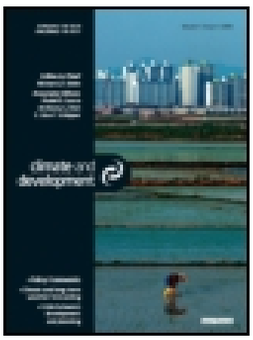

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Identifying climate information services users and their needs in Sub-Saharan Africa: a review and learning agenda

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ABSTRACT

Climate information services (CIS) involve the production, translation, transfer, and use of climate information for individual and societal decision-making. After years of focus on building CIS around available information, today the CIS community recognizes that effective CIS are aimed at specific users of the service and their particular needs. In this review, we describe practical experiences identifying CIS users and their needs, showing different approaches, assumptions, and levels of empirical support. Our uneven and limited understanding of users and their needs presents four key challenges for climate services: (1) designing effective assessments of users and their needs, (2) identifying and overcoming barriers to CIS use, (3) scaling up a CIS and (4) the cross-cutting challenge of dealing with changing conditions and changing user knowledge. Reviewing project and academic literature on CIS in sub-Saharan Africa, we assess what is known and not known relating to these challenges. We prioritize identified gaps in knowledge into a learning agenda to organize learning from practice and research such that both serve a range of needs for knowledge about users and their needs, speak to current 'good practices' in CIS design, management, and evaluation, and point the way to better practices in the future.

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Climate information services; adaptation; users; needs; Africa; learning agenda

Introduction

Climate information services (CIS) involve the production, translation, transfer, and use of climate information for individual and societal decision-making. Ongoing improvements in the modeling and prediction of near-term weather and climate, including advances in the prediction of amounts and seasonal distributions of precipitation in many parts of Sub-Saharan Africa, have made CIS an increasingly attractive vehicle for the achievement of development goals in a variable and changing climate. Attention from development donors and implementers has, in turn, shifted the emphasis of CIS from the packaging of existing climate analysis toward addressing pressing social concerns. Thus, where once CIS might have been framed around generating and making climate information available to people who might use it in whatever manner they wished, today the starting point for an effective CIS is attention to the potential users of the service and their particular needs (for a detailed discussion see: Vaughan & Dessai, 2014). A designer of services must first identify the intended users of climate information, work to establish how climate information could be useful in the context of their lives, and plan to deliver credible, salient, and legitimate climate information that meets one or more of their needs. Similar attention to users and their needs is needed for an effective management of services, one that responds to the ways in which design goals are or are not being met. For example, are the potential users receiving the information and is it helpful for decision-making? Can the services be improved? Attention to users and user needs is also critical for broader, cross-project concerns, such as justifying support for programs, priority setting, and planning future efforts.

Our review began with the goal of learning what practical guidance on these questions could be gained from the experience with CIS to date. We have found that, despite long-standing warnings about the ways in which potential users might be excluded from a CIS (e.g. Archer, 2003), the practical experience of identifying CIS users and needs remains uneven across the field. Different projects have taken different approaches to identifying users and needs, informed by different assumptions, often with limited testing of either. We use the term assumptions here because, for example, there are gaps in our knowledge related to which populations (and who within a population) can best be helped by climate information, what climate information meets user needs, and what are the most productive means by which to identify these populations and their needs. Further, there has been very little exploration around the critical question of how to generalize knowledge about users and needs. How much locale-specific knowledge is needed for effective design? In the absence of clear answers to these and other questions, current CIS design and implementation often rests on unsteady foundations.

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The practical implications of these knowledge gaps for CIS design and implementation motivates the organization of our review. We have identified four key challenges in designing CIS for development related to those gaps and ask how project experience and the associated literature informs those challenges. The four challenges are: 1) designing effective assessments of users and their needs, 2) identifying and overcoming barriers to CIS use, 3) how best to scale up a CIS and 4) dealing with changing conditions and changing knowledge. The fourth challenge cuts across the others, since many circumstances can change, not only within the communities served by a CIS, but also among service funders and providers. As a result, it is difficult to predict the changing conditions a CIS might be expected to address, or the changing expectations of users, funders, and providers that a CIS may experience as it functions over many years.

We begin with an illustration of these challenges, the experience of Mali's Agrometeorological Advisory Program. This case is especially informative because the program has evolved considerably over its long history and the evolution has raised many of the critical issues that guide our review. Further, this program has been extensively documented, so that the issues have been sharply defined. The case illustrates the complexities that arise in characterizing CIS users and their associated needs, the significance of targeting specific users and needs for achieving project goals, and the challenges in delivering broad-based benefits through a CIS.

After a brief discussion of the approach we have taken to identifying relevant literature and the questions we have asked of it, we then present the findings from our review. The presentation of findings proceeds in three stages. First we summarize the current state of practice and the literature that describes the practice. We then examine the practice of CIS design and implementation described in this literature to ascertain what is known and not known relating to the first three of the users and needs challenges described above. This process provides an identification of gaps in knowledge that are specifically associated with the three challenges. Finally, we consider the problem of changing circumstances and changing knowledge posed in the fourth challenge, identifying knowledge gaps associated with this challenge and the issues that will arise in meeting them.

We close by framing the knowledge gaps we have identified as a learning agenda. The learning agenda identifies areas of needed research and synthesis and makes recommendations for the sequence and timing to fill the knowledge gaps; it thus organizes a process of inquiry that builds upon itself to inform both CIS research and practice. This agenda offers guidance for assuring that academic inquiry and project monitoring and evaluation serve the multiple needs for knowledge about users. In aspiring to practicality, there is also guidance for making the agenda achievable in practice, keeping it alive, and adapting it over time. Thus, this paper speaks to current 'good practices' in CIS design, management, and evaluation, while pointing the way to better practices in the future.

Complexity: Meteo Mali

Mali's Agrometeorological Advisory Program is a complex and increasingly well-documented story of CIS design that illustrates both the importance of understanding the users of a CIS and their needs and the issues that can arise in trying to make such identifications (Carr, 2014a; Carr, Onzere, Kalala, Owusu-Daaku, & Rosko, 2015; Carr & Onzere, 2018; Carr & Owusu-Daaku, 2016; Hellmuth, Diarra, Vaughan, & Cousin, 2011). The program was designed in the early 1980s to address acute, drought-associated food insecurity by providing weather and tailored agricultural advice to farmers that would lead to better agricultural decisions and an increase in yields and food availability (Moussa & Traore, 2014). This effort therefore targeted variable and insufficient rainfall as the key stressor impacting agricultural yields and food availability in the country.

Because it was designed and implemented by Malians with experience and expertise in agrarian communities, the program demonstrated a deep understanding of the variable agency and vulnerability of its target users. Rather than assume that all farmers in southern Mali experienced drought in the same way, or would be able to employ these advisories to augment harvests in the same way, the program produced a CIS targeted to those who held the most agricultural decision-making authority. Among the targeted user populations in Southern Mali, these were senior men. These men are responsible for making sure their families are fed through the cultivation of rain-fed staple grains. Therefore, they make the agricultural decisions about these staples for their households, and often for extended family units organized into concessions. Information delivered by the advisories focused on these staples. A multidisciplinary group of representatives from across the Malian government, including the National Meteorological Directorate (DNM), Malian Company for Textile Development (CMDT), High Niger Valley Office (OHVN), Institute for Rural Economy (IER), and the National Agricultural Directorate (DNA), translated weather and climate information, including the onset of seasonal rainfall, the likely amount of rainfall during the season, and the likely duration of the season, into place-specific advisories that suggested optimal varieties by cycle length for these crops. Adding more complexity, Malian designers of this service understood not all senior men were capable of acting on the new climate information, as only senior men heading families that owned ploughs and animal traction had the material ability to respond to advisories in a timely manner, and thus tailor their variety selection to the expected characteristics of the season (Carr, Onzere, et al., 2015; Carr & Onzere, 2018; Carr & Owusu-Daaku, 2016).

Thus, in its initial design, the Agrometeorological Advisory Program was a CIS whose design was deeply informed by a contextual understanding of what crops were to be targeted to address the problem of food insecurity, who made decisions about those crops, and who had the ability to act on new information to make different decisions. The program's identified needs (advisories that would better help farmers pick varieties appropriate to seasonal precipitation such that they maximized yields) were informed by an understanding of the users that preceded project design, carefully considering the relationship between users and needs when deciding what information to provide. A subsequent assessment of the program (Carr, 2014a; Carr, Onzere, et al., 2015) suggests that this design successfully targeted users with useful information. While the

assessment could not calculate the benefit of these advisories in terms of yield or income due to methodological, temporal, and budgetary constraints, more than 25 years after the design of the project senior men who owned the agricultural equipment necessary to respond to the advisories were still closely following the advice regarding variety selection (Carr, 2014a; Carr, Onzere, et al., 2015). This strongly suggests that these farmers, who have access to traditional sources of information that might inform decisions to plant other varieties, find these advisories useful and of some positive impact.

