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Using a Climate Change Risk Perceptions Framing to Identify Gaps in Climate Services

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Given the rise in climate services for decision-making, it is important to understand whether these services are meeting the context-specific needs of decision-makers, including identifying any gaps in current climate services. This study sets out to investigate the efficacy of current climate services provision in east Africa through the lens of climate change risk perceptions. Risk perceptions have established relationships with important aspects of the decision context and have been shown to influence the kinds of information people use in making decisions, therefore, an understanding of how elements of risk perceptions relate to climate services use can provide valuable insights for enhancing climate services. Using this premise, the relationships between determinants of climate change risk perceptions and the use of climate services information are explored through a combination of statistical survey analysis and qualitative interview analysis. The analysis revealed three main gaps in climate services in east Africa. These gaps include the lack of long-term climate change projections disseminated through National Meteorological Services (NMS), limited locally ground-truthed delivery of impact-based forecasts and the requirement for specialist capacity to use some complex climate services. Filling these gaps will require enhanced collaboration between the NMS, other providers of climate-related information (such as research institutes) and the practitioner and user communities in order to facilitate the coordinated delivery of locally ground-truthed impact-based forecasts, facilitate capacity development across the user-producer spectrum and augment the role of the NMS as conduits of climate change information.

Keywords: climate services, climate change risk perceptions, Africa, evaluation, climate risk

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INTRODUCTION

Climate variability and change represent a significant threat to developing countries, disproportionally more so than to developed countries (IPCC, 2014). Given this threat, there is a growing need to plan for climate change. This need has resulted in the rapidly growing field of climate services (Hewitson et al., 2017; Vogel et al., 2019) that, at the fundamental level, seek to provide weather and climate information that is useful for informed planning.

Alongside this escalation in climate services is a burgeoning literature base that attempts to evaluate the quality and effectiveness of currently-available climate services for Africa (e.g., Vaughan and Dessai, 2014; Vaughan et al., 2016, 2018; Carr and Onzere, 2018; Tall et al., 2018). Evaluating current climate services has two main purposes. First, it allows for the design and

delivery of currently-available climate services to be improved so that they are better aligned to the individual user decision context (Steynor and Pasquini, 2019). Second, evaluations allow for the identification of pitfalls or gaps in the currently available climate services in relation to the specific user needs (the focus of this present study).

Evaluations of climate services have been useful in informing recommended changes to climate services in the past. For instance, at the continental scale, a comprehensive evaluation of the offerings from selected National Meteorological Services (NMSs) in Africa informed a set of recommended interventions for strengthened climate services provision (Winrock International, 2018). The evaluation framework developed as a result of this work forms the basis for regular World Meteorological Organisation evaluations for international reporting purposes (Dinku et al., 2018a; Cullmann et al., 2019). At the country level, an evaluation of climate services in Malawi revealed that major barriers to the use of climate information (particularly the use of climate change projections) was the incomprehensibility of the climate information and the lack of consensus amongst different climate information sources (Vincent et al., 2017). The evaluation recommended the development of a national set of climate change scenarios to make long-term information more accessible to policy users. This recommendation led to the development of a national climate brief which outlined historical climate trends and future climate projections (Mittal et al., 2017).

While these examples provide a snap-shot of the utility of evaluations in informing climate services, the evaluations literature, to date, has been largely focused on evaluating individual project offerings through user consultations, surveys, independent audits or website statistics of use (Vaughan et al., 2018). In augmenting these traditional techniques, new methods for evaluating climate services are needed, especially if they have the potential to identify gaps in climate services that may not be uncovered by these traditional evaluations.

On this basis, this study (i) demonstrates the efficacy of an evaluation approach based on statistical (quantitative) analysis, supported through qualitative interpretation, as a methodology for evaluating current east African climate services and (ii) identifies gaps in the current east African climate services landscape. While mixed qualitative/quantitative methods are already recommended in the evaluations literature (Tall et al., 2018), the approach presented here is novel because it utilises individual climate change risks perceptions as a conceptual framing.

Climate change presents a significant risk at both an individual and societal level. There is preliminary evidence to suggest that the perceptions of climate change risk are heightened in the African context, where climate change is considered to be impacting society already (Selormey et al., 2019; Steynor and Pasquini, 2019; Steynor et al., 2020b, 2021; Simpson et al., 2021). Climate change risk perceptions have established relationships with important aspects of the decision context that influence the use of climate services. For instance, climate change risk perceptions have been shown to influence both willingness to act on climate change (Spence et al., 2012; Lo and Chan, 2017; Smith and Mayer, 2018; Xie et al., 2019) and actual action on climate change (Blennow et al., 2012; Fahad and Wang, 2018; van Valkengoed and Steg, 2019). Heightened risk perceptions have been shown to increase an individual's information seeking behaviour (Kahlor, 2007) and the desire for climate information amongst natural resource planners when acting on climate change risk in the workplace (Peters et al., 2018). The perceived proximity of a risk has also been shown to influence the kinds of information people use in making decisions (Brügger et al., 2016). For instance, if climate change is perceived to be happening already then decision-makers may focus less on long-term climate information. Instead they may focus on trying to address climate change with short-term climate information that offers them concrete information such as potential short-term impacts (Steynor and Pasquini, 2019). Therefore, climate change risk perceptions are a useful conceptual framing with which to evaluate the fit of currently available climate services, because the types and timescales of information used within the decision context vary depending on perceptions of climate change risk.

Climate change risk perceptions are influenced by several underlying determinants (van der Linden, 2015; Steynor et al., 2021), for example social norms and experience of extreme weather events (amongst others). Given the role that climate change risk perceptions play in influencing the use of climate information in decision making, each of these risk perception determinants should also be considered when utilising a risk perceptions framing because they may also be reasonably expected to have an influence on the types of climate information used in addressing climate change-related risks. Therefore, exploring how each of the determinants of climate change risk perceptions relate to climate information use is proposed as a way of gaining insight into the climate services information use landscape and, in turn, what is currently missing from the landscape.

To this end, this paper begins with an introduction to the existing landscape of climate services in east Africa, as the region of study (Section The Existing Landscape of Climate Services Provision in East Africa). This presentation of the existing landscape is followed by the methodological approach for exploring the relationship between determinants of climate change risk perceptions and the current landscape of climate services information use (Section Methods). Section Results and Discussion presents the statistical results and qualitative analysis. Finally, Section Filling the Gaps in Climate Services for East African utilises the insight gained to identify current gaps in east African climate services and offer potential solutions for filling these gaps.

