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Climate Change and Indigenous Weather Forecasting among Pastoralists: Analysis of Hazard Monitoring System in Borana, southern Ethiopia

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Abstract

Pastoralists are increasingly under pressure, experiencing downward spiral, resource depletion and diminishing resilience to climate-change-induced disasters. This study explores pastoralists' innate capacity in weather forecasting, using indigenous indicators that are instrumental in initiating integrated community based early warning system (CBEWS) – synergizing indigenous and formal early warning systems. The study is based on qualitative data collected through observation and key informant interviews (KIIs) and focus group discussions (FGDs) conducted in four pastoralist associations in Borana Zone of Oromia State, southern Ethiopia. Data were analysed thematically. Findings identified pastoralists rich indigenous' knowledge in weather forecasting, using their own hazard monitoring tools, which are useful for action planning by the grassroots, the government and other actors. Integration of indigenous forecasting methods with contemporary scientific approaches offers a potential pathway to an improved community preparedness and timely responses to environmental challenges. Findings further underscore the importance of recognizing and valuing indigenous knowledge in policy formulation for impactful disaster risk reduction and sustainable pastoral development.

Key word: Borana, Innate capacity, Drought, Indigenous weather forecasting, Pastoralism

1. Introduction

Pastoralism is a livelihood and production system adapted to environments often characterized as ecologically fragile or ‘harsh,’ including arid and semi-arid drylands, mountainous regions, and cold environments where climatic conditions are marked by erratic rainfall, seasonal resource scarcity, and extreme weather variability. In such settings, livestock production depends primarily on natural pastures, while mobility remains a central adaptive strategy enabling herders to access dispersed grazing and water resources across space and time (Tamou et al., 2018). The frequency and spatial extent of mobility vary across pastoral regions, ranging from short-distance seasonal grazing shifts to extensive inter-seasonal migration across large territories. During drought periods, migration often intensifies as pastoralists search for safer ecological zones with better pasture and water availability. In some semi-sedentary systems, livestock husbandry may additionally rely on feedlots designed for fattening and market production (Johnsen et al., 2019).

Historically, food production and livelihood sustainability within these environmentally challenging landscapes have depended heavily on Indigenous Knowledge (IK) systems accumulated through centuries of human–environment interaction. Indigenous knowledge is locally developed, socially embedded, and transmitted across generations through observation, practice, and oral traditions (Johnson, 1992; Steiner, 2008; Ngulube, 2017; Mbewe et al., 2019). Such knowledge embodies collective ecological memory and practical understanding of environmental processes, enabling communities to interpret ecological signals and make informed livelihood decisions.

Across Africa and elsewhere, indigenous communities facing recurrent climatic and environmental risks have long relied on indigenous knowledge as a foundation for managing livestock, natural resources, and subsistence activities (Eyong, 2016; Alemayehu and Doda, 2020). For rural and pastoral populations whose livelihoods depend directly on weather and climate conditions, the ability to understand, anticipate, and respond to environmental variability is indispensable (Balehegn et al., 2019). Indigenous weather forecasting therefore represents an important component of pastoral adaptation and disaster preparedness.

Indigenous weather forecasting refers to the locally developed capacity to predict future weather conditions through interpretation of environmental and ecological indicators (Rautela and Karki,

2015). Such forecasting systems provide communities with advance information that supports preparedness for rainfall variability, drought, and other climatic hazards while helping reduce climate-related risks at local levels (Chisadza et al., 2015). Pastoralists in north-eastern Kenya and southern Ethiopia, for instance, monitor cloud formation, animal behavior, vegetation changes, wind patterns, celestial bodies, and bird migration to forecast seasonal conditions (Kagunyu et al., 2016; Dejene and Yitbarek, 2022; Guye et al., 2022). These forecasting systems contribute to sustainable livelihoods and disaster preparedness by offering early warnings of both favorable and adverse seasons, thereby facilitating timely planning and risk management (Zuma-Netshiukhwi et al., 2013; Lwasa et al., 2017; Masgo and Livhuwani, 2025).

Climate change, however, increasingly challenges the ecological foundations upon which indigenous forecasting systems depend. Although climate change is a global phenomenon, its consequences are disproportionately severe in developing countries where livelihoods remain strongly dependent on natural resources and adaptive capacities are often constrained (Salza, 2019; Kidemu et al., 2020; Boru et al., 2026a). Pastoralism is particularly vulnerable because of its close ecological dependence and exposure to climatic variability (Zuma-Netshiukhwi et al., 2013). Rising temperatures, erratic rainfall, prolonged droughts, and changing ecological conditions have altered many of the biophysical indicators traditionally used in weather prediction, affecting the interpretation, reliability, and practical utility of indigenous forecasting systems (Salite, 2019).

While indigenous forecasting has historically enabled pastoralists to navigate environmental uncertainty and make adaptive livelihood decisions, several interrelated pressures now threaten its effectiveness and continuity. These include increasing frequency and severity of droughts (Kidemu et al., 2020), disappearance or alteration of ecological indicators (Ayal et al., 2015), inadequate documentation and coordinated research (Radeny et al., 2019), and broader socio-economic, political, and cultural transformations associated with globalization and modernization (Kimani et al., 2014). Numerous scholars have observed that climate change and heightened weather variability have reduced the predictive reliability of some indigenous forecasting indicators (Roncoli et al., 2002; Ayal et al., 2015; Kagunyu et al., 2016). Consequently, pastoralists in parts of Ethiopia's arid and semi-arid regions are increasingly abandoning traditional forecasting practices (Balehegn et al., 2019).