As the acute drought and food insecurity that motivated the design and implementation of this CIS dissipated, farmers, members of the government, representatives of industry, and development donors suggested new types of information that would be of use to both existing users and new users. These suggestions were incorporated into ever-more complex advisories (Moussa & Traore, 2014). As a result, as the project scaled up it began to take on a wider set of perceived needs and users. As this new information was added to the existing program, there is no evidence that there was a corresponding reconsideration of the relationship between needs and users presumed by each new piece of information.

The same assessments of the program's impact demonstrating senior men's continued use of advisories after 25 years (Carr, 2014a; Carr, Onzere, et al., 2015) also demonstrate that these more complex, comprehensive advisories continue to overlook women's agricultural roles, and therefore their particular CIS needs. For example, while women have little control over rainfed staple grain production, they often are responsible for irrigated market gardening in the dry season. Such production does not require climate information, except perhaps to warn of excessively low groundwater levels that might hinder irrigation. Instead, these women require market price information that might suggest when and where demand and therefore profits for their production is greatest. Despite the wide range of information available in the advisories, it appears that the user base remains constrained to relatively wealthy, powerful older men. However, these findings cannot be interpreted as a failure of initial project design. As Carr and Onzere (2018) argue, at the time of its design, the advisory program was focused on the particular vulnerabilities of a very specific set of users. A more accurate framing of this program and its outcomes is that it was the victim of a flawed scaling-up, and a failure to adapt to changing conditions, including an end to severe drought and changing donor and government priorities.

The successes and failures associated with Mali's Agrometeorological Advisory Program highlight the importance of identifying the diverse users of CIS and their needs. Under this broad heading, this case points to four specific challenges that designers of CIS face when identifying users and needs. The first of these is **designing effective assessments of users and their needs.** This particular CIS demonstrates the challenges inherent to balancing the need to engage with and appropriately assess the vulnerabilities, opportunities, and needs of what are always heterogeneous populations with the desire to target specific populations and needs in CIS design. This national-scale program's initial success rested on an understanding of the heterogeneity of the potential users (and their roles and responsibilities) even at the level of the household. This example is consonant with a wider literature exploring the intersection of livelihoods, vulnerability, and identity that demonstrates how vulnerabilities (and opportunities) take shape around identity-based roles and responsibilities, which in turn shape the activities in which individuals participate (Blakie, 1985; Carr, 2013; Carr, Abrahams, De la Poterie, Suarez, & Koelle, 2015; Gaillard, 2010). However, the initial design was lost over time and replaced by the assumption that this design would work for scaled up, more complex advisories. That experience highlights the importance of re-examining assumptions about users, their needs, and their capabilities as new information arrives and program goals change.

Second, this case raises the question of **identifying and overcoming barriers to CIS use**. The initial design of the advisory program identified user needs via the experience of the individuals who conceived the project. It furthered this identification via the expertise and experience of various parts of the Malian government engaged with agriculture and agricultural extension. This expertise allowed for a design that accounted for effective demand in the target populations, and worked with social barriers that inhibited the rapid uptake and use of this information. However, it is not clear who was responsible for the continued assessment of changing demand for services over time, or if the additional services added to the advisories represent the demands of farmers who used the advisories. Moreover, the creation of ever-more complex advisories did not result in dramatically larger or more diverse user populations, suggesting that the new information added to the advisories was not considered in light of effective demand or barriers to the use of that information in the same way as under the initial program design.

Third, it raises the question of **how best to scale up a CIS**, and to what level a well-designed CIS might be scaled. In the case of the advisory program, its *initial* goals and information scaled up to different parts of southern Mali because the various ethnicities engaged in agriculture in this part of the country structured their livelihoods decision-making in very similar ways (Carr, Onzere, et al., 2015; Carr & Onzere, 2018). Thus, the project could be taken to *spatial* scale in areas where it was appropriately designed for the social context in which agricultural livelihoods take shape. However, it was difficult to take to *social* scale, as the constraints on women's and junior men's demand remained in place because of the relatively consistent social context. While the field of CIS has developed a base of knowledge that broadly identifies tools that are of use to those living in agrarian settings in sub-Saharan Africa, such as drought monitoring and prediction, seasonal forecasts, and seasonal onset, far less is known about which of these tools are most effective in a given context and why. As a result, the CIS and development communities face challenges when trying to prioritize tools in situations where resources are limited.

Each of these broad areas, along with the challenge of **meeting changes over time** (our fourth, cross-cutting challenge), represents a concern within the literature and practice of CIS. We now turn to a review of literature and practice to lay out the state of knowledge regarding these challenges.

Approach taken in the review

This paper is an analysis of gaps in knowledge and practice identified through the analysis of primary documents, both academic and grey literature, that describe processes of CIS design and implementation in sub-Saharan Africa. As such, the review, the questions raised by that review, and the learning agenda we construct to organize those questions is not a meta-analysis of other critical literature, but instead a primary analysis of its own. Our analysis rests on the study of 57 documents, both peer-reviewed and gray literature, addressing 16 projects and 4 coordinating organizations in sub-Saharan Africa. While we review both peer-reviewed and grey literatures, both are largely descriptive, reporting on the goals and design/implementation experience of one or more projects. Therefore, this literature serves as primary evidence about the practice of CIS design and implementation, rather than a source of critical scholarship on CIS. The geographic scope of this analysis is shaped by the interests of the USAID-funded Climate Information Services Research Initiative (CISRI) supporting this work. This paper focuses on CIS projects and programs, ranging from small projects, focusing on specific locales to larger efforts working across regions or even continental sub-Saharan Africa. To identify efforts and lessons learned from each of these projects, they had to be in an implementation or post-implementation phase.

The majority of the peer-reviewed articles considered in this review were identified through Google Scholar searches and Clark University's library resources, using key topic terms such as: 'user*,' 'need*,' 'climate information,' 'climate information services,' 'sub-Saharan Africa,' and 'Africa.' We also used the references cited in these articles to identify other documents useful to this review. Given the limited number of implemented CIS projects in sub-Saharan Africa, we sought to be as inclusive as possible in our literature search. We identified academic studies that either directly or indirectly spoke to the rationale and methods of design for a particular project or national program. For grey literatures, we employed a Google search using the same key topics as well as expert consultations within and parallel to our own CIS networks to identify relevant donor, project, and evaluation documents describing the rationale and methods of design for the CIS in question. Finally, the four coordinating efforts described below were identified through our networks of CIS practice and through the Google searches mentioned above.

We conducted a structured analysis of all documents, organizing them by: 1) what types of users were identified/targeted and how 2) what types of needs were identified/targeted and how, and 3) background information of the project (e.g. location of implementation, scale of operation, funder of the CIS, duration/timing of project). In this review, we do not focus on boundary organizations. While such organizations have the potential to further our understanding of CIS users and needs, the current practice of CIS usually brings such organizations into the conversation after the project has been designed, and with the goal of better translating and delivering climate information to specific users to address specific needs. Table 1 lists the projects we have reviewed and the literature, both project documents and peer-reviewed studies, that describe them. This table also describes the location, spatial scale, and time period of the projects and provides an abbreviated characterization of the approach taken within each project to define users and their needs.

In many projects users and their needs were simply assumed, sometimes explicitly but quite often implicitly. Some peer-reviewed literature probed more deeply into the assumptions associated with particular projects, particularly assumptions about user needs. These papers are listed in Table 2. Here the abbreviated characterization of approaches taken to identify users and needs describes the approach of the scholars to the projects, not necessarily the approach taken in project design. Thus, this table lays out current academic practice around the identification of CIS users and needs.

A final set of organizations provide frameworks for project coordination (Table 3). These frameworks serve to coordinate various projects and institutional partners (e.g. government leaders, climate scientists, implementing organizations) but are not explicitly focused on end-users (e.g. farmers, pastoralists, other local users). Tables 1 and 3 are not mutually exclusive and coordinating efforts identified in Table 3 often support CIS projects in Table 1 by providing data, institutional support, and other resources aimed at facilitating the design and implementation of these projects. Interrogating how these organizations might indirectly shape the identification of users and needs in particular CIS is outside the scope of this article.

Identifying CIS users and their needs: state of practice

In the majority of the CIS projects and programs reviewed, the identification of CIS users, their needs for climate information, and the goals of a given CIS program or project were so closely linked as to make the explicit investigation of users and needs apparently redundant to the implementers; however, many assumptions, which may or may not have empirical support, can be obscured by this linkage. We begin our review by first asking a series of questions related to how the projects listed in Table 1 identify users and needs. The questions are based on the four challenges we identified earlier. In answering these questions, we can go beyond the simple characterizations of Table 1 with implications for improving project design and for acquiring useful new knowledge.

