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Mobilizing Climate Information for Decision-Making in Africa: Contrasting User-Centered and Knowledge-Centered Approaches

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This study examined ways in which climate information was mobilized for use under Future Climate for Africa (FCFA), an applied research program to improve the use of climate information to support medium-term (5–40 years) policies and planning in sub-Saharan Africa. Past research has underscored the interdependent relationship between user engagement and knowledge mobilization in effective climate knowledge uptake. The study used a document analysis of 46 program ou tputs and semi-structured interviews with 13 FCFA researchers to contrast user-centered and knowledge-centered approaches to effectively mobilize climate information uptake for use. A total of 20 knowledge mobilization tools and approaches were identified across the program and analyzed. This analysis reveals a complex interplay between user engagement and knowledge mobilization processes, including the strategic or flexible use and re-use of knowledge products as the user engagement process evolved. These findings have important implications for future programmatic design and planning in promoting engagement and mobilization approaches that can contribute to long-term policy and decision-making.

Keywords: climate information, climate services, knowledge mobilization, knowledge co-production, user engagement, Africa

INTRODUCTION

Despite the widely-documented exposure of lives, livelihoods, and assets in the global South to rising climate risks, the integration of information about those risks into planning and decision remains limited (Webber, 2019). In particular, researchers have highlighted challenges associated with encouraging the use of medium to longer-term climate information in many developing countries (Jones et al., 2017). As a recent review by (Singh et al., 2017: 394) notes, despite the critical need to consider decadal and multi-decadal time scale information in planning,

"there are very few clear examples of long-term climate information linking directly to on-the-ground decision-making." Numerous recent studies have sought to better understand the barriers to this integration, highlighting factors related to the nature of the climate information (its salience, legitimacy, credibility, and accessibility); and the nature of the ties between producers and users of that information (Cash et al., 2003; Jones et al., 2017). They also point to individual, organizational and systemic constraints that affect actors' capacities to act appropriately on information, including technical, financial, social, and psychological barriers to action (Watkiss and Cimato, 2015; Singh et al., 2017; Vincent et al., 2017, 2020b; Carr et al., 2020).

The challenges related to the uptake of this information are particularly salient in the context of the growing number of investments being made through bilateral and multilateral funding initiatives into research and capacity strengthening for National Meteorological and Hydrological Services (NMHSs), particularly in sub-Saharan Africa (see Harvey et al., 2019a; Mahon et al., 2019; Carr et al., 2020). Rising investment into major applied climate research programs aspiring to improve both the quality and use of climate-related information offers an opportunity to advance our understanding of this gap between knowledge production and its integration into use. These programs reflect a growing range of strategies, tools and approaches to knowledge mobilization and, hence, an important opportunity to assess their effectiveness. The programs also stand to contribute to improved outcomes for communities in the sites where they are being implemented.

This study addresses this opportunity space by examining an array of user engagement strategies and knowledge mobilization approaches, which were implemented over a common time period and under a common program, and which sought to improve medium- to long-term (5–40 years) policies, planning and investment by African stakeholders and donors. More specifically, we look at work carried out under the Future Climate for Africa (FCFA) program in 14 African countries between 2015 and 2019. We have focused our analysis on two complementary entry points for promoting the use of climate information: *user-centered* engagement (strategies used to identify and build links to particular communities of potential users of the information), and *knowledge-centered* approaches (knowledge mobilization used to organize, translate, and present this information for users). Through this work we sought to understand:

1. How user engagement strategies and knowledge mobilization approaches were put into practice across particular user groups and decision contexts; and
2. The reported barriers and enablers of their effectiveness.

Analysis for these two questions, however, also revealed important additional insights on the ways that user engagement and knowledge mobilization are being brought together within successful program strategies. We explore these insights in the discussion that ensues.

Limited comparative evidence of this nature has been published to date. In doing so we are able to draw lessons related to particular forms of engagement and mobilization of climate information, as well as broader lessons about how climate research programs can better contribute to positive social and political outcomes.

Evolutions in Climate Information Use in Sub-Saharan Africa

There is no single universal strategy or solution to promoting the use of climate information amongst a range of users, especially considering the wide range of contexts in which it might be used. Initially it was the inherent uncertainty in the climate system itself, as well as limits in forecasting capacity, that significantly impeded the availability of weather and climate information (Hulme et al., 2001). Subsequent critiques highlighted that the scientific presentation of information, for example use of terciles in probabilistic seasonal forecasts, impeded its use (Patt and Gwata, 2002). Case studies in a variety of locations across Africa highlighted that issues of accessibility and comprehension were impeding its use in decision-making (Vogel and O'Brien, 2006; Roncoli et al., 2009; Hansen et al., 2011). In short, the information produced in early iterations of user-oriented climate information did not meet the criteria for "actionable knowledge," namely for it to be legitimate, credible, and salient (Cash et al., 2003).

The recognition that decision-makers often failed to take up climate information prompted the development of the field of climate services. The rise of climate services has placed much more explicit focus on providing timely and tailored information to suit decision contexts (Hewitt et al., 2012; Buontempo et al., 2014; Vaughan and Dessai, 2014). This has led to increased interest in strategies that can most effectively *mobilize*[1] climate information for use in decision contexts—whether by improving availability of information, translating information into more accessible formats, or enlisting "intermediaries" to broker more effective communication between climate information producers and users (McNie, 2012; Jones et al., 2016; Vaughan et al., 2016; Harvey et al., 2019a). Despite these advances, there remain well-recognized challenges with many climate service initiatives, including concerns about institutional capacity to develop and sustain the services (Dinku et al., 2014; Harvey et al., 2019a); availability of and access to the climate information itself (Jones et al., 2017; Vaughan et al., 2019); as well as concerns about the impact of commercializing services as a means of ensuring their availability and sustainability (Webber and Donner, 2017).