The erosion of indigenous forecasting knowledge raises important concerns, particularly in regions where scientific meteorological services remain inaccessible, generalized, or insufficiently tailored to pastoral contexts. Loss of this knowledge threatens not only livelihood security but also the disappearance of culturally embedded skills, environmental stewardship practices, and adaptive strategies developed over generations (Kimani et al., 2014). Recognizing this concern, studies across pastoral Ethiopia increasingly advocate integration of indigenous knowledge with scientific early warning systems to strengthen climate resilience and disaster preparedness (Ayal et al., 2015; Kagunyu et al., 2016; Balehegn et al., 2019; Benti, 2021; Dejene and Yitbarek, 2022; Guye et al., 2022). Integrating indigenous forecasting within formal early warning frameworks can improve relevance, legitimacy, and effectiveness of climate information and disaster response interventions (Robert, 2018).

The Borana pastoral system of southern Ethiopia offers an important context within which to examine these dynamics. Beyond conventional climatic variability, climate change has increasingly affected Borana livelihoods through recurrent drought, resource degradation, and heightened livelihood insecurity. Nevertheless, Borana pastoralists continue to employ sophisticated indigenous forecasting systems and locally developed hazard monitoring indicators to anticipate weather variability and manage environmental risks. These practices, exercised through culturally embedded institutions and specialized knowledge custodians, have historically supported resilient pastoralism and adaptive decision-making. Despite their significance, however, Borana indigenous weather forecasting and hazard monitoring systems remain insufficiently documented and inadequately analyzed within contemporary climate change and disaster risk reduction scholarship.

Against this background, this study investigates indigenous weather forecasting and hazard monitoring systems among Borana pastoralists in southern Ethiopia. Specifically, it examines locally developed forecasting indicators, early warning practices, and monitoring systems within the broader context of climate change and pastoral resilience. By generating empirical evidence on the interaction between climate change and indigenous forecasting knowledge, the study seeks to contribute to ongoing debates on people-centered early warning systems and provide insights for strengthening locally grounded and integrated disaster risk management strategies.

2. Materials and Methods

2.1 The study area

The study was conducted in two purposively selected districts of Dubuluk and Dilloo in Borana Zone of Oromia State. The Zone is located between 3°41'20" and 4°43'20" N latitude and 37°41'20" and 38°22'40" E longitude. Yaballo town, the administrative capital of the Zone (Fig 1), is situated at 570 kilometres south of Addis Ababa - the capital city of Ethiopia. Altitude ranges between 500-1500 and 1,485 meters above mean sea level, forming arid and semi-arid agro ecological zonation. The area receives rainfall twice a year, where 60% of the 300-900mm annual rain occurs during March to May long rainy season (*Ganna*) and the remaining 40% between September and October short rainy season (*Hagayya*) (Tache, 2008, Zemenu, 2009). Despite climatic challenges and subsequent emergence of other life-supporting activities, pastoralism remains the dominant source of livelihood in the study area.