How have users been identified or targeted?

Historically, the bulk of CIS targeted particular populations and their perceived need for new climate information, though some were aimed at institutional users like government ministries. These projects drew legitimacy and momentum by enhancing existing CIS and/or leveraging institutional contexts where new CIS could draw on existing knowledge, interest, and funding. It is therefore not surprising that the vast majority of CIS projects surveyed for this paper were designed with users already defined. For example, in a project in Ethiopia and South Africa, Bryan, Deressa, Gbetibouo, and Ringler (2009) targeted farmers as their users because the project goal was to understand the factors influencing farmers' decision to adapt

Table 1. Climate information service projects reviewed in this manuscript with descriptions of their sources of funding, location, scale, timeframe, approaches to identifying users and needs, and references to their associated literature. Documents included in this table are those which describe the approaches taken by the project.

CIS Projects Included in This Review								
					Project Methods for Identifying:		References:	
Project	Funder	Location	Project Period	Scale	Users	Needs	Peer-reviewed	Grey
AGRHYMET	Varies by specific country	Burkina Faso, Mali and Niger	1974-present	national/ regional	Assumed through project design	Assumed but tested through existing literature and survey questionnaire with key stakeholders (regional directors or leaders) that disseminate weather information in W. Africa (Mali, Burkina Faso and Niger)	Mertz et al., 2016	
Mali Agrometeorological Advisory Program (Meteo Mali)	Swiss Agency for Development and Cooperation (SDC) and Government of Mali	Mali	1982-present	village	Drawn from the knowledge of Malian designers and multidisciplinary working group	Defined in response to 70s/80s W. African Famine	Carr & Owusu-Daaku, 2016; Carr & Onzere, 2018	Hellmuth et al., 2011; Carr, Fleming, & Kalala, 2015
Climate Forecasting for Agricultural Resources (CFAR)	United States Department of Agriculture (USDA)	Burkina Faso, Malawi, Tanzania	1997-present	village	Assumed	Empirically identified: various participatory approaches	Ingram et al., 2002; Roncoli et al., 2009	
Grameen Uganda SMS-based farmer advisory	World Meteorological Organization (WMO) and Bill & Melinda Gates Foundation	Uganda	1997-present	national	Assumed	Assumed		Grameen Foundation, 2015
Pastoral Risk Management (PARIMA)	United States Agency for International Development (USAID) and Global Livestock Collaborative Research Support Program (GL-CRSP)	S. Ethiopia and N. Kenya	2000–2002	village	Assumed	Assumed but tested through econometric approaches (direct and indirect) of results of 300 hh interviews (30 in 10 villages) based on data from DMC (Drought Monitoring Center)	Luseno et al., 2003; Lybbert et al., 2007	
African Farm Radio Research Initiative (AFRRI)	Bill & Melinda Gates Foundation	Tanzania, Uganda, Mali Ghana, Malawi	2001–2010	national	community rapid appraisals	Assumed but tested through focus groups, workshops, partners, and analysis of listener feedback		Perkins et al., 2011; Bill and Melinda Gates Foundation 2017
IFPRI - Food and Water Security under Global Change: Developing Adaptive Capacity with a Focus on Rural Africa (3) projects	Federal Ministry for Economic Cooperation and Development (Germany)	Ethiopia & South Africa, Kenya	2007–2009	district/ regional	Assumed	Empirically identified: hh surveys and participatory rural appraisals (PRAs)	Bryan et al., 2009; Deressa et al., 2009; Bryan et al., 2013	Ringler, Bryan, Hassan, Alemu, & Hillesland, 2011
ACTED Appraisal & AMEU, 2013	ACTED and Government of Uganda	Uganda	DEWS, 2008-present, evaluation 2012	district	Assumed	Empirically identified: hh survey, focus group discussions, key informant interviews		ACTED Appraisal & AMEU, 2013
SERVIR	National Aeronautics and Space Administration (NASA) and USAID	Eastern and Southern Africa	2008-present	national	Assumed	Assumed		SERVIR, 2017
Adaptation Consortium (ADA)	Department for International Development	Kenya	2009-2013; 2014–2018	Counties	Empirically identified: community driven	Empirically identified: community consultation		ADA Consortium, 2014
Zambezi River Basin Initiative (ZBRI)	International Federation of Red Cross and Red Crescent Societies (IFRC)	Angola, Botswana, Malawi, Mozambique, Namibia, Zambia, Zimbabwe	2009–2018	regional	Assumed	Assumed		IFRC Southern Africa, 2010

(*Continued*)

Table 1. Continued.

CIS Projects Included in This Review								
					Project Methods for Identifying:		References:	
Project	Funder	Location	Project Period	Scale	Users	Needs	Peer-reviewed	Grey
Global Framework for Climate Services (GFCS) Adaptation Programme in Africa (4) projects	WMO	Burkina Faso, Malawi, Tanzania	2011-present (selected projects 2014-2016)	district	Empirically identified: structured individual hh questionnaire (via stratified random sampling design) & key informant interview guide (via purposive sampling design)	Empirically identified: structured individual hh questionnaire (via stratified random sampling design) & key informant interview guide (via purposive sampling design)		Hampson et al., 2014; Coulibaly, Kundhlande, et al., 2015; Coulibaly, Mango, et al., 2015; Daly et al., 2016
METAGRI OPS	State Agency for Meteorology in Spain (AEMET) and WMO	West Africa	2012–2014	regional	Inherited from original METAGRI project and modeled from Meteo Mali	Inherited from original METAGRI project: original methods multidisciplinary working group, model farmers (farmer observers), agromet information, participation and capacity buildiing with extension farmers		Tarchiani, 2015; WMO, 2015
Participatory Integrated Climate Services for Agriculture (PICSA)	International Fund for Agricultural Development (IFAD)	Kenya, Tanzania, Malawi and West Africa	2012-present	village	Assumed through project goals	Empirically identified: PICSA approach	Dayamba et al., 2018	Dorward et al., 2015
Senegalese River Basin Initiative (IRIS)	IFRC	Senegal, Mauritania, Mali and Guinea	2014-present	regional	Assumed	Assumed but tested through Vulnerability and Capacity Assessments (VCA)		Diallo, 2017a; Diallo, 2017b
Climate Information Services for Increased Reslience and Productivity in Senegal (CINSERE) (CCAFS)	CGIAR Trust Fund, Australia (ACIAR), Ireland (Irish Aid), Netherlands (Ministry of Foreign Affairs), Switzerland (SDC), UK Aid, USAID, EU, IFAD	Senegal	2016–2019	national	Empirically identified: key stakeholders	Empirically identified: project coordination, participatory approaches		USAID, 2016; USAID/ CINSERE, 2016

Table 2. Approaches to the identification of CIS users and needs found in the academic literature. While often focused on one or more specific projects, documents in this table were not part of project design or implementation and therefore references to methods reflect the approach taken by the study, not the project itself.

Academic Approaches to the Identification of CIS Users and Needs				
			Methods for Identifying:	
References	Location	Scale	Users	Needs
Glantz, 1977	West African Sahel	regional	Assumed due to the nature of the study	Empirically identified: questionnaire
Broad & Agrawala, 2000	Ethiopia	household	Assumed	Assumed
Archer, 2003	South Africa	village	Assumed	Assumed but tested: mixed methods (surveys, interviews, meetings, statistical analysis)
Tarhule & Lamb, 2003	West African Sahel	regional	Empirically identified: questionnaire	Empirically identified: questionnaire
Hansen & Indeje, 2004	Kenya	district	Assumed	n/a
Ziervogel, 2004	Lesotho	national	Assumed with rationale	Empirically identified: surveys and participatory tools (role-play game)
Ziervogel et al., 2005	Lesotho	national	Assumed with rationale	Empirically identified: Agent-based social simulation (ABSS), surveys, workshops, and participatory tools (role-play game)
Klopper et al., 2006	South Africa	regional	Empirically identified via SAWS seasonal forecast mailing list	Empirically identified: interviews and retroactive test period
Hansen et al., 2009	Kenya	district	Assumed	Assumed but tested: general circulation model (GCM) and APSIM model
Sultan, Barbier, Fortilus, Mbaye, & Leclerc, 2010	Senegal	regional	Assumed	n/a
Ngugi et al., 2011	Kenya	district	Assumed	Assumed but tested: interviews via questionnaire
Gebrehiwot & van der Veen, 2013	Ethiopia	regional	Assumed	n/a
Vellinga et al., 2013	UK GloSea4 for predicting the West African Monsoon	regional	Assumed	Assumed but tested: reanalysis of GloSea4
Mudombi & Nhamo, 2014	Zimbabwe	district	Assumed	Assumed but tested: interviews and survey
Roudier et al., 2014	Senegal	village	Assumed	Assumed but tested: particpatory approach
Carr, Fleming, et al., 2015; Carr & Owusu-Daaku, 2016; Carr & Onzere, 2018	Mali	village	Empirically identified: LIG approach	Empirically identified: LIG approach
Carr et al., 2016	Senegal	village	Empirically identified: LIG approach	Empirically identified: LIG approach
Egeru, 2016	East Africa	district	Assumed due to the nature of the study	Empirically identified: hh-heads survey, focus-group discussions, key informant interviews
Zongo et al. 2016	Burkina Faso	village	Assumed	Assumed but tested: statistical analysis on survey data

Table 3. Efforts aimed at coordinating the production and implementation of CIS across a range of stakeholders. These efforts do not specifically address the project-level identification of users and needs, but likely influence how specific projects make such identifications. This table combines seven different regional climate outlooks into a single row. While these outlooks are marked by different approaches and goals, these differences are not currently clearly reflected in their approaches to climate information users and needs.

