Exploring the Information Needs of Somaliland Pastoralists: Design Considerations for Digital Climate Adaptation Services

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ABSTRACT

Pastoralists in Somaliland are suffering the impacts of climate change, and need relevant, timely, and practical information about water resources and pastures. However, these communities are sparsely distributed and distant from decision-making centres, which impedes rapid dissemination of climate-related information that could allow them to build resilience to climate impacts. Although smartphone adoption rates are low, mobile services are widespread across Somaliland, presenting opportunities for supporting communities through mobile technologies. We interviewed 30 Somali pastoralists to understand their climate information needs, access to technology, and the potential for technology support. We also conducted a focus group with four Somali development experts to explore the cultural context and possible impacts of different design choices. Our results highlight and explore tensions around different design directions, and suggest possible ways to mitigate these. Designing systems that navigate such considerations can contribute to much-needed climate resilience for pastoralist communities in Somaliland and beyond.

CCS CONCEPTS

• **Human-centered computing → Human computer interaction (HCI)**.

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KEYWORDS

East Africa, mobile phones, ICTD, ICT4D, HCID, HCI4D, rural computing, climate change, climate resilience

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1 INTRODUCTION

Climate change presents great challenges for dryland regions, especially in communities where livelihoods are tied to the consistency of seasonal rainfall. In the drylands of East Africa, drought is a major threat to rainfed agriculture and available pastureland for livestock. Climate change is projected to increase drought frequency and severity in the region [19, 33, 35], causing not only humanitarian emergencies, but ongoing disruption to lives and livelihoods, increased risk of conflict [25, 40, 64], and even the displacement of local communities [20]. The resilience of such communities can be improved through proactive adaptation to the changes they face. Central to climate adaptation are climate services providing timely information about upcoming seasonal rainfall. However, rural dryland communities tend to be sparsely distributed and distant from decision-making centres — this can impede systematic dissemination of climate information, and make such communities difficult to access for those designing and planning systems to support this. Among communities in East Africa, those in Somaliland are one of the most difficult to access and hence have their needs underrepresented in the literature on climate services.

Somaliland is an autonomous state within Somalia located in the Horn of Africa, with a population of approximately 5.7 million. Somali people are highly dependent on the land: about 60% are nomadic or semi-nomadic pastoralists who raise and herd livestock [52], which accounts for 23% of the GDP [60]. From a climate impacts perspective, Somaliland has suffered multiple episodes of drought, food shortage and famine in recent decades [19]. Due to the direct reliance on the consistency of seasonal rainfall, pastoralist livelihoods in Somaliland are facing tremendous challenges under frequent droughts and climate change [34], such as limited access to grazing lands, longer and more distant journeys to find pasture, declining herds, and fluctuating market prices [20, 25]. Somaliland presents a valuable socio-environmental landscape for exploring the possibilities offered by technology-based climate services: although livelihoods are predominantly rural, due to the so called "leapfrog effect" (i.e. the adoption of the latest version of a technology without going through its earlier stages), telecommunication services are rapidly growing [6].

In Somaliland, there is a confluence of remote rural livelihoods closely dependant on climate, devastating consequences of drought and the need for adaptation, the importance of timely climate information, and possibilities offered by mobile technologies. Therefore, in this paper we explore the information needs and decision making processes of Somaliland pastoralists in relation to climate adaptation, and the potential for digital technology to play a role in supporting this. We present two studies conducted by an interdisciplinary team of researchers from the UK and Somalia. First, we describe a qualitative study based on interviews with pastoralists within Somaliland, which focused primarily on the existing ways in which they access climate and weather information, availability of digital technology, and barriers and opportunities with regard to its use. Next, we present a focus group discussion with four Somali development professionals which further explored how decision-making takes place in pastoralist communities, offered a more detailed and nuanced understanding of how these communities are changing, and explored tensions that designers need to negotiate when developing digital services for such communities.

Our results highlight several considerations for designers when developing climate change adaptation services for rural populations. First, new services should be compatible with community decision making practices rather than purely individualistic ones. Second, designers should promote inclusivity and sharing to ensure the equitable provision of information, even among those who may not have direct access to technology. Third, designers should be mindful of existing power structures within communities, and how new systems might reinforce or challenge these. Fourth, designers should be mindful of the enormous value placed on trust, and how they can build this trust in a new system to ensure uptake. Finally, designers should be cognisant of the many changes that rural communities are currently experiencing, and how these may affect ongoing user needs. We discuss these considerations in detail and provide suggestions on how designers could work with pastoralist communities in Somaliland and beyond to develop climate adaptation services and other tools that support climate resilience.

We make several contributions to HCI that will support the design of technology-based climate adaptation services. To the best of our knowledge, this paper presents the first study of the availability, use of, and attitudes to technology (and other means) to gather climate information in Somaliland pastoralist communities. It also provides insight into how decision-making takes place in these communities, and how technology could be integrated into this process. Finally, it identifies opportunities and tensions that face the designers of digital services working with such communities.

2 BACKGROUND

Currently there is a lack of literature on Somaliland climate adaptation, despite the region suffering from regular droughts and the serious consequences that can follow [1]. Over the last decade, political instability and conflict in the region have impeded travel and research activities in Somaliland (and Somalia), and the climate information needs in this drought-impacted state are not well understood. As mobile phone adoption rates are high in the region [45, 47, 53, 76], mobile-based services present an opportunity to develop applications for information dissemination to the whole population, including communities from remote areas. In the following sections we discuss access to mobile phones in rural communities, climate services in East Africa, and resources available for pastoralists. Where possible, we provide details focused on Somaliland, but where this information is not available we use information from neighbouring countries to provide context while being mindful of the differences.

2.1 Mobile phones in rural communities

Mobile phones are widely used in rural East Africa [69] and thus are a suitable tool for sharing climate related information. In Somalia, about nine in ten Somalis aged 16 or over own a mobile phone [45, 52], although smartphones have been banned in areas controlled by Al-Shabaab militants [27, 30]. There are no publicly available smartphone usage statistics for Somaliland, but it is known that the Internet and telephone coverage reaches approximately 95% of the country [6].

Despite the popularity of phones and widespread use of micro payments in Africa (e.g. Zaad in Somaliland [6, 45] and M-Pesa in Kenya [42]), the quality of devices or available services is low. For example, a study conducted with smallholder farmers in Kenya and Zambia showed that due to frequent unsolicited advertising, people saw mobile services as unreliable [74]. Moreover, low-quality counterfeit handsets meant that people found older mobile phones more reliable, as newer models were less durable, had low-capacity batteries, and were rarely fixable by mobile phone repairers [74]. People in rural areas also experience issues with lack of airtime credit, worn-out or cheap replacement phone batteries that do not retain charge, and limited access to charging points [75]. To be able to use the phones, they develop several battery preservation approaches, which means that the devices are not always available. For example, many people avoid using their phones for activities that drain the battery (e.g. games, alarms) [75] or keep phones switched off to preserve battery [74].

Another issue that limits access to mobile phones in rural East Africa is literacy, including basic literacy (reading and writing skills), English language literacy, and technology skills [13]. In general, people mostly use their phones to make calls [13] as sending a text message requires a steep learning curve [73]. For example,

some languages in Kenya (e.g. Swahili, Bukusu, and Luo) do not lend themselves to texting as they are characterised by imprecise spellings and long words [73]. The low levels of literacy are also an issue in Somaliland [46, 54] and Somalia [61], where main languages are Somali and Arabic. Moreover, navigating menus in English and switching between letters and other symbols on feature phones can be confusing and often deters users [73]. All this makes dissemination of climate information challenging.

2.2 Climate services in East Africa

To improve the resilience of communities to the impacts of climate change, climate services are used across Africa to provide information about upcoming seasonal conditions [65]. Due to the reliance on rainfed agriculture and pastoralism in East Africa, rainfall projections are extremely important for informing agricultural decision making, such as timing of crop planting, moving animals to pasture, and general drought preparedness [16]. A key part of climate services provision in East Africa is the Greater Horn of Africa Climate Outlook Forum (GHACOF), one of the World Meteorological Organisation's (WMO) Regional Climate Outlook Forums [48] which produces objective and user-relevant climate outlooks. In many East African countries, national meteorological services provide seasonal rainfall forecasts for their region and share with their governments and other organisations [28].

