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RESEARCH ARTICLE

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Climate services for the Greater Horn of Africa: interviews exploring practitioner perspectives from Kenya and beyond

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ABSTRACT
Climate and weather services support important decision making in many sectors across the Greater Horn of Africa. Though constantly improving, there is a mismatch between the provision of these services and the needs of target stakeholders. To better understand this, we interviewed 23 practitioners who work with climate, weather, and hydrological information in East Africa, to gain a qualitative understanding of their work and how they use climate services. We found a complex network of stakeholders within this climate services ecosystem, each with their own foci that dictate their information needs and use cases. We found that information is typically transferred from one stakeholder to another by means of a value chain structure. Thematic analysis provided a deeper understanding of participants' needs and motivations, revealing trust and information suitability as key issues in encouraging uptake. We also found that participants had strong motivations to overcome barriers to improve the livelihoods of end-user communities. We argue for evaluating the broader interconnected climate services ecosystem in a more holistic manner, instead of focusing only on impact in end-user communities, which can lead to the design of better systems and benefits for all stakeholders.

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1. Introduction

The East Africa region comprising Sudan, South Sudan, Eritrea, Ethiopia, Djibouti, Uganda, Rwanda, Burundi, Kenya, Tanzania, and Somalia is often labeled the Greater Horn of Africa (GHA) (Gebremeskel et al., 2019). Largely a dryland region, its rural population is dependent on rain-fed agriculture and pastoralism (Biazin et al., 2012; Kirkbride, 2008), leaving society particularly vulnerable to the effects of hydroclimatic variability exacerbated by climate change. Seasonal rainfall is becoming less predictable (Funk et al., 2014; Funk et al., 2019; Shongwe et al., 2011) and often cannot reliably supply water for crops and animals, or even for human use. Droughts have become more frequent and severe due to increasing frequency and strength of ocean-atmospheric climate phenomena, exacerbated by land use changes (Gebremeskel et al., 2019; Nicholson, 2014) and other human activity. Conversely, flooding caused by periods of extreme rainfall has also increased (Nicholson, 2014; Shongwe et al., 2011). Such extreme events are drivers of famine and chronic food insecurity (Kogo et al., 2021), reduced household incomes (Rufino et al., 2013), and conflict (Meier et al., 2007). Aside from purely humanitarian concerns, agriculture and pastoralism are major components of the regional economy (Nyasimi et al., 2013), which are particularly vulnerable to climatic variability and extreme events (Herrero et al., 2016; Kotir, 2011; Muller et al., 2011). Inconsistent hydroclimatic conditions significantly affect GDP growth in sub-Saharan Africa, with drought being particularly detrimental (Brown et al., 2011).

Many organisations in the GHA are responding to challenges arising from seasonal climate variability and long-term climate change. These include intergovernmental groups such as the Intergovernmental Authority on Development (IGAD), national and local government departments, and many NGOs and charities. Central to these efforts are climate and weather services, which assist stakeholder decision making and planning (Vogel et al., 2019). These services provide information to different timescales, including short-term forecasts for the coming days and weeks, seasonal forecasts for the next few months, and longer-term projections. However, the local context presents challenges to their implementation and uptake. Much of Africa remains data sparse in terms of *in-situ* observations of hydroclimatic and environmental conditions (Dinku et al., 2018), leading to poorly-constrained models and inaccurate forecasts. Furthermore, unreliable infrastructure makes reaching some stakeholders difficult, especially 'last-mile' rural communities, and they may lack the training or skills to interpret and act on climate information when received.

Despite significant barriers, climate information services are widely used in the region. Prior research has examined the broader network of climate services and the different systems and processes contained within, from inception to implementation and maintenance, to identify areas for

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improvement. One identified weakness is the rigour and scope of evaluation, particularly outside of direct end-user benefits (e.g., increased crop yields) (Tall et al., 2014; Vaughan & Dessai, 2014). In this paper, we offer different perspectives on the use of climate services by eliciting the opinions of practitioners who engage with climate information in their work. Through interviews with professionals in climate change adaptation and development roles in GHA, we gain a qualitative understanding of how climate information is produced, used and disseminated, and a greater understanding of practitioners' needs and motivations. We also argue that a more holistic approach to assessment and evaluation of climate services, beyond a particular service and its impact, can facilitate more effective adoption and work-flow implementation.

2. Related work

2.1. Climate services

Climate services or *climate information services* are systems providing climate and climate-related information to inform decision making (Hewitt et al., 2012). They encompass various types of information, including seasonal weather outlooks, long-term climatological projections, and other environmental conditions (e.g., soil moisture, crop health). They may target different users, from scientists and policymakers to individual citizens. Climate services and climate information are arguably distinct from weather services and weather information – the former typically refers to long- and medium-term predictions and the latter to shorter-term forecasts. However, the terms are poorly delineated (Vaughan et al., 2018) and often used interchangeably (Tall, 2013). Therefore, we discuss both in this paper as *climate services*. Furthermore, climate services exist within a broader interconnected system of multiple climate services, related processes, institutions, and stakeholders (Vaughan & Dessai, 2014). We refer to this as the *climate services ecosystem* throughout this paper.

Climate services can provide demonstrable benefits to society and individuals (Anderson et al., 2015). In the case of agriculture, farmers can make decisions based on expected conditions, such as which crops to plant and when to plant them (Dobardzic et al., 2019), potentially increasing yields, food security, and household incomes. However, climate information is probabilistic and often lacks spatial discrimination – this can make it difficult to interpret for some users and inaccurate at local levels, potentially leading to losses (Vaughan & Dessai, 2014). Climate services also support broader impacts outside of individuals and their households – institutional decisions can build societies' resilience to extreme events (Wilby et al., 2009) and guide longer-term development (Jones et al., 2015), and less reliance on natural resources and agricultural inputs can have environmental benefits (Selvaraju et al., 2011).

Recognising the role that climate information has in mitigating the negative effects of climate variability, there have been attempts to coordinate efforts to develop climate services. The Global Framework for Climate Services (GFCS) seeks to promote and develop climate services globally (Hewitt et al., 2012), prioritising developing countries and four areas of application: agriculture and food security, disaster risk reduction, health, and water resources. The framework is intended to provide a unified approach to developing climate services. However, climate services is still an emerging field and many services are developed *ad hoc*.