Efforts Aimed at Coordination Across Relevant CIS Stakeholders					
Project	Donor	Location	Coordinating Period	Scale	Reference
Regional Climate Outlooks (7)	WMO	Continental Africa	1997-present	regional	Patt & Gwata, 2002; Patt et al., 2005; WMO, 2015
SERVIR	National Aeronautics and Space Administration (NASA) and USAID	Eastern and Southern Africa	2008-present	national	SERVIR, 2017
AfriClimServ	African Development Bank Group	Continental Africa	2011-present	continental	AfriClimServ, 2017
ClimDev-Africa	UK Aid, USAID, Swedish Government, European Union (EU), Nordic Development Fund	Continental Africa	2012–2014 (pilot), additional phases	continental	Mohamedahmed & Diabi, 2010; ClimDev-Africa, 2016

to perceived climate change. In their follow-up project, Bryan et al. (2013) expanded their project goal to include Kenya. Because the follow-up project builds from previous efforts in Ethiopia and South Africa which targeted farmers, there was little chance to either verify or challenge this framing of the project in the follow-up.

The example of the project implemented by Bryan et al. (2013) highlights another set of cases in which targeting is a product of path dependence induced when the project at hand builds on previous projects, contributing new data or refining an area of focus for an ongoing project. Such expansions and contributions target users based on the framings that led to the original project. For example, forecast advisories associated with the Southern African Regional Climate Outlook Forum (SARCOF) were originally conceived as a tool for aiding food security planners in response to El Niño related famine in the early 1990s. Only after the advisories were initially implemented in 1997 did the government of Zimbabwe extend the project to provide advisory information for *all* farmers (Patt, 2006). Patt notes that despite this effort to scale up the use of this advisory information, the information rarely reached the smallholder farming community. Instead,

it was most useful for large-scale white commercial farmers (2006). This was also true of the GFCS programme in Tanzania (see Coulibaly, Mango, et al., 2015; Daly, West, & Yanda, 2016), which framed its identification of users around the pre-existing priorities of funders and implementing partners in the programme's pilot districts.

There are also cases where targeting of users is related to the opportunities created at the coordinating level (Mohamedahmed & Diabi, 2010; Patt & Gwata, 2002; Patt, Suarez, & Gwata, 2005; SERVIR Global, 2017; WMO, 2015; "AfriClimServ,", 2017) and at the project level (ACTED Appraisal & AMEU, 2013; Coulibaly, Mango, et al., 2015; Coulibaly, Kundhlande, Tall, Kaur, & Hansen, 2015; Deressa et al., 2009; Grameen Foundation, 2015; Hampson et al., 2014; Tarchiani, 2015). For example, two pieces reviewing the Global Framework for Climate Services' (GFCS) Africa Programme in Tanzania and Malawi (Coulibaly, Mango, et al., 2015; Coulibaly, Kundhlande, et al., 2015) note that the project was broadly intended to 'improve climate services for agriculture, food security, health and disaster risk reduction in Tanzania and Malawi.' The ambiguous language of the programme goals reflects an effort to build on existing interests and knowledge of these contexts (whether detailed enough or not) in these countries, while targeting opportunities to reduce the gap between routinely available information and what those engaged with the programme knew to be useful for farm decision-making. Thus, the empirical engagement with the question of who the users were and what their needs might be was largely confined to refining these targets and setting up a baseline for monitoring and evaluation.

What methods or tools have been used to empirically identify users and their needs?

The contemporary practice of CIS design carries the risk that the initial assumptions behind the targeting of specific populations will bias the questions asked about the needs of that population, their capacities, and the constraints they face, thus obstructing learning and the adaptive management of CIS projects. A growing number of projects are addressing this challenge, and suggest some ways forward for empirically identifying users and needs without starting from deeply embedded assumptions about one or both. Explicit efforts to identify CIS users and their needs most frequently employed literature searches or surveys. **Literature searches** typically reviewed the sociocultural practices of targeted user groups, the prevalence of particular (climate-related) shocks and stressors, or both (Broad & Agrawala, 2000; Mertz, Rasmussen, & Rasmussen, 2016). The quality of the resultant reviews, however, is constrained by the amount and currency of the information available about that user group. **Surveys** are a particularly challenging tool to use for needs identification. In implementation, this challenge emerges around the close link between project goals, user identification, and user needs identification (ACTED Appraisal & AMEU, 2013; Bryan et al., 2013, 2009; Coulibaly, Mango, et al., 2015; Coulibaly, Kundhlande, et al., 2015; Daly et al., 2016; Deressa et al., 2009; Egeru, 2016; Ingram, Roncoli, & Kirshen, 2002; Roncoli et al., 2009; Tarhule & Lamb, 2003). In research, this challenge is manifest in the constraints on learning that surveys, with predetermined questions, can impose. In both cases, surveys rest on fixed questions that often reflect the initial biases of the survey designer. Thus, a survey that assumes a particular need might ask questions principally about that need, or about activities associated with that need, thus reinforcing the perceptions of the project. For example, in assessing user satisfaction with CIS associated with the GFCS programme in Tanzania, Daly et al. (2016) employed surveys, semi-structured key informant interviews, and focus groups at the local, district and national levels in country. While the surveys differed in themes and locations, the research team agreed to a common set of questions allowing for qualitative comparison at each location. One question, asked near the end of the survey, was if the respondent was 'aware of weather-related advisories issued by the Tanzanian Meteorological Agency (TMA)' (Daly et al., 2016). While this represents an effort to avoid skewing the data in the survey by only asking direct questions about advisories after other data have been gathered, it still presents risks. Such a question tells the informant the purpose of the project. In less-thoughtful survey designs, asking such a question at the outset of the survey can bias the informants' answers to emphasize the importance of a given stressor, or the need for a particular tool, whether or not that informant would give the same answer without information on the interviewer's interests. But even in a more careful design such as that implemented by Daly et al. (2016), informants within a community or household will discuss their experiences of the survey with one another, thus transmitting this information to at least some subsequent informants, which might similarly bias the responses of those informants.

Other projects identify user needs through **participatory approaches** such as vulnerability and capacity assessments (ADA Consortium, 2016; Diallo, 2017b, 2017a; International Federation of Red Cross and Red Crescent Societies: Southern Africa, 2010) and participatory rural appraisals (Bryan et al., 2013, 2009; Deressa et al., 2009). While these participatory approaches aim to address some of the gaps and shortcomings described above, as currently implemented they exhibit many of the same assumptions as more survey-based approaches. For example, participatory rural appraisals may minimize interview bias by incorporating local knowledge and information into various design or implementation processes of intervention (e.g. Chambers, 1995; Chambers, 1997). However, the identification of who participates in targeting processes remains rooted in assumptions about vulnerability and need common to contemporary CIS. As a result, they are vulnerable to the same challenges as more survey-based approaches.