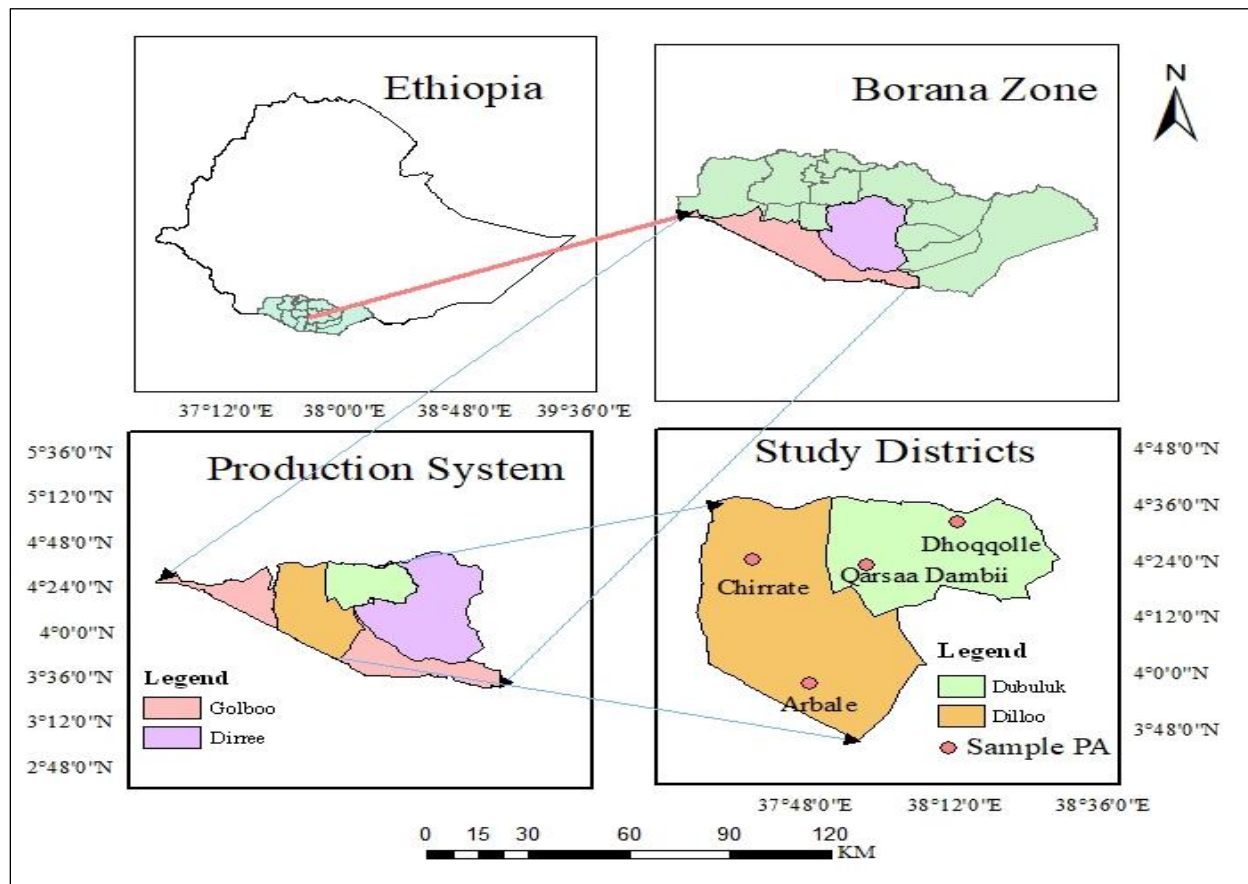


Fig.1 Location map of the study area (Ethiopian Geospatial Information Agency, 2018)

2.2. Sampling and data collection techniques

The study is based on qualitative data collected over the period of November - December 2024, through focus group discussions (FGDs) and key informant (KIIs) interviews conducted to understand innate capacities of the pastoralist communities in weather forecasting. Interviews were conducted in four randomly selected Pastoralist Associations (PAs). Accordingly, two PAs per district (Dhoqqolle and Qarsaa Dambii from Dubuluk) and (Arbale and Cirrate from Dilloo) were picked at random.

FGDs and KIIs respondents were selected purposively based on preliminary interviews held to identify the individuals recognized for their IK in weather forecasting. Purposive sampling is a tool that enables researchers to determine what information is needed, and to identify individuals who possess relevant knowledge and are willing to share it (Bernard, 2002). In this context, the preliminary community interviews helped us obtain the name list of the individuals to consider for the FGDs and the KIIs. FGDs are said to be effective for collecting data on shared perspectives and the underlying meanings of those perspectives (Mishra, 2016). We organized four FGDs, one in each PA, with knowledgeable elderly men and women aged between 50 and 85 years, and young and middle-aged members of the community. Each session comprised six to eight mixed-gender participants. They discussed indigenous event forecasting practices, identified hazard monitoring indicators, prediction indicators, seasonal events calendar, and early warning response actions, all facilitated by the lead researcher. Indicators were then visualised to show what each represented in the sketch (see Tables 1 and 2), and used to develop a format for disaster risk prediction.

Regarding the KIIs, respondents comprised community members and civil servants. From the community side, key informants were selected based on their roles in the community, knowledge, and past performance in predicting events. From the civil servants, two district early warning specialists participated on an account of their relevant experience on the subject. The interviews contained semi-structured (but open-ended) questions that allowed us to tease out and capture themes emerging in the process. In total, seven and five KIIs for each PA's were conducted with community informants and the government employees respectively. Data collection continued until thematic saturation was achieved, whereby no substantially new information emerged from subsequent interviews and focus group discussions. Ethical approval was obtained from the relevant institutional review board of Jimma University. Prior informed consent was obtained from

all participants before interviews and focus group discussions. Confidentiality and voluntary participation were maintained throughout the study.

2.3. Data analysis

Theme-based data analysis technique was employed as thematic analysis enables researchers to become familiar with the data, establish a thematic framework, code, organize, and interpret the information (Bazeley, 2016; Nowell et al., 2017). The themes included various indigenous weather forecasting methods and detailed practices related to observing different indigenous hazard monitoring indicators for upcoming weather events. The analysis followed a three-stage procedure outlined in the literature: preparing the data for analysis through transcription, reducing it to themes via coding, and representing the findings.

3. Results and discussion

3.1. Indigenous weather forecasting practices and hazard monitoring indicators

3.1.1 Major hazards monitoring indicators

Community Focus Group Discussions (FGDs) identified drought, conflict, human diseases, animal diseases, and floods as the major hazards affecting livelihoods in the study area. Community members emphasized that exposure and vulnerability to these hazards vary considerably according to socio-economic status, gender, and age. Likewise, the capacity of households and individuals to withstand, adapt to, and recover from such shocks is shaped by asset ownership, social networks, clan affiliation, and individual characteristics. More broadly, the ability of pastoral communities to cope with climate variability and environmental stress is influenced by a combination of demographic, socio-economic, and institutional factors (Ndamani and Watanabe, 2016; Ayal and Leal Filho, 2017; Gebru et al., 2020; Awiti, 2022). These findings underscore that vulnerability and resilience are socially differentiated and embedded within broader livelihood and governance contexts.