Climate services are typically delivered top-down through a 'value chain' (Anderson et al., 2015; Vogel et al., 2019): a sequence of value-adding steps required to implement a service. Though this may include engagement with different stakeholders, climate scientists at the top of the chain are often disconnected from the needs of other users in the system (Porter & Dessai, 2017). This mismatch between information supply and user demand leads to a 'usability gap' (Lemos et al., 2012). Furthermore, the 'deficit model' has been identified, where simply supplying information to fill a knowledge deficit may not lead to effective action (Roudier, Muller, d'Aquino, Roncoli Climate Risk ..., and undefined, 2014; Vogel et al., 2019). In response, there have been efforts to encourage greater stakeholder interaction through co-production (Meadow et al., 2015), whereby knowledge production is approached as a collaborative effort through iterative and interactive processes (Lemos & Morehouse, 2005). Using this approach can foster understanding and bilateral relationships to ultimately deliver more effective climate services (Bremer et al., 2019).

2.2. Climate services in Africa

Africa has been a major area of focus for climate services, due to the continent's sensitivity to the effects of climate variability and its reliance on agriculture, which remains a popular focus for climate services (Vaughan & Dessai, 2014). Climate services in Africa are typically provided by a combination of international agencies (e.g., WMO), regional organisations (e.g., IGAD), and National Meteorological and Hydrological Services of individual countries. Regional Climate Outlook Forums (RCOFs) also play a key role in disseminating forecasts for the upcoming season, reflecting on impacts of the previous season, and providing a venue for other related discussion and interaction between scientists and other stakeholders (Daly & Dessai, 2018). Relevant to this paper is the Greater Horn of Africa Climate Outlook Forum (GHACOF), which is organised by the IGAD Climate Prediction and Application Centre (ICPAC).

Despite obvious applications, there are many barriers to the effective deployment and use of climate services across Africa. These include a lack of awareness, understanding, and accessibility; lack of information relevance and capacity to act; and a lack of trust in the services and the information provided (Nkiaka et al., 2019). Furthermore, though provision for climate services is improving, there is still a lack of institutional infrastructure to adequately provide climate information for the development and humanitarian sectors (Dinku et al., 2018; Nkiaka et al., 2019). Limited and uneven coverage of observation stations results in gaps in the data that underpin climate services (Dinku et al., 2018), and there are challenges in presenting and delivering information to intended recipients that prevents uptake (Nkiaka et al., 2019). To fill this void, various initiatives have been established to expand and promote climate services in Africa. The Enhancing National Climate Services (ENACTS) framework improves regional data availability by combining weather station data with satellite data and climatological models (Dinku et al., 2018), and the Weather and Climate Information Services for Africa (WISER) and ClimDev Africa projects also focused on continuous improvement of climate services in Africa (Vogel et al., 2019).

2.3. Assessing and evaluating climate services

Though much previous work has focused on developing and implementing new climate services and systems, formal assessment and evaluation have typically been lacking (Tall et al., 2014; Vaughan & Dessai, 2014). Furthermore, research that does implement or encourage evaluation has focused on the direct benefits and impacts on 'end users' (commonly smallholder farmers), which may still suffer from methodological shortcomings (Vaughan et al., 2019).

Vaughan and Dessai (2014) suggest the need for an evaluation framework to assess climate services across different criteria: problem identification and the decision-making context; the characteristics, tailoring, and dissemination of the climate information; the governance and structure of the service, including the process by which it is developed; and the socioeconomic value of the service. Nevertheless, robust evaluation is uncommon – a systematic review of climate services for farmers identified only 25 studies featuring evaluation, and only 14 in Africa (Tall et al., 2014). However, numerous evaluation methods were identified, both qualitative and quantitative, and *ex-ante* and *ex-post*. The authors also suggest recommendations for enhancing evaluation, such as building it into the entire project timeline, and using a holistic and mixed-methods approach.

3. Current study

Climate services research often focuses on end users (typically rural communities) and the accuracy of scientific data, exposing a lack of research detailing personal perspectives of other stakeholders and practitioners. Furthermore, assessment and evaluation tend to focus on one specific climate service, rather than the wider ecosystem encompassing many services and actors. To further understand the processes, users, and stakeholders within this broader ecosystem, we interviewed practitioners at different levels of the climate services value chain.

We addressed the following research questions:

1. What are the roles of different users, and how do they fit into the climate services ecosystem?
2. How is climate information obtained, used, and disseminated to facilitate interventions?
3. What are their motivations and needs that can inform climate service development?

This study aims to give a snapshot of the climate services ecosystem in the GHA, as told by people working within it. This allows for a better understanding of the needs, barriers, and everyday experiences of a spectrum of actors, and ultimately gives insight into areas for improvement. Such qualitative assessment and evaluation is uncommon in this domain, and adds another facet to a comprehensive understanding of climate services and their users, while also demonstrating the effectiveness of this methodology by including nuance and personal experiences.

3.1. Ethical considerations

Ethical approval was obtained from the lead author's institution (*details omitted for anonymous submission*). Participants gave informed consent, and transcribed data were anonymised. As part of a larger ICT for Development (ICT4D) project, we were conscious of the *Minimum ethical standards for ICTD/ICT4D research* (Dearden & Kleine, 2018).

3.2. Participants

Twenty-three professionals (six female, 17 male) working on climate- and weather-related issues in the GHA were interviewed. We recruited via email using opportunity sampling, using personal contacts, organisational websites, and the GHACOF participant lists. Due to the international nature of this type of work, English is typically the working language and so all correspondence was performed in English. Table 1 describes the participants and their roles.

3.3. Procedure

Participants were asked to participate in an interview about their work via email. Semi-structured interviews were conducted remotely, and audio recorded for transcription. English was used throughout this process. Topics included general information about the participants' role and their organisations, experiences and issues in working with climate information, quality and effectiveness of the information, interfacing with other organisations; and decision making.

