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High reliability professionals and networks in pastoral areas of northern Kenya and southern Ethiopia: a new approach to development?

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Seeing pastoralism as a "critical infrastructure" consisting of networks of "high-reliability professionals" has the potential to support and sustain resilient pastoral livelihoods. In this article, we examine cases from northern Kenya and southern Ethiopia where reliability is generated through deliberating on early warning systems; gaining access to grazing and water resources; creating fodder reserves; managing complex value chains and market exchanges; providing small-scale credit and generating peace and security. We argue that approaches that focus on local practices, relationships, processes, and unique knowledges are best placed to build resilience in the face of external shocks. We find that high reliability professionals and their networks engage in active and deliberate processes that assemble multiple actions to support the larger system during and between crises. These individuals work across social and economic realms, through markets and across regional and national borders to respond in real time to unfolding and variable conditions, continuously averting disasters. Working together with external agencies, local networks of high reliability professionals offer an alternative approach to humanitarian and development response in pastoral areas that is locally embedded and less reliant on externally imposed projects and aid finance. The implications for development interventions in pastoral areas are significant.

KEYWORDS

critical infrastructure, drylands, high reliability, pastoralism, resilience

Introduction

Pastoral areas are often presented as sites of disaster and crisis, in need of external humanitarian and development intervention. In northern Kenya and southern Ethiopia, recurrent droughts have resulted in a flood of aid programmes that have attempted to generate early warnings, encourage anticipatory interventions, and build resilience,

alongside long-term humanitarian assistance efforts.[1] But have they worked? While such programmes have provided important temporary relief in times of extreme need, in many cases they have failed to facilitate long-term, sustainable development in pastoral areas (Akall, 2021; Stites et al., 2024). Too often, such interventions have been framed in terms of shifting the system away from pastoralism, encouraging – for example – settled, irrigated agriculture rather than supporting pastoral systems (Mohamed et al., 2025). Yet pastoralism has long been an effective response to climate variability and dryland conditions where frequent droughts are common (Oba, 2001; Derbyshire et al., 2024). By starting with how pastoral systems work and identifying the people and networks central to effective drought responses, perhaps an alternative approach to development interventions can emerge.

In this article we ask: how is reliability generated in pastoral systems in the face of high levels of variability and many uncertainties? Who are the people and networks involved? How do they avert disasters, through what knowledges and practices? Can we learn from and augment, enhance and support such approaches as a way to rethink pastoral development in the drylands? We argue that, following Roe (2020), pastoralist systems are best understood as a critical infrastructure. Responding to potential disasters continuously in real-time, pastoralists depend on a network of high-reliability professionals who help to hold the system together through the provision of information, support and other inputs. High reliability professionals draw on the long-established ways of response in the community, connecting through social networks and a range of people who support these processes (Tasker and Scoones, 2022; Mohamed and Scoones, 2023;[2] Hassan et al., 2024)[3].

Despite the potential of pastoralists' local mechanisms to navigate challenges, many pastoralists in the Horn of Africa are caught in a cycle of multiple shocks, which often escalate into humanitarian crises. Climate shocks, for instance, account for massive livelihood losses over the years, with the repeated failure of rains along with political and economic marginalisation affecting local capabilities to respond (Herbert and Birch, 2022; Mkutu, 2008). Despite these challenges, evidence from many pastoral contexts demonstrates how pastoralists confront and seek to manage the high levels of variability in environmental, social and political spheres. This variability renders futures unpredictable and uncertain, but pastoralists live both with and from uncertainty through use of a range of strategies and tactics (Krätli and Schareika, 2010; Nori, 2019; Scoones, 2021). Recent literature on resilience in pastoral settings focuses on pastoralists' ability to adapt aspects of their daily strategies, such as herd composition and mobility patterns, to respond to fluctuating conditions (Scoones, 2023a; Scoones, 2024). The idea of living with and from uncertainty recognises the ability of pastoral systems to turn unstable conditions and processes into opportunities and to support livelihoods in variable conditions. These knowledge and skills are critical to how pastoralists understand crises and shocks and seek to avert disasters.

One way that pastoralists manage within this context is through a moral economy of social support, reciprocal exchange and a focus on the wellbeing of the collective (Nori and Davies, 2007; Mohamed, 2022; Scoones I., 2023). Pastoralists across different settings sustain livelihoods through reciprocal norms that are geared towards prioritising communal security and herd health over individual or household gains (Bollig and Lesorogol, 2016).

For instance, in the Afar region of Ethiopia, pastoralists share animal products through clan-based networks that support community members during dry seasons and droughts (Tache and Oba, 2008). Pastoralists in different regions of Somalia mobilize funds across clan, family and diaspora ties as a means of social protection and support to be used during emergencies (Kleist and Abdi, 2021; Edle et al., 2026). In Kenya, multiple customary practices blend informal solidarity based on clans, neighbourhood groups and broader networks with external support and social protection schemes, reshaping how resources are shared and obligations enforced (Hassan et al., 2024).

This interlinked and collective understanding of pastoral systems, we argue, requires a reframing of external perceptions and responses in dryland areas. The proposed new approach is more in line with the local realities and with what pastoralists themselves do to ensure resilience and to support those in need through flexible and caring responses attuned to the local ecosystems. Reshaping the assumptions that guide external understandings of pastoralism, we suggest, offers revised approaches to humanitarian and development interventions. Central to this, we propose, is a perspective centred on a relational understanding of high reliability professionals, operating in networks and as part of a critical infrastructure.

The article is organised as follows. First, we introduce the idea of high reliability professionals operating as part of a critical infrastructure. Next, we provide an overview of the study area and our methodology. Following this, we present six case studies, highlighting the role of high reliability professionals in responding to crises and averting disasters. We then draw out five principles from a thematic analysis of the case study material.

1 For example between 2015 and 2020, the European Union Trust Fund for Africa allocated 1.1 billion euros across 131 resilience-building projects (European Commission, 2022). Combined Evaluation of the European Union's Humanitarian Interventions in the Horn of Africa, 2016–2020, and DG ECHO's Partnership with the International Committee of the Red Cross. Brussels: European Commission. Available at: https://ec.europa.eu/echo/files/evaluation/2022/EU%20Humanitarian%20Interventions_Final%20Report%20September%202022_Executive%20summary%20EN.pdf

2 Available at: https://pastres.org/2023/05/19/building-resilience-from-below-the-vital-role-of-reliability-professionals-and-their-networks/

3 Available at: https://www.ilri.org/knowledge/publications/building-resilience-below-exploring-pastoralists-high-reliability-networks

Finally, we conclude with a reflection on the wider implications of the proposed high reliability approach for pastoral development.

Pastoralism as a critical infrastructure: the role of high reliability professionals

The concept of pastoralism as a critical infrastructure borrows from global infrastructure management, whereby systems such as water supply or the electricity grid are essential for the reliable provision of services in the face of high input variability (Roe and Schulman, 2008; Roe, 2020). Like a complex infrastructure, pastoralist systems are made up of multiple actors who play different but overlapping roles to hold the system together. These individuals and networks work within different settings to navigate daily challenges, offer options and improvise solutions within locally available resources (Roe, 2013; Roe, 2020). These practices are based upon a long-established repertoire of how to respond to risks and uncertainties. These responses are not, as sometimes described, simply a means of passive "coping," but rather a set of active and deliberate processes. These processes transform the pastoralism infrastructure with new adjustments and patterns to continuously avert disasters, keep livestock alive and sustain other services and activities critical to pastoralism. At the same time, a growing body of evidence shows how pastoralists respond to risks and variability through continuous adaptations that draw on uncertainty (Scoones I., 2023; Nori and Scoones, 2019). These protective adaptations build on relational resilience with an emphasis on local knowledge, practices, and relationships through which pastoralists are able to adjust their livelihoods (Konaka and Little, 2021; Berkes and Ross, 2013).