Among the identified hazards, drought emerged as the most recurrent, complex, and damaging threat to pastoral livelihoods. Drought is widely recognized as one of the most challenging natural disasters because of its slow onset, cumulative impacts, and extensive socio-economic consequences (Wilhite et al., 2005; Sivakumar, 2014; Van Loon and Anne, 2015). It generally occurs when seasonal precipitation falls significantly below long-term averages, resulting in

prolonged moisture deficits and ecological stress (Wilhite et al., 2005). In pastoral systems, drought-induced disaster risk becomes particularly severe when rainfall shortages persist across two or more consecutive seasons, triggering progressive depletion of pasture and water resources, livestock losses, and food insecurity.

As a major manifestation of climate change, drought has increasingly affected countries across both developed and developing regions, intensifying environmental and livelihood vulnerabilities (Gutierrez et al., 2014). In Ethiopia, drought occurs across diverse agro-ecological zones when seasonal rainfall declines by approximately 30–50% below normal levels (Hughes, 2015). However, its impacts are often more devastating in pastoral areas where livelihoods depend heavily on climate-sensitive resources and adaptive options remain constrained. In such contexts, recurrent drought not only threatens livestock production and household food security but also aggravates poverty, displacement, conflict over scarce resources, and long-term livelihood instability

3.1.2 Prediction indicators

The disaster prediction and monitoring system documented in this study primarily concerns community-based forecasting and monitoring practices grounded in indigenous knowledge systems. The system is designed to monitor the occurrence and progression of hazards through locally developed indicators and forecasting mechanisms (Table 1). Focus Group Discussions (FGDs) identified two broad categories of prediction indicators: specialized forecasting conducted by indigenous experts (*Ayyaantuu* and *Uuchuu*) and prediction based on observation of animal behavior. The former represents a highly specialized body of knowledge that enables custodians to anticipate the likelihood of hazards through careful interpretation of celestial bodies, particularly the positions and movements of stars, the sun, and the moon within specific seasonal contexts. Similar findings have been reported in pastoral areas of Ethiopia and elsewhere, where indigenous forecasting relies on astronomical and ecological observations to predict seasonal variability and climatic events (Balehegn et al., 2019; Dida, 2020; Guye et al., 2022; Dinsa et al., 2023). Animal behavior-based prediction, by contrast, is more widely known and practiced among community elders and pastoral households.

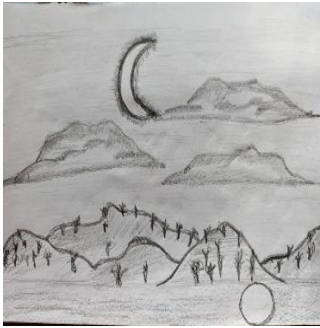
Ayyaantuu forecast weather conditions for a given rainy season by interpreting the appearance and orientation of the new moon, seasonal calendars, and historical drought patterns preserved within community memory. Beyond predicting weather conditions, *Ayyaantuu* provide guidance on

impending hazards and advise communities on precautionary actions and safe responses. In contrast, *Uuchuu* performs prediction through interpretation of the intestines of freshly slaughtered animals, particularly cattle, goats, or sheep. Although intestine reading may not always provide the same level of precision attributed to *Ayyaantuu* forecasting, it nevertheless constitutes an important source of early warning information within Borana society. *Uuchuu* are traditionally recognized as possessing specialized skills to interpret intestinal features in order to forecast weather conditions, societal wellbeing, individual fortunes, and prospects for peace or conflict ranging from local to broader societal scales (Ayal et al., 2015; Mekonnen et al., 2021; Dejene and Yitbarek, 2022; Mosgo and Livhuwani, 2025). These forecasting practices illustrate the complexity and cultural embeddedness of indigenous early warning systems and their continued relevance in pastoral risk management.

Table1: Prediction indicators

Indicator	Description
	Intestine The <i>uuchuu</i> read intestine to assess what lies ahead in life and livelihoods of the society. For example, they assign meaning to blood vessel linings across a fresh animal intestine; position of a lymph node in relation to what symbolizes the cattle kraals, or to the house where the family lives, etc. The <i>uuchuu</i> acquire the knowledge from their seniors, and develop it further through observation and experience. As a result, the community trusts the interpretations given by these experts and uses it in daily life, although the degree of accuracy and reliability varies by age, experience and reputation of each expert.
	Position of the stars Positions of the stars serve as one of the indicators that the <i>ayyaantuu</i> observe to predict performance of rain during an imminent rainy season, prospects of peace, health and general societal wellbeing. These traditional astronomers identify seven prominent stars that can be seen with unaided eyes. Positions of stars shift with seasonal changes, and the pattern of their movement varies irregularly based on the time of the year. Specific alignment of these stars in relation to seasons is used to forecast potential disaster risks related to drought, conflict, or diseases.