3.3.1. Thematic analysis

The transcribed interviews were analysed by three researchers using reflexive thematic analysis, as described by Braun and Clarke (Braun & Clarke, 2006) and later refined (Braun & Clarke, 2019; Lyons & Coyle, 2012). We performed the first phase, *familiarisation with the data*, through transcription, listening to the audio again, and reading the transcripts. Phase two, *data coding*, organises sections of raw data (from words to sections of text) under a unifying label relevant to the research questions. This was approached inductively – codes were generated and refined during the coding process, rather than imposing a predetermined structure. Multiple passes were conducted, and codes were iteratively discussed and refined. Resulting changes were retrospectively applied to the data.

The 206 codes were transferred to a collaborative sticky note system for phase three, *generating initial themes*, allowing easy visualisation and grouping into candidate themes. Researchers initially performed this individually using their own copy, then described their initial themes to the other researchers. This resulted in three distinct interpretations –

Table 1. Participant profiles.

P	Organisation type	Position	Location	Area(s) of work
1	Livestock development	Agroclimatologist	Kenya	IGAD region*
2	Climate science	Senior climate scientist	Kenya	GHA region
3	Pastoralist resilience	Regional project coordinator	Kenya	Ethiopia, Uganda, Kenya
4	International food security	Hydrometeorologist	Kenya	Somalia
5	Disaster risk	Disaster risk assessment specialist	Kenya	IGAD region, Tanzania, Burundi, Rwanda
6	International NGO	Director of research and development	Rwanda	East and southern Africa
7	Food security	Food security analyst		East and central Africa
8	International NGO	Capacity building in climate services	Kenya	IGAD region
9	International food security	Field scientist		East Africa
10	Meteorology department	Meteorologist and forecaster	Kenya	Kenya
11	International research institute	Research assistant	Sweden	Kenya, Ethiopia
12	International research institute/freelance	Consultant		Kenya, Ethiopia
13	International food and nutrition non-profit	Program officer	Kenya	Kenya
14	International food security	County Coordinator	Kenya	Kenya
15	Drought management	County Coordinator	Kenya	Kenya
16	International child health charity	Field Supervisor	Kenya	Kenya
17	International agricultural research	Principal Scientist and project coordinator	India	Kenya
18	Local faith-based	Project Coordinator	Kenya	Kenya
19	Meteorology department	Research Assistant Director	Kenya	Kenya
20	Local government	Hydrogeologist	Kenya	Kenya
21	Local government	Water, Sanitation and Hygiene (WASH) Coordinator	Kenya	Kenya
22	Local government	Extension officer	Kenya	Kenya
23	Local government	Extension officer	Kenya	Kenya

'*P*' column denotes participant number.
*'IGAD region' denotes member countries of the Intergovernmental Authority on Development – Djibouti, Eritrea, Ethiopia, Kenya, Somalia, South Sudan, Sudan and Uganda.

as themes are actively constructed by researchers who bring their own insights, rather than waiting to be discovered (Braun & Clarke, 2019), this outcome was not unexpected.

Phase four, *reviewing and developing themes*, was completed individually, taking into account points raised about the initial themes. It was agreed that one of the approaches was most grounded in the collective understanding of the data, and this was therefore developed. This fed into the *refining, defining and naming themes* phase, which was completed collaboratively. Each researcher presented their ideas for the final themes, which were discussed until a consensus was reached. This resulted in five themes: (1) *Collective focus on benefits for end users*; (2) *Appropriateness of information and dissemination is key for impact*; (3) *Trust and acceptance is important at all levels*; (4) *Hierarchy and value chain model allows for decentralised decision making*; and (5) *Adapting to and overcoming barriers*. These are described in the following section.

4. Results

The 23 interviews lasted between 00:30:13 (HH:MM:SS) and 01:24:00 (*mean* = 00:47:36, *SD* = 00:11:53). We present our results in two parts – the general findings and the thematic analysis results.

4.1. General findings

4.1.1. Information types

Rainfall information was the main focus for our participants. This is to be expected due to its importance to the GHA region, which cuts across multiple sectors. Participant 2 (P2) explained:

> It's the single most important weather element that we focus on mostly. […] So if there is rain, the smallholder farmer is able to get his food on the table. If there is no rain, then there is hunger.

Other information used depended on participants' roles, e.g., agriculture specialists were interested in soil moisture, but livestock specialists were not. Participants said they obtained information from numerous sources, though most commonly from climate and meteorology centres – e.g., participants referenced ICPAC and the Kenya Meteorological Department (KMD). Typically, these data were presented as seasonal, monthly, 10-day, and weekly forecasts. Some participants with scientific training used raw data, especially those practitioners providing processed information for use by others. However, participants were mostly receivers of information provided in a processed form at the aforementioned temporal resolutions. Table 2 provides an overview of the information participants discussed.

4.1.2. Decision making and information flow

Participants saw their role as intermediaries within a larger ecosystem, in line with the typical value chain model (Anderson et al., 2015) (see Figure 1). Figure 2 shows a generalised diagram of the types of entities involved in this ecosystem and the flow of information, which we derived from our data. Participants receive data and information from different sources, give it context and meaning with regard to their specific application area. Participants played various roles within this flow, with many contributing to decision making. Some participants stated that they only issued recommendations and advisories, and that it was up to the receiving party to take action. However, we categorised these as decisions informed by climate information.

P3 described this in terms of managing possible disease outbreaks:

> If we see that two or three countries on the same border area receiving higher rainfall, there are particular diseases that are related with that […] So we release a press release that countries

Table 2. Information and sources mentioned by participants.