THE EXISTING LANDSCAPE OF CLIMATE SERVICES PROVISION IN EAST AFRICA

Climate services encompass a wide range of activities associated with the production, tailored delivery and uptake of weather and climate information into decision-making (Vaughan and Dessai, 2014) as well as the associated user engagement and capacity development (Vincent et al., 2018). In the present study we

focus principally on the information provision component of climate services.

While it is important to draw a distinction between weather and climate information, the line between the two is somewhat blurred in the climate services space, primarily because, in order to provide a seamless information product for decision-making, it is important that information on both weather and climate timescales operate together (Tall, 2013). Further, products such as historical observations and trends of weather are essential for informing the production of numerical weather prediction models as well as climate models. This interconnectivity has led the World Meteorological Organisation to adopt a framing of climate services that includes consideration of all timescales of information from historical observations through to climate projections data (e.g., Cullmann et al., 2019, 2020). For the purposes of this study, therefore, we have adopted this comprehensive framing of climate services.

We focus this section on the current actors in the climate services provision space, and the types and timescales of available information, for the Greater Horn of Africa (hereafter referred to as east Africa) with particular focus on the countries of Ethiopia, Kenya, Rwanda, Tanzania and Uganda (as our study's focus countries). This section draws on review of the literature and on review of each country's online offerings through their NMS (**Table 1**).

Climate Services in East Africa

The provision of climate services in east Africa are supported by several internationally-funded research and implementation programmes. These programmes range from short-term research and practise-based interventions (such as the Weather and Climate Information Services for Africa programme) to sustained development solutions (such as the Famine Early Warning Systems Network). In addition, the World Meteorological Organisation-affiliated regional centres, namely the African Centre of Meteorological Applications for Development and the Intergovernmental Authority on Development Climate Predictions and Application Centre (ICPAC) provide focused regional support (Ngari et al., 2016). The latter (ICPAC) has a specific mandate to focus on addressing the east African regional challenges associated with climate risks (Percy et al., 2021). To this end, ICPAC disseminates weekly, monthly and seasonal forecasts at the region scale as well as rainfall and crop monitoring products[1]. ICPAC also has regional climate modelling capacity allowing for modelling of longer-term climate change projections (Percy et al., 2021). ICPAC is instrumental in convening the Greater Horn of Africa Climate Outlook Forums (GHACOFs) which allows for collaboration between regional, national and international climate experts in developing national seasonal forecasts (Cullmann et al., 2019; Percy et al., 2021). The GHACOFs are attended by representatives from each of the NMSs in the region as well as sectoral representatives and users.

[1]https://www.icpac.net/

Climate Services at the National Level

The primary mechanism for delivery of climate services at a national level is through each country's respective NMS (Singh et al., 2018), who are the mandated national authorities for provision of climate services (Hansen et al., 2019). While we recognise that each NMS is complemented by various public and private (both non-profit and profit) sources of climate services, these sources are too numerous to document here. Examples of these additional sources include private sources such as a Where (Ngari et al., 2016) or tailored climate services provided through ministerial bodies, such as the Ministry of Health or Agriculture (Kadi et al., 2011). Given the complexity of the national landscape, our country-level review is focused on the online climate service offerings provided by each of the five country's NMSs (**Table 1**). This focus is justified given the prominent position occupied by the NMSs as the authoritative climate services provider in each country.

The sale of observational data (**Table 1**) is a common financial model replicated by NMSs across Africa (Hansen et al., 2019). It a vital mechanism for supplementing the income of the NMSs and, in turn, supporting their sustainability as a national service (Hansen et al., 2019). A recent initiative that sought to improve the availability and equitable access to historical information was the Enhancing National Climate Services initiative (Dinku et al., 2018b). Through a collaborative approach between the International Research Institute for Climate and Society at Columbia University with each NMS, the project enabled access to satellite-derived reanalysis products through map rooms hosted by each NMS (Dinku et al., 2018b). This satellite-derived data can act as proxies for observational data for some applications (Dinku et al., 2018b) providing a potential alternative to station observation data. The map rooms hosted at each NMS (**Table 1**) and at the ICPAC regional centre are a legacy of this initiative and provide a foundation for the addition of further services based on the emerging user need (Dinku et al., 2018b). To this end, training was provided to NMS staff on how to create and maintain the map rooms (Dinku et al., 2018b).

Beyond observational data, the main focus of east African NMSs is on short-term forecasts (daily to seasonal forecasts) (**Table 1**). African NMSs work closely with each country's respective disaster management authorities in leveraging these short-term forecasts to provide early warning advisories of extreme weather events, where possible (Cullmann et al., 2020). In addition, when compared to other regions in Africa, east Africa has a reasonably strong base of impact-based forecast information on the daily to seasonal timescales (Nkiaka et al., 2020). It should be noted, though, that impact-based forecasts currently focus, primarily, on the national or regional level and at daily, weekly to seasonal timescales (**Table 1**).

While the literature documents ready access to longer term information in the region (including climate change projections) (Singh et al., 2018) these are not provided by any of the five country's NMSs and are, almost exclusively, provided by international sources such as the Intergovernmental Panel on Climate Change (IPCC) and the Coordinated Regional Downscaling Experiment (CORDEX), amongst others (Hansen et al., 2019). Ethiopia is an exception in this regard, with

TABLE 1 | Climate services offered to the public by each country's National Meteorological Service (NMS) (collated through an online review of each NMS's website, undertaken in May 2021).