Moon condition



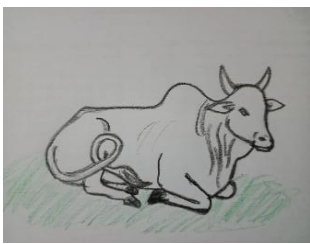
The condition of the moon in a particular month also gives a meaning to *ayyaantuu* as to what is forthcoming. They check the date in a month and a season in which the condition of the moon features: new moon, half circle moon, full moon, the direction where the new moon points to (left or right), whether the moon appears in full brightness, yellowish or cloudy, etc. If the date and the season of appearance of half moon or full moon do not coincide with the normal patterns known to the *ayyaantuu*, it is interpreted as some strange phenomenon is about to occur to the community. However, the *ayyaantuu* predict occurrence of a specific hazard by combining the results from observation of the moon with other prediction indicators.

Sunrise



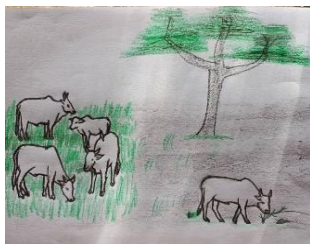
Sunrise is also used along with its position in a particular season. For instance, it rises in south east during the rainy season, and changes position regularly and proportionally across each month until it reaches the north east during the dry season. It then repeats the same pattern to the south if the season is a 'normal season'. However, if the sun stays longer in the north east, it is said to denote a prolonged dry season and failure of the expected rain in the main rainy season. However, the traditional experts warn that applicability of this indicator is limited to drought prediction alone.

Ring tail



Animal behavior is another indicator identified by the *ayyaantuu*. According to them, if a cow in the cattle herd sleeps forming a ring with its tail, and rests the tail on its leg at the same time, this is an indicator of an imminent conflict breaking out in the next three months. They further interpret the behavior as a symbolic communication from the animals with their owners to flee the area and escape from the looming danger.

Bulls grazing alone and avoiding mating



Among the animal behaviors that the *ayyaantuu* and other elders use as indicators, is the behavior of bulls. If a bull shows a propensity to graze alone by isolating itself from the herd (even in a normal season when resources are plenty), or shows no interest to mate, these suggest imminent drought and resultant feed scarcity. For the pastoralists, bulls avoid mating in order to avoid calving during a drought period.



Animals' sleeping conditions

Animals in the herd usually sleep scattered, filling the whole kraal, predicting good condition of natural resources in the coming season. If they congest themselves near the entrance of the kraal, however, this points to a bad condition ahead, particularly drought-induced herd loss.



Animals leaking each other's neck

If animals leak each other's neck, this is another indicator that predicts cattle herd loss to drought. Contrary to this, if it is on shoulders, it predicts a good season ahead.



Animals excreting in a laying position

Under normal conditions, animals excrete in a standing position. However, if they defecate in a laying position, it suggests a difficult time ahead.



Cattle avoiding good pasture

The cattle herd avoiding good pasture and preferring to graze in an opposite direction indicates the likelihood of conflict outbreak in the direction of the avoided good pasture, and suggests a safe migration root in the opposite direction.

Source: Summarized with visualization by the authors, based on the results from the FGDs, Dec. 2024

3.2 Prediction matrix

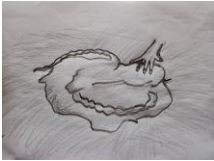
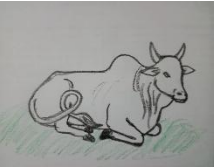
Prediction matrices and monitoring formats were collaboratively developed by pastoral communities with the objective of institutionalizing and integrating indigenous environmental knowledge (IEK) within formal scientific and governmental early warning systems (Table 2). The matrix consists of two major components: an indicator component and a monitoring component. Seasonal prediction is conducted by community experts, while monitoring takes place bi-annually using a monitoring format jointly developed by communities and government institutions (Table 2). The prediction chart combines indigenous forecasting indicators with the seasonal calendar and outlines corresponding actions at both community and district levels. Such locally grounded forecasting systems demonstrate how indigenous knowledge can be formalized into operational planning tools without losing its cultural and ecological context.

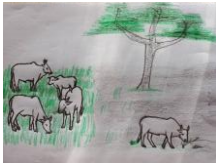
This approach aligns with studies highlighting the complementary role of indigenous ecological knowledge in environmental monitoring and climate prediction. Chisadza et al. (2015) argue that local communities possess valuable ecological insights capable of complementing scientific observations, particularly in understanding seasonal variability and environmental change. Indigenous forecasting systems are increasingly recognized as repositories of long-term ecological memory developed through sustained interaction with local ecosystems (Hiwasaki et al., 2014; IPCC, 2022). The Sixth Assessment Report of the IPCC (2022) emphasizes that Indigenous and Local Knowledge (ILK) systems contribute substantially to climate adaptation, risk reduction, and environmental governance, especially where scientific data are limited or locally generalized.

Community participation in environmental monitoring further strengthens the credibility and applicability of environmental information. Robert (2018) argues that active involvement of local communities in environmental data collection and interpretation improves the accuracy and reliability of monitoring outcomes. This enhanced reliability emerges from the contextual understanding and experiential knowledge that communities contribute, enabling identification of locally meaningful indicators and adaptive monitoring strategies (Kidamu et al., 2020). Likewise, participatory monitoring approaches have been shown to generate socially legitimate and operationally relevant early warning information because indicators are rooted in local livelihood systems and ecological realities (Danielsen et al., 2014; Oliver et al., 2021). Community-based monitoring therefore functions not merely as a data collection exercise but as a process of co-producing environmental knowledge and strengthening local governance capacities.