P	Information types	Sources	Timescale
1	Rainfall	IGAD Climate Prediction and Applications Centre (ICPAC)	Seasonal
2	Rainfall	IGAD	Seasonal, monthly, 10-day
3	Rainfall	IGAD, ICPAC	Seasonal
4	Rainfall, river levels, groundwater levels	National Meteorological Agency (Ethiopia), Kenya Meteorological Department (KMD), IGAD	Seasonal
5	Rainfall	ICPAC, International Livestock Research Institute	Seasonal, monthly, 6-day
6	Rainfall	NASA, CHIRPS (global rainfall dataset)	Seasonal
7	Rainfall, general weather forecasts	ICPAC	Seasonal, monthly, 10-day
8	Advisories from the Greater Horn of Africa Climate Outlook Forum	ICPAC	Seasonal
9	Rainfall, water levels, wind	NASA, CHIRPS, Copernicus (EU Earth observation programme)	Seasonal
10	Rainfall, temperature	ICPAC	Seasonal
11	No specific examples given	Government and international organisation websites	N/A
12	Rainfall, temperature, distance to water sources	Kenya National Drought Management Authority (NDMA), Famine Early Warning Systems Network (FEWSNET)	Monthly
13	Rainfall, temperature	National and county ministries, KMD, media (television, radio)	Seasonal, short-term weather forecasts
14	Rainfall, harvested rainwater	KMD, Ministry of Water and Environment	Seasonal
15	Rainfall	KMD, Kenya Agriculture Sector Development Support Programme (ASDSP), Kenya NDMA	Seasonal, monthly, weekly
16	Rainfall, temperature, agricultural and nutritional advisories	Subcounty Ministry of Agriculture	Seasonal
17	Rainfall, temperature, soil moisture, relative humidity, general weather forecasts, historical trends	KMD, aWhere (private provider)	Semi-annual
18	Rainfall	KMD	Seasonal
19	Rainfall, temperature, soil moisture	Kenya NDMA, KMD	All temporal scenarios
20	Groundwater levels, hyrdogeological surveys	Ministry of agriculture, water and livestock development	Daily
21	Rainfall, temperature, ground and surface water levels, stream flow	KMD, Kenya NDMA, Kenya National Environment Management Authority	Not stated
22	Rainfall, temperature, general weather information	Machakos weather station (Kenya), direct from farmers	Daily
23	Rainfall, temperature, agricultural advisories	KMD, county government Department of Agriculture	Seasonal

'*P*' column denotes participant number.
Note: this only features information that participants specifically mentioned, and so is not exhaustive.

> have to prepare. Prepare in terms of vaccine, like rift valley fever, or some kind of disease will appear.

However, some participants working closer to community level made more concrete decisions and recommendations. P6, a researcher working at both country and community level, described resource allocation based on rainfall information:

> If a country team is trying to make a decision on whether to distribute fertiliser, or whether to advise farmers to apply it, they look at cumulative rainfall up to a certain point in the season to define a yield ceiling, and then determine how much fertiliser is worth applying.

P12, a development consultant, also gave examples of information directly guiding decisions:

> If I'm building a climate resilience program, then the hydrological information that exists, plus the climate information, would help me design. Where would I place a borehole? Which area is in dire need of water?

4.2. Thematic analysis results

The thematic analysis described in Section 3.3.1 produced five latent themes, i.e., themes that go beyond surface meaning to identify underlying ideas. Listed in no particular order: (1) *Collective focus on benefits for end users*; (2) *Appropriateness of information and dissemination is key for impact*; (3) *Trust and acceptance is important at all levels*; (4) *Hierarchy and value chain model allows for decentralised decision making*;

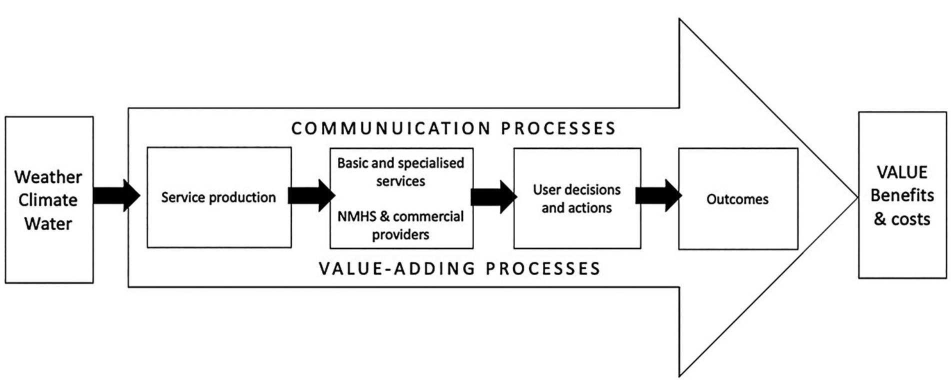

Figure 1. Diagram of the climate services value chain, adapted from Anderson et al. (Anderson et al., 2015).

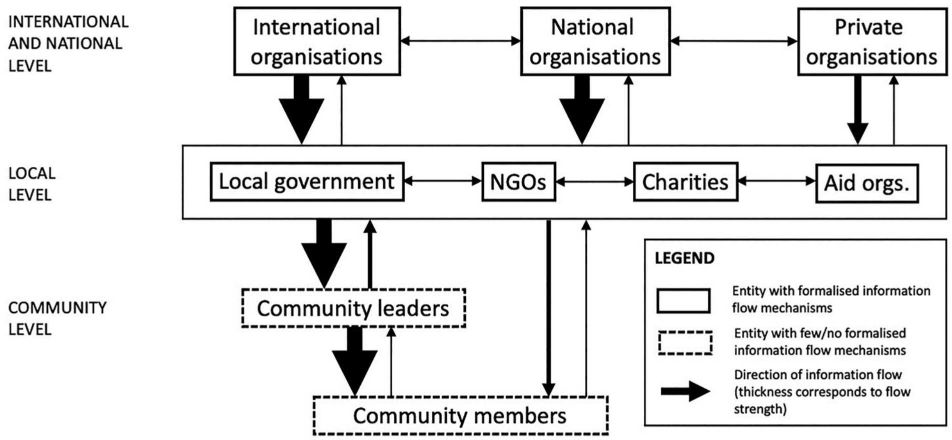

Figure 2. Generliased diagram of entities and information flow derived from our data. Note – this is non-exhaustive.

and (5) *Adapting to and overcoming barriers*. These will be described in turn.