In Somalia and Somaliland, the implementation of climate services differs from other countries due to a lack of formalised Meteorological Services [17]. However, capacity building continues to strengthen available climate and weather information provision, such as through the Food and Agriculture Organisation's *Somalia Water and Land Information Management* (FAO SWALIM) programme [67]. In Somaliland, the government relies heavily on FAO SWALIM's updates [67], who work with the Disaster Management Authority and Ministry of Agriculture to provide climate services. To reach community-level users, the information is shared via TV, radio and community representatives. For instance, during drought or flood seasons, SWALIM partners with *Radio Ergo* which reaches more than 4 million people across Somalia and Somaliland [17]. FAO SWALIM also has a SMS early warning service called *Digniin* (Somali for "warning") [15], used to warn vulnerable communities about floods and other events through registered community representatives who inform others upon receipt of information [17]. However, the scale and coverage of this system is not known.

Although there is an existing provision of climate services, there are barriers to their uptake [44]. In the context of agricultural end users, there is often a disconnect between the information provided and the information farmers and pastoralists need [39]. This mismatch has been recognised in climate information services research, and has been termed a "usability gap" [32]. This is often the result of simply attempting to fill a knowledge deficit without fully understanding the recipients' needs, which ultimately may not lead to effective action [66]. Furthermore, official information (e.g. from the government) is often very general and not relevant at a local level [39], while local communities require more detailed information and often rely on indigenous knowledge (e.g. lunar cycles, behaviour of animals, appearance of plants or clouds) to inform their decisions [4, 39]. These issues can lead to low adoption rates of existing services and interventions aimed at farmers and pastoralists.

2.3 Resources for pastoralists

Pastoralists across East Africa need to make decisions on where to graze animals in response to climate impacts, such as flooded rivers or drought-stricken pastures [10]. These decisions affect livestock health, with knock-on consequences for food security, and longer-term sustainable livelihoods. As such, many pastoralists are willing to pay to access relevant information [76]. Machado et al. [36] found that providing pastoral communities with maps showing the condition of vegetation and water sources is positively received and can lead to improved animal condition, though must be provided consistently and reliably to maintain uptake.

As smartphones become widespread, services aimed at rangeland livelihoods have appeared [68]. However, these are few in number, and fewer still are developed for East African pastoralists. A particular example is the AfriScout mobile app, developed by Project Concern International [51] and co-designed with pastoralists. The service provides geospatial information about pasture status (similar to the paper maps in Machado et al. [36]), helps to estimate the distance to new grazing locations, and allows people to share information (e.g. adding information about wild animals, conflicts or disease to the maps) [14, 31]. Another available mobile app is MyAnga, a weather app that also provides expected moisture and drought conditions [21, 71]. At the time of writing, MyAnga was being piloted in Kenya [71]. While the AfriScout and MyAnga apps appear to have been successful, there are no apps designed specifically for pastoral communities in Somaliland — perhaps due to the lack of research in the area and limited access to smartphones.

Though there are mechanisms for delivering information and services to rural communities, there are barriers preventing access. While web services and apps aimed at pastoralists exist, they are not widely available. Furthermore, when rural communities do have access, they may not possess the literacy skills to understand and use the advice [55] and, as discussed earlier, low levels of literacy are common. These limitations mean that if pastoralists do use technology — commonly feature phones — it is not to access specific services, but to exchange climate-related information with each other [10]. Therefore, the most trustworthy and reliable information is shared between family members and friends. Other studies also highlight similar issues with trust, e.g. among Samburu pastoralists in Northern Kenya [5].

Moreover, despite technological advancements, research from poorer regions in Kenya shows that poor and ultra-poor pastoralist communities do not benefit from these new developments [3], even though these are the communities that need reliable information the most as they do not have resources to bounce back after disasters (e.g. after losing their livestock due to droughts). Therefore, a service aimed at the poor communities could provide beneficial information to the most remote, disconnected and vulnerable parts of the population.

To better understand how such as service could be designed, a team of UK and Somali researchers and development professionals co-designed and conducted two studies. We conducted 30 face-to-face interviews with pastoralists from Somaliland and a workshop

with four Somali development experts. We describe both studies in the following sections.

3 LOCAL AND CULTURAL CONTEXT

In Somalia and Somaliland the clan system of patrilineage is a major feature of society that affects local decision making [56], and though Somaliland has moved towards a more contemporary party-political system, clan-based governance still features heavily [23, 56]. Leadership and governance is dominated by men, and women are marginalised — families are typically headed by men, and elder males are respected as leaders, law enforcers, and decision makers [22]. In rural areas, allegiances to a clan, sub-clan, and further group subdivisions majorly influence relationships and interactions with different pastoralist groups, and are used to govern access to resources such as water and pasture. Furthermore, governance and law enforcement is usually in the context of the *xeer* system of customary laws, which is particularly important in rural areas for resolving grievances [22].

In addition to exclusion from decision making, women's access to technology also appears to be limited in Somaliland, in turn limiting access to important climate and weather information. UNICEF Somalia [62] report that only 3.4% of women aged 16-24 from rural areas reported "ever using Internet"; only 2.5% reported using it in the last 12 months. However, the survey was conducted in 2011 and did not include questions about mobile devices and there are no newer data available. Similarly, literacy amongst women in East Africa is lower than men [18]. In Somaliland, less than half of primary school age children receive primary care education, and girls are less likely than boys to attend schools [46, 54, 61]. School systems are also ill-suited for nomadic lifestyles, which further impedes access to primary education [46, 54]. This lack of education may mean that many women would not be able to effectively make use of technology and climate information, even if they had better access it.

3.1 Researcher positionality

This project is a collaboration between UK and Somali researchers, led and funded by UK research institutions. We therefore acknowledge the different authors' positionality in this research. The Somali authors are employees of Transparency Solutions, a Somali social enterprise that is committed to Somali-led social change, and acts as an interlocutor between international organisations and local people. The UK-based researchers are European and based at well-resourced universities. While they approached this project with an open mind and an appetite to learn more about rural Somali communities, they likely bring their unconscious biases and typical Western perspectives on how research should be performed. Biases may also arise from holding Western secular liberal values, when the communities being engaged with are religious and socially conservative. Furthermore, the UK's historical role as a colonial and military power in East Africa may influence power imbalances when interacting with collaborators and research participants. The Somali authors therefore provided important guidance and knowledge on how to counter these, as well as in-depth domain expertise that helped co-create research appropriate to the local context. They also performed the data collection in Study 1, meaning that they had the only face-to-face contact with participants in that study. Study 2 was conducted online and while it was facilitated by an UK researcher, the Somali co-authors were involved in the planning, participant recruitment and the workshop discussions.

4 STUDY 1: INTERVIEWS WITH PASTORALISTS

The pastoralist way of life, gender roles and access to technology need to be considered when developing services for these communities. The 20 million pastoralists in the Horn of Africa are from a range of cultural and ethnic backgrounds, with particular needs based on their location and specific livelihoods. These factors influence how they access and use information. Therefore, in this study, we sought to better understand the climate change information needs of pastoralists in Somaliland, and to explore the potential for technology to support their decision making within the context of their cultural and societal norms. The study was co-designed by Somali researchers and UK researchers, and conducted by two Somali researchers.

4.1 Method

4.1.1 Site selection and ethical considerations. We selected the pastoralist regions Balligubadle, Sallaxley and Bandarwanaag (see Figure 1) due to their proximity to Hargeisa where our researchers are based, allowing return travel within one day. The selected rural communities were extremely poor and the pastoralists interviewed had very little food. Pastoralist households are often moving, but individuals travel to small community or village centres to trade goods, food, or water; we conducted the interviews at those small gathering centres. In Somali culture, gift giving is customary when meeting — whether it involves formal interviews or informal conversations. Therefore, interviewees received rice and water supplies worth around $15 for participating, which covers subsistence for approximately 10 days.

Performing research in Somalia and Somaliland presents challenges, especially for foreign researchers. Political instability and the presence of terrorist groups has resulted in many governments warning against travelling to the region for security reasons. Furthermore, ethical issues related to power and authority arise when foreign researchers work in developing regions [11, 59]. To mitigate these issues, the interviews were conducted by two Somali researchers who live in Somaliland and have experience in working with local communities on topics related to climate change. Their organisation maintains an internal ethics committee which reviewed this project, and we also obtained ethical approval from the lead author's institution. Furthermore, decisions made around appropriate research methods, compensating participants, partnering with local entities, and generally being cognisant of the cultural context comply with the *Minimum ethical standards for ICTD/ICT4D research* [12].