Because environmental prediction requires specialized knowledge and cultural expertise, *ayyaantuu* and *uuchuu* were incorporated into the Pastoralist Association (PA)-level Early Warning Committee (EWC), despite not being part of the original nomination framework. The *ayyaantuu* interpret celestial indicators, particularly the position and movement of stars and the sun, while the *uuchuu* analyze animal intestines to forecast seasonal conditions. Their inclusion demonstrates the institutional recognition of indigenous forecasting specialists and reflects the embedded nature of prediction knowledge within Borana social institutions. Similar findings from pastoral systems across the Horn of Africa indicate that indigenous forecasters continue to play central roles in drought prediction, rangeland assessment, and communication of climatic risks through customary institutions (Speranza et al., 2008; Balehegn et al., 2019).

Table 2: Prediction monitoring matrix

Indicator	Seasons			
				
	✓	✓		
	✓	✓		
	✓	✓		
	✓	✓		
	X	X		



X

X



X

X



X

X



X

X



X

X

Source: FGD results, Dec. 2024

The prediction matrix (Table 3) shows that the positions of stars and the sun, interpreted by *ayyaantuu*, together with animal intestine readings interpreted by *uuchuu*, predicted favorable conditions during the long rainy season (*ganna*) and the cool dry season (*adoolessa*). In the matrix, the tick sign (✓) represents prediction of a normal season. Drawings included in Table 3 depict negative animal behavioural indicators; consequently, the crossed mark (x) should be interpreted as the absence of abnormal animal behaviour and therefore as a predictor of seasonal normalcy. Indigenous forecasting among the Borana commonly incorporates interpretation of animal behavior, livestock conditions, plant responses, and astronomical observations, which collectively function as ecological indicators of rainfall variability and environmental change (Oba, 2014; Balehegn et al., 2019).

Field observations confirmed that both communities and government institutions actively use the monitoring format in the study districts. At the community level, the Pastoralist Association and

Early Warning Committee coordinate prediction and monitoring activities, whereas government Development Agents (DAs), deployed across all PAs, represent formal institutional structures. Development Agents compile community prediction reports and submit them to the District Early Warning Committee (DEWC). Analysis of the monitoring outcomes (Table 3.2) revealed that community-level EWCs predicted normal seasonal conditions for the subsequent six months, and this prediction was later confirmed through monitoring results. Importantly, the analysis demonstrated that indigenous prediction outcomes are directly linked to Community Managed Disaster Risk Reduction (CMDRR) planning processes, thereby strengthening local preparedness and guiding disaster risk management interventions.

Integrated monitoring systems provide governments and communities with a lead time of approximately two seasons (six months) before ecological stressors begin to affect livelihoods. Such lead time enables closer environmental surveillance, contingency planning, and timely implementation of response measures. Studies on community-based early warning systems show that integrating indigenous and scientific knowledge enhances anticipatory capacity and strengthens resilience because warnings become more locally relevant, trusted, and actionable (Hiwasaki et al., 2014; IPCC, 2022). Participatory monitoring systems also ensure that indicators reflect community priorities and lived experiences, thereby increasing institutional responsiveness and accountability (Oliver et al., 2021).

The works of Olivier et al. (2021) and the IPCC (2022) provide important conceptual frameworks for institutionalizing indigenous early warning knowledge within local governance structures. These frameworks recognize communities as custodians of deep ecological knowledge that can be formalized through prediction matrices and integrated monitoring systems to reduce disaster risks and enhance resilience to climate variability. Increasingly, contemporary disaster risk reduction scholarship advocates movement beyond parallel indigenous and scientific systems toward co-production of knowledge, where complementary epistemologies jointly inform adaptation planning and environmental governance (Tengö et al., 2017; IPCC, 2022). Consequently, the Borana prediction and monitoring system represents not only a culturally embedded forecasting practice but also an emerging model of hybrid governance capable of strengthening locally grounded climate resilience.

3.3 Early warning indicators

Focus group discussions identified indicators that signal warning and show different stages of disaster risk with their corresponding magnitude (Table 3). The indicators assess conditions of rainfall, pasture, crops, water wells, ponds and underground cisterns, food availability, human security (including killings), migration, and conflict. These indicators are consistent with those identified by Damtie and Asmare (2020) in eastern Ethiopia, who documented environmental and livelihood-related indicators such as rainfall variability, temperature changes, grazing conditions, water source status, crop performance, and livestock health as key components of indigenous early warning systems. Beyond these biophysical indicators, recent studies emphasize that effective disaster and drought early warning systems require a broader and more integrated framework that captures both environmental and socio-economic dynamics.