Central to these processes are high reliability professionals. These are key individuals within pastoralist communities who form intricate networks to manage extreme uncertainty and provide information, skills, connections and strategies to support livelihoods (Roe, 2020). Such professionals must both scan the horizon for future risks and threats and respond to the day-to-day contexts, adjusting processes to respond in real time as uncertainties emerge. This may mean shifting between different operational performance modes, from "just-in-time" responses involving improvisation to "just-in-case" anticipatory exploration of different options and "just-for-now" responses when options are few and system volatility is high (Roe, 2020). It may also result in generating different forms of resilience, whether applicable in times of emergency, recovery or restoration (Roe, 2020).

Maintaining this form of dynamic balance is what the control room operators, connected to IT professionals, brokers, suppliers, repair engineers and others must do when ensuring that a highly variable electricity supply, coming from different generation systems and across multiple sources, is transformed into a relatively stable and reliable flow of electricity for consumers. These professionals and this infrastructure ensure that, despite the volatile and uncertain contexts, the lights stay on. In the same way, pastoralists provide a steady supply of varied nutrients and water sources across a vast ecological area to support their herds, despite uncertain conditions emerging from a combination of drought, conflict events, disease outbreaks, market volatility and political disputes. This requires continuous real-time attention in addition to much skill and knowledge, which is drawn from diverse sources in response to fast-changing circumstances.

High reliability professionals are at the centre of different networks, with each network providing different types of support. Networks may overlap, and high reliability professionals often act as brokers between different networks, facilitating flows of information, resources and skills among them. For example, in North Horr, Kenya, among the Gabra pastoralists, brokers include indigenous healers (chilres) who, in the event of an outbreak of human or livestock disease help to connect networks of pastoralists to networks of health-focused NGOs and relevant county authorities (Tasker and Scoones, 2022). Among Somali pastoralists, clan leaders and knowledgeable elders play an important role in supporting community grazing schedules and information on mobility. At the same time, key individuals involved in livestock markets like the *dilaah* (broker) were found to offer information to the community on prevailing livestock prices thereby forming an important part of pastoral networks of information (Schelling, 2013; Haydarov et al., 2016). Similarly, Hesse and MacGregor (2006) found that pastoralists across East Africa engage in organised access to common pool resources like land and water relying on knowledge of the landscape and reciprocal relations in different contexts.

Sustaining such networks requires continuous interaction and investment in social relations. These relations may be based on pre-existing kin or clan relations, but other relations—such as those with external actors—may have to be (re)cultivated on an on-going basis. Maintaining these relationships requires particular skills including tact, sociability and communication (sometimes across languages) (Lewis and Mosse, 2006).

Networks of high reliability professionals are particularly important resources in periods of hardship, complexity, or crises. Local responses to shocks rely on these networks. Facilitated responses are likely to combine livestock movement, sharing and distribution of animals, exchanges of food and milk products, and the prediction and planning in anticipation of different shocks and crises. Pastoralists also rely on a range of different networks to organise access to fodder and water, to negotiate access to markets, mobilize credit and maintain peace and security. Leveraging their networks, high reliability professionals innovate during and manoeuvre through complex challenges by drawing on their social and economic

connections within and across borders, population groups and dynamic landscapes (Roe, 2020; Nori, 2023). A key strength is that such reliability professionals are generally viewed locally as legitimate and trusted, even if they are unknown and largely ignored or dismissed by external agencies and governments (Hassan et al., 2024). The actions and interactions between the networks of high reliability professionals and local communities help to create a web of social support or resilience. Resilience in this form is not geared specifically towards mitigating catastrophic situations; rather it is about long-term communal transformations and everyday practices that strengthen and support pastoralist systems.

This article builds an understanding of high-reliability professionals and critical infrastructure to outline alternative approaches to building resilience in pastoral settings. We frame this discussion in a context that prioritises local knowledge, networks within local practices, and governance processes that operate both separately from and together with external interventions. In contrast to the standard narratives of dryland pastoral areas, which often characterize these regions as disaster-prone and crisis-ridden, our approach recasts pastoral areas as places where often hidden and rarely appreciated high reliability professional networks work with local communities in challenging, variable and uncertain settings to continuously mitigate the impacts of shocks.

Our research on pastoralism as a critical infrastructure recognises that locally embedded practices for crisis preparation and response may not always eliminate the effects of shocks and disasters. Similarly, we acknowledge that—like all networks—local high reliability networks will invariably exclude certain individuals and/or population groups. Focusing on high reliability networks will not provide a simple panacea or quick fix for the complex challenges present in the drylands, but does offer an alternative way of thinking about how to support pastoral systems in light of the repeated failures of development and humanitarian interventions. One of the problems with external interventions is that—even those which claim to be 'community-based'—they often exclude behavioural norms of customary authority and sanctions that have been in practice for centuries (Roe, 2009). By highlighting the role played by high-reliability professionals, this article provides insights into how new forms of resilience, rooted in local relationships and networks, can be better supported by external actors.

Materials and methods

Data for this research draws from five rounds of qualitative fieldwork conducted between 2022 and 2025 in dryland regions of northern Kenya and southern Ethiopia. Research on local forms of resilience and the actions of communities in the face of shock took place in five villages in Marsabit County, Kenya, two villages in Isiolo County, Kenya, and two villages in the Borena Zone of Oromia Region of southern Ethiopia. We purposively selected study locations to illustrate cross-border ties (in the Marsabit/Borena areas), heterogeneity of livelihoods (pastoral, agro-pastoral, and peri-urban), differences in access to markets and infrastructure, and to reflect experiences of conflict with neighbouring groups. Ethnically, the study sites are all predominantly Borana. Figure 1 shows the study sites.

The qualitative study employed an iterative approach over the multiple rounds, thereby allowing for new insights from one round to be further investigated in the next (Tracy, 2019; Seidman, 2019). Tools included individual open-ended interviews, focus group discussions (FGDs), and key informant interviews (KIIs). The exploratory and flexible process of the design allowed the team to gradually build an understanding of how local people organised different activities and to identify critical individuals and networks supporting these activities. The iterative design also allowed the team to follow the dynamic nature of how people engage and the complex relationships that exist between such interactions (Mohajan, 2018).

The research team consisted of three Kenyan researchers, one Ethiopian researcher, two northern academics, and ten local researchers from pastoral communities in the cross-border region. The team was balanced by gender. The repeated site visits over multiple rounds allowed both respondents and researchers time for contemplation by respondents and resulted in more nuanced conversations and rich contextual information (Lokot, 2021; Creswell and Miller, 2000). Preliminary analysis and debriefs between rounds of data collection resulted in revised interview guides and checklists for subsequent rounds. The fieldwork started with a multi–day qualitative training that included ethical considerations for the entire team; subsequent rounds began with refresher trainings. Data analysis took place in all-team workshops.

Within the FGDs, researchers used mapping exercises to identify pastoralists activities and individuals and networks that offered support. FGDs were gender and age specific to help ensure the comfort of participants in sharing their views and experiences. Key informant interviews took place with individuals identified as high reliability professionals discussed in the FGDs; local leaders, people of influence (of both genders and different ages), local and international humanitarian actors, and state officials also served as key informants.

The team conducted a total of 60 individual interviews and 57 FGDs, for a total sample of 293 respondents (180 men, 113 women). Study participants included herders, male and female youth, male and female elders, and formal and informal leaders. We sought to balance male and female respondents to the extent possible across all categories.