The combined challenges of lower-than-expected engagement of users of climate services, weak accuracy and availability of highly localized or contextualized climate information, and broader concerns about the presumed primacy of Western science in some African decision contexts have also prompted an epistemological shift toward co-producing climate services (Lemos et al., 2012; Meadow et al., 2015; Bremer and Meisch, 2017; Vincent et al., 2018). In co-production

[1]Canada's Social Sciences and Humanities Research Council (SSHRC), describes knowledge mobilization as "an umbrella term encompassing a wide range of activities relating to the production and use of research results, including knowledge synthesis, dissemination, transfer, exchange, and co-creation or co-production by researchers and knowledge users" (SSHRC, 2019).

processes, rather than emphasizing the supply and "transfer" of knowledge to specific audiences (also referred to as "push"-style communication), the aim is to transform the process of knowledge construction to one where the ontological pluralism of producers and users is leveraged to generate new, actionable knowledge (Dilling and Lemos, 2011; Mach et al., 2020). As such, knowledge co-production often brings user engagement and knowledge mobilization together into a single process where the distinction between producers and users of knowledge becomes blurred (Pohl et al., 2010). However, empirical evidence on how this process of co-production is undertaken in practice, or agreement on how to best gauge its impacts remains scarce (Jagannathan et al., 2020; Mach et al., 2020; Vincent et al., 2020a). As a consequence of this ambiguity, argue Mach et al. (2020, p. 31), co-production persists as an "idealized, yet also diversely and imprecisely defined concept that inevitably falls short of meeting its own standards," and risks crowding out other forms of interactive science methods and practices.

FRAMEWORK AND METHODS

This study examined the user engagement and knowledge mobilization activities undertaken under the Future Climate for Africa program, a 5-year, £20 million program funded by the UK Department for International Development (DFID) and Natural Environment Research Council (NERC). The program was implemented by five research consortia, each featuring an international set of partner institutions (see **Table 1**). Together these consortia worked toward FCFA's three primary aims:

- Significantly improving scientific understanding of climate variability and change across Africa and the impact of climate change on specific development decisions.
- Demonstrating flexible methods for integrating improved climate information and tools in decision-making.
- Improving medium term (5–40 years) decision-making, policies, planning, and investment by African stakeholders and donors.

FCFA research consortia adopted a range of different strategies for and approaches to promoting the uptake of climate information, thus creating a valuable opportunity to compare and draw lessons from across their practices. Preliminary data collection was undertaken through an analysis of 46 program publications to identify the range of user engagement and knowledge mobilization tools and approaches that were used and the lessons that were documented on their use. A total of 20 different tools and approaches were identified, with some being used by more than one consortium. We then conducted semi-structured interviews with representatives from all five FCFA consortia to better understand how the tools and approaches that were identified were used in practice, and whether that use evolved over time. A total of 13 researchers were identified using purposeful sampling, based on their roles in developing or implementing the tools and approaches identified. This included interviews with two Principal Investigators, 10 Co-Investigators and one Early Career Researcher, of whom four were from partner organizations based in Africa. In terms of disciplinary focus, four respondents were from the physical climate sciences, three were social scientists, and six were from applied sciences.

In line with principles of action learning (Zuber-Skerritt, 2002), our analysis also draws on the extensive experiential knowledge of four members of the author team, who were active participants in many of the consortium meetings and field activities over the life of the program. These insights informed our collective analysis of the data, and were critical in understanding the generalizability of evidence from anonymized interview data. One member of the author team was also an interview participant, though her responses (along with all other interview data) were anonymized prior to collective analysis.

Recent research has increasingly underscored the interdependent relationship between *user engagement* and *knowledge mobilization* in the uptake of climate information into decision-making (Dilling and Lemos, 2011; Lemos et al., 2012; Harvey and Cook, 2018). As noted at the outset of the paper, user-centered and knowledge-centered approaches are different entry points to achieve the same output (knowledge uptake). User engagement strategies often seek to establish connection, contextual awareness, and trust between producers and specific communities or individual users of climate information. Knowledge mobilization, in contrast, tends to start with the information or knowledge that producers aim to see used more frequently or effectively. It involves identifying and implementing approaches that best align with the specific information type, intended use contexts, users, and desired outcomes or impacts (Phipps et al., 2016).

However, the nature of the links between these processes is not consistently set out in the literature, or in practice (Harvey et al., 2019b). The reasons for this inconsistent framing of the relationship are multiple, but often stem from competing ontological and epistemological positions on the nature of knowledge and knowledge production. Differing disciplinary starting points have also shaped orientations to both the potential users of climate information and the processes aimed at promoting the integration of this information into practice. Researchers and practitioners have, for instance, adopted approaches grounded in communications and social marketing theories, knowledge brokering and knowledge management theories, theories from participatory development, from the learning sciences, as well as more recent theories specifically focused on knowledge co-production, not to mention initiatives that have brought two or more of these orientations together (Harvey et al., 2012). While there are clearly intersections between these different disciplinary orientations, each brings its own norms and assumptions regarding the sequencing, prioritization, and assumed relationship between engagement with potential users of information and the development of tools, technologies and other products to synthesize or translate information and facilitate its use. To study these two inter-related dimensions of promoting the uptake of climate information—user

TABLE 1 | FCFA Consortia and their respective focus areas.

Acronym	Full name	Research and geographical focus
AMMA-2050	African Monsoon Multidisciplinary Analysis 2050	Understand how the West African monsoon will change in future decades, and how this information can be used to support climate-compatible development in the region; case studies in Burkina Faso (water resources) and Senegal (agriculture)
FRACTAL	Future Resilience for African Cities and Lands	Increase the climate resilience of nine southern African cities by including climate knowledge in decision-making processes; case studies in Lusaka, Maputo, Windhoek, Cape Town, Johannesburg, Durban, Blantyre, Harare, Gaborone.
HyCRISTAL	Integrating Hydro-Climate Science into Policy Decisions for Climate Resilient Infrastructure and Livelihoods in East Africa	Improve understanding of East African climate variability and change, their impacts, and support effective long-term (5–40 years) decision making; case studies in Uganda and Kenya on climate-resilient livelihoods and water management
IMPALA	Improving Model Processes for African Climate	Develop a very high-resolution pan-African climate model that better captures key processes and local-scale weather phenomena, including extremes.
UMFULA	Uncertainty Reduction in Models for Understanding Development Applications	Improve climate information for decision-making in the water-energy-food sectors in central and southern Africa; case studies in the Rufiji basin in Tanzania and Shire basin in Malawi.
CCKE	Coordination, Capacity Development and Knowledge Exchange Unit	Cross-cutting support to the five research consortia.