4.2.1. Collective focus on benefits for end users

Though our participants had diverse roles, all were focused on improving livelihoods of communities and protecting them from negative impacts of climate- and weather-related events. Every participant spoke at length about the effects of their work on end-user communities, regardless of their role or level of contact with them. It was common to hear detailed anecdotes of successes and failures of projects that they had been involved with. Interestingly, participants had a strong tendency to talk about their organisation and its overall aims rather than their own personal roles, even when questions were clearly focused on the participant. Thus, the interviewers frequently had to refocus the discussion on the participants themselves. P11 spoke about their concern for those without basic resources:

> We have many, many people who are still being isolated from development for many, many years. They are living very destitute lives. […] My hope, at least, is to let everybody have the basics. […] It's sad when people are asking you for food and people haven't had water for drinking for many, many days.

More positively, participants gave particular focus to intended outcomes and improvements. They generally seemed optimistic about the improvement of systems and services:

> P1: Increasingly we have seen the member states have increased awareness on the use of climate information at national level, at sector level. […] If I look back maybe ten years, fifteen years ago, there is actually more in cooperation of climate information in terms of planning. At least at national level.

P9 spoke about improvements in Kenya, where devolved governmental process has allowed for better administration of funds:

> We have a devolved government, so a lot of resources now going to county level. So they're able to prioritise, provide more support than there is when we had the national government trying to prioritise across many different diverse challenges. So over the recent years, I've seen major improvement in terms of support at the lowest level within the counties.

This concern for individuals and communities could arise for multiple reasons. Firstly, the effects of climate change are more obvious and keenly felt in the GHA region than in many other places, engendering a shared sense of impact. Secondly, farming and pastoralism feature more prominently in everyday life than in other regions. For example, the Horn of Africa (consisting of Djibouti, Eritrea, Ethiopia, Somalia and the self-declared state of Somaliland) is home to approximately 20 million pastoralists (Ginnetti & Franck, 2014). In Somalia and Somaliland alone, 60 percent of the population rely on pastoralism as their main livelihood (Hartmann et al., 2009). In Kenya, the agriculture sector for 60 percent of employment and 51 percent of GDP (World Bank, 2018), with smallholder farms accounting for 78 percent of agricultural production (CIAT and World Bank, 2015). It is therefore likely that our participants have family and friends working in agriculture.

4.2.2. Appropriateness of information and dissemination is key for uptake

Participants were clear that information should be understandable and usable for the intended recipient, and the method of dissemination should be tailored. For example, there would be little point in writing emails to farmers with no internet access or low literacy skills, but it would be very appropriate to reach intermediate-level stakeholders such as local governments or NGOs. To reach other intermediate users, such as local meteorologists or extension organisations, email, phone calls and WhatsApp were considered effective:

> P7: For the monthly forecast, we would send an email to the extension officer. […] And the extension officer pulls these participating farmers one of the days and goes through the forecast very quickly. […] And we found it was cheaper and effective. […] Technology can solve big issues.

Email was widely used and considered effective up to where information needs to be disseminated to communities. P5 spoke about the difficulty of facilitating this 'last mile' of information delivery:

> It's very difficult, actually, to say that all our information has reached the last mile and is used to take preparedness measures. […] Sometimes we are very good in detecting the risks, but reaching to those people which are at risk is still a challenge.

P22, an extension officer, describes how they receive information via email, but then have to conduct community visits to disseminate it further:

> The first thing I do in the morning is to check my email […]. Number two, each and every day I have to meet a group of farmers, so that we can discuss the weather patterns, whatever is the environment, how is everything.

To reach the community level, the best dissemination method seemed to depend on the individual communities. A range of dissemination modes were discussed with participants, and they spoke of efforts to identify the most effective methods. P2 spoke about this:

> When we have pilot projects, we are determined to find out the best way to get information directly to the beneficiary and feed back.

Even with the limitations of participants' individual roles in terms of scope, and the barriers faced, initiative was needed – workers displayed a level of freedom in terms selecting the best methods. P14, a food security specialist, spoke about this responsibility:

> Once the information comes from up there, it lands on my desk, then it is up to me. Now, we need to channel this information down to the community to ensure they have the right information is received, and just ensure that they have understood.

One dissemination method repeatedly mentioned was stakeholder forums, which can occur at regional level, e.g., the GHACOF. P3 described how this mechanism channels climate information from regional to national level:

> Information is released at the regional level, called IGAD Climate Outlook Forum [GHACOF]. And then the national meteorological departments cascade down to the [member] states.

At community level, multiple participants spoke about using chief-led meetings (a *baraza* in Kiswahili) to effectively reach community members. P22 described their effectiveness:

> One of the most effective ways the government uses to transmit information down here is actually through the barazas, which are usually coordinated by the chiefs and the sub-chiefs. So if we can be able to capitalise on the chief's barazas, we can be able to relay the information much better, and the information can be able to reach more people.

Participants said that information format and presentation is also important, and is typically tailored for the intended user. For high-level and intermediate users, a level of scientific understanding can be expected. However, if information is intended for community-level use then it should be simplified. Participants spoke about the difficulty of conveying probabilistic information to end users:

> P2: [The users] don't like this probability thing. They want to say if it will rain or it will not rain.

> P10: That has been our biggest challenge – communicating probability to our users. So when we give out the forecasts, for example, the weekly one, we would say there is a chance or there is a likelihood [of rain]. […] And so that is one of the things that they ask. What do you mean when you say 'likely' or 'there is a chance'?

P6 recognised that helping individuals develop a better understanding of the probabilistic nature of forecasts as a key area of opportunity for improvement:

> Real-time helping farmers understand and respond to emerging opportunity and risk associated with weather would be, we think, a pretty huge opportunity.

The importance of the appropriateness of information and dissemination agrees with previous work highlighting the need to meet the intended users' needs (Bremer et al., 2019; McNie, 2007; Vaughan & Dessai, 2014). However, our findings reveal participants often playing a mediating role, with intermediate information users employing their expertise, judgement, and initiative to identify and implement the most suitable way to communicate and present information to ensure uptake.

4.2.3. Trust and acceptance is important at all levels

Trust in information and providers is important to ensure it leads to action. Participants spoke about how trust needs to be built over time to ensure fruitful relationships with communities:

> P2: Trust is not a one-time event. Trust is built, time by time. When we started this, some decades ago, there was a complete lack of trust in our products.