	Ethiopia national meteorological agency	**Kenya meteorological department**	**Rwanda meteorological agency**	**Tanzania meteorological authority**	**Uganda national meteorological agency**	**Synthesis commentary**
Observed data	✓ Daily data available for purchase. Map room containing historical climate analyses	✓ Daily data available for purchase. Map room not operational	✓ Daily data available for purchase (with exceptions for research and government contractors). Map room containing gridded reanalysis/satellite datasets as well as climatological averages	✓ Daily data available for purchase. Map room containing gridded reanalysis/satellite datasets as well as climatological averages	✓ Daily data available for purchase. Map room not operational	All NMSs facilitate the purchase of daily observational (station) data. This data is not freely available, with the exception of Rwanda where free access to observational daily data can be obtained for use in research or for civil infrastructure. All NMSs host "map rooms", however, at the time of the review, two of these map rooms were not operational. The map rooms provide access to gridded reanalysis data and satellite data in Rwanda and Tanzania. The map rooms also offer access to additional historical climate analyses, such as Malaria risk in Ethiopia, Rwanda and Tanzania.
Daily to weekly forecasts	✓	✓	✓	✓	✓	The focus of the NMSs is on short-term forecasts from days to seasons. Most of the seasonal forecast bulletins also provide high-level advisories for chosen sectors within each country
Monthly forecasts	✓	✓	✓	✓	✓	
Seasonal forecasts	✓ Includes sectoral impact advisories for health, agriculture and water	✓ Includes sectoral impact advisories for: agriculture, food security and livestock; environment and natural resources; disaster management; health; transport; water and energy	✓ Includes broad-scale impact advisory (not sector specific)	✓ Includes sectoral impact advisories for: agriculture and food security; livestock and fishery; tourism and wildlife, transport; energy, water and mineral; local authorities; health; disaster management; media	✓ Includes sectoral impact advisories for a selection of: agriculture; livestock; fisheries; forestry; health, water and energy; works and infrastructure	
Separate sectoral advisories (including impacts information)	✓ Health, agrometeorological and hydrometeorological bulletins. Map room: Historical Malaria risk, historical and future water conditions and historical analysis of climate variables relevant to agriculture	✓ Bio and agrometeorological bulletins. Map room not operational	✓ Agrometeorological bulletin. Other sectoral services for purchase Map room: Historical Malaria risk, historical analysis of climate variables relevant to agriculture, climate summaries for local governments	✓ Agro - and Hydrometeorological bulletin. Restricted access aviation forecasts. Other sectoral services for purchase Map room: Historical Malaria risk.	✓ Restricted access aviation forecasts Map room not operational	All NMSs provide some broad sectoral advisories as stand-alone bulletins, with the level of detail dependent on the individual NMS.
1–5 year projections	X Not available	X Not available	X Not available	X Not available	X Not available	None of the NMSs provide climate information beyond the seasonal timescale
Climate change projections (5 years or further into the future)	X Not available	X Not available	X Not available	X Not available	X Not available	

The final column presents a synthesis interpretation of the similarities across each of the NMS offerings.

an in-country dedicated Ethiopian Panel on Climate Change established by the Ethiopian Academy of Science to provide a country level interpretation of the IPCC fifth assessment report (Ethiopian Panel on Climate Change, 2015).

It is within the context described above that we position our current study. We seek to understand how well this landscape of climate services actors and provision of information matches the current needs of climate services users at the policy level.

METHODS

The study employed an explanatory sequential mixed-methods approach (Creswell and Creswell, 2017). This approach starts with quantitative analysis and then builds on the results of the quantitative analysis to explore and explain them through qualitative research. This mixture of quantitative and qualitative approaches recognises their complementarity but also their differential explanatory power for answering specific research questions.

As a framing, our study uses the model introduced by Steynor et al. (2021), which offers an east African framework for identifying and prioritising the various determinants of climate change risk perceptions that motivate action on climate change in the workplace of policy decision influencers. The Steynor et al. (2021) model includes the following climate change risk perceptions determinants: observance of social norms, the psychological distance of climate change, experience of extreme weather events, personal values (both self-enhancing and self-transcending values) and the socio-demographic variables of age, gender and education. Each of these risk perception determinants are further explained in Section Survey Measures.

Design and Participants in the Survey

Following the target community defined by Steynor et al. (2021), we focused our research on policy decision influencers in east Africa, as the frequently targeted recipients and users of climate services. Policy decision influencers, in this context, were defined as individuals who are able to influence natural resource policy and would be expected to use climate services in this regard. For instance, policy decision influencers included national and local government officials (71% of the sample), academic researchers, non-governmental organisations (NGOs), private enterprise, international development agencies and parastatals (organisations owned by the government). An evaluation of climate services amongst this group is important because it is comprised of individuals who have the authority to influence local and national planning around climate variability and change.

Data to inform the study were collected through 474 surveys (a participant response rate of 77%) with policy decision influencers in the five east African countries of Ethiopia, Kenya, Rwanda, Tanzania and Uganda (hereafter referred to together as "east Africa") between September 2018 and January 2019. The minimum number of country surveys collected was 49 (Uganda) and the maximum number was 138 (Kenya). Relevant policy decision influencer organisations in the region were identified through a consultative exercise with stakeholders at an earlier project workshop and specific respondents at each organisation were identified based on the criterion that they would be expected to use or benefit from the use of climate services in their role.

The surveys were administered in English by trained enumerators in each country. Each survey was conducted in-person, with the exception of the section on individual values, because of its potential to be subject to social desirability bias. The values section was completed by the respondent themselves, independent of the enumerator, in order to minimise this potential bias. Participants took part in the survey on a voluntary basis and were granted anonymity through a consent form. The final sample consisted of 29.7% females and 70.3% males with an average educational attainment of an undergraduate university degree and an average age of 30–39 years.

Survey Measures

Brief descriptions of each of the survey measures are included here. More detailed descriptions of each of the risk perception determinant survey measures are included in Steynor et al. (2021).

Observance of Social Norms

Social norms refer to the external expectations on an individual to behave in a certain way and are generally understood to be unwritten rules or standards set by a social group (Popenoe, 1983). Social norms have been shown to have a strong influence on human behaviour at home and in the workplace (Inoue and Alfaro-Barrantes, 2015), including influencing pro-environmental behaviour (Doherty and Webler, 2016).

Six survey items were included to measure the observance of social norms for action on climate change and use of weather and climate information at work amongst this group. Three questions measured descriptive norms (what most people around them do) and three measured prescriptive norms (what most people around them approve of). The responses to the survey were measured on a five-point Likert scale from "strongly agree" to "strongly disagree".