engagement and knowledge mobilization—we conducted a thematic analysis of the data drawing on two established frameworks:

Examining User Engagement Through the Lens of Co-production

There is a recognized need to identify and engage potential users of climate information, whether to understand their information needs, build trust, or to prioritize who should be engaged. Knowledge co-production has increasingly been framed as a "gold standard" of sorts for engaged science (Lemos et al., 2018: 722) and climate services (e.g., Vincent et al., 2018; Bremer et al's., 2019; Carter et al., 2019), albeit one that remains idealized, as noted above. Descriptions of co-production processes (e.g. Mauser et al., 2013; Vincent et al., 2018; Carter et al., 2019) often begin with stages of stakeholder identification, trust-building, and joint meaning-making before advancing to the collective development of products or solutions. This offers a useful framing for applying a "user-centric" analysis of how climate information and services have been conceived and developed for use in FCFA. To capture the full extent of this engagement, we coded participant responses by adapting Carter et al. (2019) and Vincent et al.'s (2018) frameworks for knowledge co-production, which set out four stages of climate services co-production: Identifying actors and building partnerships; co-exploring need; co-developing; co-delivering solutions; and evaluating the results of user engagement. Our adoption of this framing does not imply that all user engagement activities in the field of climate services were (or indeed should be) instances of co-production. However, the framework's four stages provide a useful point of reference for understanding the form and extent of user engagement that has shaped the approaches under study.

A Spectrum of Knowledge Mobilization Practices

We use the term "knowledge mobilization" to describe a range of approaches and processes used to organize, translate, and present information for users at the science-to-decision interface. Interpretations of how terms like knowledge brokering, knowledge translation, knowledge transfer, knowledge exchange, and knowledge mobilization differ from one another vary across the literature, leading Shaxson et al. (2012) to coin the term "K*" to highlight the fuzzy boundaries between definitions and functions of these terms. To clarify the distinctions between these different orientations to knowledge mobilization, Shaxson et al. (2012) and other scholars in the field of climate and environment (e.g. Michaels, 2009; Harvey et al., 2012; Hammill et al., 2013; Jones et al., 2016) developed a spectrum of approaches to knowledge mobilization categorizing forms of knowledge mobilization, from relatively linear information provision (information intermediation), which tends to focus on making information available in appropriate formats, to approaches aimed at influencing the decision contexts and the wider climate services system (innovation brokering) (see **Figure 1**). Jones et al.'s (2016) use of this framework for studying the contributions of NGOs in supporting climate service delivery provides a reference point for our own analysis.

There is always an element of subjectivity in situating activities on a spectrum, for instance in deciding whether a particular knowledge mobilization activity is better described as knowledge brokering or innovation brokering. To address areas of uncertainty we reviewed our assessment collectively as an author team and compared written descriptions of particular activities with FCFA members' interpretations of how these unfolded in practice.

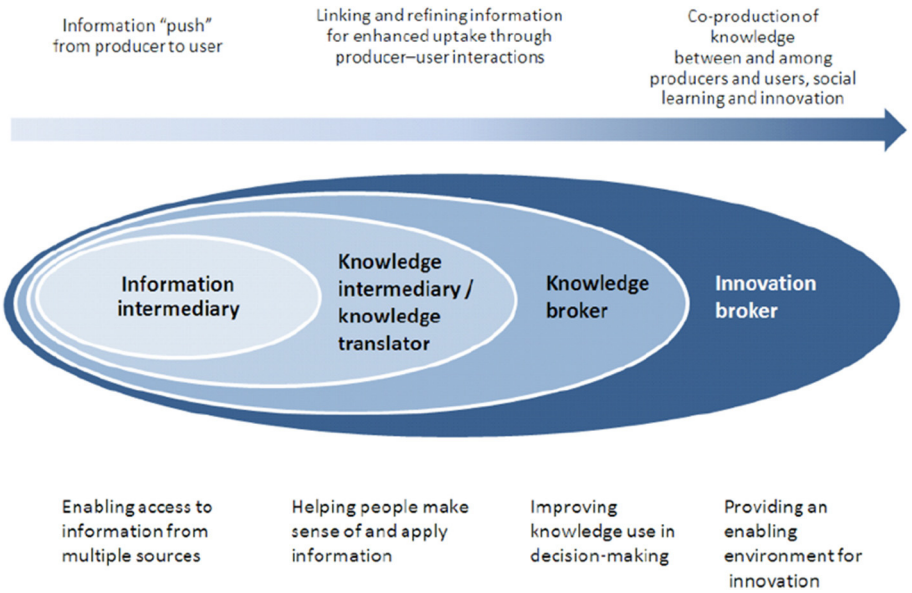

FIGURE 1 | A spectrum of knowledge mobilization approaches (from Hammill et al., 2013).

It is also important to note that, while our analysis considers user engagement processes and knowledge mobilization approaches in turn, in some cases these have been planned together and exist under a common strategy. In other cases, these are attended to sequentially, with user engagement and knowledge mobilization building upon one another. The dynamics between these processes ultimately form an important dimension to how we understand efforts to promote the use of climate information. In doing so we seek to extend Lemos et al.'s (2012) call to "delve deeper into understanding the processes and mechanisms that move information from what producers of climate information hope is useful, to what users of climate information know can be applied in their decision-making" (p. 789).

RESULTS

Strategies for User Engagement

Regardless of the approaches to knowledge mobilization adopted, there is a need to identify and engage with potential users of climate information. Through a series of interviews, we sought to understand which strategies they deemed effective in engaging potential users of climate information and knowledge. We used thematic coding to group responses around the four stages of climate services co-production adapted from Vincent et al. (2018) and Carter et al. (2020) and have noted the frequency with which respondents from one of the five consortia mentioned each strategy listed as being effective (**Table 2**).