4.1.2 Data collection. As Somaliland is a clan-based society, clan elders are a useful mechanism for contacting potential participants as they often liaise with the heads of villages who can find participants. We discussed our study with clan elders in Balligubadle, Sallaxley and Bandarwanaag, who gave us details of potential participants. Participants were recruited amongst those who would be

Figure 1: The location of research sites (Balligubadle, Sallaxley, Bandarwanaag and Hargeisa) where the interviews were conducted.

travelling to the selected sites to attend market and therefore could be interviewed while there. To increase the number of participants, after initial interviews in Bandarwanaag, we also interviewed pastoralists who travelled from across Somaliland to sell their livestock at the market in Sayladda Hargeisa. Participants interviewed in Hargeisa were from Sallexley, Gumburaha, and Ina Guuxaa. In total, we conducted 30 individual interviews.

Participants were interviewed at community centres located close to the market in the selected sites. The interviews were conducted individually in a designated space at each centre. As men tend to be responsible for livestock and women for water and farming, and thus may require different types of climate and weather information to support different types of decisions, we aimed to interview an equal number of men and women. In addition, we interviewed members of the same households separately to ensure that women were able to speak freely, which might not have been possible in the presence of their husband. For this reason, we also ensured that women were interviewed by a female researcher.

At the beginning of each meeting, the researcher described the study and obtained informed (written or verbal) consent. The interviews were structured and included both closed and open-ended questions. Questions covered pastoralists' technology use and ownership, access to information sources, information needs (what is available versus what they need), barriers to access, and concerns (see Table 1 for the full list of non-demographic questions). We also showed them examples of existing apps for pastoralists (e.g. MyAnga; see Figure 2) to collect feedback about the potential usefulness and relevance of available information and its presentation. The screenshots were in English (no Somali version was available) and translated for participants by the researchers. Questions were tightly focused, and interviews lasted around 20 minutes.

The interviews were conducted in October 2019. Each site was visited 1–2 times, aiming to interview 5–10 participants per site. For participants' convenience, the interviews were conducted in Somali and were audio-recorded with consent. The rice and water supplies were distributed to all participants simultaneously at the end of each day.

4.1.3 Data analysis. The Somali interview recordings were transcribed and translated into English (or paraphrased where there was no direct translation) by the researchers who collected the data to ensure data integrity. Due to the use of a structured interview format, participants' answers were short and to the point, with very little additional information. The transcripts were analysed thematically using an approach based on framework analysis [58]. To do so, interview extracts were summarised in a framework table where rows indicated individual participants, while columns represented interview questions. This made it possible to compare and contrast data across participants and questions, and to identify key trends and themes. After the table was completed, one researcher prepared a summary of demographics and background data, while another identified key trends and potential wider themes. These findings were then discussed with the research team, resulting in two key areas of interest (technology access and ownership, climate change and information needs) and two themes underpinning the data (the need for visual and audio formats, and the importance of community members as sources of information). The findings are reported in the next section and summarised in Tables 2 and 3.

4.2 Study 1 Results

4.2.1 Participants' background. We recruited 16 women and 14 men. Ten participants were interviewed in Balligubadle, 10 in Sallaxley, four in Bandarwanaag and four in Hargeisa. Ages ranged from 40 to 73 years ($mean = 54$, $SD = 9$; $n = 26$ as four participants did not wish to disclose their age). All identified as pastoralists, the majority stating that all or most of their household income was from the sale of milk from their livestock, which they bring to community centres to sell. Fifteen participants were household primary providers; one of them was a woman. The remaining participants, all women, also contributed to the household income but to a lesser degree and reported having less input on major decisions.

No participants spoke English, and they either did not know written Somali (nine participants) or their writing skills were poor (20 participants); only one person reported good Somali writing skills. There were no stark gender differences related to literacy:

Table 1: Interview questions from Study 1 (excluding demographic questions).

#	Question
1.	Are you worried about climate change and its impact on your livestock?
2.	If so, what information do you use to mitigate this?
3.	What other information is relevant to you? (e.g. droughts, floods, etc.)
4.	How do you use that information to make decisions? (e.g. related to livestock or water)
5.	How do you access climate and weather information? (e.g. community extension workers, mobile apps, SMS, radio, etc)
6.	How often do you access this information?
7.	Is the information you access reliable?
8.	What are the reasons you choose these information sources?
9.	What information would be useful to you, but is not available?
10.	What are the barriers to accessing the information you need?
11.	What mobile technologies are available to you? (e.g. phones, smartphones)
12.	What technologies do you have available at home? (e.g. radio, TV, internet)
13.	Who in the household has access to these technologies?
14.	How frequently do you use these technologies?
15.	Do you use any phone apps?
16.	Who in your family uses phone apps? (e.g. wife, husband, sister, children, etc.)
17.	Have you heard of AfriScout or myAnga apps? (interviewer demonstrates app to participant)
18.	If so, do you use this app (AfriScout, myAnga) or a similar app to make decisions?
19.	Would an app giving information about different water stores (e.g. soil moisture, ground water) be helpful for you?
20.	What information would you want from the app?
21.	How would you want that information presented? (e.g. visually, audio, etc.)
22.	Over what period would like to see that information? (e.g. monthly, seasonally, yearly)
23.	How would you use that information to make decisions?
24.	Can you give examples of kinds of decisions you would make to adapt to events such as droughts?
25.	What would prevent you from using the app? (e.g. lack of phone, internet, etc.)

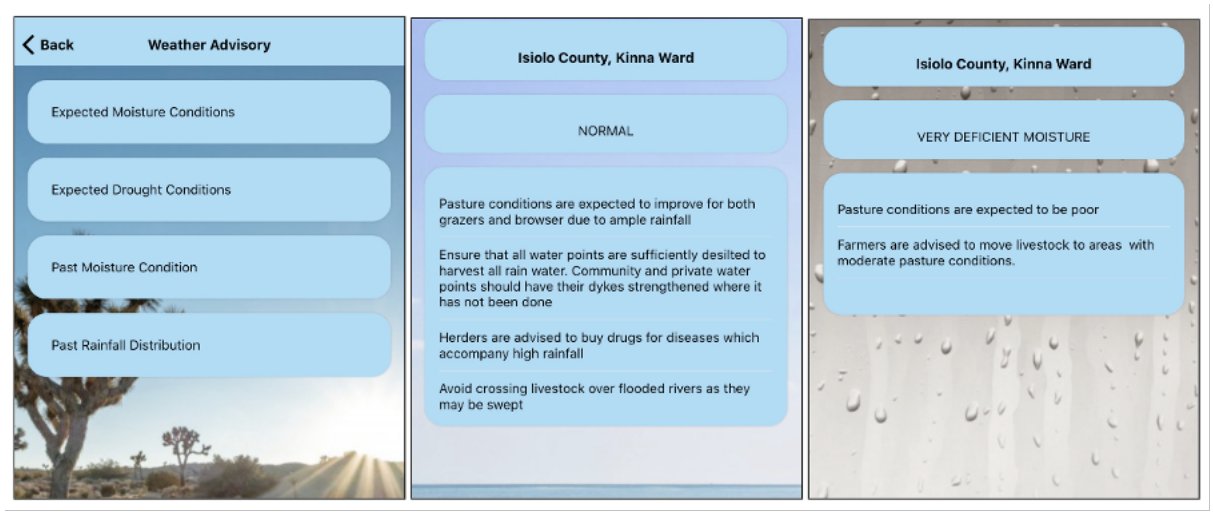

Figure 2: Screenshots of MyAnga app that were shown and explained to participants during the interviews. As MyAnga does not provide information for Hargeisa, we used locations in Kenya for illustrative purposes.

10 women reported "poor" skills and six reported "none", while 10 men reported "poor", one reported "good" and three reported "none". See Table 2 for more detail.

4.2.2 Technology access and ownership. We first asked participants about the technologies they had access to (e.g. they were available in the household or a family member owned it, but the participant could use it if needed) and then separately about technologies they personally owned. When asked about technologies available in their

Table 2: Summary of attitudes towards climate change, general trends related to technology use and access to information, barriers to access and language proficiency. All answers except language proficiency were extracted from transcripts from responses to open-ended questions.