Topics covered included historical shocks, communities' experiences of shocks, strategies that communities draw upon, the sequence of responses, and differences in responses based on

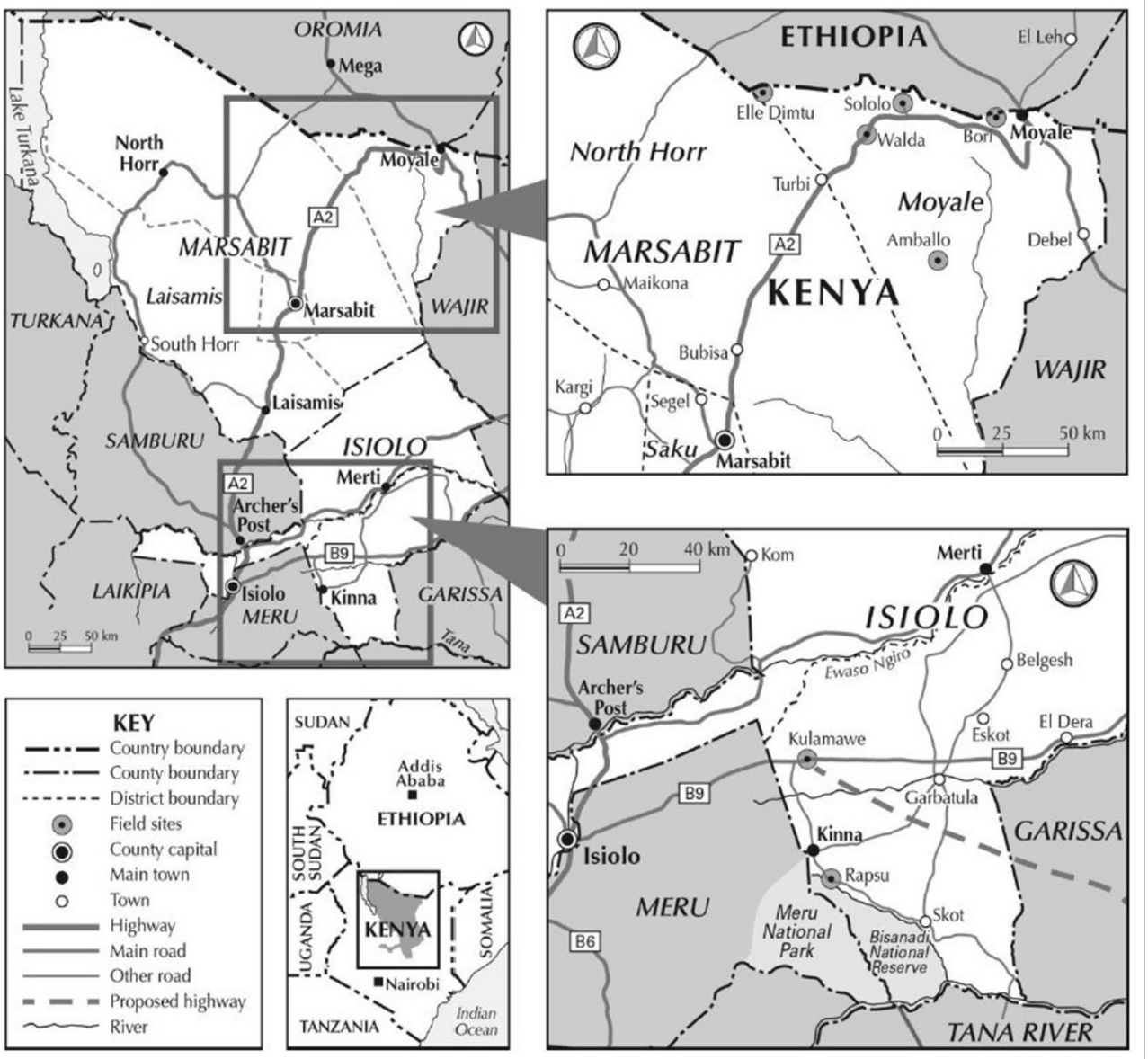

FIGURE 1
Fieldwork study sites in northern Kenya and Southern Ethiopia.

age, gender and social status (wealth, marital status, asset holding, etc.). In addition, we examined specific components of humanitarian action in the drylands, including indigenous and external early warning systems, drought response (including livestock movements, fodder management, water supplies, and cash transfers/credit support), and conflict negotiation/peacebuilding across official, formal, and local, informal spaces. Special attention, including through participatory mapping with FGDs, was paid to local networks and individuals who provide for various needs, information, services and advice. Interviews were audio-recorded and later translated into English and transcribed. Local researchers were central to the analysis process, which occurred through daily reviews of findings in team meetings during the fieldwork, transcript review and identification of themes, and coding of quotations. We held three synthesis and analysis workshops with the teams in Isiolo and Marsabit Counties.

Ethical approval for this study was obtained through the relevant institutional review processes of the participating research institutions. The study was conducted in accordance with established ethical guidelines for social science research, including principles of voluntary participation, informed consent, confidentiality, and minimisation of harm. Prior to data collection, the research objectives and methods were

explained to all participants in locally appropriate languages, and informed consent was obtained from all participants. Consent was obtained verbally due to varying literacy levels among participants, and this approach was approved as part of the ethical review process. Participation in the study was voluntary, and participants were informed of their right to withdraw at any time without consequence. To protect confidentiality, all personal identifiers were removed from the data, and pseudonyms are used throughout the manuscript. Verbal informed consent was obtained from the individual participants for the publication of any potentially identifiable information included in this article.

We now turn to discussion of the main themes emerging from the analysis. All themes occurred in each study site, but we have chosen one case-study to illustrate each theme. Names of participants have been changed to ensure anonymity.

Results

High reliability professionals among pastoralists of northern Kenya and southern Ethiopia

In this section, we present six themes, each illustrated by an in-depth case. The themes represent different challenges for pastoralism and illustrate how variability in conditions and uncertainty in knowledge is navigated. The cases are illustrative while also highlighting how high reliability networks are constructed based on our data and cases selected and how high reliability professionals work; sometimes successfully, sometimes less so. From this thematic analysis, we draw out five overarching principles that characterise high reliability in pastoral settings, with the aim of drawing wider conclusions to improve development approaches to the drylands. These principles are not exhaustive, but they represent important issues affecting pastoral settings across and therefore critical for achieving reliability.

Early warning information sharing and deliberation

Herders are gathering in the mid-morning, ready to water their livestock at the Bori borehole and meeting point around 25 km from the border town of Moyale, a subcounty under Marsabit County in northern Kenya. The rains are back, but the effects of the failed rains in the last five consecutive seasons from 2021 are still on everyone's mind. Community members share how they initially ignored prior warnings of the possible failure of rain and serious drought and loss of livestock from the '*Uchu*', an indigenous early warning expert who, based on her reading of livestock entrails, relayed information about the difficult situation that awaited the community. As one male herder commented:

> The *Uchu* is a skilled community member, and everyone has been referring to her warning and concerns in the last 2 years. For instance, she found us with a group of male herders watering our cattle and told us that these animals may not make it to the next season as her reading of the intestines showed the rains would fail and therefore she could see the 'mona'(kraal) will be empty. (FGD, male herder, Bori, Kenya, July 2023).

In the above, we see a local forecaster communicating early warning information based on a culturally embedded skill. Community members gather such information from different sources and in some cases differing in detail and focus. The early warning information is also shared by the "*Ayaantu,*" indigenous astrologers, who are skilled in reading the patterns of the stars and offer possible weather predictions. Community members in a nearby area describe a trusted astrologer who they rely on for early warning information:

> Boru is an *Ayaantu* in his late fifties. He got his knowledge from his father, who passed it down from his grandfather. He provides intricate information about early warning - whether there will be enough rain, drought, and/or delays. He also provides information regarding which areas would receive more rain for us to plan our movement with our livestock. (KII, community member, Bori, Kenya, July 2023).

Emphasizing the cross-border nature of information systems, the important role played by the Kenyan *Ayaantu* in the Bori community is recognised by herders just across the border in Ethiopia:

> We know that Boru has special information for us, and we are always keen to hear what he has to say. We know that with his information and predictions, we can make plans in advance before the drought. (FGD, community member, Dambi, Ethiopia, April 2024).

The *Ayaantu* shared how he derives this information:

> There is a specific star *(bakalch)* that when it is not seen, we know that there's no rain. It has happened before that the star disappeared, and we knew that there would be no rain. This led to the loss of our livestock. (KII, *Ayaantu* (star reader), Marsabit town, Kenya, February 2025).