We find close alignment between the user engagement strategies highlighted by interview respondents and those set out in the co-production framework. Consortia have used a wide range of strategies to engage current and potential knowledge users, but we see clear trends in using in-person engagement (directly or via trusted intermediaries) for identifying entry points and engaging with potential users, and use of long-term multi-prolonged engagements in building trust with key stakeholders (e.g., Steynor et al., 2020). These are not unusual practices but they underscore the fact that effective engagement strategies start early and remain intensive through the duration of program activities—regardless of the approaches to knowledge mobilization that accompany them. Given FCFA's focus on medium term climate change, the process of co-exploring needs included an emphasis on being open about the inherent limits in data and models.

The third stage of the user-engagement framework sees users and researchers engaging in the co-production of specific knowledge products or processes. In practice, not all tools or processes that emerged from the user engagement were co-produced—as we discuss in the sections that follow. Respondents reported instances where these strategies were not used and the consequences that sometimes resulted. One researcher recounted the challenges of effectively sequencing research plans and developing knowledge mobilization strategies that met the needs of a range of users:

> The first kick-off meeting we talked about what the key metrics of high impact on climate change were in different sectors and that was good to get [...] everybody on the same wavelength, and then the climate scientists went off and produced those [in] a long and technical way, bringing in new bias corrected data sets and training early career scientists. So that process was [...] definitely good in terms of building the skills of early career scientists. But then we, you know, produced big [...] documents that hang off our website, they were [...] even within the consortium, people found some of them a bit tricky. [...] The way that they were presented made sense to a scientist but not necessarily to a policy-maker.

TABLE 2 | User engagement strategies highlighted by FCFA consortia mapped to stages of co-production.

Identify actors and build partnerships	• Stakeholder meetings, early scoping visits, and in-person visits (4/5); • Draw on well-connected personnel and prior contacts (4/5); • Enhance receptivity by using project brochures/presentations to communicate goals and potential outcomes (4/5). • Monitor demands for information and training that are communicated directly or indirectly to the project (1/5). • Prolonged engagement through events and regular communication (3/5); • Joint production of knowledge products (2/5); • Establish a relationship coordinator and personal rapport (2/5); • Draw on credibility of partnering institutions, reputation of the project team (3/5);
Co-explore need	• Demonstrate commitment to partners' needs (3/5). • Transparency about the uncertainties in data, models, research process, and futures (4/5); • Knowledge sharing through workshops or training sessions (2/5); • Communicate through scenarios, instead of uncertainty (3/5); • Use visual aids paired with in-person support for interpreting (3/5).
Co-develop and co-deliver solution	• Ensure that the communication formats of climate information are most accessible to users (4/5); • Encourage participation through co-production (2/5); • Use iterative engagements to inform development (2/5)
Monitor/evaluate the results of engagement	• Monitor changes in policy or user engagement through key informant interviews, surveys, and document analysis (3/5); • Monitor requests from partners coming through ongoing correspondence (2/5); • Look for evidence of use noted in other data collection activities (3/5); • Specific case studies of evidence use (1/5)

The final stage of the co-production process cycle is to evaluate the effectiveness of the process and its results. Here we found limited evidence of results from the evaluation of user engagement activities that aimed to promote use of climate information, though some consortia reported having conducted some preliminary investigations. Respondents for three consortia suggested that it was premature to assess whether there had been uptake of the information or recommendations being shared. A member of the AMMA-2050 consortium, for instance, noted that the results of uptake would take time to unfold, so their current strategy was to look for "evidence of change" through informal discussions and email exchanges with partners. This strategy was part of AMMA-2050's broader evaluation framework for tracking institutional and individual changes against project baselines.

Respondents in other consortia shared some common approaches to monitoring uptake, as set out in **Table 2** above. While these are effective monitoring approaches, we note that only one of the approaches highlighted involves a structured analysis of context-specific progress or outcomes. Claims that it is premature to evaluate impact have merit, particularly in longer-term behavioral change processes. However, past research highlights the risk that evaluation plans left until the closing stages of the program often encounter time, human and financial resources constraints that impinge on their implementation (see Harvey et al., 2019c), as well as lack of reliable data if baselines and monitoring processes have not been set up to gather the data required for effective analysis. This concern was recognized by one consortium co-lead who noted the need for tracking long-term program impacts "after the project ended," but observed that doing so requires the project management team to "maintain a strong network."

Categorization of Knowledge Mobilization Activities in FCFA

Having reviewed the strategies used in FCFA to engage users, we then looked at how knowledge was mobilized to enable access to new climate information for decision-making among the range of potential users. Particular attention was paid to how the function of knowledge varied according to context. **Figure 2** illustrates the distribution of the categories of FCFA's knowledge mobilization activities.

While we see a distribution of tools and approaches across this spectrum, we find a predominance of cases in the intermediary and translation categories, which emphasize ensuring that information and knowledge are available and are in accessible language or formats. This is perhaps unsurprising, given that such tools (such as the production of policy briefs and brochures) have long been used by projects to translate and communicate information for targeted audiences. However, evidence suggests that, used in isolation, such tools tend to be less effective for engaging with non-expert audiences, for building capacity, or for shifting behavior (Bielak et al., 2008; Turnhout et al., 2013). They may nonetheless be helpful for raising the awareness among actors already active in the climate information and services field (such as other researchers). Also worth considering in these intermediary and translation categories is the ways in which these activities are embedded in wider processes or strategies of engagement to enable knowledge uptake. We explore this point in section Interplay Between User Engagement and Knowledge Mobilization Processes below.

We also find examples of more interactive approaches to knowledge mobilization being used by most consortia. These include the co-development of stories and narratives describing climate risk, and forums. These approaches have tended to be used as conversation starters to engage targeted stakeholders in more sustained knowledge mobilization processes. As one FRACTAL researcher noted in speaking about the power of these interactive knowledge production and uptake process,

> Fundamentally it's the process that has produced the uptake of the information, but I just want to emphasize, it's not just information, it's the understanding. It's the relational capacity amongst the participant groups, it's the exchanges across the cities.