In pastoral and agro-pastoral areas of Ethiopia, rainfall performance and pasture availability remain primary indicators because they directly influence livestock production, mobility, and household livelihoods. Studies in southern Ethiopia demonstrate that pastoral communities closely monitor temporal rainfall variability, drought frequency, and rangeland conditions as precursors of livelihood stress and disaster risk (Tesfaye et al., 2023). Indigenous forecasting systems among pastoral groups similarly rely on environmental signals, including vegetation conditions, water availability, animal behavior, and seasonal climatic patterns to anticipate drought and food shortages (Guye et al., 2022). Recent evidence further indicates that monitoring water and pasture resources through locally grounded early warning systems can substantially improve anticipatory action and resilience-building among pastoral communities (Alemayehu et al., 2025).

Moreover, contemporary early warning approaches increasingly recognize that socio-economic indicators are equally critical alongside environmental observations. Food security assessments that consider the four pillars of food security availability, accessibility, utilization, and stability provide essential information for detecting household vulnerability and impending crises. Rainfall and temperature variability have been shown to significantly influence food access and dietary security in southern Ethiopia, highlighting the need to link climatic monitoring with livelihood and nutrition assessments (Yagaso et al., 2024). Likewise, resilience studies in pastoral Ethiopia demonstrate that household food access, water availability, infrastructure, and livelihood assets strongly shape community capacity to withstand drought shocks (Alemayehu et al., 2025).

In addition to environmental and food-related indicators, price and market trends including livestock prices, cereal prices, supply chains, and demand fluctuations should be incorporated into early warning checklists because markets often provide early signals of stress before humanitarian conditions deteriorate. Conflict, insecurity, and population movement are also increasingly recognized as important dimensions of disaster monitoring, particularly in pastoral areas where resource competition and migration intensify during drought periods. Evaluations of multi-component early warning systems in pastoral areas of Ethiopia show that combining community-based indicators with institutional surveillance and broader socio-economic monitoring improves the timeliness, representativeness, and effectiveness of response mechanisms (Baertlein et al., 2024). Therefore, disaster early warning systems should move beyond narrow climatic indicators and adopt integrated monitoring frameworks that combine indigenous knowledge, environmental observations, market dynamics, food security assessments, and social vulnerability indicators to enhance preparedness and risk reduction.

Table 3: Early warning indicators

Indicator	Description
	Rainfall
	The Borana low lands receive rainfall from mid-March to mid-May (long rainy season – <i>ganna</i>) and from September to October (short rainy season – <i>hagayya</i>). They contribute 60% and 35% to the total annual rainfall, respectively. Rainfall often features fluctuation in amount, temporal and spatial unpredictability, and even a total failure. In the past, under less scarce pasture condition and more flexible herd mobility, a delay in rainfall on-set, or a shortfall in a season, were stressors that made inter-seasonal transition difficult. In the current context of increased drought frequency, shrinking rangeland and constrained mobility, mere seasonal fluctuation make serious impacts on the herds. Moreover, the magnitude of the impacts worsens with absence of rainfall in a single rainy season, causing herd loss, crop failure and subsequent starvation. Hence, rainfall is identified as a major indicator of normalcy or an imminent disaster.



Pasture conditions

The community identified pasture condition as an important indicator whose availability or scarcity seriously affects pastoralists' livelihoods. Among others, scarcity will have an impact on animal body condition, availability of direct animal products, market value, with implications for household food security.



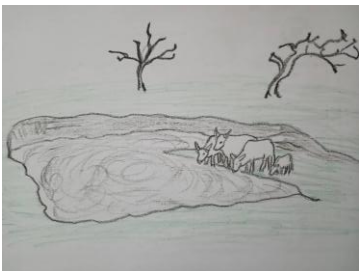
Crop conditions

As crop performance is directly linked to the amount of rainfall received, crop condition suggests the amount of rainfall received. Particularly crop conditions at different stages in plants growth process indicate the nature of on-set and cessation of rainfall during the growing season. This indicator carries utmost relevance for agro-pastoralist areas of the Zone.



Water wells

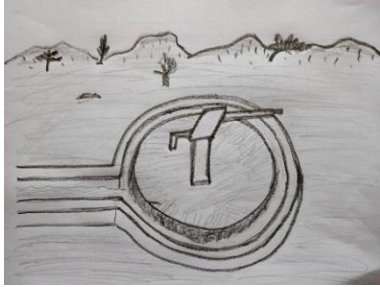
Traditional water wells (*eela*) provide perennial water for both livestock and human consumption in dry seasons when surface water sources dry up. It follows then that the wells giving service before the fall of a dry season is an indicator of a potential scarcity.



Ponds

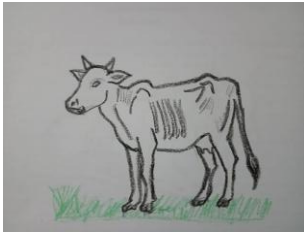
Unlike wells, ponds provide surface water service in post-rainy season period, during which perennial water sources are put to rest. Inadequacy in the amount of pond water means continuous dependence on wells, which often causes resource depletion in the middle of a dry season. Such a scenario implies the need for early intervention before the situation degenerates into crisis.