Psychological Distance of Climate Change

Psychological distance is a measure of the perception of a threat as either far away or near (Pahl et al., 2014). It is measured on four dimensions, namely how close a threat is socially (the threat to oneself or ones social group), spatially (the geographical proximity of the threat), temporally (whether the threat is happening now or in the future), and hypothetically (the certainty of the threat) (Trope and Liberman, 2011). Previous studies have demonstrated a relationship between the psychological distance (closeness) of climate change and perceptions of climate change risk, i.e., the more psychologically close climate change is, the more it is perceived as a risk of concern (Spence et al., 2012).

The psychological distance of climate change was measured using seven survey items covering each of the four dimensions of psychological distance. These survey items were based largely on those proposed by Spence et al. (2012) and included two questions on social distance, two questions on spatial distance, two questions on hypothetical distance and one question on

temporal distance. Responses were recorded on a five-point Likert scale from "strongly agree" to "strongly disagree", apart from the question related to temporal distance which was measured on a five-point Likert scale of "never" to "the effects are already being felt".

Experience of Extreme Weather Events

Previous experience of extreme weather events have been shown to increase climate change risk perceptions because experience renders the potential impacts of climate change more real or tangible (Akerlof et al., 2013; Demski et al., 2017). Experience of extreme weather events were measured through four items in the survey, namely how often, in the past 5 years, participants had experienced (i) floods, (ii) droughts, (iii) high temperatures/heat events, and (iv) changes to the rainy season pattern. Responses were captured on a five-point Likert scale from "very often" (more than ten times) to "never".

Values

Values are defined as core beliefs or standards that guide ones attitude, priorities and behaviour (Rokeach, 2008). Broadly, values can be grouped into four higher-order categories including self-transcending values (a focus outside of oneself for the greater humanitarian good), self-enhancing values (a focus on the prosperity and achievement of oneself), conservation (a focus on maintaining the current situation and traditions) and openness to change. In this study, we focussed on self-transcending and self-enhancing values, which have both been shown to have a relationship with perceptions of climate change risk. Self-transcending values have been linked to higher climate change risk perceptions (Poortinga et al., 2011, 2019), whereas self-enhancing values have been linked to lower climate change risk perceptions (Smith and Leiserowitz, 2012).

Values were assessed in the survey by using the Schwartz (2003a) 21-item Portrait Values Questionnaire and responses were recorded on a seven-point Likert scale from "very much like me" to "not like me at all". Using guidance from Schwartz (2003b), the responses were converted to centred scores and the two higher-order values of self-transcending values and self-enhancing values were extracted for use in the analysis.

Demographics

Demographics such as age, gender and education have all been shown to have a relationship with climate change risk perceptions (van der Linden, 2015). Therefore, demographic data including age range (in 10-year bands from 20 to 29 onwards), educational attainment (highest qualification) and gender were collected in the survey.

Types of Climate Services Information Used

One survey item was included with respect to what climate services information types are currently being used for decision-making. Survey participants were asked to select all weather and/or climate and/or impact information they currently use for their job. Choices included observed weather data (i.e., historical records), daily to weekly weather forecasts, seasonal forecasts (3 months), 1–5 year projections of climate, projections of climate 5 years or further into the future and impact-based forecasts. Impact-based forecasts were described as including, for example, forecasts of dam levels, of crop yields, of river levels, of climate-related disease outbreaks, etc. Responses were coded as a binary variable of use vs. non-use for each information type.

Trust in Sources of Information

In order to assess the participant's most trusted source of climate services, participants were asked to rank their top three most trusted sources for receiving climate services information. Choices included: university scientists/other research scientists, government scientists, representatives of national government, representatives of local/regional government, politicians, the country's NMSs, independent companies that provide weather and climate information (for example AccuWeather), friends and family, environmental consultants, non-governmental organisations (NGOs), community leaders, television, radio, newspapers or other. Responses were recorded on a ranking schedule from first to third trusted source.

Interview Design and Participants

In order to further explore the findings from the survey, a set of in-depth semi-structured interviews were conducted in two countries in the region. While interviews are an effective way of gaining a deeper understanding of quantitative findings (Baxter and Jack, 2008), it was only possible to conduct interviews in two countries, due to resource and time constraints. Therefore, although there are many socio-cultural and political similarities across the region, it should be acknowledged that the interviews would not have captured subtle nuances from the other three countries. The interviews took place in the countries of Kenya and Ethiopia during August and September 2019, respectively. Interviews were conducted with 20 participants in Kenya and 16 participants in Ethiopia (a total of 36) with eight participants from national government, three from local government, three from the private sector, seven from NGOs, two from international development agencies, five from parastatals and eight academics/researchers. No incentive was offered for participation and each interview lasted ∼1 h. The interview cohort consisted of a range of respondents that spanned the same sectors and similar organisational affiliations as the survey respondents and were identified through introductions or by approaching relevant organisations. Care was taken to ensure an equitable gender balance in interview respondents and all interviewees were assured of confidentiality.

The interviews covered a range of topics of relevance for further understanding the survey findings. Of importance to the present study, the interviews sought to gain an understanding of what climate services information types were being used, what facilitated or hindered their use, from where that information was obtained and what it was used for. All interviews were recorded and transcribed.

Analyses

For the purposes of analysing and presenting the quantitative regional survey results, the data from each of the five countries were aggregated together to represent the "east African region". This decision was justified due to the homogeneity in the types

of climate services information used across all the countries. These similarities were likely a result of the region experiencing similar climate risks, having similar products available from their respective NMSs (**Table 1**) and receiving joint regional support from mechanisms such as ICPAC and the GHACOFs.

The quantitative data from the survey was statistically analysed in SPSS Statistics 26 to ascertain the relationship between each climate change risk perception determinant and the current use of each climate services information type in decision-making (described in Section Survey Measures above). Robust statistical analysis requires 10 participants for each included parameter (Schreiber et al., 2006), therefore the sample size of 474 more than adequately met the minimum criteria of 140 participants.

The non-parametric Mann Whitney *U*-test was chosen for the analysis because of the Likert scale nature and non-normal distributions present in the risk perceptions data. As the only categorical variable, the relationship between gender and climate services information use was analysed with Chi-Square analysis.

The qualitative data from the interviews were coded through a multi-step process in NVivo. First, the data were deductively coded into broad pre-defined categories of interest related to climate services information access and use, such as the use of the different types and timescales of climate information, barriers to the access and use of climate information, source of climate information, etc. Through repeated subsequent coding processes, these categories were then further sub-divided into sub-categories representing repeated ideas or patterns in the responses arising from the data. These sub-categories were used to detect consistent overarching themes in the data, providing further understanding and explanation of the statistical findings.