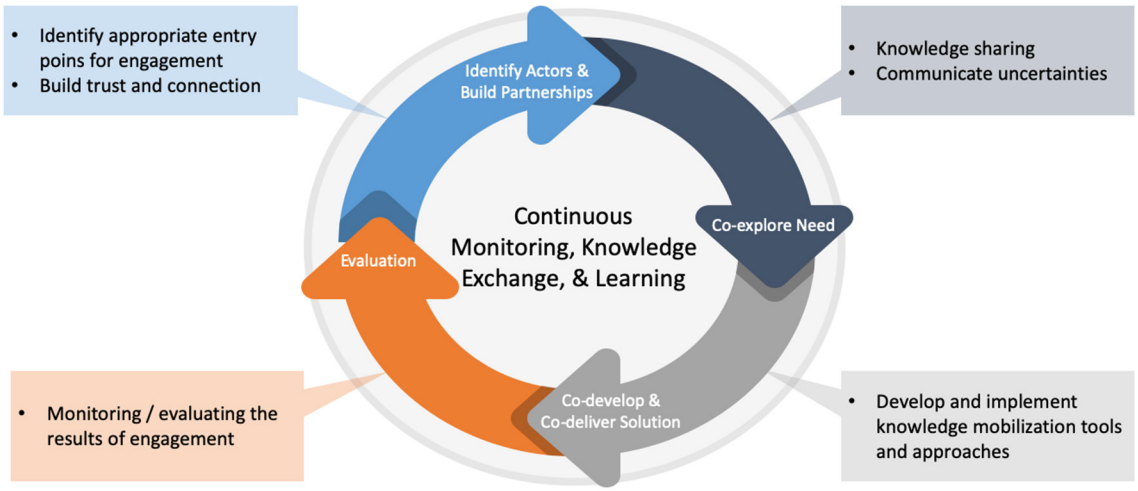

FIGURE 2 | Stages and indicative strategies for user engagement in knowledge co-production.

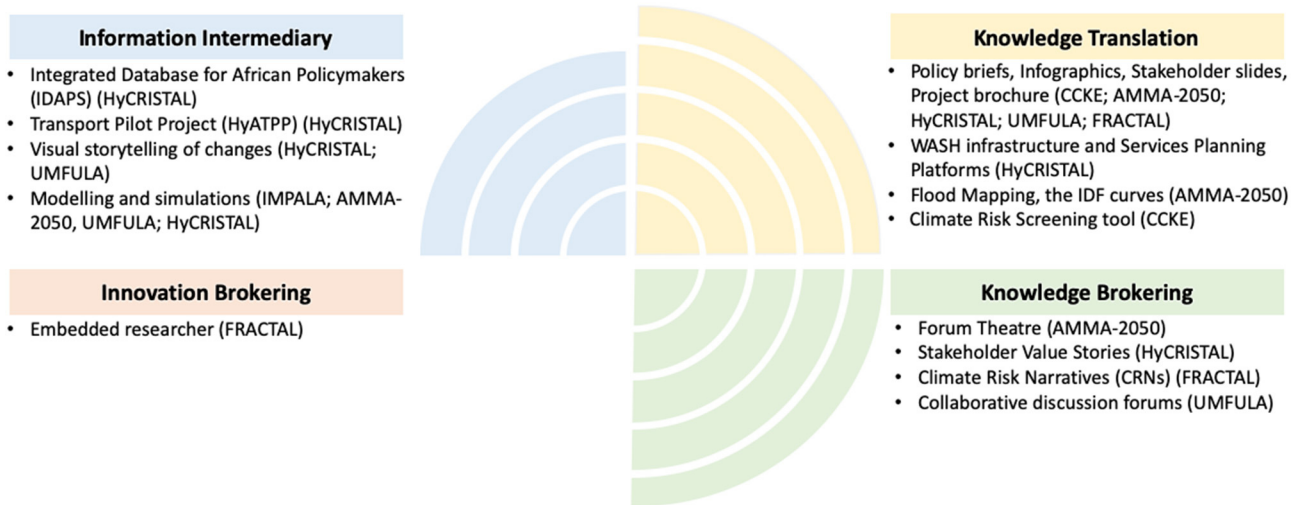

FIGURE 3 | Categorization of knowledge mobilization tools and approaches used in FCFA.

The lack of examples categorized as "innovation brokering" is also noteworthy. These are tools and approaches that operate at the level of climate information systems (the network of actors, institutions, policies, and infrastructure that govern the production and use of climate information) to open up the possibility for innovations in practice. These systems-scale approaches can offer scope for deeper transformations in the technical, social and institutional relationships that shape knowledge production and use, but require time and sustained resourcing required to affect this kind of change (Klerkx, 2012). Recent studies have highlighted the potential mismatch between project-based initiatives and these more systemic efforts at transformation, and may help to explain the relative lack of these systems-level approaches in FCFA (Harvey et al., 2019b).

Distribution of Tools and Approaches by Context and Intended User Groups

Having established the overall distribution of the categories of knowledge mobilization activities, we then looked at the alignment between the tools and approaches used and the contexts and audiences that were targeted. As evidenced in **Table 3**, the tools and approaches used by FCFA consortia spanned a wide range of user types and scales. While some tools and approaches appeared to target a diverse set of users, the majority target a clearly defined audience and/or use context. This is in line with the growing awareness of the importance of context-informed knowledge mobilization, and may also be due to the expectation that all FCFA activities have clearly targeted stakeholder groups at the proposal development stage. However, in looking at categories of mobilization and their

TABLE 3 | Tools and approaches to knowledge mobilization and uptake by targeted users.