The *Uchu* and *Ayaantu* work closely with their community and draw on different sources of information in the cross-border area. The *Ayaantu* shares his information after consultations as well: "I always consult my uncle who lives in Ethiopia, and we exchange what we see from our reading of stars." Like the *Uchu*, the *Ayaantu* is a skilled expert, trained through intergenerational knowledge transfer to provide critical information relating to

local weather. Community members draw on external sources of early warning as well, such as the national meteorological office, government early warning drought bulletins and radio programmes. One particular radio station—Ibse radio in Marsabit—runs one show where listeners call in to share information and other talk shows where invited experts answer listener questions. The Ibse radio programmes have become important sources of early warning information for many community members.

The Ibse radio information is trusted and appreciated because the deliberation style of the call-ins and talk shows aligns with the typical local approach, whereby people consider different sources of early warning information and discuss their meaning together. As one group participant commented: 'When everyone has spoken – the *Uchu*, the *Ayaantu*, the Meteorology office—we discuss with each other . . . We even consult [with people] in Ethiopia' (FGD, community member, Bori, Kenya, February 2024). Such deliberations may occur spontaneously at meeting points—most notably the Bori watering point—or may be called by the disaster committee, established by a local NGO, CIFA. This committee occasionally convenes different groups, including elders and indigenous forecasters, to deliberate. These processes of information gathering, sharing and— crucially—deliberating on conflicting sources of information are critical for knowledge and preparedness within the pastoral system.

Even within collective deliberations, people may choose to follow different interpretations and pieces of advice, and later jointly reflect on the veracity and the associated outcomes. One respondent described just such a situation:

> [At one time], there was conflicting information as the *Uchus* were not [in agreement]. The Meteorology Office people said that there was worse [drought] to come, and that we should sell [our livestock], and we indeed sold them at very low prices. However, one of our colleagues, Mr. Galgallo, rejected this and listened to the *Ayaantu* who had a different view. People laughed at him then, but now he has cows!' (FGD, community member Bori, February 2024).

Similarly, as mentioned above, herders in Bori described failing to heed warnings from their local *Uchu* in the run-up to a devastating drought. While these particular respondents chose to ignore their *Uchu's* warnings, others took action in response to the same warning and some effectively mitigated losses. These examples demonstrate the diversity of information, interpretation and actions arising from indigenous early warning systems. This characteristic of local systems stands in marked contrast to external early warning systems, whereby the information often appears to be less nuanced, more absolute and allows little room for deliberation or interpretation. Importantly, even when local predictions contradict each other, community members argued that they trust their local experts who provide early warning information. For instance, a community member explained that they trusted the local *Ayaantu* or *Uchu* because "he is part of our community and he understands that the livestock are our sole livelihood. We trust that he has our interests at heart" (FGD, community member, Elle Dimtu, Kenya, July 2024).

Access to pasture and water

"*Fini Borana marraf bisan"* translates to "the prosperity of the Borana livelihood is dependent on access to pasture and water." Ali shares this saying in Kulamawe, a rangeland area in Isiolo hosting critical resources for pastoralists, including the Waso Borana who live along the Ewaso Nyiro river. Ali is a male elder who, along with others like him, form the local *deedha* committee, a traditional Borana institution responsible for managing grazing and mobility routes and schedules. These local governance bodies make crucial decisions regarding access to pasture and water across both wet and dry seasons. *Deedha* committee members are normally trusted elders with different herding skills. Among them is Ali, the chairperson of the committee and a respected community leader. Boru describes Ali's role:

> Ali works closely with us in the *deedha*. Based on his knowledge of our landscape and the different resources, he advises us on where we should graze, especially during drought or when animal diseases are reported. Our area is also a fallback grazing area for other neighbouring communities, and, during drought, we receive a lot of requests for grazing from outside. Ali has a strong network with communities from Sericho and Merti who contact him seeking assistance. Ali shares this information with the committee and manages the movement of the neighbours' livestock as well as food for the herders when they are in the Kulamawe area. During the last serious drought in 2021, Ali mobilized foodstuffs for the herders given that they had lost a lot of their livestock . . . Ali also called on the county and national government to [ask for their] support. After consultations, the politicians mobilized resources and transported [some of our] herds to Tana River County, further south in Kenya, to another Borana community which offered the herders pasture and water. (KII, community leader, Kulamawe, Kenya, July 2024)

The *deedha* committee and Ali specifically work closely with Jarso, the *Abba herega* (water manager) in Kulamawe. Jarso is also a religious leader at the local mosque. In his role as water manager, Jarso manages the boreholes and the pumping of water to different points for household use and watering livestock. "It is a difficult role," Jarso explains. He continues:

> We only have two boreholes that everyone relies on, especially during the dry seasons when the temporary water points from the rains have dried up. Community members and livestock all rely on these boreholes. We have a system that pumps water to specific tanks and community watering points in the centre. Everyone is then expected to pay some amount every month to support in managing the borehole. (KII, community leader, Kulamawe, Kenya, October 2024).

Community members laud Jarso's skills in managing the water meters and the payment accounts. Jarso is clearly trusted with the money and people are content with the level of the consumption-based monthly fees. One FGD member reported:

> Jarso is fair. He is a Muslim and knows the rules of being just. He is always kind to those who cannot afford to pay but need water. Jarso is always resolving complaints and conflicts from those who need more water; he can manage all the needs as well as find a system that works. For example, we know which days and times are scheduled for watering cattle and camels, and the time to water goats. Even when we have neighbours joining us to herd, this procedure has to be followed. (FGD, community member, Kulamawe, Kenya, November 2024).

Jarso must at times make decisions based on changing and emerging needs. For instance, in collaboration with the *deedha* committee, he must ensure that livestock can access water on their scheduled day. As a herder in charge of the livestock roster he informs the *deedha* when the schedule is full. Jarso must stay on top of this information to ensure adequate water access both for local herds and for those coming in from other areas. This requires not only coordination skills, but also maintaining trust and a reputation for reliability within the community. Jarso must also problem-solve when problems arise with water sources or with household use, as he explains:

> Our borehole broke down once and we needed to mobilize the county government to send engineers to fix it. The process took a long time, but we worked locally to make a temporary solution to ensure the water was running ... The record keeping of the water consumption is also important in helping everyone track their use. Sometimes we get requests from community members that they cannot afford to pay that month, and we allow them to continue accessing the water. The community at the mosque is also closely linked to the water management, given that some fundraising for community needs happens at the mosque. The money is passed to me as the water manager to be the custodian of the money collected. (KII, community leader, Kulamawe, Kenya, October 2024).

Ensuring reliable access to grazing and water is crucial for any pastoralist, and institutions such as the *deedha* and the water management system are essential. The high reliability professionals involved in these local institutions, such as Ali and Jarso, must have deep contextual knowledge of water and pasture resources, including seasonal availability, and of animal nutrition and behaviour. They must manage competing demands, including from outsiders. They have to keep records of grazing and water use, including payment systems for water, and must respond quickly to pump breakdowns. They must negotiate with the state. They must also raise funds from community members, the mosque and the government. These are not simple tasks, requiring a range of skills, expertise, and access to multiple and varied networks. The roles of Ali and Jarso in Kulamawe illustrate the extent to which local communities rely on local institutions, such as the *deedha*, and upon the highly skilled and connected individuals who work within these institutions. Contrary to narratives of vulnerability and disempowerment, these accounts demonstrate the depth and breadth of local systems of resilience and support.