RESULTS AND DISCUSSION

Results of the Statistical Analyses

For the purposes of this study, only statistically significant results (ρ-value < 0.05) were taken as relevant for identifying the relationship between risk perception determinants and the current use of climate services information types. Therefore, while tests were performed for all combinations of risk perception determinants and information types (**Table 2**), only statistically significant results (presented in bold) are further interpreted in the final column of the table. The Chi-Square analysis revealed no statistically significant differences in types of climate services information used between the two genders.

Qualitative Results and Discussion

The semi-structured interviews allowed for further exploration, in two countries, of the statistically significant relationships between individual drivers of climate change risk perceptions and the use of climate services information types in the regional survey. The qualitative results and discussion are presented per climate change risk perception determinant.

The Relationship Between Observance of Social Norms and the Use of Climate Services

The statistical analysis of the regional survey revealed that observance of social norms for climate change action and use of climate services information at work was higher amongst those who used seasonal forecast information than those who did not (**Table 2**). The interviews provided insight into the reasons why this relationship between observance of social norms for climate change action and the use of seasonal forecast information may have existed. The interviews revealed that planning along seasonal timescales was considered to be part of taking action on climate change, thereby encouraging the use of seasonal forecast information in acting on climate change. This understanding was revealed when respondents were asked to provide examples of how they were planning for climate change: 13 respondents provided examples of addressing climate change through interventions aimed at coping with climate risk on a seasonal basis, a proportion greater than the number providing examples of taking action on climate change on any other timescale. For instance, when asked about expectations to prepare for climate change in job activities, one national government respondent provided an example of climate change action by saying they needed to provide advice to farmers on how to deal with inadequate rainy seasons.

> *"Yes* [there is a strong expectation on us to prepare for the impacts of climate change] *because most of our farmers out there are relying on rain-fed agriculture. So, they need directions from the specialists, that is like our ministry here, to give them the best way forward, in the event that the rain is short, it's not adequate to see the crops through the season."* Respondent K9, national government, Kenya

If taking action on climate change is conflated with taking action on the seasonal timescale then it would make sense that those who have a higher observance of social norms for action on climate change would also report the use of seasonal forecasts in taking action.

Despite this focus on the seasonal timescale, a few respondents ($n = 5$) acknowledged that this type of seasonal response mode was not a holistic approach to adaptation planning, and it meant that there was limited consideration of longer-term climate change information in climate change planning/action. This was demonstrated by a respondent from local government who stated that they had not used longer-term climate information, but he believed that it would be good to use it for resilience planning.

> *"The nature of our activity has not taken us there. But I want to believe that it will be good if we can see what the weather is going to be in the future, so that we, as a county, are able to do long-term planning... so that you can be able to prepare for the city to be resilient."* Respondent K14, local government, Kenya

One respondent explained the focus on the seasonal timescale by saying it resulted from agriculture being a sector of priority economic importance.

> *"Of course we know the government should be planning with the long-term climate information, but if you look at the priority areas*

TABLE 2 | *r*-values (bold where ρ-value < 0.05) of the Mann Whitney *U*-tests between risk perception determinants and current use of climate services information types.

***N* = 474**	**Observed data**	**Daily to weekly forecasts**	**Seasonal forecast**	**1–5 years projections**	**>5 years projections**	**Impact-based forecasts**	**Interpretation of statistically significant relationships**
Observance of social norms for action on climate change and using weather and climate information at work	0.08	0.08	**0.14****	0.07	0.08	0.04	Observance of social norms was greater for those who used seasonal forecasts (Mdn = 23; Mean rank = 251) than for those who did not (Mdn = 22; Mean rank = 211), $\rho = 0.003$.
Psychological distance	0.02	0.01	0	0	0.05	0	
Experience of extreme weather events	0.04	0.05	0.01	0.02	0.01	**0.11***	Reported experience of extreme events was higher amongst those who used impact-based forecasts (Mdn = 13; Mean rank = 257) than those who did not (Mdn = 12; Mean rank = 227), $\rho = 0.022$.
Self-enhancing values	0.07	0.05	0.01	0.05	**0.11***	**0.22****	Self-enhancing values were lower amongst those who used projections further than 5 years into the future (Mdn = −0.58; Mean rank = 209) than those who did not (Mdn = −0.38; Mean rank = 246), $\rho = 0.013$ and lower for those who used impact-based forecasts (Mdn = −0.62; Mean rank = 197) than those who did not (Mdn = −0.31; Mean rank = 260), $\rho = 0.000$.
Self-transcending values	0.09	0.06	0.01	0.02	0.07	**0.13****	Self-transcending values were higher amongst those who used impact-based forecasts (Mdn = 0.58; Mean rank = 261) than those who did not (Mdn = 0.43, Mean rank = 224), $\rho = 0.005$.
Education	**0.11***	0.06	0.06	**0.14****	**0.19****	**0.14****	Level of educational attainment was higher amongst those who used observational data (Mdn = 3, Mean rank = 250) than those who did not (Mdn = 3, Mean rank = 222), $\rho = 0.018$, amongst those who used 1–5 year projections (Mdn = 4; Mean rank = 264) than for those who did not (Mdn = 3; Mean rank = 226), $\rho = 0.002$, amongst those who used projections of further than 5 years into the future (Mdn = 4; Mean rank = 283) than those who did not (Mdn = 3; Mean rank = 224), $\rho = 0.000$, and amongst those who used impact-based forecasts (Mdn = 4; Mean rank = 262) than those who did not (Mdn = 3; Mean rank = 224), $\rho = 0.002$.
Age	0.06	0.09	0.02	0.01	**0.11***	**0.10***	Those who used projections of further than 5 years into the future (Mdn = 2; Mean rank = 265) were older than those who did not (Mdn = 2; Mean rank = 229), $\rho = 0.013$, and those who used impact-based forecasts were older (Mdn = 2; Mean rank = 254) than those who did not (Mdn = 2; Mean rank = 228), $\rho = 0.035$.