Topic	Description	N (%)
Attitudes towards climate change	Concerned about climate change	30 (100%)
	Aware or already experiencing its negative impact	26 (85%)
Types of information currently received	Availability of water	23 (70%)
	Dry season and droughts	16 (53)
	Availability of grass and pastures	15 (50%)
	Upcoming rains and their intensity	13 (43%)
	Upcoming storms and floods	5 (17%)
	Location of recent rainfall	3 (10%)
	Seasonal changes	3 (10%)
Perceived accuracy of climate information currently received	Accurate information	25 (83%)
	Depends on the source	3 (10%)
	Not sure	2 (7%)
Current frequency of receiving climate information	Daily	16 (53%)
	Few times per week	4 (13%)
	Weekly	3 (10%)
	Depends on the season	7 (23%)
Types of information that is currently unavailable but would be useful	Rain and storm predictions	12 (40%)
	Amount of water available/changes in water supply	8 (27)
	Size of grazing land available	8 (27%)
	Rain density	4 (13%)
	Upcoming droughts	4 (13%)
	Peace/conflict in the area	2 (7%)
	Seasonal changes	2 (7%)
	Not applicable: receive all information they need	8 (27%)
Barriers to accessing relevant information	Literacy skills or education	12 (40%)
	Cost	9 (30%)
	Network connectivity issues	6 (13%)
	Lack of phone	5 (17%)
	Limited access to information sources	3 (10%)
	Limited technical skills	2 (7%)
	Clan conflicts	1 (3%)
	No barriers	2 (7%)
Access to technology (i.e. technology available in the household)	Radio	21 (70%)
	Zaad/SMS enabled phone	21 (70%)
	Smartphone	8 (27%)
	Internet	1 (3%)
Phone ownership (i.e. uses the phone as personal device)	Smartphone	5 (17%)
	Zaad/SMS enabled phone	14 (47%)
	No phone	6 (20%)
Barriers to technology access	Cost	10 (22%)
	Connectivity	6 (13%)
	Literacy skills or education	9 (20%)
	Other reasons	7 (15%)
Language proficiency	Spoken English skills	0 (0%)
	Good written Somali	1 (3%)
	Poor written Somali	20 (7%)
	No written Somali skills	9 (30%)

household, 21 participants (70%) reported having access to a radio, 21 (70%) mentioned access to a feature phone with SMS/Zaad functionality (Zaad is a mobile money service widely used in Somaliland, launched in 2009 [6]) and 8 had access to a smartphone. However, a smaller number actually owned the device: 14 participants (47%)

reported owning a regular mobile phone and 5 (17%) reported owning a smartphone. Amongst participants who used smartphones, only 2 mentioned using apps, mostly WhatsApp and YouTube; no one reported using apps to access climate change or weather information. Three participants reported that their children had a smartphone but used it mainly for communication (WhatsApp).

4.2.3 Climate change and information needs. All participants reported being worried about climate change. The majority (26 participants) reported being acutely aware of it, or already experiencing its negative impacts (e.g. extensive droughts, unpredictable rain, increasing lack of reliable water and pasture) on their livestock. They also believed it influenced the wellbeing of their families and communities. Almost all participants mentioned the possibility of their livestock dying because of droughts, while several mentioned that they had already lost livestock due to starvation and malnutrition:

> *"For the last drought I used to cook food for my livestock three times a day like human being because there was no grass. It was so hard and challenging because we did not get rain in the rainy season. Most of the livestock were dead due to the lack of grass and water, and the hot weather. At the moment all of our livestock are dead because of drought."* — Participant 1 (P1), woman

All participants thought that access to relevant and timely information was important, especially related to availability of water and pasture. This applied to information they currently have access to, consider highly relevant, or information that could be available via a hypothetical app like MyAnga (see Table 2). Participants also highlighted the importance of different aspects of rain-related information: upcoming rains and their intensity, potential storms and floods, locations of recent rainfall, and seasonal changes. In particular, participants were interested in predictions related to water and grazing land size, as this determines whether it would be worth moving animals to the new area:

> *"We also need to know more about changes in the water availability, and sometimes it is costly to call the city for this kind of information. It has happened many times where we travel to a distant place and later realise that there is not enough pasture and water. These areas easily become overpopulated. This happened in times where we were unable to send my husband to verify the information."* — P1, woman

When asked how they currently access information, participants cited a range of sources, although most could be simply summarised as different types of "word of mouth", either delivered through mobile phones or in person (see Table 3). They reported relying mostly on phone calls (63%), unspecified word of mouth (43%) and sending a scout (a *sahan*, the literal meaning in Somali is "to search") to check the location (20%). Due to the limited time available, researchers were not able to follow-up or unpack the responses to this question, which resulted in ambiguous and overlapping answers. Nevertheless, there seemed to be an agreement that other people were the main source of information. Eight participants (27%) reported being satisfied with the types and reliability of the weather, water and pasture information they currently receive. Despite different roles in the household, we did not find any gender differences related to information needs.

While most participants reported checking weather information daily (n=16, 53%), when asked about the use of a hypothetical mobile app to provide information, the majority expressed an interest in doing so less often (n=10, or 33%, few times per week and n=7, or 23%, weekly), possibly because of limited access to smartphones and network infrastructure. Regardless, regular and semi-regular access was seen as necessary for decision-making. However, not everyone had access to the information they needed, mostly due to lack of or limited literacy, cost, and unreliable network connections.

4.2.4 The need for climate information in visual and audio formats. During the interviews we showed participants screenshots of existing apps and, where possible, researchers showed them on their phones. Twenty-six participants were happy to discuss these, and none were aware of AfriScout or MyAnga, or similar apps. They generally agreed that an app could be useful for easily checking the information they need in one place without requiring much effort or resources. However, often unprompted, participants mentioned factors that would likely prevent them from using such app. These echoed the barriers that were already preventing them from using technology to access climate information, including no access to smartphones, lack of technical knowledge and low literacy:

> *"I am quite sure that* [an app] *will make my life easy and we will not lose so much energy and cost in information gathering.* [But] *there is a skills gap when it comes to technology use and we have a limited ability to read and write as well."* — P5, woman

Due to literacy issues, visual information was deemed necessary to convey information provided via mobile phones. Although the lack of spoken English reported by all participants may play a limited role, the lack of written Somali language skills is likely to be of far greater significance. For example, when discussing AfriScout and MyAnga, 18 participants indicated that they would prefer information to be presented visually. Seventeen participants also indicated that an audio format would be preferable, which echoes the general preference to access information via word-of-mouth or telephone. Using audio and visual information together would potentially be the most effective, and could help to overcome the literacy barrier.

> "[An app should show] *information on rain, climate forecasting, storms, floods and water availability. Both visual and audio on all necessary information when it comes to weather changes."* — P5, woman

Four participants expressed no interest in using or looking at an app and therefore we did not discuss this with them. They were all women who reported only having access to a radio in their household, with no phones of any kind.

4.2.5 Community members as trustworthy sources of information. One key theme underpinned all responses: the important role of community as a trustworthy source of information. As mentioned earlier, participants reported that their primary sources of information were other people, either through word-of-mouth in person or phone calls. Contacting others directly was also a way to ensure trustworthiness of information. This trust increased when

Table 3: Sources of climate information as reported by participants (note that some participants provided multiple answers).