Category of mobilization	Name of tool or approach	Tool type	Targeted users	Example of outcomes
Informational functions (Information intermediary)	Integrated Database for African Policymakers (IDAPS) (HyCRISTAL)	Online database of climate modeling, agronomy and hydrology	Policy-makers at national, district, and sub-district levels	The modules of IDAPS have been tested in Uganda to support livelihood and policy decisions
	Transport Pilot Project (HyTPP) (HyCRISTAL)	Reports on current- and future-climate analysis	World Bank and their consultants	The reports were shared by the World Bank at a workshop in October 2018
	Visual storytelling of changes (HyCRISTAL; UMFULA)	Videos	Local communities; Local government; International donors	Too early to assess.
	Modeling and simulations (IMPALA; AMMA-2050, UMFULA; HyCRISTAL)	Large-scaled synthesized data with simulations and modeling	Research institutions	A high resolution meteorological dataset is expected to be published in the UK CEDA and used in collaboration with other universities
Informational-Relational functions (Knowledge translation)	Policy briefs, Infographics, Stakeholder slides, Project brochures (CCKE; AMMA-2050; HyCRISTAL; UMFULA; FRACTAL)	Written briefs; infographics; summary slides; brochures; etc.	A wide range of stakeholders (e.g., farmers, researchers, NGOs, policy-makers)	The briefs are used in various policy documents.
	WASH infrastructure and Services Planning Platforms (HyCRISTAL)	A web-based data sharing platform	Policy-makers and practitioners	
	Flood Mapping, IDF curves (AMMA-2050)	Maps of inundated area with land use scenarios	City planners, infrastructure companies	Decision-makers have requested IDF curves for particular infrastructure project
	Climate Risk Screening tool (CCKE)	Screening tool	Rwanda Green Fund staff, expert reviewers and project developers	Too early to assess
Relational functions (Knowledge brokering)	Theater Forum (AMMA-2050)	Play designed to enable dialogue.	Scientists, government officials, farmers, and more.	Promoted discussion on adaptation options with National and regional decision-makers, and researchers.
	Stakeholder Value Stories (HyCRISTAL)	Stakeholder narratives of information use	Policy-makers	Used to inform the IDAPS database development.
	Climate Risk Narratives (CRNs) (FRACTAL)	Textual descriptions of plausible climate futures	City decision-makers	Contributed to the city-specific strategy and action plan in Windhoek, Namibia
	Collaborative learning fora (UMFULA)	Multi-stakeholder discussion on climate impacts, decision trade-offs and robust options	Policy and decision-makers at the national and river basin levels	Too early to assess (ongoing)
Systems functions (Innovation brokering)	Embedded researcher (FRACTAL)	Researchers embedded in city government	City decision-makers	Developed networks with decision-makers

alignment to user types, no strong trends emerge. We do see a tendency for interactive knowledge brokering approaches to focus on policy makers (at a range of scales), which is in line with past reviews (see Harvey et al., 2012). While this could suggest a lack of clear consensus on which categories of knowledge mobilization are most effective with particular stakeholder groups, it may also highlight that the alignment of knowledge mobilization tools and approaches with specific user groups can depend on additional factors. Indeed, we find that additional variations in the use of similar tools (briefing notes, for instance) such as the intended outcomes and stage of user engagement at which they are used, can greatly shape how they "fit" within the knowledge generation process. We explore this finding below.

Interplay Between User Engagement and Knowledge Mobilization Processes

Our analytical framework examined approaches to user engagement and knowledge mobilization processes in turn, recognizing them to be complementary entry points to achieve common outcome (knowledge uptake). However, interviews with consortium members underscored the significance of the interplay between these two processes and the varied ways that they were brought together in program initiatives. One HyCRISTAL researcher, for example, noted that, although "each pilot [study] has its own specific knowledge product, [...] they were not used independently" as "a source of knowledge" for a specific targeted user group. Instead, a combination of knowledge tools and approaches was used "in conjunction with the [climate] narratives and other tools" to engage stakeholders. This use of combinations of tools and knowledge products within user engagement processes helped the teams achieve smaller, interim steps toward their overall project objectives. One FRACTAL researcher also explained that their policy briefs "were not targeting [city learning lab] participants," but were rather designed to help participants "in their roles [...] to inform their bosses or their stakeholders." In the context of the learning labs, which focused on co-learning and co-production of solutions, knowledge mobilization tools could "only work within a process that allows for engagement and conversation" to build "relationships and trust." As the researcher argued, "were any of those products outside of that process, I don't think we'd really have achieved much."

In other cases the interplay between mobilization and engagement processes revealed a strategic or flexible use and re-use of knowledge mobilization tools as user engagement processes evolved. For example, policy briefs in UMFULA were initially designed to translate project baseline evidence, but ultimately served as "the key" in getting consortium researchers invited to contribute to Tanzania's national climate policies. In FRACTAL's work in Zambia, although the primary objective of developing policy briefs was to increase awareness of climate change in Lusaka, the process of co-producing the briefs guided the rest of "the research activities [and] all the engagement activity for most of the learning lab process." Policy briefs thus acted as a boundary object shared by the researchers and stakeholders in both FRACTAL and UMFULA to initiate more extended engagement processes, some of which included knowledge co-production activities (see **Box 1**).

The dynamic use of knowledge products in concert with extended user engagement processes highlights the importance of being "responsive and flexible" in enhancing the uptake of climate information. FRACTAL members emphasized the learning component of "listening to what participants were requesting" and being willing to change the research team's view about "what was either needed or important or how things [should] be communicated" in their City Learning Labs. As one member described, the Maputo City lab "was an example where the engagement didn't work very well" at the beginning, so the team had to "reframe the information" and "change directions [...] a few times to try and find some traction."

These examples of the successful interplay between user engagement and knowledge mobilization processes reveal a number of important insights. First, in many of these cases the contribution of knowledge products themselves (briefs, guides, etc.) rested less on the credibility, legitimacy and saliency of their content (in terms of knowledge translated or transferred), and more on the spaces they opened up for more extended interactions. Second, the co-productive dimensions of many of these processes were emergent over time, rather than designed. Together, these insights suggest a more complex relationship between production and use of climate knowledge than is reflected in many models of evidence use. We reflect on these insights below.

