Santa Cruz, California	https://www.nature.com/articles/nclimate2350.pdf; and https://www.sciencedirect.com/science/article/pii/S2214629617304413
Ted Shepherd	University of Reading, UK	https://royalsocietypublishing.org/doi/full/10.1098/rspa.2019.0013
Rob Wilby	Loughborough University, UK	https://iwaponline.com/hr/article/50/6/1464/70340/A-global-hydrology-research-agenda-fit-for-the, and https://onlinelibrary.wiley.com/doi/full/10.1002/rra.3506

[79] E. Nkiaka et al., "Identifying user needs for weather and climate services to enhance resilience to climate shocks in sub-Saharan Africa," Environ. Res. Lett., vol. 14, no. 12, p. 123003, Nov. 2019, doi: 10.1088/1748-9326/ab4dfe.

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