Category	Information sources provided by participants	N (%)
Word of mouth	Mobile phones/phone calls	19 (63%)
	Word of mouth (unspecified)	13 (43%)
	Other community members (in person)	6 (20%)
	Communal places and gatherings outside of immediate community	5 (17%)
	Drivers passing through	1 (3%)
	Researchers in town	1 (3%)
Other	Sahan/community member who goes check the location	6 (20%)
	Observing the weather	1 (3%)
	They get no information and instead wait to see what happens	1 (3%)

information was directly sourced or confirmed by clan leaders and older (presumably seen as more knowledgeable) members of the community:

> *"The trustworthiness of the information depends on the messenger of the information. If the person who gave information is a responsible individual such as an elder, I consider the information to be reliable."* — P1, woman

In cases where the collected information was considered unreliable or not trusted, community elders would send a sahan to visit the area of interest to collect or verify the information about the available water and pastures. This information would then be shared with the community. However, several participants mentioned that this was expensive and time consuming:

> "[I access information] *On a daily basis by using my mobile phone* [...] *As a matter of fact, the mobile phones make life easier and we did not send a sahan most of the time if we have enough trust in the source. Sahan is more costly in terms of time and energy."* — P2, woman

The reliance on others was also reflected in the access to technology: it was often the (male) head of the household who owned a phone or children (who often had smartphones). This meant that while in theory the participants (mostly women) had access to mobile phones and smartphones, in practice it was someone else (mostly their husband) who used the device to access the information and make decisions, while the women had to use their own sources:

> *"My husband has a mobile phone and for the most part he is the one that acquires the information. Sometimes I get information from the other female pastoralists or my family members."* — P12, woman

5 STUDY 2: FOLLOW-UP FOCUS GROUP WITH SOMALI DEVELOPMENT EXPERTS

Study 1 aimed to better understand information needs and barriers to access of members of pastoralist households in Somaliland. The results showed that participants mostly used word-of-mouth and phone calls to access information about potential pastures, as this helped to assess the trustworthiness of the information. In particular, community elders were cited as the most reliable sources of information. Participants also reported that sending a sahan to assess a new location was a common, albeit expensive, method of verifying information. However, while this sheds some light on information sources, it was still unclear how decisions are actually made once information are available. Therefore, to help us better understand how existing decision-making structures and processes could affect design choices for potential future interventions, and how they could be used to disseminate climate adaptation information, we decided to conduct a follow-up focus group study with experts working with pastoralist communities. To do so, two additional Somali researchers not involved in Study 1 joined the team — a program manager overseeing projects with rural communities and a researcher with experience in community engagement in Somaliland; both co-authors of this paper. Together, the team reviewed the earlier results and planned the study described below. The study received ethical approval from the lead author's institution.

5.1 Method

5.1.1 Participants. Through our contacts, we recruited four Somali development experts with experience working with pastoralist communities in Somaliland. We decided to focus on experts as they would be able to share their experiences on engaging with local communities and developing interventions, and therefore were familiar with local decision-making processes that affect their work. Our participants included: a male researcher from a local organisation with 20 years of experience working on humanitarian projects (E1); a male director of planning and research of a national authority (E2); a female staff member from an international NGO with experience in monitoring and planning (E3); and a female researcher from the department of health sciences with agricultural background (E4). As all participants worked and frequently collaborated with researchers from abroad, they all could speak English fluently. All participants were based in Somaliland, but were not co-located.

5.1.2 Procedure. The focus group discussion took place in January 2023 using an online video conferencing system, and was conducted in English. It was facilitated by two of the authors who were based in the UK (but not co-located). Also present were two other authors, both of whom are Somali and have extensive experience in conducting research in this area (a program manager overseeing projects with local communities and a researcher with experience in community engagement in Somaliland). Their role was to to provide clarifications and support the discussions, and they were

Table 4: Some example questions from the Study 2 focus group.

Question
"Should we target specific individuals with information, or the entire community?"
"Who specifically should be targetted with information?"
"Do you think there would be a difference between the way we would target women versus men?"
"You mentioned conflict within the community. Can you give an example of what that might look like?"
"If we were to design some technology or an intervention, how should we try and balance the indigenous and scientific knowledge?"

located in Somaliland (but not co-located). The focus group lasted 60 minutes and was recorded to support the analysis.

The session started with the introduction of the project and a summary of our results to date. To better understand the decision-making processes and how they could be affected by a new intervention, we identified some "tensions" highlighting potential conflicting approaches. As a result, we talked about different approaches to information dissemination (e.g. through individuals versus aimed at the community as whole), the need for supporting traditional values as part of the intervention versus potential impact of challenging them, and providing advice based on scientific knowledge versus indigenous and traditional knowledge. We discussed each topic separately to collect participants' views, in particular focusing on pros and cons of different approaches and their impact on the pastoralist communities. The focus group finished with a general discussion. Table 4 shows a small selection of some of the questions asked.

5.1.3 Data analysis. We used Reflexive Thematic Analysis [8, 9] to analyse the focus group data. Firstly, the session was transcribed, and the transcript and recording were shared with the research team to allow for familiarisation with the data. The lead author, one of the focus group facilitators, then coded the transcript using qualitative analysis software. Coding was performed inductively, and multiple passes were performed. This resulted in 51 codes that were mainly semantic in nature. These were then copied onto virtual sticky notes using an online whiteboard system. Through affinity mapping [26], three researchers then independently grouped the codes into potential themes. The researchers then came together to discuss the different interpretations of the thematic structure, which were reviewed and developed to move towards an agreed set of four themes. The themes were shared with the rest of the research team to gather their feedback. Finally, the agreed themes were refined and named, and are described below.

5.2 Study 2 Results

The thematic analysis resulted in the following four themes focused on the role of traditional structures, community decision-making, the fact that pastoralist communities are undergoing several transitions, and opportunities for technology-based solutions.

5.2.1 Importance of traditional structures and practices. Echoing the results of Study 1, the focus group confirmed that elders not only were seen as trusted sources of information, but also played a central role in the community decision making. Pastoralist communities were described as conforming to well-established community structures, with elders seen as uniquely placed to contribute their own experience and knowledge to decision-making processes.

> "[The pastoralists] *have got their own community elders* [who] c*an manage and discuss* [...] *the existing situation. Whether it is drought, whether it is the outbreak of livestock diseases, whatever... those community elders, they have their own knowledge that they can* [apply] *in the local environment. "* — E1

> *"The knowledge is still* [with] *the old people. We need their knowledge."* — E3

In particular, participants highlighted that the governance and decision making was overseen by committees of elders and other community representatives, and such leadership was seen as an important way of implementing unified actions. Therefore, they argued that any new interventions should engage with these structures. This was for multiple reasons — for example, E4 explained in detail that community representatives were gatekeepers that could allow access to communities, and could therefore make or break any project. As such, endorsement by these representatives could increase uptake among a community, as people look to them for advice and guidance. Finally, E4 also highlighted that it was important to show respect to those who oversee various elements of community life and keep them informed, as bypassing this could cause disharmony and negatively affect the community.

> *"Community leaders are the ones who always make the decisions,* [the ones] *who will let you to go into the community.* [...] *We have to start from community rules. Then we can demonstrate through that to the other parts of the community. That could be very productive and very effective.* [...] *If we go directly, without telling and informing and also getting the allowance from the community leaders — if we go directly to the women, or maybe to young boys and girls — that could lead to a conflict of 'why did you pass me?', 'why didn't you tell me', 'why didn't you take my opinions?', 'why didn't you obey me?'.* [...] *So it could lead to conflict."* — E4

Furthermore, as everyone may interpret the same information differently (especially due to limited literacy levels), such wide dissemination could make decision-making harder and lead to the lack of unified action. Our experts therefore recommended targeting information at respected individuals in the community:

> *"Focus on the* [specific target] *individuals, because if we try to disseminate climate information across different communities and across different pastoralists it may just create sensitivity.* [...] *Every person can interpret his own way of understanding, you know?* [...] *This is determined by the level of his consciousness and also determined by the level of his knowledge or illiteracy.* [...] *And so in order to ensure that the climate information that is being disseminated to the pastoralists is unified,*

> *we must target* [specific] *individuals in each particular location."* — E2

The experts also spoke about a strong culture of information sharing within and between communities. These networks have the potential to be utilised to enable wider dissemination of information, even where people do not have the resources to receive it first-hand:

> *"If they are pastoralists that are moving from certain location to another, and they find a family that are living in a certain location, he just... he chats.* [...] *He asks how the situation is, where there is a rain, where there is pasture* [...]. *They normally chat on the basis of their concerns, particularly with the focus of their most pressing needs."* — E2

Most decision-makers and trusted community members who can influence main decision are still older men, and there is still the expectations that men and women have different roles. However, things are slowly changing.