A very small number of projects have adopted **intensive, holistic efforts** to capture the different users and needs in a population. The PICSA approach implemented by Dorward, Clarkson, and Stern (2015, p. 10) mixes survey data and case studies to understand both users and their needs and the impact of a climate service on those users. PICSA begins with an assessment of the current activities and decisions of farmers targeted for climate services, which creates 'a starting point from which to explore ways of using climate and other information' based on an understanding of 'the differences between farmers in the group regarding their activities and access to

resources.' At the ethnographic end of the methodological spectrum, the Humanitarian Response and Development Lab (HURDL) at Clark University has employed a rapid ethnographic approach called Livelihoods as Intimate Government (LIG) (Carr, 2013, 2014b) to the identification of CIS users and needs on projects in Zambia (Carr, Abrahams, et al., 2015), Senegal (Carr, Fleming, & Kalala, 2016, 2015), and Mali (Carr, Onzere, et al., 2015; Carr & Onzere, 2018). LIG expressly holds in abeyance the question of who the distinct users of a CIS might be until fieldwork has been undertaken to identify the stressors which different members of the community perceive as sources of vulnerability. Both LIG and PICSA present more holistic opportunities to understand the opportunities for and constraints on CIS use. For example, the use of CIS might be shaped not only by climate-related events and processes, but also economic shocks that reduce access to agricultural assets, or the sometimes-severe consequences for those that depart the roles and responsibilities associated with their identities (gender, seniority, ethnicity, etc.) by taking on a new livelihoods activity or practice.

Co-production efforts, which in principle might seem like obvious means to the identification of CIS users and their needs, are in practice much more challenging to implement meaningfully. As the large critical literature on participatory development (e.g. Cornwall, 2003; Leal, 2007; McKinnon, 2007; Nelson & Agrawal, 2008) and a growing critical literature on participation in CIS (e.g. Archer, 2003; Peterson et al., 2010; Roncoli, 2006; Roncoli et al., 2009; Roncoli, Orlove, Kabugo, & Waiswa, 2011a; Roudier et al., 2014) suggest, constructive co-production requires answering several important questions, all centered on the question of who to co-produce with. For example, are there people with whom co-production is critical because their existing knowledge and understanding is needed to inform project design and implementation (as in the initial Mali project design)? And how do we know when this existing knowledge is in fact adequate? Without answers to these questions, it is difficult to determine when co-production can replace a detailed needs assessment. Further, as in all participatory development approaches (for discussion, see Chambers, 1995; Chambers, 1997; Chambers, 2008), efforts to co-produce climate services must negotiate the demands of funders, the institutional realities of development implementation, the existence of biases that dismiss or downgrade the knowledge of the poor, the lack of knowledge and formal education among some users, and the difficulties in gaining the participation of a broad set of users, for example due to pervasive gender biases in a particular user population. Identifying these barriers to co-production and addressing them requires research and thought, but to this point very little of this work has been conducted for CIS (but see the work of Peterson et al., 2010; Roncoli et al., 2011).

Who is targeted by CIS?

CIS in sub-Saharan Africa most frequently target agriculturalists (Bill and Melinda Gates Foundation, 2017; Bryan et al., 2013, 2009; Deressa et al., 2009; Dorward et al., 2015; Hansen & Indeje, 2004; Ingram et al., 2002; Nyamwanza & New, 2016; Patt, 2005; Patt & Gwata, 2002; Perkins, Ward, & Leclair, 2011; Rader et al., 2009; Roudier et al., 2014; Tarchiani, 2015; Ziervogel, 2004; Ziervogel, Bithell, Washington, & Downing, 2005; Zongo et al. 2016). Projects less frequently target agropastoralists (Coulibaly, Mango, et al., 2015; Coulibaly, Kundhlande, et al., 2015; Daly et al., 2016), and when they do they often target them along with another group, such as farmers or pastoralists. Few projects target pastoralists (Egeru, 2016; Luseno, McPeak, Barrett, Little, & Gebru, 2003; Lybbert, Barrett, McPeak, & Luseno, 2007). Several projects target governmental and other stakeholders in the service (ACTED Appraisal & AMEU, 2013; "AfriClimServ,", 2017; "Climate Services Partnership,", n.d.; Grameen Foundation, 2015; Kadi, 2010; Mertz et al., 2016; National Aeronautics and Space Administration, 2016; Regional Centre for Mapping of Resources for Development, 2014; SERVIR Global, 2017; Tarchiani, 2015; Vellinga, Arribas, & Graham, 2013). Finally, some projects broadly targeted vulnerable communities (Diallo, 2017a, 2017b; International Federation of Red Cross and Red Crescent Societies, 2009).

Those CIS which empirically identified users before project goals were set generally reference a wider, more heterogeneous set of users than seen in the field of CIS as a whole. For example, rarely did these projects limit their focus to agriculturalists. Instead, these projects often included or focused on agropastoralists and pastoralists (Broad & Agrawala, 2000; Carr, Abrahams, et al., 2015; Carr, Onzere, et al., 2015; Deressa et al., 2009; Egeru, 2016; Luseno et al., 2003; Lybbert et al., 2007; Roncoli et al., 2009; Tarhule & Lamb, 2003), as well as specific actors in commercial or public sector information chains (Klopper, Vogel, & Landman, 2006).

What information needs are targeted by CIS?

The majority of the projects reviewed for this paper based their targeting on either existing knowledge of potential users or opportunities to reach new users by leveraging or improving existing services and development initiatives. These projects therefore targeted needs that, while perhaps part of the literature or the tacit knowledge of the project team, either were not verified with targeted users (Luseno et al., 2003; National Aeronautics and Space Administration, 2016; Regional Centre for Mapping of Resources for Development, 2014; Tarchiani, 2015; "AfriClimServ,", 2017; "Climate Services Partnership,", n.d.; Grameen Foundation, 2015) or were tested largely as a means of refining initial targeting based on literature reviews or tacit knowledge (Daly et al., 2016; Hansen & Indeje, 2004; International Federation of Red Cross and Red Crescent Societies, 2011, 2014; Lybbert et al., 2007; Mudombi & Nhamo, 2014; Orlove, Roncoli, Kabugo, & Majugu, 2010; Patt & Gwata, 2002; Patt et al., 2005; Perkins et al., 2011; Roudier et al., 2014; Vellinga et al., 2013; Zongo et al. 2016).

These projects focused on addressing broad concerns related to the impacts of climate variability on various sectors, with a particular focus on the mitigation of famine and food insecurity within the agricultural sector. Projects explored the use of GCMs for predicting crop yields at a field scale (Hansen & Indeje, 2004), predicting seasonal monsoons to inform rainfed agricultural production decisions such as crop and variety selection, planting dates, and input application (Carr, 2014a;

Vellinga et al., 2013), and designing early warning systems for events and seasons that might compromise production (ACTED Appraisal & AMEU, 2013; "AfriClimServ,", 2017; "Climate Services Partnership,", n.d.; Broad & Agrawala, 2000; Kadi, 2010; National Aeronautics and Space Administration, 2016; Perkins et al., 2011; Sultan et al., 2010). For example, ACTED is interested in climate information for contributing to the Drought Early Warning System (DEWS) in Karamoja, Uganda to prevent the impacts of widespread famine and food insecurity (2013). We note here that the focus on famine and food security in the event of disasters is a particular narrowing of the needs that users might have for climate information, one that can limit what is considered in CIS design and implementation. Other possibilities could include maximizing expected yields, increasing the stability of production, or expanding the types of crops grown. Or alternatively, a goal could be better-informed farmers who make their own decisions about the balance between taking risks to increase production versus avoiding the potential for bad yields.

Given the close connection between identification of users and identification of needs in CIS, it is not surprising that those projects which seek to empirically target users before finalizing project design tend to capture a more heterogeneous set of users' needs than seen in the CIS field as a whole. For example, when focusing on the use and utility of seasonal forecasts, these projects are first interested in the awareness and use of seasonal forecasts for supporting the users they have identified, whether smallholder farmers, pastoralists or users such as climate partners and commercial farmers (Archer, 2003; Luseno et al., 2003; Mudombi & Nhamo, 2014; Ngugi, Mureithi, & Kamande, 2011; West, Roncoli, & Ouattara, 2008; Ziervogel, 2004; Ziervogel et al., 2005). This is a wider set of users, with a wider set of needs, than generally seen among projects that target users without empirical verification. Further, these projects move beyond interests in awareness and use of seasonal forecasts to include understandings of the utility of these forecast for supporting agricultural and crop management for smallholder farmers in parts of Sub-Saharan Africa (Carr, Onzere, et al., 2015; Dorward et al., 2015; Ingram et al., 2002; Mudombi & Nhamo, 2014; Patt, 2005; Roudier et al., 2014; Tarhule & Lamb, 2003; Ziervogel, 2004). Finally, there are a few projects that are interested in particular needs for a specific group of users, such as the use of seasonal forecast for improving farmer-pastoral conflicts (Mertz et al., 2016) and the role of decadal climate information for anticipatory adaptation for climate variability (Nyamwanza & New, 2016).

Knowledge gaps related to identifying CIS users and their needs

While contemporary practices in CIS design and implementation continue to improve the design, delivery, and use of weather and climate information in development, disaster risk reduction, and adaptation efforts, these practices also highlight the four key questions, introduced at the start of this article, that must be addressed if the field is to achieve its potential. Below, we point to that which we must learn if we are to answer them more fully and move the field forward.