$^*p < 0.05$, $^{**}p < 0.01$.

like agriculture, then they tend to look for seasonal forecasts." Respondent K1, NGO, Kenya

Agriculture is of high economic importance in many African countries (Nkiaka et al., 2019; Carr et al., 2020) and, as such, is a primary focus for policy decision influencers. This importance was demonstrated through the interviews in which 26 respondents cited impacts on agriculture or farming when providing examples of climate change impacts. Agriculture is particularly sensitive to seasonal climatic patterns such as variations in the onset and cessation of rainfall, droughts and prolonged heat events (Adhikari et al., 2015). For instance, heat stress during development and flowering of a crop can cause poor crop quality and yield (ibid) and planting during a false onset of the rainy season can result in lower yields or the need to replant the entire crop (Lala et al., 2021).

With agriculture as a primary economic focus, it is likely that the seasonal planning timescale became the predominant planning timescale because, as explained below by the same NGO respondent as above, planning on the seasonal timescale enables interventions in the agricultural sector, providing tangible economic outcomes and benefits to policy decision-makers within their typically short-term policy planning cycles.

"A season is very small and if I am told rains will come then you take action, and you will reduce certain losses or increase the yields then it is short term and the outcome is likely to be realised in the foreseeable future. But when you start talking of long term, then some people will not be keen, especially from the political level... they are interested in the next five years, when they are sure of being in the office, so they want to do things within that time frame." Respondent K1, NGO, Kenya

This focus on short-term policy planning cycles was a factor noted by 9 interview respondents, therefore it is likely that the focus on agriculture, together with the need to demonstrate tangible impacts within policy planning cycles, is an influential factor behind the focus on seasonal planning as the predominant planning horizon. However, as the policy planning cycles can be anything up to 5 years, the policy cycles do not fully explain why projections longer than seasonal are not used more in planning. The interview results suggest that there may be a further reason for the predominant use of seasonal information in climate change planning.

When asked about their main sources of climate services information, 28 respondents said they obtained this information primarily from the NMS, with 13 stating that the NMS was the mandated or authoritative source of climate services information for the country. This finding aligned with the results from the regional survey which found that the NMS was the most trusted (first rank) source of climate services information by 59.5% of participants (**Supplementary Figure 2**). However, the longest timescale of forecasts currently provided by the NMSs in the region are seasonal forecasts (**Table 1**), meaning that those receiving their information from the NMS would not have access to projections longer than the seasonal timescale.

Lack of accessibility to longer-term climate projections was cited as a barrier to use of this information by 8 respondents, suggesting that despite the scientific literature documenting ready access to longer-term climate information outside of the NMS (Singh et al., 2018), its use is limited because of the prevalent role that the NMS plays in information dissemination at the national level. For instance, one respondent stated that he did not use longer-term projections because he didn't know where to get them, despite demonstrating that he believed he ought to know where to get them as a specialist in his field.

"*We are not using that* [long term projections]. *We don't have the access, even I don't know where to get that kind of information.*" Respondent E13, NGO, Ethiopia

Additional barriers to the use of longer-term climate information also emerged from the interviews. These included difficulty in understanding the longer-term projections and/or how to use them ($n = 9$) and a distrust of longer-term climate information because of its inherent uncertainty or the evolving nature of the science ($n = 7$).

This section's analysis of the relationship between social norms and the use of climate services suggests that the lack of longer-term climate projections provided by the NMSs, together with limited trust and capacity to use longer-term information, are potentially posing structural barriers to the uptake of longer-term climate information into planning, thus potentially further reinforcing the seasonal timescale as the predominant planning time horizon. This highlights a potential gap in the provision of accessible climate services, particularly if the climate services community wish to promote the use of longer-term climate information in planning.

The Relationship Between Experience of Extreme Weather Events, Values, and the Use of Climate Services

The statistical analysis of the regional survey found reported experience of extreme weather events to be higher amongst those who used impact-based forecasts when compared to those who did not use impact-based forecasts (**Table 2**). Experience of extreme events can evoke strong emotions, making the events memorable and concrete, often associated with vivid negative consequences (Loewenstein et al., 2001; Weber, 2006). Furthermore, experiences of extreme weather events have been shown to play a role in bringing climate change psychologically closer (Steynor et al., 2021) thereby influencing how individuals mentally construe climate risk (Reser et al., 2014) and, in turn, the types of information they use to act on the risk (Trope and Liberman, 2011; Brügger et al., 2016). When in a mental processing mode associated with a risk that is construed as psychologically close, individuals seek out concrete, actionable information (Brügger et al., 2016).

Considering all interview respondents ($n = 36$) recalled at least one recent extreme weather event that impacted negatively on the region, it makes sense that greater experience of extreme weather events might lead them to use impact-based forecasts, which are likely to provide the kind of concrete, actionable

information required in this mental processing mode. A local government official explicitly linked his experience of specific past extreme weather events to the desire for future impacts information to support planning, particularly around similar events, by saying:

> "[W]*e usually look at what kind of impacts we anticipate; what kind of losses will occur. And when we are seeking information, we also start thinking what kind of information is necessary so that we are able to avert such events, that is in terms of preparedness. Some of these areas where we have previous experiences, for example, flood-prone zones, we also start thinking this has been a problem for us, but moving in the future, what we want to do so that it doesn't happen* [again]." Respondent K14, local government, Kenya

The regional survey results also revealed self-transcending values to be higher, and self-enhancing values to be lower, amongst those who used impact-based forecasts. As these values lie in opposition to each other, their relationship with the use of impact-based forecasts is not surprising and can also be explained through the different ways these groups may construe climate risks. Those with predominantly self-transcending values (the majority of this cohort), who, by definition, have a more outward-facing awareness of the world around them, being motivated to help others and the environment, might therefore be more aware of climate risks and the associated impacts experienced by communities and ecological systems. This awareness might translate to a state of construal that leads them to seek concrete, impact-based information to mitigate the potential for future impacts. The hypothesised link between the use of impact-based forecasts and this cohort's outward-facing desire to help wider society was found in 10 of the interviews. For instance, a national government official linked the use of impact-based forecasts to the need to provide government assistance during periods of drought.