5.2.2 Community decision-making and the role of community representatives as facilitators. Despite the importance of traditional approaches described above, the experts also highlighted the increasingly collaborative decision-making structures. While elders and committees play an important part, they do not dominate decision making. It may appear they have ultimate responsibility, but they often guide, facilitate, and broker this process through committees and other community members with the necessary skills and knowledge:

> *"Every member of the community will be included, but the decision is always only on the community leaders. They can guide us, they can direct us, they can lead us. Like, 'these are the right people you want* [for] *this', 'these are the right people for the community so we can do this'. Especially if we are having something technological —* [...] *younger people are good, are better than older ones. So there won't be someone in the older community who will say 'I'm the best at it', so they will lead you to the youth and say to you 'this is the community who can understand more to that, so can you please communicate and teach them so we can learn from them'."* — E4

As such, community representatives could be suitable targets for climate information, acting as a community entry point. This can then be disseminated to the rest of the community through trusted community members, e.g. teachers, or informal networks:

> "*In each particular location there is a committee. In each particular location in each particular village, and there is a head of village. And so when we are trying to disseminate climate information in a particular location, we can just*[see them as] *target individuals which we can provide or convey the information to.* [...] *The members of that committee include the traditional leaders and the elders."* — E2

The experts in particular highlighted the role women and their networks play in sharing information, and suggested that these networks could be also used to support the dissemination of climate adaptation information:

> *"We want that information to go through all the community.* [...] *So the main reason I specifically selected women is so that information can go very far. Somali woman community are very talkative and they know how to receive news from each other, so they can be good messengers."* — E4

The quote above echoes comments from a female pastoralist from Study 1, who confirmed that she was getting information from other female pastoralists (see Section 4.2.5). Furthermore, the experts mentioned that women were increasingly involved in committees, partly due to female-led households, and partly because Western aid agencies operating in the area require a presence of women as part of decision-making structures. They saw this as very important:

> "*In our community there is what we call 'female-head house' where* [...] *the female is responsible for all* [of the] *family.* [...] *For example, when we want to create a community group, the maximum the minimum number of females to be in is three or four. So the representation of females [...]will be very important. Because the impact* [...] *also affects the females.*" — E3

5.2.3 The impact of changes and ongoing transitions. The increasing role of women was not the only change the participants mentioned. They also highlighted the shifts with the communities who are experiencing transition away from indigenous knowledge as a source of information. E1 remarked that *"many people who have this kind of knowledge have already died"*. This knowledge is not only lost together with elder members of communities, but quite often it loses accuracy. As climate change affects vegetation, water levels and migration patterns, these natural signs pastoralists are used to rely on are becoming less reliable as a guide to future conditions:

> *"The indigenous knowledge of pastoralist communities* [with] *which they have been forecasting — now it is interrupted due to the climate change."* — E1

However, this transition is not complete: while some communities are moving away from indigenous knowledge, they do not fully embrace scientific knowledge, often because they do not have access to it yet. This has led to some communities being left without important information to guide their decisions:

> *"Some of the communities have shifted from the indigenous knowledge,* [but] *they have not fully adopted the scientific approach of climate information. So they are in a in a cross-border situation whereby they are not fully under the indigenous systems and they are not fully under the scientific systems. And this has caused the community not to find or not to gather relevant climate information, increasing their vulnerability due to climate shocks and the unpredictable climate impacts in Somaliland."* — E2

Furthermore, our experts mentioned that many pastoralists they work with were becoming less nomadic, with many becoming resident due to development programmes providing them with reliable resources.

> *"Before, the pastoralists have been moving in search of fodder and water and something like that. But most of*

> *the pastoralists at this time, they are resident. They do not move. They have got a water point."* — E1

Having a more settled location with reliable utilities would make servicing these communities with climate information and other resources much easier for development planners, as permanent or semi-permanent infrastructure could be used. In the case of technology interventions, reliable power and internet connections would be especially beneficial, and our participants reported that settled pastoralists were more likely to have access to both.

5.2.4 Opportunities for technology in a changing world. Moving away from traditional practices also presents opportunities. As demonstrated in the Background section, technology and telecommunications are growing quickly in Somalia and Somaliland [6] — this was also confirmed by our experts who also highlighted how young people are drivers of technology use:

> "[There] *are young people. They have access to every kind of technology and telecommunication. Telecommunication is the main factor."* — E1

At the same time, our participants told us of the desperate need for climate information in pastoral communities to combat ongoing drought. To this end, these communities are ready and willing to welcome new sources of information, particularly through technology:

> *"They have experienced consecutive droughts, which are non-stop droughts that affecting the livelihood of pastoralists. So, they will welcome whatever initiatives and interventions that support* [...] *the technology and also and the information sharing mechanisms.* [...] *Pastoralists are* [giving] *the most priority to how to get the livestock fodder, and livestock water, livestock medicine, whatever* [will improve] *their lives. So for all those things, they need information. They need improved technology. If there is an intervention supporting all those areas... Pastoralist communities, they are really ready to support and welcome everything."* — E1

This opens up opportunities for new interventions, as there is a clear need and openness to technological solutions. Furthermore, despite some communities apparently moving away from using indigenous knowledge, this is not true for every community. As such, our experts saw value in traditional knowledge systems and suggested that we needed to understand them more, and advocated for a combined approach using both knowledge systems to better serve the needs of communities. One participant specifically referenced the United Nations' Sendai Framework Disaster Risk Reduction [63] as a motivator for this:

> *"I recommend at least to integrate together the scientific and the indigenous approach,* [...]. *When you are looking at the Sendai framework — the international framework for disaster risk reduction — it also emphasises to consider the indigenous knowledge. But for the time being,* [we need] *to have thoroughly studied the potential of having indigenous knowledge here in Somaliland. What can be improved with the existing indigenous knowledge, and how best this can serve for the information that we require from the prevailing climate change. So it needs for us to crystallise the applicability of this indigenous knowledge in the changing environment* [...] *But then we cannot just ignore the scientific* [knowledge]*"* — E2

Thus, expanding our understanding of indigenous knowledge and combining it with scientific knowledge could present additional opportunities to reach some communities in a way that is both familiar and trusted. To some degree, this could also help to address the issue with decreasing accuracy of indigenous knowledge mentioned earlier.

6 DISCUSSION

Climate change can have a devastating impact on pastoralists whose lives depend on access to water stores and grazing land [10]. However, with appropriate climate information and advice, communities can be more proactive in their response and therefore more resilient, at least to some extent. With the widespread and growing access to mobile phones across East Africa [52, 69], technology has a potential to support pastoralist communities and aid in the dissemination of climate adaptation information. However, the most vulnerable rural communities who would benefit most from this information have limited access to technology, live outside the reach of mobile networks, and often lack language and technical skills necessary to take advantage of technological advancements [3]. Our results have highlighted the importance of community and widespread trust in traditional structures, as well as pointed towards ongoing changes that affect Somali pastoralists alongside climate change, including the reduced accuracy of indigenous knowledge. We have also identified the openness towards technology-based solutions, provided they take into account pastoralists' needs, their limited literacy and preference towards audio and visual information. In the following sections we explore these factors in more depth, with the aim to highlight considerations designers should bear in mind when developing digital climate change adaptation services.

6.1 Designing for community decision making

Most smartphone apps aim to provide a service to an individual "user" who interacts directly with a system for their own benefit, subscribing to the Western liberal concept of prioritising the autonomous individual [2, 70]. In the context of pastoralism, this would correspond to getting information (e.g. through a mobile app) to each family unit and them making an individual decision as to how to respond to this — such as choosing to move their herd, or reduce its size through destocking in anticipation of a drought. However, our research suggests that such an approach is unlikely to be suited to pastoralist communities in Somaliland. Mutual information sharing, collective decision making (particularly by elders and other community representatives), and collective action all play an important role in pastoralist communities [4, 5, 10], which was reflected in our findings. The need to coordinate action between households to be effective, and to make collective decisions regarding the allocation of precious community resources — such as the time and/or financial commitment of sending a scout to investigate an area — means individual actions can undermine the overall coherence and resilience of the community (as reflected by P1 who highlighted issues with moving to overpopulated areas in Study 1;

see Section 4.2.3). This community-based approach, and the relative lack of access to smartphone technology, suggests it would be appropriate to consider the wider community as collective beneficiaries and indirect users of any technological intervention, rather than individual community members as users. For that reason, designers working with such communities must adopt a different mindset and ask themselves the following questions:

- How best could technology feed information (and potentially advice) into a collective decision-making process?
- Who are the most effective 'conduits' into this?
- How could these 'conduits' be encouraged to ensure the information reaches the groups of people who need it, when it is needed?