Such relationships are often built between specific workers and communities through repeated visits:

> P14: Over time, we've built a trust with each other. Because my duty is just working with this community […] the kind of training given to them or the community over time has built […] a lot of trust and confidence in us. Therefore, they normally take that information very positively and act on it.

P23 spoke about how the information source is also important in engendering trust:

> They receive information from credible sources and when I get to the community, they also trust me because am also receiving that information from credible sources, from the government. People usually trust the government results.

Participants spoke about how it is effective to interface with community representatives and opinion leaders. By convincing them that information is authentic and gaining their endorsement, other community members are more likely to trust it. This allows for the community hierarchy to be used for timely dissemination of information. P13 spoke about how gaining the trust of a chief builds trust among the community:

> Involving the chief […] is paramount […]. Once they see the chief, and you are sitting with the chief, and you are saying all this and the chief is there, they actually trust that the information is right and good for them.

Participants also highlighted the importance of incorporating indigenous knowledge and local forecasters. These are well established and trusted in many communities (Radeny et al., 2019; Ziervogel & Opere, 2010), and often in agreement with scientific forecasts according to our participants.

> P2: We have also tried to go through what is common to [the communities] – the traditional way of doing things, which they trust, they follow like a gospel truth.

These findings suggest a ‘trust by association’ phenomenon – associating with trusted entities, and using trusted, familiar concepts such as indigenous forecasting methods increases the chances of information sources being trusted and accepted. This also suggests that interventions from organisations unfamiliar to local communities should be aware of this, and partner with trusted parties. P8 discussed this in the context of mobile phone apps for farmers:

> So if [the farmers] are talking to someone who they trust, then they will trust the information. But, if it’s an app, then there would need to be a lot of groundwork to be done for them to trust the app. […] You need a trustable point of entry. […] They are going to plant based on that information. They will either gain or lose for a full season. So they might not be able to trust an app from the word go.

Trust can be difficult to gain, but is easily lost. Participants discussed how unclear or incorrect information can erode trust with communities:

> P3: You will say that in prediction is that sixty percent the rain of this season may perform above [normal]. You will understand what sixty percent is. Too difficult to explain [to the farmers] what happened to the remaining forty percent, and in most of the time, you will also lose trust. Because you have talked of probability and then opposite happens. [Farmers will say,] ‘okay? Forget about these guys. They’re always talking, it is not happening’.

Incorrect forecasts can also lead to material losses, further eroding trust in future forecasts:

> P13: KMD information says it’s going to rain in this period, and then it does not rain. Especially farmers say, ‘you told me it will rain and I planted my maize. I planted and now I’ve lost’.

Trust in information and providers was also important to our participants in their work. Often, participants were partnered with government agencies and ministries, who were trusted completely. This also trickles down to community level. P23, an extension officer, described how this trust is propagated:

> Local government, the department of agriculture, we trust them a lot. They are our leaders. They receive information from credible sources and when I get to the community, they also trust me because am also receiving that information from credible sources, from the government.

However, some participants who interacted with commercial providers information were wary of its veracity and value due to lack of transparency. P6 spoke of a crisis of trust in commercial providers for this reason:

> With the private sector, we have this difficulty that they’re just trying to sell us stuff and don’t necessarily want to open up the hood. Yeah, we aren’t sure necessarily where to go or who to trust. We know who’s out there. We just aren’t sure who to believe.

P13 also spoke of viewing private entities with suspicion, and reinforced government information as the gold standard:

> We are also bringing [a] meteorologist as a private person. But those ones, we are reluctant in maybe obtaining resources from them. Though, we sit with them, we listen to what they say and try to compare the information the government is giving us and the information they are giving us.

Such caution is justified, as incorrect information or advice can have very real effects on people’s lives. P18 described one such example of information from the private sector:

> We’ve had cases like those ones where they advise farmers based on the marketing information. […] There was this wave of keeping quail birds, which came from, of course, farm business people, and farmers entered into that. Then in the long run, it turned out like it was a big scam.

Again, these findings agree with previous research highlighting the importance of trust and two-way relationships between information providers and users (Adams et al., 2015; Lemos et al., 2012; Tall et al., 2018). Responses from our participants showed that they were acutely aware of the need to develop and maintain trust, and actively used their expertise, judgement and local knowledge to do so.

4.2.4. Hierarchy and value chain model allows for decentralised decision making

The broader climate information ecosystem in the GHA described by our participants was one of information passing through a chain of different parties. As part of this, our participants were aware of the scope of their duties and were reluctant to impose on, or intervene in, the work of others. Their interview responses demonstrated that they are a single component of a larger system, though they were aware of importance of their work and the value of their roles. P9 and P2 described how implementing decisions is outside of their remit:

> P2: We don’t want to do a role which is not ours. As climate scientists, our work ends with research output. But now the good thing we do … Because if you do a good analysis and it doesn’t end up with the end user, it is useless. So we make sure that we partner with some intermediaries, that can make a meaningful outcome out of this analysis. Then we trust them with it, to deliver it to the right stakeholder.

> P9: We do not go into what needs to be done. It’s not [our organisation’s] mandate.

P2 and P9 generally did not work directly with communities, possibly explaining this reluctance to dictate and micro-manage interventions. However, P16, a community-facing project manager, also stressed that they would only advise:

> We normally tell them, ‘You are the solution and you are the decision makers. You bring your problem, then we guide you on how to solve it’. […] We don’t dictate to them.

The value chain model allows for the decentralisation of decision making. While institutions and the working culture within may be hierarchical, decisions related to climate information are typically not made unilaterally but through the confluence of numerous parties. As mentioned above, the GHACOF is an important event to discuss and contribute to the forecast for the coming season and any necessary action. Some of our participants described this process:

> P8: The information that ICPAC produces as the forecast – the seasonal forecast – comes into the GHACOF, where everyone is able to input, digest, and come up with a more user friendly product, that can be easily disseminated and understood at different levels.