> "*If it was a drought, and we need to get maybe livestock feed or we need to know how to take care of people in those areas... part of the information that we prepare is possible impacts of that weather forecast.*" Respondent K9, national government, Kenya

While the survey revealed that impact-based forecasts were used by 36% of policy decision influencers (**Supplementary Figure 1**), the interviews revealed a mismatch between the readily available impact-based forecasts and those suitable for local application by the user community, with 15 respondents reporting that they generated their own impact-based forecasts based on the information received from the NMS. For instance, a national government official in Ethiopia noted that, while the NMS did provide impact-based forecasts, this information required further strengthening through ground-truthing with local information in order to be applicable to the local decision context. This ground-truthed information was produced in-house.

> "*The met*[eorological] *people are trying to give that* [impacts] *forecast. But the detailed one is prepared here, with ground information. So, we are using that ground information, so we can strengthen the information that we get from the met*[eorological] *office."* Respondent E14, national government, Ethiopia

Given the prominence of the NMS as a source of climate services information (Section The Relationship Between Observance of Social Norms and the Use of Climate Services), this mismatch between the readily available impact-based forecasts from the NMS and what is required for on-the-ground decision-making revealed a potential shortcoming in the current delivery of impact-based forecasts.

Finally, the regional survey analysis found that self-enhancing values were lower amongst those respondents who used long-term projections (projections of climate further than 5 years into the future) than among those who did not. This relationship was more difficult to explain through the interviews, especially as respondents did not openly report self-enhancing tendencies (which may be perceived as undesirable). However, speculative reasons for this relationship can be drawn from the literature. Those with higher self-enhancing tendencies tend to have a lower engagement with climate change and are less concerned about it (Corner et al., 2014). On this basis, it can be hypothesised that those with high self-enhancing values would be less likely to engage with long-term projections of changing climate, primarily because of their lower engagement with climate change. Therefore, this may then explain why the respondents using long-term projections of climate change have lower self-enhancing values.

This section's analysis of the relationship between experience of extreme weather events and the use of climate services revealed a gap in the provision of climate services with regards to the delivery of decision-relevant, locally ground-truthed impact-based forecasts. As decision makers are likely to continue to seek concrete, actionable information to address the impacts of climate change going forward, the enhanced provision of impact-based forecasts is likely an important area of focus for climate services improvement.

The Relationship Between Education, Age, and the Use of Climate Services

The statistical analysis of the regional survey revealed that the level of educational attainment was higher amongst those who used observational data, 1–5 year projections, projections of further than 5 years into the future and impact-based forecasts (**Table 2**). All of these information types were used less than daily/weekly forecasts or seasonal forecasts by the regional survey respondents (**Supplementary Figure 1**). An understanding of the reasons behind their lower use provides insight into their relationship with educational attainment.

Starting with the use of longer-term information (1–5 year projections and projections 5 years or further into the future), the interviews revealed that reasons for not using longer-term information included: difficulty in understanding the longer-term projections and/or how to use them ($n = 9$), lack of accessibility ($n = 8$), and a lack of trust in the longer-term climate information ($n = 7$) (Section The Relationship Between Observance of Social Norms and the Use of Climate Services). Of these reasons, the difficulty in understanding longer-term

projections and their use would seem to be the reason that best explains why respondents who use these types of information are the most educated respondents. It seems reasonable to suppose that the relationship between the use of longer-term information and higher educational attainment would be explained by the potential for education to provide the required capacity to access, understand and interpret this information.

With regards to observational data, the interviews highlighted a requirement for specialist capacity for pre-processing or filling incomplete datasets before they could be useful. The skills required to pre-process incomplete data are often acquired through higher educational attainment. For instance, a senior hydrologist with a Masters degree noted that he had to pre-process observational data from the NMS before he was able to use it:

> "*This climate information we got from the National Meteorological Agency, there is a lot of data gaps... so, we have to prepare it, we have to fill it. It is difficult to fill the data gaps.*" Respondent E4, private sector, Ethiopia

The same requirement for specialist capacity can be applied to explain the relationship between the use of impact-based forecasts and educational attainment. As evidenced in Section The Relationship Between Experience of Extreme Weather Events, Values, and the Use of Climate Services, many of the impact-based forecasts were produced in-house in response to specific user needs. As noted by a respondent from Kenya, the ability to generate these in-house forecasts or advisories requires specialist knowledge.

> "*When you look at the seasonal forecast, they* [the NMS] *will give you some* [impact] *advisories, but I find that these advisories could apply in any season, anytime, anywhere... So, a lot of people have to interpret the forecast for themselves. The extent that is possible also depends upon capacity, knowledge.*" Respondent K5, NGO, Kenya

The statistical analysis also revealed that those who used climate projections of further than 5 years into the future and those who used impact-based forecasts were older than those who did not. Unfortunately, the age of the interview respondents was not recorded, so it is not possible to explain the relationship between age and the use long-term climate information and impact-based forecasts through the interviews. However, a speculative reason for the existence of these relationships may be that older policy decision influencers have, through experience, come to appreciate the limitations of planning based on short-term information alone and have also come to understand the added value that impact-based forecasts might provide them for planning.

This section's analysis of the relationship between education and the use of climate services revealed that the specialist knowledge required to use some climate services is potential posing a barrier to their uptake.

FILLING THE GAPS IN CLIMATE SERVICES FOR EAST AFRICAN

The analysis of the intersection between climate change risk perception determinants and the use of climate services provided useful information in understanding and explaining current climate services use. The analysis also allowed for the identification of potential gaps in the services supply landscape. These gaps are noted below, alongside recommendations for responding to them.

The Need for Provision of Longer-term Climate Projections Alongside Short-term Forecasts

The extent to which short-term information is used by policy decision influencers emphasises the need to continue providing short-term information for decision-making. However, it was revealed that there was limited use of longer-term information among policy decision influencers, despite some recognition that they should be using it. One reason for this limited use seems likely to be due to the gap in provision of longer-term climate information from the NMSs, who are the mandated and trusted information source in each country.

To support the uptake of longer-term, particularly climate change information, into planning, the NMSs could be encouraged to act as conduits for climate change projections while continuing to provide shorter-term information. This provision of longer-term climate information may begin with simple messages around the direction of change of future climate (for example from the United Nations Framework Convention on Climate Change national communication documents) and move towards developing an approach that integrates both short-term weather forecasting and longer-term climate change projections into a continuous forecast of the future (Singh et al., 2018), also known as seamless forecasting.