Designing effective assessments of CIS users and their needs

While efforts to carefully identify both users and their needs through empirical research appear to yield nuanced, contextually-appropriate information of great value to designers of climate information services, the success of such approaches rests on asking appropriate questions of the users, and asking those questions in a manner that facilitates learning from the users. This opens an important question for CIS: how are we to identify and assess user needs in a manner that does not swamp information from the users with biases from the designers? Answering this question remains a significant challenge for CIS, especially those targeting particular populations or needs. We suggest that the approach to this question of bias in the design of CIS can be divided into four critical questions:

1. How often does bias obscure important information about users and needs?

Targeting users and needs remains the most common mode of design for CIS. However, such targeting often reflects the interests, knowledge, and priorities of funders and implementers, not users. There are many pressures that promote such approaches, including donor and other funder demands for budget and performance. These pressures are likely to continue until there is clear evidence that such bias is pervasive and not easily managed by literature reviews or survey methodologies.

2. What is the impact of project design bias on project outcomes?

It is clear that approaches that obscure information about users and their needs will challenge the efficacy of CIS projects, and that such bias could be pervasive. However, we must establish the impact of such bias on projects and their outcomes to appropriately deploy effective tools and build appropriate budgets. Many types of information are needed to identify impact: these include capturing the number of different kinds of users and needs identified by the project and the percentage of the target population able to use the information, establishing who in the population (e.g. gender, economic status, social status, ethnicity, etc.) is reached and how they make use of the information, and characterizing the achievement of goals beyond income, such as disaster risk reduction or increases in the resilience of livelihoods.

3. What are the differences in the users and needs identified through different methods? What methods are most effective in which situations? What kinds of things do different methods help us to learn, and how might different approaches be integrated to draw on strengths and eliminate gaps?

When designing needs assessments for CIS, it is a mistake to seek out the ideal or correct method. Methods always involve tradeoffs in information or applicability. For example, while surveys can be applied to large populations relatively rapidly,

they are often designed with assumptions about that population that overlook critical points of heterogeneity, and which therefore result in questions that do not draw out vulnerabilities and needs critical to some in the population. On the other hand, findings from more ethnographic tools, whether the traditional extended fieldwork often associated with academic research or rapid assessment approaches such as participatory rural appraisal, are often very place-specific, calling into question the generalizability of the findings of any such work. More research is needed to 1) clearly identify the sorts of information that different methods can and cannot provide and 2) pilot innovative combinations of these approaches that might, for example, use ethnographic data to serve as a more rigorous basis for the interpretation of survey data, while at the same time using that survey data to test the generalizability of ethnographic findings.

4. How can we identify 'enough' heterogeneity to enable effective initial project design such that differences among people in their use of climate information can be addressed and previously unseen heterogeneity can emerge?

People differ in their interests in using CIS and in their capabilities for using them. An effective CIS will be appropriately tailored to those differences to have a sufficiently broad impact. However, there are practical limits to how much tailoring is feasible, as CIS cannot be designed for the specific needs of each individual. As discussed under question 3 above, it is a mistake to expect and seek a 'correct' scale for investigating heterogeneity. There are always tradeoffs between the depth of information and the practicality of obtaining it in a timely fashion. The challenge then is to create processes for users/needs identification that balance the broad opportunities provided by particular CIS capabilities with the identification of those characteristics of potential CIS users that are relevant to CIS design. The further challenge is to design projects to be adaptive so that changes in CIS can be made and new opportunities realized based on new knowledge about people's needs and interests, and changes to those needs and interests as users' knowledge increases and/or user/implementer/government/funder conditions change.

Identifying and overcoming barriers to CIS use

The literature on barriers to CIS use has been mainly focused on issues of access to information, timing of information, and building understanding of the information among users. More recently, a focus on wider social constraints to the use of climate information and CIS has emerged to address variable decision-making power and responsibility in target populations. The literature on this subject is relatively small, and heavily focused on gender as a constraint (e.g. Archer, 2003; Carr, Abrahams, et al., 2015; Carr & Onzere, 2017; Carr & Owusu-Daaku, 2016; Carr et al., 2016; Roncoli et al., 2009; Roncoli, Ingram, & Kirshen, 2000). However, the constraints on CIS use are multifaceted, emerging around many different, often intersecting identity categories. For example, in southern Zambia rural residents' abilities to use flood early warnings depended on the timescale of the early warning (Carr, Abrahams, et al., 2015). Wealthier men in the community, who owned cattle in which their wealth was stored, could not relocate these animals with less than a few weeks' notice. Rather than abandon the animals, and risk being reduced in economic and social status, the men in this situation often chose to stay with their cattle in extreme flood events, even though this decision put their lives at risk. Thus, these individuals faced a significant social barrier to the use of early warning systems that has to be addressed if such warnings are to benefit all members of the community.

The more complex findings of empirically-grounded efforts to identify users and needs before project design speaks to another major challenge for the design of CIS: the constraints on their use by targeted users. Effective demand constraint, in which expressed demand for a product or service is shaped by constrained resources or knowledge that limits what services are requested, takes shape around the climate-related knowledge of targeted users. For example, rural farmers cannot be expected to articulate needs around climate information products or communication processes to which they have never been exposed, or which might be technically feasible if otherwise unavailable. Some of this constraint will be addressed through time and experience, as targeted users are exposed to a greater range of technically feasible information, and are engaged by participatory tools and processes in both project design and eventually monitoring and evaluation. This will improve user capacity to articulate their more context-specific and nuanced needs. However, identifying and addressing these barriers and constraints point to significant knowledge gaps in CIS practice and scholarship:

1. Are there broad categories of effective demand constraints that might inform CIS co-production efforts?

There are few studies of effective demand constraints on the co-production of CIS with targeted users. More studies are needed to identify and understand user goals, as well as to establish effective means of dialogue through which constraints might be overcome to increase the number of users of a given service and/or change the goals and targets of that service to those that are achievable and appropriate.

2. Are there broad categories of social constraints to CIS use that might inform CIS design and co-production efforts?

The field of CIS needs more work on the social constraints to the use of climate information. Those studies that exist are very ethnographic and context-specific, and tend to focus on gender. A larger number of cases will enable synthetic efforts to identify common challenges across contexts and user groups, while identifying new social constraints to use that have not yet been considered by CIS designers and implementers.

3. What are the most effective means of implementing the co-production of CIS with user populations?

Co-production efforts are very challenging to implement meaningfully, but thus far very little work has been conducted on the coproduction of CIS.

4. What are the climate science constraints that limit the efforts of climate service providers to meet user needs?

While the subject of much discussion in the climate science literature (e.g. Briley, Brown, & Kalafatis, 2015; Kirchhoff, 2013; Porter & Dessai, 2017), the CIS policy and implementation community evinces a very thin understanding of the constraints providers of climate services face, and how those impact CIS use. For example, the current limits of climate science may preclude the sorts of forecasts that a particular subset of users need. Ministries within governments have to compete for funds by keeping diverse constituencies (for example, legislatures and end-user farmers) happy, forcing technical decisions to compete with political decisions. These and many other issues must be much more fully explored if we are to understand the spaces within which co-production can take place, and if we are to understand the design, implementation, and observed outcomes of different CIS.

Bringing CIS to scale

Work drawing out the heterogeneity of CIS user populations and needs points the way to more comprehensive understandings of the range of needs in a given population and the likelihood a particular intervention will be taken up by its target population. However, this work also presents unique challenges for CIS. This work tends to focus at the scale of the community, and draw out intra-community and even intra-household differences. These studies have not addressed the generalizability of their findings. Yet within the CIS community there is significant interest in scaling services up for replication and use beyond the original target area or target population (Grameen Foundation, 2015; Hansen, Mishra, Rao, Indeje, & Ngugi, 2009; Kadi, 2010).

Scaling down raises a related set of questions. How much value can be added by developing, incorporating, and delivering more localized or otherwise specific information? For example, Hansen and his colleagues are interested in the potential value of downscaling GCMs for seasonal precipitation forecasts for decisions regarding maize planting and fertilizer management in high-risk smallholder agriculture (2009). Thus, for both scaling up and down, CIS are confronted with the critical questions: how can information at a particular spatial or social scale be extrapolated to other situations? With what confidence can such extrapolations be made, and are there identifiable factors that shape the generalizability of information? And what is the value of these extrapolations?