> P2: We do what we call a Climate Outlook Forum […] where we bring all scientists, all stakeholders, from these eleven countries

under one roof. Then we discuss the focus, and we discuss the impact and the possible consequences.

Regional Climate Outlook Forums, developed by the WMO, are used around the world to develop and disseminate forecasts, though previous research has questioned their effectiveness (Daly & Dessai, 2018; Gerlak et al., 2020). Nonetheless, participants spoke only positively of the GHACOF.

The value chain model has previously been criticised due to the mismatch between information provided and user needs (Vogel et al., 2019). While co-production processes have been incorporated into some climate services to mitigate these shortcomings (e.g., developing stakeholder networks, interaction and collaboration between stakeholders, iterative design and production processes, and meeting user needs) (Beier et al., 2017; Lemos & Morehouse, 2005) real-world implementation is often ill-defined and messy (Vogel et al., 2019). In our interviews, co-production was mentioned in passing, but there were few concrete accounts of this other than nominally via the GHACOF.

Participants were asked about feedback mechanisms available for end-user communities to facilitate upwards information flow, and mixed responses were given. P11 described the lack of feedback processes in one of their projects:

> The only points of such communication happen when we are on the ground, when [community members] are able to communicate to us and let us know, but we don't have channels where they can reach out to us.

Feedback mechanisms present were typically informal, and often a *post hoc* assessment from users, rather than involving them in the production process:

> P13: Somebody can just greet you and tell you, 'OK, the meeting we held, it was very good for me. And me, I'm doing one, two, three. I've now started constructing a farmer's pond, or even a water tank, and now I want to harvest water from the dam'.

In some cases, assessment and feedback were conducted on behalf of the end users rather than by themselves. Though there are good reasons for this, such as implementing a comprehensive quantitative assessment of programme effectiveness, there is a danger of further distancing community members from stakeholders further up the chain and removing feedback opportunities:

> P16: We developed our charts, […] whereby we've listed all the farmers in the programs, then categorised the water storage, nutritional value, agriculture crop harvesting, the yields that they got in that particular season and so on. So that's where we fill the feedback that these farmer harvested this amount of maybe grain in this particular area that he or she tilled. So, that's what we normally gauge on our input in the community.

On the other hand, P10, a meteorologist and forecaster, discussed how technology can facilitate engagement and feedback:

> We get a lot of engagement with climate information. We also have a lot of criticism. And so we get this on Twitter mostly. So, yeah, it also gives us the opportunity to answer some questions that users have, and they haven't previously had channels to reach us about the specific issues.

While there was some upward flow in the system in terms of feedback mechanisms, these were generally informal, and there was still a much stronger downward flow of information typical of a value chain approach (see Figure 2).

Despite this apparent lack of formal co-production processes, there was evidence of informal negotiation and brokering of information close to community level, which influenced dissemination and acceptance. For example, negotiating with a village chief to obtain their endorsement, or coming to a compromise with local forecasters using indigenous knowledge. Though only at the end of the value chain, this type of two-way relationship is compatible with co-production approach, and presents an opportunity for development into a more robust co-production methodology.

4.2.5. Adapting to and overcoming barriers

Despite difficulties, it was clear that interviewed practitioners were doing their utmost to tackle challenges with available resources. Barriers to effective production and dissemination were often related to institutional capacity. A common concern was a lack of necessary data for effective interventions, leading to a desire for improvements to observational networks:

> P8:A rain gauge or weather station is supposed to cover […] thirty by thirty [kilometres]. But now you have areas that is covering one-hundred by one-hundred […] Then you would be getting people saying, 'you gave a forecast of 'expect rains today in the afternoon', but it did not rain'. But one area rained and another did not rain, within the same one-hundred by one-hundred area.

> P5: There might be some needs in terms of getting products at a much better resolution. […] One thing lacking is maybe the met stations. They are really sparsely populated.

They also highlighted the need for localised forecasts (which could be produced as a result of more localised observations) – participants were working with communities with different livelihoods, located in areas of diverse topography or land use, meaning that regional-, country-, and even county-level forecasts were often too general:

> P4: The climate or the weather of a place is also influenced by the local systems, like the topography of the area and all that. We are not able to do that. So we heavily rely on the global models. So if we can get access of some [at] local level, I think this would be very useful to us.

Moreover, accurate advance forecasts were especially important. Many communities work on seasonal timescales, and therefore need accurate information ahead of time to plan effectively and react:

> P3: The three months forecast can give you an overview, but it's also good to continue providing that information […] maybe two weeks forecast or a month forecast. And so [the forecast] would improve. I know it's difficult for our culture because you really plan for longer term than a ten-day forecast, because you have already taken action.

Participants were asked about desired improvements, both in their own work and to aid communities. P22, an extension officer, was still without basic equipment and resources, but still managing to work despite this:

> If I can get my own laptop, […] which I don't have – I'm making use of my phone […] I can record everything there. […] I used to

> rely on the motorbikes provided by the county, […] but actually assigned to somebody else. So sometimes I have to borrow it to be able to move around. Some of the time, it is really very busy and I cannot use it, so I have to maybe hire or talk to the farmers and get a motorbike to get to them. Number two, I can maybe get an office, get a reliable network whereby I can when I get those e-mails. […] The farmers can be able to reach me conveniently.

The barriers described by our participants ranged from easily solvable to deeply complex. Some can be addressed with more funding and resources and represent relatively easy ways to make improvements, such as providing basic equipment. Others are more difficult to address, such as institutional inefficiencies and sub-standard observation networks. There are also much greater challenges requiring significant political and/or humanitarian solutions that will likely be present for the foreseeable future, such as lack of access to education and political instability. Within the scope of climate services, such problems must often be designed around.

5. General discussion

While we do not claim to present a holistic view of climate services in the GHA, our results give a nuanced picture of practitioners and their use and perception of climate services, perspectives which have often not been a focus of climate services evaluation. Though some of our results are in alignment with prior research, incorporating the type of qualitative interviews in this paper with other evaluation methods can improve validity through triangulation – this can strengthen findings and lead to a more robust evaluation protocol. Prior work has repeatedly identified evaluation of climate services as lacking (Tall et al., 2014; Vaughan & Dessai, 2014). However, this assertion typically focuses on assessing the 'value' produced by these systems, and often in terms of direct benefits to end-user communities, such as those engaged in various agricultural livelihoods (Tall et al., 2014). Though we agree these are important metrics, we argue that there are gains to be made in evaluating all areas of the climate services ecosystem.