As noted above, the decision-making process is coordinated by the elders and community committees. In some cases, an elder may have access to technology, but our findings suggest that younger members of the community tend to be the earlier adopters and so have potential to act in this role. In some cases, such younger members may hold positions of respect within the community, such as the teacher. An essential aspect of the design of a digital service, therefore, will be the use of 'collective use cases' which identify who will convey information into the community and how. As with all such designs, this is best identified in a participatory way with the community.

6.2 Designing for inclusivity and sharing

Any digital intervention should recognise the relatively low levels of smartphone ownership and literacy levels in pastoralist communities, and design with this in mind. There is a potential for using visual information to support understanding and communication. However, implementing it practically in a way that reflects existing cultural norms would be challenging. Sending a sahan to scout a new area or to verify information received about a specific region highlighted the need to show the current status of pastures and access to water, and so any visual information would need to be of high enough resolution and level of detail to be seen as equally reliable. For those with multimedia-enabled phones and simpler handsets that can handle graphics, this could be achieved by allowing elders to forward images from a potential service to help people visually assess the drought levels. To save bandwidth, a library of pre-existing pictures that could be used (and reused) would reduce the need to transfer the images via limited networks while still conveying the key information. The use of images would also address the literacy issue, which our participants highlighted, and which is in line with wider trends in the region [13, 46, 54].

Another approach would be to use pre-recorded voice messages describing the environmental conditions, such as water levels and rainfall (e.g. "no rain expected for X days"), which has been suggested by prior research (e.g. [4]). To access the service, people could call a phone number associated with their region to listen to latest pre-recorded forecast. However, the service would not have to be one-way. Given the proliferation of feature phones, a voice-based forum service similar to Avaaj Otalo [50] could be developed. Avaaj Otalo was created to disseminate farming information amongst rural farmers from Gujarat, India. Using a simple feature phone, users were able to record questions and answers posted on the forum, listen to announcements from the Development Support Center who provided a regular radio service aimed at farmers, and access their archive of recordings. The evaluation of the service showed high user engagement. This approach could potentially work within pastoralist communities, although may not be feasible on a larger scale due to the cost.

Our results confirmed that the sharing of information — both within and between communities — is a core practice among Somali pastoralists [24]. At present this is primarily verbal, and takes place face-to-face and over the phone. Any digital service should take into account this practice, and encourage sharing both to promote inclusivity and to fit with existing community practices. Hence, service designers should consider the different ways in which it may be shared as part of the design process, including considering the following questions:

- How does information currently flow through communities?
- What are the formal and informal information networks, and do they overlap?
- What devices are prevalent within communities and could be used?
- Are there any hubs or activities where community members gather and share information? Could technology be integrated with them in any way?

These questions should ideally be explored with community members in a participatory way. For example, in a community meeting a digital device could be used as a shared object, passed between participants to view an image. A voice message from a service may be played by the phone owner to others in their community who don't have a phone — as takes place with the Avaaj Otalo service described above. Images and messages may be forwarded to others both in this community, and in others. To encourage inclusivity, thought should be given both to design of services to facilitate this sharing, and also approaches to actively encourage sharing within the community, particularly with more marginalised members.

6.3 Designing with power structures in mind

Our findings, particularly from Study 2, emphasised the importance of working within the traditional power structures and potential issues with bypassing them. For example, younger community members having direct access to a climate adaptation service through phones, bypassing community leaders. While not an explicitly finding of the study, we hypothesise this is a consequence of a potential service providing "official" information from governmental and non-governmental organisations. It may be that, for example, a young person accessing weather information from a generic weather app would not cause concern, but if a young person is receiving official information this could undermine the status of the elders. Alternatively, it could be a concern about individualised service access resulting in fragmentation of the community. Research conducted in rural China showed that introduction of technology to support decision-making among farmers did not fit within existing practices and highlighted a generational divide, with younger farmers trusting online sources and older farmers preferring to maintain the status quo [49], which could lead to conflict and questioning older members' advice.

However, our findings also show that the elders often do respect and value the technical expertise of younger members of the community, and are happy to encourage its use. Hence, one possible approach would be to work with communities to allow them to decide on a number of people (likely younger) to act as information conduits to the decision making process as "technology champions". By being chosen by the community, and by having an explicitly acknowledged role in the process, this would be less likely to undermine the status (and therefore support) of the elders, and would fit in with their existing practices.

By aligning with (and therefore not challenging) existing power structures and practices, a new digital service would require relatively little change in practice within communities, and so may encourage acceptance. Furthermore, it could potentially benefit entire communities — including those with limited access to technology — because of the culture of collective decision making and information sharing. However, technology can amplify existing inequalities and disadvantage vulnerable members of the community [72], and explicitly targeting those with most power as users increases that risk. An alternative approach, adopted for example by social technology company *Gram Vaani* in India, is to explicitly empower marginalised voices in communities to challenge local power structures [41]. In such situations, as Karusala et al. [29] reflect, it "may not be appropriate for design to disrupt in ways that challenge status quo by imposing unwelcome values, but it may still support women in the struggles they choose to engage in".

While amplification of inequalities may be lessened in communities with a culture of egalitarian information sharing, our data show that women had limited access to information and relied on other sources, such as personal or community networks — despite a culture of information sharing about the environmental conditions in pastoralist communities in Somaliland (as discussed by E2 in Study 2). Because women are expected to prioritise taking care of the household, children and animals, they are not considered decision makers and so it is unlikely this information is shared with them. However, once a decision is made based on some information, it is expected that women will become aware of the information naturally through family or social networks (as illustrated E4 who described information sharing through women's personal networks). As a result, aiming the service at community elders in patriarchal pastoralist societies could potentially further disadvantage women who already have limited access to technology. Therefore, designers need to consider questions that will help to think about both positive and negative impacts of the systems they are developing:

- How does the system integrate with existing power structures (if at all)?
- Does the system challenge existing power structures, either overtly or covertly?
- How can information be shared equitably throughout communities?
- Which groups may be unfairly privileged or disadvantaged by the proposed system?

Reflection on such questions must take place alongside a nuanced and culturally sensitive consideration of what aspects of existing practices are static, and thus should be conformed with.

In summary, consideration of the impact of power structures is essential when designing a digital service for Somali pastoralist communities. Understanding power structures can both support acceptance of such services, and also highlight (and therefore potentially mitigate) exclusion from information and decision making, particularly exclusion of women.

6.4 Designing to build trust

Somali pastoralist society typically values communication of information through spoken word and between trusted individuals. Written words, particularly from an abstract or unknown source, may be less trusted and valued and therefore disregarded [5]. This was evident in the results from Study 1: even though participants had limited access to timely information, they were satisfied with the information they received as they considered it to be reliable enough to make good decisions. This was because they deemed their sources trustworthy, who were mainly family, friends and other community members. Therefore, trustworthiness of any new service and the information it provides (and how to build this trust) should be carefully considered by designers from the outset, as this is an important predictor of uptake amongst Somali pastoralists.

Endorsement by trusted community members such as elders is also important to ensure the uptake of new information, especially when community members have not received it directly. As approval from other community members determines whether people will trust the information [4], designing a service that integrates this approach could help build long-term trust in the information flowing through it. Regular usage by elders could increase the perceived trustworthiness of the source, and would work as endorsement for other pastoralists who are considering using it themselves. Furthermore, clearly showing the source of information or specific individuals who have verified it could act as further reassurances. Gaining the endorsement of a new system by key community members is similar to the Village Phone project from Bangladesh [7] where individuals with mobile phones acted as local information sources for communities. They served the role of early adopters and technology evangelists, helping people understand the phone's capabilities, which encouraged others to buy their own devices once the network coverage improved and prices started to decline.

Further taking advantage of the trust given to the spoken word, new services could go beyond phones and be delivered by, or integrated with, radio broadcasts — an approach which has already been considered as a potential solution for disseminating official weather forecasts for farmers in Western Kenya [39]. However, trust in the radio service would first have to be built among pastoralist communities, which could again be achieved via regular use and endorsement by elders. As pastoralists tend to trust voice communication — including radio — more than written sources [4], this could expedite uptake assuming the information is reliable [4]. The use of established radio sources together with smartphones could be used to engender trust in a hitherto unfamiliar mobile service — as radio is a technology familiar to many pastoralists (often with few barriers to use, assuming access to a receiver), it could be used to encourage use of the mobile service, which can offer hyper-local information that radio typically does not. The benefits of such a mobile service could be clearly communicated, as

well as the ultimate source of the information to demonstrate that it is reliable. This kind of hybrid approach would ensure the greatest number of people have access to important climate information, as it would serve both phone and radio users.