Creating fodder reserves

Rapsu in Isiolo County is part of a growing agro-pastoral population that was relocated to the area following the displacement of the local community due to prolonged conflict in the 1970s (Gachuhi, 2024)[4]. We meet Hassan, the chairperson of a fodder group, who practices both crop farming and livestock rearing. Born in Rapsu, he is 45 years old and holds various community leadership roles. Over time and under Hassan's leadership, the fodder group has evolved into a cooperative for cash crops (such as onions) as well as fodder. Hassan describes the group's origins:

> In the past, droughts occurred roughly once every 10 years. However, now, even when rain is expected, there is no guarantee that it will come. And, if it does, it is often minimal. This small amount of rain allows only a little grass to grow, which is quickly consumed by livestock. During the dry season, animals from other regions also migrate to our area in search of pasture. Since the pasture is insufficient, many animals die from starvation. We started this fodder farming initiative 10 years ago due to the recurring droughts brought about by climate change. (KII, community leader, Rapsu, Kenya, October 2024).

In addition to managing the internal aspects of the group, Hassan also works with other officials of the fodder group to identify external partners to support their group. The members

4 Available at: https://www.standardmedia.co.ke/article/2001493972/how-vagaries-of-climate-change-have-pushed-pastoralists-of-isiolo-county-to-crop-farming

include men and women who are herders, farmers and those who run small-scale businesses:

> We noticed that during droughts, development partners and the county government often purchase grass to support affected areas. They buy the grass from us, which has provided a source of income. Some of us use the income to pay school fees, medical bills, and other expenses, including settling debts. (KII, community leader, Rapsu, Kenya, January 2025).

Community members describe the critical role played by Hassan, both in chairing the group and in encouraging others to grow fodder and join the group. "The fodder group chairperson plays an integral role in the growth of the association. We have seen our membership grow over time. He provides leadership and is key in linking members with other external actors" (FGD, community member, Rapsu, Kenya, January 2025). The fodder group has seen a rise in demand in recent years and has supplemented the stock from members with external supplies. They have also diversified the content of the product. This requires Hassan and group members to employ their expertise in rangelands and livestock nutrition. Hassan explains how the cooperative serves herders across the region:

> Our customers include herders from Isiolo, Kinna, Garbatula, and Marsabit, with some traveling from far away to buy [our] fodder in lorries . . . Fodder production now includes nutritious grass types such as Sudan grass, known for its high crude protein content, which significantly improves livestock health. The cooperative has 1,700 bales of fodder in stock, 600 of which come from members' farms. (KII, community leader, Rapsu, Kenya, January 2025)

The evolution of this fodder group into a successful cooperative under Hassan's leadership is an example of a high reliability professional using his skills and network to develop a larger enterprise with the capability to benefit a wider community. Hassan not only has the skills to manage the group and link with external actors but also has been successful in convincing community members to grow fodder and join the cooperative. The sale of fodder provides income for members of the cooperative while also offering a critical service in times of drought.

Managing a complex value chain

Walkabana Cooperative, located in Kulamawe in Isiolo, is a group of mainly female herd owners and community members who formed a cooperative in 2010 to collect and market camel milk. Though a valuable commodity in both the local area and large urban centres, camel milk from Kulamawe has only recently entered the value chain to more distant markets. Local milk producers did not have the appropriate equipment or capital to be competitive in the larger camel milk trade, but this changed when USAID and other donors funded cooling infrastructure and provided technical support. Today, members run the cooperative without external support and the sale of camel milk has become an important source of income for members, and an important source of employment for the local women who manage the marketing and distribution. This case provides an example of how external investments can be combined with local high reliability knowledge and management to succeed. This stands in contrast to many external projects that lacked this local component and have subsequently failed.

Rukia, who advises the committee that runs the cooperative, is a quintessential high reliability professional. She discusses the history of the cooperative, explaining how three locations came together to collect milk and connect to the value chain in larger towns like Isiolo and Nairobi:

> We started in 2006 as women's groups from Boji, Kinna and Kulamawe locations and later we became a cooperative in 2010. My role was originally to seek external support to help establish our cooperative, but also to bring all the women milk sellers together with camel herders who were taking care of the herds. We have received support over time to establish our milk plant, buy a vehicle to support transport, and also manage our cooperative bookkeeping and financial records. (KII, community leader, Kulamawe, Kenya, July 2024).

Community members describe the important role played by Rukia in connecting different local and external actors: "Rukia works closely with the grazing committees and elders in Kulamawe as well as youth in the area. The youth trust Rukia to make decisions about the use of the cooperative motorbike and they share information with her on the transport challenges." (FGD, community member, Kulamawe, Kenya, January 2024).

Rukia describes her work and the multiple different actors she negotiates with to ensure the cooperative is working smoothly:

> Our members have different needs, and sometimes there are complaints, so I am in constant communication with them . . . The camel owners and herders are also very critical because they need to learn how to handle the milk. Without the herders, we would not run our cooperative, so we engage with them and train them to ensure milk hygiene. We also work with young people who operate boda boda (motorcycles) delivering milk to the cooperative. Tawakal Cooperative in Isiolo and Kenya Cooperative Creameries also buy milk from us at different times, and I have been in contact with them since we began. (KII, community leader, Kulamawe, Kenya, July 2024)

Rukia and the committee members navigate multiple uncertainties to keep milk sales going. Securing markets for the milk can be challenging, and committee members must be continuously on the lookout for potential milk producers and markets to ensure that their long-time members and customers are satisfied. Milk handling and quality is critical now that the cooperative is selling more widely, and Rukia manages compliance with this aspect. Managing the business also involves bookkeeping and working out the benefit-sharing formula, dividend distribution and loan systems. This collective organisation has evolved over time, gaining new skills and members, but remains firmly rooted in female networks of solidarity and moral economy, as one member explained:

"We have learned how cooperatives work. As members we share proceeds at the end of the year, but we are still tied together as women. We are there for each other to especially support each other in times of need" (FGD, community member, Kulamawe, Kenya, January, 2025).

In addition to supporting each other, the members must build networks with others in the value chain, including the herders who supply the milk, the transporters, and the middlemen purchasers. Ensuring that the cooperative continues to function requires continuous investing in diverse local relationships. The women are savvy in managing these aspects, as evidenced by their relationship with local religious leaders: the cooperative allows the mosque leaders to use their water coolers to provide cool water to worshippers when they break fast during Ramadan. The women explain that this is a complex value chain, with many links and embedded social relationships. Managing this reliably requires much skill, and the cooperative is highly reliant on Rukia who is at the centre, operating as a high reliability professional, assuring stable supplies of milk, negotiating relationships, and managing income streams in the context of a highly variable and complex market.

Credit support from shopkeepers

Local business owners in pastoral areas often serve as crucial sources of commodities, savings schemes, credit, and transport services that assist remote rural communities. This support is particularly critical in times of hardship when credit (in cash or kind) can be critical for households and herders.

Abdi owns two shops in the central area of Bori. Born and raised in Bori, the 34-year-old started several small businesses at a young age. Herders describe their relationship with Abdi:

> We all meet at Abdi's shop in the evening after our day with our herds. Some people come to purchase household items, others bring charcoal to exchange for household supplies. Some women deliver milk to this shop [in exchange for] household food items, and Abdi in return sells the milk to get back his money. (FGD, community member, Bori, Kenya, July 2024).

The credit arrangement at Abdi's shop makes him a very important and trusted figure in the area. Abdi tracks the credit and means of exchange of each customer, agreeing on the terms in advance. He also offers a savings scheme which is mostly used by female customers who deposit cash from their charcoal or milk sales at his shop. Sometimes Abdi transports their milk and charcoal to Moyale town with his motorbike, selling the goods for them and providing the transport at a reduced rate. Abdi explained this arrangement:

> What happens is that they bring their milk or charcoal for me to sell in Moyale. I offer to load these supplies on my motorbike as I also go to get supplies for my shop. Once the milk or charcoal is sold, I keep the money and deduct the debt at the end, and give them the balance from their sales. If their credit exceeds their sale, I ask them to top up the balance. (KII, community member, Bori, Kenya, July 2024).

Abdi's provision of credit requires him to be flexible regarding repayment mechanisms. Sometimes community members are only able to repay debt after receiving cash transfers from humanitarian assistance programmes. At other times, "the debt amounts become so high, but community members offer to repay in cash or kind (livestock)," explained Abdi.