There is very little work exploring this issue, or even expressly discussing this issue, in the CIS literature. The Humanitarian Response and Development Lab (HURDL) at Clark University has, when employing the LIG approach, argued that the logics of livelihoods decision-making it explores are likely consistent across the livelihoods zone in which they were established. This argument is predicated on the assumption that the social and economic factors which shape livelihoods decisions are contingent on time, place, ethnicity, and local environment (Carr, 2013, 2014b), all of which are generally consistent across the livelihoods zones produced by the Famine Early Warning System (see, for example, Dixon & Holt, 2010). However, this has largely anecdotal support (see Carr, Onzere, et al., 2015) with limited support from empirical testing (Carr, Rosko, Onzere, Goble, & Kalala, 2018; Onzere et al., 2018).

Knowledge gaps regarding the scaling of CIS include:

1. Over what spatial level or social groupings can a particular CIS be scaled and retain efficacy?

What are the constraining factors that limit the spatial or social scalability of a CIS? Is it agroecology, governance, social structures and expectations, or some combination of these? How might we better understand and identify such scales?

2. What is valid extrapolation for CIS?

Research directed to the problem of extrapolation should focus on 1) identifying specific characteristics of a population that are critical to making CIS useful, and 2) seeking indicators of similarities and differences in populations that can guide choices in extrapolation and suggest where and when further detail is needed.

3. What is the value of extrapolated data, whether upscaled or downscaled, for a particular CIS?

While it may be possible to rigorously generalize findings about users and needs from a particular community across larger areas, what findings generate the most added value for CIS? Similarly, where downscaling climate information is possible, does that information add value to the CIS?

Changing conditions and changing knowledge

Food production systems, and the wider rural livelihoods systems to which they belong, continue to evolve (see, for example, Alobo Loison, 2015; Bryceson, 1997; Bryceson, 2002; Harris & Orr, 2014; Ward & Shackleton, 2016). So do the capabilities of CIS, as ongoing research improves our understanding of the climate system at a range of spatial and temporal scales (e.g. Doblas-Reyes, García-Serrano, Lienert, Biescas, & Rodrigues, 2013; Meehl et al., 2014; White et al., 2017). While there is a large literature focused on the changing trajectories of rural livelihoods in sub-Saharan Africa, the CIS literature's engagement with this body of thought is minimal at best. There is little to no research in the CIS literature that specifically identifies trends (either through primary research or reviews of existing literature on agrarian transformation) in agricultural or broader livelihoods practices that can predict new uses for climate information. Further, there is surprisingly little discussion of the ways in which changes in local environments tied to climate change (shifts in precipitation and temperature) might alter the behaviors and functions of existing plants and animals that agrarian populations use to guide their livelihoods decisions. Significant knowledge gaps exist around:

1. How might the literature on agrarian change (and deagrarianization) in sub-Saharan Africa identify current and likely future CIS needs?

This gap includes questions about how the changing diversification of livelihoods that might drive increased *or* decreased reliance on CIS for livelihoods, how shifting livelihoods might change where agrarian populations are located, and

how shifting livelihoods may change the size and composition of future CIS user populations.

2. How might CIS planning leverage existing understandings of climate change and its impacts on specific ecologies such that current sources of information used to inform livelihoods decisions change or fail?

This question includes a focus on the timing of changes, such as when particular animals will shift migratory patterns or when particular trees might change the dates on which they fruit or change foliage. The projected timing of such changes will provide insights into when existing sources of climate information used by agrarian populations will no longer serve their decisions, making new forms of climate information central to agrarian livelihoods.

3. What current trends in climate research and what likely new knowledge from them can and should filter into CIS over the next 10–20 years?

This question relies on the climate science community's ability to assess its own foci, and the likely rates of advance in their predictive capabilities. Ideally, this conversation would be informed by interaction with user-facing members of the CIS community to help focus climate science research agendas that can help prioritize advances in areas of known user need.

4. How does learning about CIS change the behaviors of users and their demands for information?

A large number of CIS projects are being implemented, and over time the target populations will learn about the strengths and weaknesses of these CIS and the information they provide. One critical driver of future effective demand will come from this learning.

The gaps in our understandings of how changing conditions and changing knowledge intersect with future CIS demand and capabilities cross-cuts all the other questions we have raised above. For example, even if we can identify effective scales to which the generalization of detailed local information is possible and effective for CIS design, will those scales remain steady over time or change with market, environmental, and other conditions? While certain constraints to the use of CIS might be very prevalent now (for example, those emerging around gendered roles that exclude women from much agricultural decision-making), will those constraints persist as incomes rise, education levels increase, and livelihoods diversify? These conditions of change have brought about significant social changes in other contexts. Thus, for all of the questions raised above, there is a second set of questions that must be asked and answered (if possible):

1. What are the conditions of change that might reduce the validity of these findings or might introduce possibilities for revised findings?
2. For how long is this finding likely to be valid?
3. How frequently must we evaluate conditions to ensure our empirically-based initial assumptions have not departed significantly from conditions on the ground?
4. What mechanisms should CIS include to refresh and revise information in response to these challenges?

A learning agenda for identifying CIS users and their climate information needs

A learning agenda presents an opportunity to move the field of CIS research and practice forward in a coherent manner by organizing and prioritizing the gaps we have identified above; at the same time, the agenda should also be practical. Thus, the agenda should provide guidance for making use of existing and realistically attainable resources to build on promising work within or adjacent to CIS implementation and research.

The context for learning, and thus filling these knowledge gaps, is a critical starting point for this agenda. Though some targeted research will be needed, the opportunities for independent research to address the gaps and questions we have raised are likely to be limited. However, there are, and will continue to be, many CIS projects. If learning is incorporated into these projects, they could provide much of the information gathering needed. Collectively they could serve to facilitate critical analysis of the information and dissemination along with the use of findings.

Further, there are now multiple research groups with ties to various CIS projects (links to other related, but non-CIS projects may prove possible and productive over time). This will make the development and implementation of a cross-project learning agenda feasible if it is carefully and appropriately framed, and if expectations are calibrated to project realities. Each project will have different goals and arrangements, a different community and external context, and differences in methods of evaluation. As it is unreasonable to expect all research groups to reorient their work toward an external agenda, we propose that this learning agenda involve synthesizing information gathered across the groups, rather than establishing new controlled comparisons or tests. This approach is realistic for two reasons. First, such a cross-project effort could further the state of knowledge and thus improve the design and outcomes of participating projects by leveraging existing investments and work, leaving any new investment needed as a modest fraction of total project costs. Second, there are many potential users of the information beyond those engaged with the participating projects. They include: designers of new projects and project implementers; program planners; donors considering priorities; government agencies; and organizations with priorities adjacent to CIS (such as NGOs aimed at facilitating agricultural production). The production of knowledge that serves these wider users is an important collateral benefit that existing projects can claim in their performance reports, and donors and other funders can claim as evidence of thought leadership in CIS.

The primary goal of our learning agenda is to guide the development of better grounded and critical knowledge that will help improve existing climate services. But several secondary goals are also important and should be considered in project planning, design, and implementation. These are:

1. Supporting the broader knowledge base that can help improve living conditions in agricultural communities in sub-Saharan Africa. Climate information is only one of a number potential interventions for improvement and lessons from the CIS experience may have broader application;
2. Information gathered can and should be used to improve project management, helping to frame and support an adaptive management mode for CIS. Not all circumstances can be envisioned in project design, and not all assumptions will prove to be correct. Attention in the information gathering process to keeping track of what is working and testing assumptions can guide project adaptation;
3. Better communication between projects will be key to the synthesis needed in the learning agenda; it will also promote direct exchange of information and learning between projects that will assist ongoing planning, design, and implementation.

The implementation of a CIS learning agenda

A successful project-based learning agenda must frame learning as a means to more than accountability. While monitoring and evaluation should be tied to accountability, if accountability is framed in a punitive manner (and in development organizations it often is) there are incentives to avoid any learning that might cast project outcomes in a bad light, challenge project design or logic, or suggest needed changes in project implementation. Instead, the learning agenda must leverage the language of donor evaluation policies and strategies, which typically include a focus on knowledge production and future learning. For example, DFID's Evaluation Strategy (DFID, 2014, p. 3) states:

> The evaluation function is able **to integrate and use information generated from research, monitoring and review activities to inform evaluations**. The evaluation findings must also be **synthesised** into products looking across the entire evaluation portfolio **to enhance cumulative learning**. The evaluation function also has an outward facing role, working in **collaboration with other organisations and partners to produce evaluations and share learning** [emphasis added].