Therefore, when designing services aimed at pastoralist communities, it is necessary to identify and consider factors that can help to build and maintain trust:

- What are the trusted sources of information, and could they be used or adapted to support the dissemination of new information?
- Does the community have preference towards sources of information, i.e. are some sources seen as more trustworthy than others?
- What local practices or community members could help to increase and maintain trust?
- How could this trust be lost or damaged, and what types of interventions or sources of information should be avoided to prevent this?

These questions provide a starting point and aim to help designers think about the context in which a new system or intervention should be introduced. Trust is necessary for the long-term effectiveness of any intervention, and therefore the design and development process requires a thorough understanding of factors that affect trust, trusted sources and individuals, and any actions or information sources that may impact it negatively.

6.5 Designing in the face of change

Finally, the findings from Study 2 emphasised that Somali pastoralist communities are undergoing change in a number of ways. Firstly, the impacts of climate change mean that the seasons are changing, and that traditional and indigenous knowledge, such as plant and animal behaviour, are less reliable than in the past — thus, some communities are abandoning these knowledge systems. Secondly, women are playing more of a role in decision-making than in the past. This is through their increased presence on committees, and through female-led households where women have become the main decision maker. Thirdly, education and literacy levels are increasing. Fourthly, ownership and access to digital technology, as well as ability to use it, is increasing particularly among the younger members of the community — including those who will be elders in the future.

Any digital service to support climate adaptation should be designed with change in mind — to be responsive to the fact that current use cases may change, and flexible to the needs and opportunities of the future. For example, as smartphones become more widespread in the community, and a new generation of technically literate elders (including women) become responsible for coordinating community decision making, a new approach may be needed. It is likely that such communities will still value communication and trust between individuals and groups, but be happy to use online chat services (such as Telegram or WhatsApp) to support these discussions. Sharing of relevant information and images over such services will then provide new use cases, and any service design which met current needs but could not adapt to such a new environment would become obsolete.

As communities are constantly changing — as part of ongoing processes or forced by circumstances — there are no specific questions we can recommend to designers. In practice, being responsive to change means taking a strongly user-centred and community-centred approach that regularly re-engages with users to ensure their needs continue to be met, and implementing the system in a way that allows for modification within the constraints of the rural Somaliland context and its associated barriers. For example, a community may currently value and make use of indigenous knowledge in the form of markers in the natural world (such the appearance of plants and animals [39]), and so it would make sense to make use of these familiar analogies, such as animal or plant imagery, to convey information in a service. Later on, by once again engaging with the community the designers might assess that the users no longer engage with indigenous knowledge, and thus their needs have changed. This change could then be reflected in an updated version of the system. Such responsiveness can only be achieved by iterative engagement with the users, and a well-planned and resourced maintenance strategy.

6.6 Reflections and Limitations

Engaging in this study provided important insights to the UK-based researchers into the importance of such research to be co-created with partners who have a deep understanding of the cultures and communities being engaged with. In the early stages of designing the research, the Somali team members made the UK members aware of naive assumptions regarding what is possible and appropriate when conducting interviews with community members visiting market towns. This resulted in the design of the interviews being significantly streamlined and simplified compared with the Western academic semi-structured interview, but in a way which preserves the ability to capture the essential insights. Collectively, we also became aware of different priorities and strengths. In particular, the Somali team are less experienced in presenting research in a way that would be acceptable to a "high-status academic venue" — but also value this significantly less than the UK academics, instead prioritising insights that can be embodied in their ongoing practice and further their priorities to support Somali-led transformative change in the region.

Inevitably, the constraints in which this research took place have shaped the outcomes, and provide limitations to our findings. The difficulty and expense of travel in Somaliland meant that we opted to conduct Study 1 interviews in village markets near Hargeisa, the capital of Somaliland, where members of other communities would visit. This means our participants could be biased towards those who had the resources to make the journey to the selected villages, and who were recruited by the community leaders. It is therefore possible that there may be more marginalised members of the community who the leaders do not share information with, and we may be receiving an overly positive picture of the benign way in which information flows in the communities. Nevertheless, the community trust and sharing practices are in line with existing research focusing on rural communities in the region [4, 5, 10] and were corroborated by the experts interviewed for Study 2.

The close location to the capital also meant that the language data from Study 1 could be biased. Somali is a primarily spoken language

and thus not many people can read or write; however, more people may be able to do so near Hargeisa versus those from more remote regions. Nevertheless, a third of our participants reported having poor written Somali language skills. Their responses helped to understand information needs of those with limited literacy.

The feedback from participants in Study 1 about existing apps and their potential use ("I would find it useful") was based on screenshots and often came from people who did not use smartphones, and as such these findings should be considered with care. However, the explanations related to barriers to use and potential formats that these screenshots prompted were in line with comments about existing sources of information that pastoralists use, which makes these findings more reliable.

In Study 2, we tried to recruit participants with a collective expertise that covered a number of areas. However, it is possible that their responses do not reflect the entire range of issues that pastoralists in Somaliland may face due to their particular specialisms or focus on particular geographical areas. Furthermore, they were experts working with communities, and not necessarily parts of them. This is a limitation, although involving experts helped us understand the decision-making processes and how they affect external collaborations and interventions. Future work should involve more direct contact with pastoralists.

Finally, we have not built anything at this point. Our goal was to understand the information needs and decision-making practices of pastoralists, especially that research in Somaliland is scarce and primary sources are lacking. Nevertheless, the tensions and considerations we have identified and unpicked provide valuable insights to develop further interventions aiming to support pastoralist communities in Somaliland and beyond.

7 FUTURE WORK

This study was only the first step in the wider line of research aiming to provide climate adaptation technologies for rural communities affected by the climate change. Recent work has highlighted the opportunities for HCI in delivering climate services that is relevant to the work detailed in this paper [57], specifically around integrating scientific and indigenous knowledge systems, developing decision support tools for different users, and delivering services in a way that serves communities rather than individuals. Therefore, next steps to expand on this work could take these lines of enquiry, while also bearing in mind the questions we pose in our discussion. For example, a more thorough investigation into information flows and power structures within rural Somali communities could be developed by again interacting with the communities themselves, ideally led by Somali research partners who understand the local culture. This would then allow us to better understand where a technological intervention could be placed within a community structure. The different value given to scientific and indigenous knowledge by communities could also be investigated to ascertain the most trusted route for conveying information. Based on these insights, and working with local communities, personas and use scenarios could be developed in a participatory way [38, 43]. Note that, in contrast with typical use case development, it is important to ensure that the personas and scenarios include community members who do not have direct access to the technology. Using these, prototype mobile systems could be developed and tested in the field, perhaps taking advantage of recent developments in hydrological modelling and climate science in the region (e.g. [37]).

8 CONCLUSIONS

With climate change severely affecting rural agropastoral populations in the dryland regions of East Africa, there is a pressing need for relevant, timely, and practical information about water and vegetation resources, particularly with a view to climate change adaptation. However, pastoralist communities in Somaliland are often distant from decision-making centres, making it hugely challenging to disseminate usable information in a timely manner. The importance of face-to-face contact and direct communication, limited access to technology, and low smartphone ownership, have implications for the development of information services aimed at rural communities that present significant difficulties for designers. It may be difficult to adapt existing solutions from other East African countries — solutions that rely on a reliable mobile network, cheaper connections and increasing smartphone usage — in Somaliland and other rural parts of the region. As such, the services aimed at pastoralists could be designed for communities rather than individuals or individual households. Elders or trusted members of the community could act as part of a wider system that distributes and verifies climate change adaptation information. The technology would have to account for these social dynamics and the need for information, but it would have to be designed with care to avoid perpetuating inequalities and further limiting women's access to information. It would also have to be designed with limited technical and language skills in mind, which the presence of a human serving as the main node for disseminating information could help to address. New technology services should also be developed in a way that is responsive to the changing needs of the users, which can be achieved through repeated user engagement and a sustainable maintenance strategy.

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