Abdi exemplifies the reliability that can be created by business people who apart from making a profit, have strong commitments to their local communities. This reliability is anchored in social connections and the trust-based moral economy that characterizes many pastoral societies. Abdi describes how he sees his community and his role within it:

> Sometimes community members face crises, and the debts become impossible to pay. [When I give out many loans,] I go low on stock and the money needed to buy new stock is not available, but I just must persevere. These are my people, and I can't allow them to suffer while I can do something for them. I have to make sacrifices sometimes. (KII, community member, Bori, Kenya, July 2024).

Like other shopkeepers in pastoral areas, Abdi has critical skills that enhance both his reliability and his importance within the community, including financial literacy and good record-keeping. Abdi reports a low default rate on the credit he provides, and ascribes this largely to the trust which underpins the financial transactions. The existence of such individuals able to make profit and provide credit is vital for reliability in the absence of other sources of finance in times of stress.

Another important characteristic of Abdi's (and others like him) is his connections. His market connections in nearby towns allow him to get favourable prices when he sells local people's goods. He also provides transport, either through his connections to local male youth motorbike riders or via the shop's van. The

links to external support that provide cash transfers is important for Abdi because it provides predictable cash locally which community members use to pay accumulated debts either as individual recipients or on behalf of others in the family of wider kin group. Maintaining these networks, connections and roles generates high reliability. Abdi's financial skills, combined with his compassion for his community, are important elements within a volatile economy and make him a critical high reliability professional in Bori.

Reducing conflict and assuring peace and security

Beyond risks to life, conflict between different groups can have profound effects upon pastoral livelihoods when grazing areas and water points become inaccessible due to insecurity. Losses to livestock, disruptions of trade routes, and market upheaval are all common outcomes of even localized conflicts. Efforts to reduce conflict and promote peace are therefore vital. Halkano from Ambalo explains how the process worked when outside groups were moving into the area to access resources during the drought:

> We each have our own areas, but if there is peace we can graze in different areas flexibly. But misunderstandings over pastures and water do arise. Previously, elders would agree on movements of livestock, but now people move without our knowledge. We have politicians, peace committees and so on at the higher level who allow movement, but they do not consult us. This can result in conflict. I work closely with other community members to mobilize different groups to support surveillance as well as ensure availability of resources. We give the role to the youth to go on motorbikes and find out [what is happening]. We meet the Gabra in the rangelands when we are herding and we ensure we communicate with their elders to avert possible misunderstanding and clash during grazing. We also organize meetings among the elders. We had their contacts, and *vice versa*. We aren't strangers … [Then] the drought became more intense. There were people coming here [to Ambalo] and many rumours of what could happen. We expected conflict, but the elders kept in touch on cell phones. Later, many Gabra came here with their animals, we agreed some would go back, but some would stay. Now the rains have come [and the Gabra have returned home] but we keep in touch and keep meeting. (KII, community member, Ambalo, Kenya, February 2024).

Halkano works closely with a group of male elders from Ambalo assisted by young men on motorbikes to support in continuous conflict monitoring. Although male youth are at times dismissed as lacking a commitment to pastoralism, this case illustrates a close partnership between the male elders and youth. The village committee pays for the motorbike fuel for the youth involved in surveillance, and funds can be raised for firearms if the threat of conflict increases. While these arms are illegal, local groups indicate that herders feel safer when they organize to protect themselves. Continuous interaction and personal connections are key, with a give-and-take in times of hardship essential to build trust across the communities. Interestingly, when it comes to resolving conflict, top-down peace committees and the intervention of politicians are considered unhelpful; in some cases escalating the conflict instead of resolving it. Rather, it is the locally-built reliability, based on continuous monitoring and on-going communication managed by local elders and youth that is key in conflict *prevention*. The role of community members like Halkano is also key in managing the relations and supporting discussions among different groups. This is in stark contrast to an external approach that often waits for conflict to erupt before responding to it, by which time it is often too late to find a resolution.

Discussion

Generating reliability: people, places and times

Who then are high reliability professionals? As the cases above show, these are often not people with official positions, nor are they necessarily the best educated, most qualified, or a senior male actor. Despite the continued prevalence of an elite patriarchal social structure, women and younger people can also be high reliability professionals.

High-reliability professionals are associated with a particular set of skills and aptitudes. These include the ability to manage and invest in relationships, acute situational and system awareness, and the skill to quickly spot problems and find solutions. Such people are often flexible in nature and able to respond temporally and spatially to changing circumstances, and can switch between regular, routine operations and non-routine emergency modes. They have technical skills – for example in financial management and record-keeping - as well as have access to resources that allow mobility, including vehicles and motorbikes for transport. They can mobilize connections to urban areas, government officials and NGOs, and have the ability to speak in the language of these entities and, above all, the ability to command respect and trust in the wider community that they work with.

As we have seen, reliability often emerges in specific places, and the skills, practices, and applied knowledge is also often quite spatially specific. For example, spaces of reliability may be found in market places or around wells and water points where information is exchanged and uncertainties deliberated upon. Such spaces may exist in shops in small towns or villages where shopkeepers may be the centre of a network, offering small amounts of credit along with advice and support. Or they may be around "key resources," those last-resort places such

as Waso (the Isiolo rangelands), where grazing and water can be found, and where intensive investment in reliability management is essential. Pastoralists rarely recognise international borders and most of the cross-border areas in the Horn of Africa are avenues of exchange and cooperation among local communities aided by movement of people and livestock. The coordination of different services and reliability networks happen at the local and cross border areas especially where particular resources are shared (Schelling, 2013; Oba, 2012).

The importance of the specific spaces in different pastoral contexts, knowledge and networks illustrates that high reliability cannot just be turned on; it must emerge in context. This is why any external approaches that seek to tap into these networks must be deeply embedded in existing community practice and not imposed through "cut and paste" projects (Catley et al., 2013). Studies in other pastoral contexts have similarly linked the failure of projects to processes that ignore local systems and institutions (Fratkin and Mearns, 2003).

Reliability practices often also link to particular moments in time. These moments may not align with external concepts of "crisis and risks;" rather, they may occur before or after these markers. The idea of managing crisis and risk implies that moments can be predicted and that pastoral contexts are stable. This understanding fails to recognise that the practices deployed by different pastoral groups draw on variability and remain flexible and interconnected (Krätli and Schareika, 2010; Mohamed and Scoones, 2023). Pastoralists engage with the changing environment reflecting the uncertainties and unpredictable situations that characterize pastoral settings (Nori and Scoones, 2019).

Reliability generation is therefore a continuous process, even if the modalities shift between emergency response, recovery and in "normal times." Reliability generation may involve different actors with, at times, overlapping functions or networks. For instance, high reliability professionals and networks play a critical role in securing year-round grazing, whether through access to rangeland or the procurement of fodder. These functions are particularly important around times of shock, when responses must be more immediate, but they are not random and are always coordinated, relying on networks. When a drought looms, for example, securing fodder in advance is crucial to save the female and young animals who will form the core of a future breeding herd. The practice entails anticipatory strategies, including harvesting and storing grass, purchasing hay and accessing different crop residue (Butt et al., 2009; Hassan et al., 2024).

This requires mobilisation of extra fodder and pastoralists with the means will reach out to those who can reliably supply fodder at good rates. Even when not in a crisis, gaining access to dry season grazing areas can require negotiations with the right people, especially if the pasture is in a national park. Grazing in parks is notionally illegal in Kenya, and hence an elaborate, negotiated and relational process of accessing these critical resources during times of shortage is required (as well as often paying money to facilitate the process). The regular and seasonal movement of livestock is essential in the variable environments of the drylands and requires early scouting, negotiation with neighbours, mobilisation of labour and the agreement of elders through such institutions as the *deedha*. Maintaining these networks and systems requires regular investment in reliability over time and with different actors.