DISCUSSION

FCFA consortia have used a wide range of tools and approaches to promote greater use of climate information in planning and decision-making, which we have loosely grouped into "*user-centered*" and "*knowledge-centered*" entry points to knowledge uptake. This offers an opportunity to better understand how and why particular tools and approaches have been beneficial, for whom, and in what contexts. Having a better understanding of what has or has not worked, we argue, can help to improve the ways in which researchers engage with "user" communities, and potentially challenge perceptions about those relationships. Looking across the analysis we find some evidence to advance our understanding of how best to mobilize medium-term climate information, but also some important questions that will require further exploration.

Applying Principles of Co-production for Engaging Users of Medium and Longer-Term Climate Information

We find a strong alignment between the principles of effective knowledge co-production set out in the wider literature and practices cited as effective across the 20 FCFA examples we studied. This seems particularly significant given the range of approaches that were inventoried in **Figure 3**. The value of long-term engagement, trust-building, and in-person engagement is emphasized by respondents. This underscores the need to consider both process and product in the development of any resources for knowledge mobilization. Emphasizing the value of these principles of co-production offers a good starting point for future initiatives, particularly at planning and design stages.

Dynamic Interplay Between User Engagement and Knowledge Mobilization

While our analysis examines user engagement processes and knowledge mobilization approaches in turn, in many cases these were planned together and exist under a common strategy or approach to co-production. Though our review of literature on knowledge mobilization strategies confirms the importance of tailoring tools to particular stakeholder groups, our review of the alignment of specific categories and tools/approaches with particular stakeholder types did not reveal clear trends in FCFA.

BOX 1 | Policy briefs as boundary objects in FRACTAL's City Learning Labs in Lusaka.

The city learning processes in Lusaka have led to the "fundamental changes in key decision pathways (around water, flooding, land use and infrastructure development) to increase the [city's] resilience" (Koelle et al., 2019, p. 25). One important factor that contributed to this policy impact was the process of co-developing policy briefs with the decision-makers. In Lusaka, policy briefs acted as boundary objects (Michaels, 2009) that resided between the social worlds of the decision-makers and scientists. Boundary objects are objects or ideas that emerge through collaboration and dialogue which are both adaptable to local needs yet "robust enough to maintain a common identity" (Star and Griesemer, 1989, p. 393).

In fact, the development of policy briefs was not a pre-planned output of Lusaka's City Learning Labs. The idea came from the participants during a media training event where they recognized the need for media statements about the "burning issues" in Lusaka related to climate change. Therefore, co-developing policy briefs became a mutual priority. As boundary objects, the briefs brought city planners and scientists together for more in-depth dialogue and became "the red thread" that guided "research activities [and] all the engagement activity for most of the learning lab process in Lusaka." In the fourth and fifth Learning Labs, the decision-makers and the project teams even sat and wrote the policy briefs together "over a number of days (and evenings)" (Mwalukanga et al., 2018, p. 1). As a result, these policy briefs are now a shared product between all members involved. A shared ownership of such products is essential for medium to long-term knowledge uptake, as it allows all members to use these policy briefs as a new form of boundary objects to initiate diverse dialogues and engage future collaborations with other decision-makers, researchers and practitioners.

Since the Lusaka learning labs concluded, city representatives have expressed a desire to continue an engagement similar to the learning lab. In keeping with the aims of innovation brokering, this outcome suggests a newly established norm of policy learning in the decision-making space. It also indicates a potential benefit of the co-productive practice in establishing long-term engagement and trusting relationships between partners.

What we did find, however, were numerous cases where similar mobilization tools and approaches were being embedded in wider user engagement strategies toward quite different ends—often with those strategies being in a regular state of flux.

To take the case of the "briefing note"—one of the most commonly used knowledge translation tools for policy stakeholders—these performed a range of different functions in FCFA. This included a more traditional "gap filling" function of matching an evidence "supply" with a perceived knowledge "need;" a "priming" function where briefs served to stimulate more in-depth user engagement; a "help desk" function where briefs were generated later in the engagement process in response to stakeholder-identified needs; and a "co-production" function where jointly-produced brief served as the boundary object in a joint meaning-making process. As noted above, some of these functions emerged out of engagement practices rather than being established through a design process. While past research has distinguished between science-driven "push;" user-driven "pull;" and iterative "co-production" models of knowledge production (Dilling and Lemos, 2011), case evidence from FCFA demonstrates how extended knowledge mobilization processes may combine or move between these modes, either strategically or adaptively, as user engagement dynamics evolve.

Not all of the tools and approaches reviewed in the study reflected this form of interplay, of course. There remain knowledge mobilization activities that reflect a push to showcase research evidence with limited awareness of how the evidence might be taken up in use, or by whom. We note that the wider climate research system, including many funders and academic institutions, continues to rely on incentives and performance metrics that prioritize research "outputs" (products) over "outcomes" (societal impacts) (Jones et al., 2018). Further, we cannot conclude that those tools or approaches that did feature the interplay described here were necessarily more impactful over time. Indeed, the lack of evaluative data on these strategies within the program makes it challenging to draw firm conclusions on how to best align mobilization approaches with particular user groups, as we discuss below.

What we do observe from these examples, is the diversity of trajectories toward effectively supporting the use of climate information, even when pursued under a common programmatic framework and in line with a relatively common set of principles of good practice, as found in FCFA. We find that extended engagement processes toward co-production with intended users will not necessarily be the product of careful design as they might be in more controlled environments such as research teams (see Cundill et al., 2019). This makes the task of monitoring progress and tracking the effects of these forms of engagement over time particularly challenging, yet critical.

These insights reflect earlier reviews of knowledge mobilization practice from Ward et al. (2009), who observed that "the boundaries between [approaches] are often blurred" with many projects combining elements of different tools and approaches to meet users' needs. "This is often done" they suggest, "without recourse to any underlying model or framework of knowledge transfer or knowledge brokering and causes difficulties when evaluating individual brokering interventions" (p. 274–275). While Ward et al. appear to raise concerns about a seemingly haphazard approach to combining strategies, our results suggest that this may actually be indicative of a type of strategic agility within teams.