While integrating longer-term information into the NMS offerings seems a straightforward recommendation, it is acknowledged that anything beyond very simple messages, such as the direction of change of future climate, requires additional staffing resources and capacity (Winrock International, 2018). NMSs in the region are already notoriously underfunded and understaffed and lack the institutional legacy of capacity that some of the NMSs in developed countries have (Winrock International, 2018). Therefore, to achieve this seamless forecasting approach, opportunities lie in strengthening the international and in-country collaborations between, for instance, universities, the private sector and the NMSs, in order to draw on a range of national and international expertise in tailoring longer-term information for specific users, as well as providing guidance to ensure their robust use. However, while this kind of collaborative approach has been widely supported in the literature (e.g., Winrock International, 2018; Cullmann et al., 2019), the siloed culture of national institutions at present (Winrock International, 2018) is a hindrance to this type of collaboration, presenting a barrier that would need careful consideration in overcoming. An initial step towards

overcoming this barrier may be to embark on developing memorandums of understanding between institutions for data sharing and collaborative working or to leverage the burgeoning development of the National Climate Services Frameworks (under the Global Framework for Climate Services) to establish sustained collaborative engagement platforms.

The Need for Enhanced Delivery of Impact-Based Forecasts

While it is evident that east Africa is more advanced in the delivery of impact-based forecasts than some other parts of Africa (Nkiaka et al., 2020), there is still scope to improve the delivery of impact-based forecasts so that they incorporate more locally-specific detail. Through enhanced collaboration and coordination between, for instance, the NMS, other suppliers of climate-related information (such as research institutes and regional bodies), sectoral experts and indigenous knowledge holders there is scope to enhance the delivery of these impact-based forecasts so that they are locally ground-truthed, providing information that is more relevant for local decision-making.

Building on the mandate and authority of the NMS, as the central source of climate services information, the NMS and ICPAC map rooms provide potential for hosting these impact-based forecasts, as is currently the case for historical Malaria risk in Rwanda and Tanzania (**Table 1**). However, at the time of this review, the map rooms of the Ethiopian National Meteorological Agency and the Kenyan Meteorological Department were not functioning, which confirms the need to carefully consider the sustainability of any suggested intervention at each NMS. The establishment of a strategic oversight group within each NMS to both coordinate donor funding and lobby government for sustainability funding would likely assist in this process.

The Need for Building Capacity, Trust, and User-Focused Climate Services

The analysis revealed that specialist knowledge is required to use some climate services such as observational data, impact-based forecasts and longer-term information. With particular respect to longer-term information, limited trust in the information was also cited as a barrier.

Previous literature has commonly offered user capacity development as a solution to increase the use of complex climate information (e.g., Jones et al., 2015; Vincent et al., 2017; Singh et al., 2018; Hansen et al., 2019; Nkiaka et al., 2019), because, as highlighted in this research, higher educational attainment has a relationship with the use of some of the more specialist climate services information types. The push towards capacity development has led to a growing number of tailored and targeted short courses to enhance the use of climate services in Africa. As an additional form of capacity development, the current research suggests that mentorship between senior (older), more qualified, and junior (younger), less qualified members of staff may encourage the use of climate change projections, as it was found that older respondents were also more likely to use longer-term information.

However, while user capacity development is undoubtedly one part of the solution, the onus should not be placed solely on the users of climate services to increase their ability to use complex information. There is a reciprocal need for capacity building amongst the providers of climate services to enable them to produce usable information. This requires that the climate services producers gain a better understanding of the complexities of the user decision context (Jones et al., 2017; Müller et al., 2020), understanding what constitutes usable as opposed to useful information (Lemos et al., 2012) and how to effectively communicate climate services information in a way that maximises uptake and use (Daron et al., 2021).

Similar to the recommendations for further collaboration made in Section The Need for Enhanced Delivery of Impact-Based Forecasts, enhanced collaboration and knowledge exchange between climate services providers, intermediaries and the users of climate services are an increasingly recognised way of enhancing the utility and use of climate services information (Steynor et al., 2016, 2020a; Jones et al., 2017; Done et al., 2021; Vincent et al., 2021). These transdisciplinary collaborations have also proved to be effective ways of building trust relationships which, in turn, create trust in the resulting climate information (Vincent et al., 2018).

CONCLUSION

This study introduced a climate change risk perceptions approach for identifying the current gaps in climate services information available in east Africa. Three main gaps have been elucidated, namely the lack of longer-term climate information disseminated through NMSs, the limited delivery of ground-truthed impact-based forecasts and the limited capacity to understand, trust and use complex longer-term climate projections. While none of these gaps are surprising, the seemingly central role played by the NMSs in driving information use is important to note and could provide a valuable leverage point for increasing the use of climate services.

In addressing these gaps, a future vision for climate services in east Africa may include an approach that is premised on the enhanced collaboration between the NMS, research institutes and the practitioner communities in developing a community of practise that would facilitate the ready access to longer-term climate projections and locally-relevant impacts information. This enhanced collaboration would also provide the framework required to build capacity across the climate services community (between producers, practitioners and users) in the robust supply and uptake of climate services into decision-making. Under the auspices of each country's National Framework for Climate Services, the NMS could act as a central point or champion for this community, thereby providing a critical role in connecting the community and acting as a conduit for the dissemination of decision-relevant information, including longer-term climate change information.

While this vision appears a simple suggestion, a collaboration such as the one described above would require significant changes in the current operating culture in the region. While

some partnerships do exist, enhanced collaboration on the scale recommended here would likely be constrained due to lack of financial or personnel resources (Winrock International, 2018). Therefore, there is a need for further research to understand the cost-benefit trade-offs between focusing limited funding resources primarily on the advancement of decision-relevant products or focusing resources on the enhancement of networks and collaborative arrangements that underpin the development of these products. Given the growing need to adapt to a changing climate, this is a question that needs careful consideration within the current funding landscape.

DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available because much of the data includes identifiable information that would invalidate the anonymity granted to the participants. Requests to access the datasets should be directed to AS, asteynor@csag.uct.ac.za.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by University of Cape Town Faculty of Science Research Ethics Committee. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

AS conceptualised, executed the research, and drafted the paper. LP intellectually contributed to the execution of the study as well as reviewed and contributed to the draft paper. Both authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fclim.2022.782012/full#supplementary-material

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