High reliability thus emerges through the skills, aptitudes and connections of particular people and in particular places at particular times. Unlike the standard external humanitarian-development response, high reliability is not just about responding to a "crisis" or a "disaster." Instead, it is very much part of everyday practice (Hassan et al., in press). Reliability practices are also highly gendered, with different roles being taken within networks and different networks emerging around men and women. Very often women are involved with livestock based at the home site, while men are in distant places with the main herd (Ash et al., 2025). Women must divide their labour, care and attention between looking after children, the homestead, and the animals. In many pastoral communities such as the Maasai and Borana, women engage in combined labour of childcare while also tending to livestock, milking, feeding calves and managing fodder near the homesteads. This labour is critical in supporting pastoral livelihoods across different settings (Wako et al., 2025; Archambault, 2016).

These acts require new daily temporalities as females distribute their efforts to generate reliability. Male and female networks overlap, although some specifically support largely male-dominated activities (such as grazing and water management for mobile livestock), while others are associated with women's income earning activities (such as milk marketing) or domestic and reproduction activities within a relational network (such as informal social safety nets ensuring access to food, child care, and cash). High reliability emerges, as the cases discussed earlier show, as a process of continuous and iterative engagement across networks.

Five principles for high reliability management in pastoral areas

This section builds on the above themes to draw out five critical principles of high reliability management in pastoral areas. As we argue below, understanding these principles may help external actors identify innovative approaches to support livelihoods more effectively.

Embracing uncertainty and deliberating on diverse sources of knowledge

Most external programmes aimed at boosting resilience through early warning and risk reduction look for precise triggers to guide predictable forms of anticipatory action. Such fixed early warning indicators assume pastoral contexts as predictable and oversimplify complex processes where

mobility, multiple knowledge and local actions are critical (Derbyshire et al., 2024). Yet even technology-based early warning systems cannot fully minimise uncertainty, thereby requiring actions to be flexible and locally embedded to ensure dynamic and appropriate responses (Scoones I., 2023). Literature on pastoralists' early warning shows how different communities assess short- and long-term ecological trends through indigenous knowledge to predict and observe weather patterns (Guye et al., 2022; Luseno et al., 2002). Multiple and diverse sources of early warning calls for the need to consider indigenous and external early warning systems to support a flexible process of synthesising knowledge in different contexts (Hermans et al., 2022; Berggren et al., 2011).

As evident in the above early warning case illustrated through Galgallo's story, embracing uncertainty necessitates operating through less fixed procedures and relying on hybrid sources of information. These hybrid sources might include both the forecasts from local intestine readers and astrologers as well as information from the meteorological services and the drought management agency's early warning bulletin. Generating reliability in uncertain environments requires deliberation across these diverse information sources. Locally embedded and trusted high reliability professionals can facilitate such discussions and provide links to the different networks and sources of information. The emerging responses are more likely to reflect local realities and verified means of supporting local livelihoods. Importantly, the embrace of uncertainty and process of deliberation builds trust in ways that formal early warning systems and externally derived information systems do not.

Enhancing local knowledge and institutions for flexible, adaptive management

Pastoralist communities in the Horn of Africa have customary governance systems that oversee different access to resources and authority in building consensus. The *Gadaa* system among the Borana in Kenya and Ethiopia entails a robust system that oversees decision-making including mobilising resources to address different needs (Bassi, 2024). In other settings the role of elders and clan-based structures are important in enforcing customary norms. Among the Samburu pastoralists, elders support managing communal grazing and negotiating access to grazing land (Hassan et al., 2023). These rules are important in instances where there are overlapping rights and multiple types of land tenure (Flintan and Robinson, 2022).

As already noted, reliability emerges from a deep knowledge of complex systems and the ability to combine horizon scanning with local day-to-day responses. As illustrated by Ali's narrative on securing reliable water and pasture for livestock, this is effective when the institutional arrangements associated with the customary governance institutions (such as the *deedha*) function well. Research on the *deedha* system among the Borana pastoralists shows how grazing zones and watering schedules have been managed over time, with the rules enforced by individuals entrusted by the community to ensure equitable access to resources and conflict prevention (Hesse and MacGregor, 2006; Oba, 1994).

Key reliability professionals work closely with such institutions, ensuring movement of animals between different pasture areas and making sure that the various water resources are available at the right times. This requires careful coordination underpinned by a clear set of widely accepted rules and regulations about usage. However, such arrangements are not static. Each year is different, and the institutional system must accommodate and adapt new patterns of rainfall and external pressures from those seeking to gain access to the natural resources.

Local knowledge drives crucial daily activities, such as accessing pasture, water and markets and remaining actively engaged in networks. This knowledge encompasses a deep understanding of the environment, climate patterns, rangeland conditions and livestock characteristics. Different people are involved, as the case studies highlighted, with young men mobilized to scout for pasture and check on conflict situations, for example. Combining different sources of knowledge – supported by mobilising labour and technology in the form of motorbikes and mobile phones – improves the capacity to scan the horizon for future dangers and leads to strategic preventive actions around herd movements, fodder access, market engagement and security planning.

Deploying diverse skills and practices to reduce input variability

Pastoralist communities rely on diverse skills and practices to support different activities including livestock production and managing risks to support their livelihoods. Across different settings, pastoralists draw on these skills and practices to navigate climate variability (Swift, 2019; Oba, 2012). Examples of particular skills for generating reliability noted across the cases include identifying appropriate fodder during drought, finding root tubers for livestock, negotiating access to pasture with different groups, establishing urban linkages for trade and mobilising community members for solidarity actions. Such crucial skills are transmitted from one generation to another, through a deliberate, informal training and mentorship.

High reliability professionals frequently have deep knowledge for example of animal behaviour and have skills at training animals to move to pasture and take water, even under critical conditions. Such human-animal communication reflects a deep entanglement of human and animal worlds in generating reliability. In the same way, particular skills in understanding pastures allows for the identification of changes in grass or shrub species and so assisting the movement of animals to particular sites. What may make the big difference between animals surviving or perishing is the ability to gain access to 'key resources' in otherwise barren landscapes – certain areas with the last grass, certain trees and shrubs that can provide the right nutrition at critical moments or soils with the appropriate

mineral salts for supplements. A spatial and temporal awareness of changing landscapes must combine with an intimate interaction with animals by successful herders who can generate reliability in incredibly difficult situations.

Mobilising innovations, improvisations and technologies

The wider literature on critical infrastructures shows the important role of innovation and improvisation in deriving reliability in complex social-technical systems (Sathurshan et al., 2022; Roe, 2020). These innovations play a crucial role in pastoral systems when different scenarios are formulated based on different knowledge and available technological solutions. The pastoral system is able to adapt based upon long-standing indigenous institutions as well as modern technology (Nori, 2019). These innovations typically arise through action and in real time, representing innovation by bricolage.

Mobile technology supports critical information sharing in pastoral areas, linking relations and allowing cross border conduits of information. In Somalia, for instance, with an extensive mobile infrastructure, cell phones have become a common and useful conduit of information sharing and exchanges among pastoralists (Schelling, 2013). Similar evolving information needs among the Rendille of Kenya and Borana of Southern Ethiopia show increasing reliance on mobile technology for grazing and identifying market prospects (Debsu et al., 2016).

Similar innovations have been applied in herd management and adopting mobility routes through the use of trucks for transport, paying hired labour via mobile money and managing mutual aid support through remittances, the cooling and processing of dairy and meat products and electronic record keeping for cooperatives and shopkeepers. In these examples, technology innovations support real-time management systems anchored within the knowledge and skill systems of reliability professionals, and so providing services continuously and safely over time.

Fostering relations, connections and networks

Critical infrastructures rely on external processes and networks of connected grids. Similarly, pastoralists and mobile people rely on caring social connections of kinship and friendship as well as dense social networks beyond familial and friendship ties (Pas Schrijver, 2019; Scoones I., 2023). Based on the collective solidarity practices and rules of reciprocal assistance, such local practices remain critical in times of crises to support decision making, avert crises, and build resilience.