Better Assessing Outcomes and Impacts

Despite being a relatively large, lengthy, and well-resourced initiative, our document analysis yielded limited data reporting on the effectiveness of specific approaches to promoting the use of climate information in FCFA. Where data did exist, it was largely in relation to ongoing expressions of demand, or responses to information that had been shared rather than assessments of the outcomes or impacts of evidence use. Many respondents cited the project timeline as the biggest barrier to gathering this outcome and impact-level information—as they felt it was too early to meaningfully assess. This gap limits our ability to assess whether there are clear "best matches" between tools/approaches and particular audiences, aims, or stages of engagement, or

whether there are tools or approaches that have particularly wide-ranging utility. These are important questions for the future of research-to-action linkages on climate information services in Africa. A more robust testing of tools and approaches could yield important insights. Some preliminary analysis has been undertaken by FCFA consortia to compare the advantages and challenges of some knowledge mobilization tools and approaches (see Harold et al., 2019 for a comparison of tailored slides, policy briefs, infographics and narratives). Future investigation could examine a wider range of approaches and contexts.

A call for more robust evaluation of these approaches should not be perceived as a push for researcher accountability but rather as an opportunity to better understand how particular strategies for knowledge mobilization and user engagement contribute to evidence use and behavior change. Evaluations that focus on outcomes with specific stakeholder groups and decision settings and at different points across the co-production process seem particularly important based on the evidence from these cases. Addressing these needs would demand new emphasis on monitoring during a program lifespan, as well as methods for assessing the longer-term impacts of knowledge mobilization activities, many of which may not emerge until long after the conclusion of program activities. One promising monitoring approach that emerged from the strategies of some FCFA consortia is the use of incremental progress markers that identify and track evidence of interim steps toward longer-term changes in the use of climate information in planning and decision-making. These can include shifts in attitudes, knowledge, and behavior, for example. AMMA-2050 developed a key informant score card, combining qualitative and quantitative questions administered to a panel of researchers and decision-makers at program base-, mid- and end-line. Use of progress indicators is not new to monitoring and evaluation (see Earl et al., 2001) but their use in this context remains limited. Applying such process markers would better enable rigorous analysis of progress toward the intended impacts that are often only seen long after the end of a program. However, where responsibility for this "post-project" impact monitoring should rest remains unclear.

Limited Strategies Aimed at System-Scale Knowledge Mobilization

Finally, we note the relative absence of knowledge mobilization tools and approaches falling in the "innovation brokering" category, where attention is typically placed on enabling systems-scale changes. In an emergent field of practice like climate services, where there is a recognized need to strengthen the overall functioning of the climate information system (Dinku et al., 2014) this form of mobilization would seem to be of critical importance. However, past research has suggested that the time-bound and closely focused nature of most project-based initiatives (such as FCFA) makes efforts to support systems-scale changes (Harvey et al., 2019b). This does not mean, however, that other types of knowledge mobilization activities did not ultimately have systems-level impacts. The case of FRACTAL's City Learning Labs (**Box 1**), for instance, appears to have led to a more fundamental shift in local practices, while AMMA-2050 reports changes in institutional norms in terms of attention to decision-making needs within collaborating research institutions.

Work at this systems level involves engaging with the established norms and institutional cultures that shape work on climate services. This can be a significant challenge for initiatives led by outside organizations, or organizations working to strict timelines and budgeting constraints. Klerkx (2012), for instance, describes the "funding paradox" of innovation brokers in the context of agricultural systems, where efforts to tackle market and system failures are themselves undermined when the initiatives aiming to do so are subject to the same flawed system. Similar challenges can be found in the field of climate services (Daly and Dilling, 2019; Harvey et al., 2019a) highlighting the need to examine approaches beyond specific initiatives or programs.

CONCLUSIONS

This study has sought to better understand the growing range of ways that user engagement and knowledge mobilization are being used to promote the use of medium-term climate information in planning and decision-making in sub-Saharan Africa. To do so, we studied a sample of 20 tools and approaches emerging from a common program (Future Climate for Africa), loosely grouping them into "user-centered" or "knowledge-centered." This framing allowed us to look across a wide range of approaches to evidence uptake and use, from more traditional, linear modes of information intermediation and knowledge translation to forms of knowledge co-production that have increasingly become seen as a model of practice in climate services.

Our findings reveal the central role of co-production principles in engaging potential users of climate information, regardless of the knowledge mobilization approach being used. They also highlight the complex interplay that can unfold between user engagement and knowledge mobilization processes, dynamics that belie the sometimes narrow depictions of the relationship between knowledge production and use in the literature. These insights reflect Bremer, Wardekker, Dessai, Sobolowski, Slaattelid and van der Sluijs (2019) assertion that "recognizing knowledge co-production as a multi-faceted phenomenon, able to be worked on along several different dimensions, could help climate services scholars and practitioners more fully realize the potential of this process" (p. 49).

Recognizing the complex and often-iterative dynamics of these processes, where seemingly linear modes of engagement may actually serve to initiate, or provide boundary objects that support more extended pathways toward knowledge co-production, highlights the need for better approaches to monitoring and assessing their impact. Investment into more nuanced and longer-term assessments of the impacts and outcomes that user engagement and knowledge mobilization efforts yield for particular stakeholders and contexts, remains a significant gap. We hope that these findings serve to highlight this need, as well as opportunities for continued work to ensure climate information supports effective decision making and climate resilience in Africa.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The Research Ethics Board 2 reviewed and approved this project by delegated review in accordance with the requirements of the McGill University Policy on the Ethical Conduct of Research Involving Human Participants and the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans. (File # 50-0619). The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

Y-SH and JA led data collection. BH and J-PR contributed to data collection. BH and Y-SH led data analysis with contributions from all other authors. BH led drafting of the manuscript with contributions from all other authors. All authors contributed to the study design.

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