While the initial phase of this learning agenda must work with existing projects and existing monitoring, evaluation, and learning efforts, the longer-term success of the agenda relies on its ability to inform the processes of monitoring, evaluation, and learning that are now built into development programs, projects, and interventions. For example, USAID's Evaluation Policy (2016, p. 7) requires that such efforts be included in the design of each project:

> For each project, consideration will be given during the design phase to the performance evaluation(s) and, in some cases, impact evaluation(s) that will be undertaken. This is part of the preparation of a Project Monitoring, Evaluation, and Learning Plan … Planning for evaluation and identifying key evaluation questions at the outset will both improve the quality of the project and activity design, and will guide data collection during implementation.

It is therefore imperative that those working on donor-funded CIS engage with representatives of these organizations to bring this learning agenda to the table, as the gaps and questions presented here must be built into new projects if they are to be addressed effectively. If included as part of the learning agenda, donor staff will be motivated to participate, as doing so will result in better-informed monitoring, evaluation, and learning plans for new projects, and can identify opportunities to adaptively manage existing projects to capture the benefits of learning from their own and others' experience.

As new projects come online with the learning agenda represented in their monitoring, evaluation, and learning plans, researchers and implementers should approach their projects with a questioning spirit. This includes gathering information about the performance of the project in all its aspects, the degree to which project assumptions are holding up under the realities of implementation, and whether unexpected opportunities or challenges are emerging are opportunities to improve project performance while filling gaps in the CIS learning agenda.

The implementation of this learning agenda should not rely on formal research dissemination alone. Where possible and supported by donor and implementer staff, projects should develop means of rapidly disseminating findings, lessons, and outcomes with other projects to promote synthesis and mutual learning. Such efforts might include donor- or GFCS-coordinated webinars, workshops, and conferences where active engagement across projects is facilitated. It may be useful to extend such efforts to non-CIS efforts that have overlapping interests and concerns, such as food security programs distributing new seeds, asset-building livelihoods programs that facilitate access to agricultural resources, and health programs which target climate-sensitive diseases.

Topics to be emphasized in the learning agenda

We propose a tentative prioritization for filling the previously identified knowledge gaps based on two considerations. The first is where the gaps are, and the second is the practicalities of gathering the information needed to fill the gaps. It is structured over time to sequence efforts based how answers to one set of questions provide a foundation from which to answer others, on the availability of existing data, on potential findings from existing efforts, and on possibilities for learning from new projects. The structure has four categories. Under these categories are thirteen questions which capture the fifteen gaps identified above.

Category 1: Can be done by gathering data from existing/completed CIS, can be learned with existing data, and will set up critical follow-on efforts

- 1.1 How often does bias obscure important information about users and needs?
- 1.2 Over what spatial region or social groupings can a particular CIS be scaled? What factors affect that?
- 1.3 How might engagement with the literature on agrarian change (and deagrarianization) in sub-Saharan Africa serve to identify current and likely future CIS needs?

Category 2: Those that can be engaged through existing research teams and projects

2.1 What are the differences in information gleaned through different methods, and how might different approaches be integrated to draw on strengths and eliminate gaps?
2.2 What is the value of a particular CIS to its users? And how can that value be extrapolated for an upscaling or downscaling of the CIS? Such information can help assess the utility of particular CIS interventions now and in the future

Category 3: Major independent research projects

3.1 How might we define and target future CIS demand by integrating existing scientific understandings of climate change and its impacts on specific ecologies such that current local/traditional sources of livelihoods information change or fail?
3.1.a How might such integration inform the direction of future climate science research in support of CIS?
3.1.b How might such integration inform the likely future effective need for CIS in particular places, thus prioritizing future investments?

Category 4: To build into future projects

4.1 What is valid extrapolation for CIS?
4.2 What are the most effective means of learning about users and needs in a given place?
4.3 Where co-production is the most appropriate way to learn about user needs and designing CIS, what are the most effective means of implementing CIS co-production efforts?
4.4 What are the broad lessons we might learn about the effective demand constraints and social constraints to the use of climate information?
4.5 How does learning about CIS change the behaviors of users and their demands for information?

Figure 1 represents this structure: it shows on the x-axis the sequence in time (that is, when we might expect answers and what questions must be answered to enable the productive engagement with subsequent questions); the y-axis indicates the amount we know about them (from low-hanging fruit where much is known and simple review and synthesis is required, to broad gaps in knowledge where there are no data, or perhaps even debate about what data to collect and how). In addition, the categories of questions are shown in different colors, and arrows in the figure represents the relationships between the specific questions, suggesting a sequence of inquiry that allows for the prioritization of efforts to fill these gaps going forward. To be implemented, a research agenda such as this must secure broad agreement, so this should be regarded as a tentative proposal. Furthermore, any research agenda must be adjusted as new information becomes available. Nevertheless, we believe the categorization and temporal structure provide a useful initial framework for this agenda.

Of these questions, the one likely to have the biggest immediate impact on the effectiveness of climate services is 4.2: What are the most effective means of learning about users and needs in a given place? As the diagram illustrates, this is a pivot question between the organization of existing knowledge around CIS users and needs and subsequent questions about effective co-production, the social constraints to

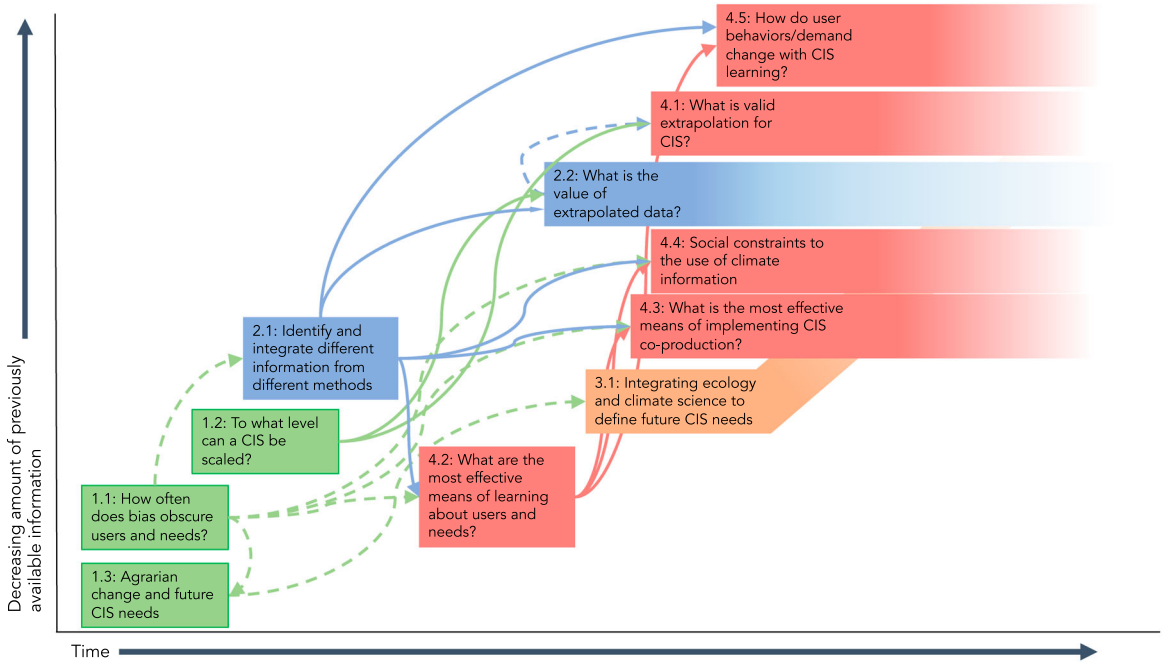

Figure 1. The learning agenda. Knowledge gaps are shown as boxes indicating when and for how long we expect them to be addressed. Their vertical position indicates how little information is presently available. The four categories of questions are color-coded and arrows show how answers from a question can be used by further questions.

CIS use, and behavioral change in the context of CIS. Answers to this question will govern the design, implementation, and monitoring and evaluation of CIS programs going forward.

Conclusion

Investigations into the identification of CIS users and their needs is a burgeoning field, with the very small body of early work being rapidly overtaken by new researchers and a growing set of projects to examine. For the field of CIS this is an exciting time, but also one that comes with the risk of unproductive duplication, or the emergence of major research themes that lack engagement with the needs of funders and implementers who will put the vast majority of CIS into play in coming years. The goal of our learning agenda is to move beyond the usual literature review that speaks to the work that has already been done, and the gaps in the literature that remain, to frame the ways in which those gaps might be filled through engagement with ongoing CIS practice. Further, we have attempted to prioritize the questions and gaps we have identified, as many gaps build from other gaps, thus allowing for the most effective use of limited research resources. Recognizing that many of the gaps and questions we have identified and prioritized here have been emerging in practice for some time, we hope the unique contribution of this learning agenda increases the value of ever-growing research into the users of CIS and their needs such that CIS policy and implementation improve, and CIS live up to their most exciting potentials.

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