These social relations build resilience by creating networks that sustain communities across pastoral landscapes. These networks include cross-border systems of market access, transportation, resource sharing and economic exchange, with shifts in directionality based on fluctuating conditions, opportunities and risks. Trust is central to the success of such pastoral networks, and clans, neighbours and friends maintain this trust through social, economic, collective actions and exchange of resources (Iyer, 2016). Pastoralists rely on these networks to share resources, manage risks and adapt to changing circumstances. These social and trust-based exchanges build resilience by creating an informal social safety net that people and communities rely upon (McPeak, 2006; Moritz, 2013).

In sum, these five principles emphasise deliberation across multiple knowledge, diverse skills and practices to manage variability and uncertainty and social networks and relationships, supported through collective solidarity and moral economies. The principles are embodied, but also elaborated, improvised and adapted by high reliability professionals, who operate across different domains within pastoral areas to support livelihoods and avert disasters. What, then, are the implications for these findings for rethinking pastoral development?

Conclusion: high reliability networks and implications for pastoral development

External actors designing and implementing sustainable livelihood development and resilience building projects rarely recognise the roles played by high reliability professionals and their networks. Yet, as we have seen, they have a critical role in building resilient and sustainable development. Although frequently unrecognised and underappreciated, these actors track on-the-ground realities and broader changes allowing for rapid and early responses based on innovation, experimentation and adaptation. In contrast to the top-down approach common in resilience projects (see Hassan et al., in press), the reliability that informs resilience in pastoralism as critical infrastructure emerges from the local level.

The calls for rethinking humanitarian response and development in the dryland pastoral areas of Kenya and southern Ethiopia are not new. Yet practical steps towards reimagining development programming and external investments in pastoral contexts are still missing. Changing aid flows and the decline in support for many projects may provoke the necessary rethink. By moving away from a project mode towards support for high reliability professionals and their networks requires addressing all five of the principles outlined above together. This suggests a new way of working, together with new priorities for support. We conclude with some tentative suggestions on the implications for aid and development.

First, if the aim is to support pastoralism as a critical infrastructure, this means recognising high reliability professionals and their networks, offering additional support where it is needed. Starting from existing people and networks and making use of existing response systems avoids the dangers of over-reliance on external projects that last until the funding dries up. Instead, the alternative means investing in the human and social infrastructure of reliability, while at the same

time enhancing the necessary skills and encouraging learning and replication of successes. External agencies thus become facilitators rather than implementers, investors in existing systems rather than trying to replace or reinvent them.

Second, a focus on high reliability requires accepting that multiple, sometimes competing and incommensurable knowledges are important in generating reliability. Ensuring that different sources of information are made available and shared is critical, requiring open, plural information systems, rather than focusing down on one single expert or technical view. Reliability generation processes need facilitators and champions who are able to source, collate, contrast and compare different sources of information, and so encourage deliberation and then action in real time. This requires skills of convening as well as facilitation, where the key process is deliberation amongst competing knowledges to build trust and so response. External agencies can assist in such processes by making sure diverse knowledge is available through supporting their generation, documentation and dissemination. This includes so-called 'expert' knowledge but also the expert sources of tacit and experiential knowledge from indigenous systems. Again, external actors become convenors and facilitators, but only in the background, while supporting reliability professionals and their knowledge networks.

Third, an acceptance that there are diverse reliability professionals and associated networks focusing on different challenges and needs is important. There is no one-size-fits-all; no simple fix. The configuration and roles of reliability professionals and networks may shift as conditions change, altering operational performance modes and improvising in order to respond. Some approaches may be important in good times; others may come into play when shocks hit or stresses to the system accumulate. The systems of reliability described in this article are not uniform, exhaustive or prescriptive. Rather, they differ based on season and year, wealth, livestock herds sizes and balances, social connections and access to social and economic services. Like pastoralism, reliability systems and the wider infrastructure must be adaptive, dynamic and heterogenous. This means that there can never be a standard 'reliability' project, delivered through a log-frame and a simple theory of change. For external actors, the focus therefore becomes less on design and delivery as in the old project mode, but on facilitation and support for an adaptive system, combined with reflection and learning over time. This must build on the principles outlined earlier but reimagine them for particular contexts and adapt them accordingly. This will require new skills and professionalism of external actors, jettisoning the blueprint models and the standard mainstream narratives about pastoralism and development.

Fourth, recognising system diversity and flexibility is important but so also is the acknowledgement that power gradients operate within and between reliability networks and professionals. These may reflect gender, age, ethnic or other imbalances. Yet, all networks must work together to be most effective. As we have discussed, the contributions of young people in scouting and in conflict alerts and prevention are vital, even if young people are too often dismissed as not involved in the 'real' work of pastoralism. In the same way, the role of women in caring for sick, young or pregnant animals at critical moments, as they balance the support of livestock production and survival with wider social reproduction commitments, is essential, even if this is not managing the main herd or flock. Access to resources essential for reliability may be brokered by gatekeepers – be they shopkeepers or market traders – and inevitably exclusions occur, meaning that some do not get access to credit or sales opportunities at decent prices to support their livelihoods at critical times. External agencies may be able to map, highlight and support more hidden professionals and networks and facilitate processes of reflection that emphasise the importance of the wider collective as part of generating reliability overall across the whole community, rather than just in relation to a particular challenge linked to a certain group.

Fifth and finally, focusing on generating reliability through locally-embedded reliability professionals operating within and across overlapping networks highlights new ways of building resilience. In this case, "from below" rather than through projects and external, expert-led intervention. This approach to resilience building recognises multiple knowledges and as a result diverse actors, cutting across conventional domains of community, state and market/private sectors (Hassan et al., in press). A different style of development - and so approaches to humanitarian response, social protection and livelihood development more broadly - thus emerges. Due to declining aid, external development actors - including states, NGOs and others now often operate with fewer project resources and have to rethink their approaches to development intervention. Rather than foisting endless projects on local people or offering seemingly continuous humanitarian or social protection assistance, a focus on reliability for resilience perhaps offers a more cost-effective alternative that suggests new roles for external actors as investors, convenors and facilitators able to share learning and experience across local networks.

A high reliability approach is not a quick-fix panacea for the challenges of pastoral development in the drylands. Many structural forces impinge on local capacities to respond flexibly and adaptively, which in turn undermine reliability and resilience. Enclosing rangelands reduces the availability of grazing and water while restricting movement options; climate change creates more extreme patterns of variability and so uncertainty in ways that local capacities and institutions become overwhelmed; experiential, indigenous knowledge accumulated over centuries may not be fit-for-purpose today under radically new circumstances; the type of open, caring, collective approaches to redistribution and support that reliability practices tap into may be undermined by more individualised, marketised practices that act to

exclude; conflicts fomented by politics; resource competition may escalate and so disrupt systems of collective, collaborative response, among many other factors. These wider structural features must be addressed in parallel as part of wider policy reforms.

However, this does not undermine the potential for reliability and professionals to be seen as central to a new way of development thinking and practice in the drylands, where external support takes on new roles and functions with funding, expertise and institutional support focused in very different ways.

Data availability statement

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

Ethics statement

The studies involving humans were approved by Tufts University Ethics Review Board and Jomo Kenyatta University Review Board. The studies were conducted in accordance with the local legislation and institutional requirements. The ethics committee/institutional review board waived the requirement of written informed consent for participation from the participants or the participants' legal guardians/next of kin because Consent was recorded as it was considered culturally more applicable to the study participants.

Author contributions

RH: conceptualization, data collection and analysis, writing - original draft, review and editing. IS: conceptualization, data collection and analysis, writing, and review. ES: Conceptualization, data collection and analysis, writing, review, and editing. JW: Conceptualization, data collection and analysis, writing. HW: Conceptualization, data collection and analysis, writing, and review. All authors contributed to the article and approved the submitted version.

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