Climate services can be viewed as another system of interactions between users and technology, meaning we can apply user-centred design principles and research methods from the field of human–computer interaction (HCI) to design and build more effective systems [Preece et al., 2019, Chap. 2] – i.e., iterative methods that focus on and involve users to ensure their needs are understood and met. This can help to develop a detailed understanding of users and the context of use (the real-world conditions and situations in which a system is used) of climate services, which is integral to fully understand user needs (Bevan, 1999; Maguire, 2001) [Preece et al., 2019, Chap. 1]. Furthermore, prior research has advocated for transdisciplinary approaches to climate services research (Daniels et al., 2020; Owen et al., 2019). By taking a human- and user-centred approach, we can better support users at all levels, leading to greater efficiency for decision makers and ultimately better outcomes for those most reliant on these services. This approach draws parallels with the philosophy of co-production of climate services (e.g., participatory design methods). However, it differs in that it focuses on designing systems for specific users, rather than incorporating different stakeholders in various stages of knowledge production (though does not preclude it). A review of climate services by Vaughan et al. (2018) found that fewer than half of the studies examined mentioned specific user groups, and even fewer involved the users in any stage of development, despite the frequent calls for stakeholder cooperation through co-production. This therefore suggests employing user-centred processes an area for improvement.

Our interviews gave only a rough overview of decision making and how it incorporates different climate information and services. Though participants spoke about resource allocation and advisories being affected by environmental conditions, the details were not clear and the intricacies of the decision making process remain something of a black box. This presents opportunities for further research – in-depth focus on practitioners' particular tasks or decisions could develop a more detailed understanding of the exact mechanics and processes of their work, where it could be broken down into the required steps, information, and expertise necessary to perform their work tasks. By understanding these processes in detail, we can better understand how to support this work, e.g., with decision support tools. This is supported by prior research, which recommends taking a process-based and decision-driven approach (Beier et al., 2017; Daniels et al., 2020; Vincent et al., 2018). The *contextual inquiry* method from HCI could be used to achieve this, whereby the researcher interviews participants during their work activities in their workplace setting (Holtzblatt & Jones, 2017).

This research highlights that the value chain model is still the norm for climate services in the GHA, despite criticism calling for a less producer-driven approach (Vogel et al., 2019) and efforts to incorporate co-production principles. A strong downward flow of information was described, with little opportunity for feedback and expertise to meaningfully travel back upwards. Feedback from end-user communities was typically informal and *post hoc*, without systems in place to react to it in a timely and actionable manner. Nevertheless, participants working directly with communities displayed a high level of awareness of the needs of different communities with whom they worked, established through longstanding, trusted relationships. These personnel seemed to have the opportunity to use their initiative and react to situations and opinions on the ground, and freedom to use different resources to solve problems. Hence, though a relatively fixed value chain delivered information to end-user communities, there was some form of co-production at the point of use, where community-facing workers engaged with community members to decide how best to use and disseminate information and advice. We suggest that these informal processes could be incorporated into more formalised co-production processes – interaction with end users could be improved and expanded, and the initiative and detailed local knowledge of community-facing stakeholders could be better exploited.

While incorporating co-production is often seen as the ideal destination for climate services, implementing this in entrenched cultural, political, and socio-technical systems is nontrivial. However, facilitating a more agile system in the interim would surely be beneficial. This may be possible by making more use of dialogues with intermediaries, practitioners who interact with decision makers, rural communities, and climate service providers. For example, more simple mechanisms to allow feedback and experiences to travel back up through the system could be effective and relatively straightforward, and could give way to fully-fledged co-production methods in the future.

6. Limitations

Many of our participants primarily focused on Kenya. This potentially limits the generalisability of our findings to the wider GHA region, as each country has distinct institutional structures and processes, with differing levels of capacity. Despite sub-optimal availability of scientific data in Africa (Dinku et al., 2018), Kenya has a relatively well-developed observation network and telecommunications infrastructure, as well as relative political stability. This makes it a popular research location, leading to consistent improvements. However, for 11 of the 23 participants Kenya is not their sole focus, and many worked for regional organisations that seek to build capacity across the wider GHA region.

Participants spoke at length about the effects of their work on end-user communities. However, we could not conduct fieldwork to elicit community members' opinions directly due to Covid-19 travel restrictions. Remote interviews were not feasible due to technology and telecommunications difficulties, and probable language barriers. We also encountered difficulty in recruiting participants in community-facing roles, such as extension officers – as discussed, they were often without basic equipment and reliable internet access. They were also unlikely to be listed on organisational websites, making them less discoverable remotely. However, using local contacts and allowed us access to these individuals, e.g., participants 22 and 23.

These limitations could be examples of technological amplification, whereby technology – in this case, climate services and their development – magnifies pre-existing inequalities (Toyama, 2011). This leads to some voices going unheard and benefiting less from improvements. To mitigate this, we hope that community-based, 'last mile' research will be feasible as the Covid-19 travel restrictions ease, so that we can hear from these users directly. Also, building partnerships with local organisations can facilitate access to underrepresented groups to ensure their needs are considered.

7. Conclusion

We interviewed 23 practitioners who work with climate and weather information in the GHA to better understand the roles, needs, and motivations of intermediate users of climate services, as well as how information flows and is used within these services. This revealed a complex system of actors and stakeholders involved in the production and use of climate services, and also drew attention to the many barriers. Thematic analysis of the interviews gives us a nuanced view of the climate services ecosystem and a better understanding of intermediate users. These findings can inform the design and evaluation of climate services going forward, through a better and more detailed view of the motivations and needs of these users, their work and the challenges they face. We also argue that a greater understanding of practitioners and the broader climate services ecosystem (rather than a single service) can be established using qualitative methods, which could be used more broadly in this space to deliver more robust evaluation processes and allow us to further understand how different services and users interact.

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