Cisterns



A cistern is a cement-walled in-ground infrastructure developed to harvest surface run-off. Non-state actors introduced water cisterns in the 1980s into typologies of the sources of water in Borana lowlands (Tache, 2000). Nowadays, cisterns are widely used to meet domestic demands and serve some herd/flock classes around the homestead as well. It is a common practice that if the floodwater is exhausted, a cistern owner hires a tanker truck to refill the cistern. Nevertheless, limited financial capacity commonly constrains an individual household to sustain the service, and therefore, people resort to hiring a truck in group as we witnessed in Arbale PA for instance. In the present context of increased drought frequency, availability of this infrastructure itself has been facilitating emergency water rationing in several PAs.

Livestock body condition



Livestock body condition indicates state of the environment. Feed-scarcity-induced stress exposes animals to emaciation and a decline in livestock products and market values. FGD participants state, however, that monitoring animal body condition should be both seasonal and inter seasonal in order to understand specificities in each season and inter-seasonal comparison to see trends over time.

Availability of milk



Milk availability is a direct indicator of household food availability situation, especially for predominantly pastoralist households. Under a normal condition, milk availability during a rainy season and in its immediate aftermath serves as a strong indicator. Hence, monitoring needs to be conducted seasonally. If milk is not available during a dry season for instance, it shows a normal condition unless other indicators suggest otherwise.



Availability of grain

Grain availability for a household is an indicator of food availability in agro-pastoral PAs in particular. Hence, monitoring should be carried out in relation to a season. For instance, if grain is unavailable during the rainy season, this does not necessarily indicate a crisis for stock-rich households that might be meeting their food demands by direct animal products.

Market

Market has become an important venue through which households acquire goods and services, particularly in dry seasons when livestock products are scarce. This involves sale of animals or other tradable items (forest products for example). In an extreme crisis, market prices often disfavour pastoralists when the price of a sack of maize, for instance, exceeds what a young bull could fetch. Such a circumstance triggers herd depletion due to unfavourable terms of trade. However, as terms of trade alone does not suffice to draw a conclusion based on the price of one particular animal species, monitoring should give attention to other elements. These include type, sex and the number of animals supplied to the market as each element indicates different stages of crisis.



Draining blood from a live animal

Drinking blood of live animals is a common tradition among pastoral households, to cope with food scarcity. They tie the neck of an animal and pierce the jugular vein to draw out and collect fresh blood. They drink the blood by diluting it with milk, or as it is. This practice is an early indicator of household food insufficiency.



Wild fruits and roots

Excessive consumption of wild fruits, roots and tubers indicates severe crisis.

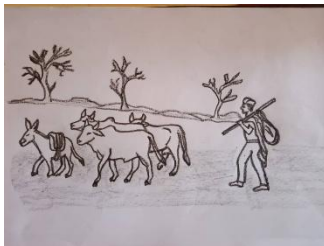


Child body condition



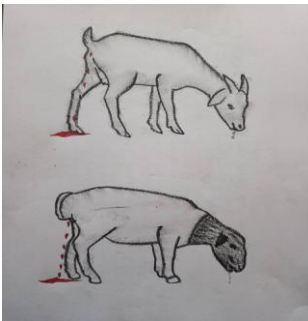
Child body condition is also an indicator of food availability or its lack. The tradition of the community in the study area favours children by according priority in the feeding order and quality of the food served. Moreover, during the time of scarcity, parents offer the meagre available food to their children but go hungry themselves. This preferential treatment has traditionally kept child malnutrition and stunting in Borana to the lowest. Any significant change in the body condition of a child is, therefore, an important indicator of the level of food crisis in a household. So is a body condition of breast-feeding mothers and the aged.

Migration



If people migrate to unfavourable areas in search of food or cash income to acquire food, this denotes a distress-induced people's outflow and is an indicator a crisis.

Outbreak of diseases affecting goats and sheep

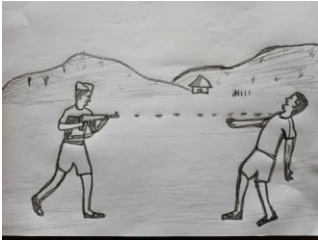


Occasional incident of animal disease is usually not considered as a major hazard that jeopardises communities' livelihoods as such. During the field work, an unidentified disease of unknown origin broke out and killed a significant number of goats and sheep. An initial symptom is a bloody diarrhoea, followed by serious loss of energy, as a result of which the sick goat/sheep becomes unable to browse/graze, and dies ultimately.

Raid



Raid stands as a major indicator of an imminent conflict. It is a precursor of a more serious clash between two or more groups. Once raid occurs, members of the belligerent groups avoid using common markets, pasture and water points.



Killings

Killing a member of another clan or ethnic group is another major predictor of conflict. It can be both a cause and a consequence of armed conflict. Once a member of a clan or an ethnic group is killed, the grieved party mobilizes to retaliate by killing a member of the killer group. This may ignite a large-scale battle, and lead to more crises ultimately.



Fully-fledged conflict

Existence of a conflict may indicate loss of life and properties. Armed conflict usually cause displacement of people, road blockades, loss of access to key resources, and disruption in the normal livelihood systems.

Source: FGD results, Dec. 2024

3.4. Early warning monitoring matrix

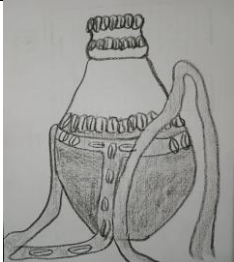
The community-developed early warning monitoring matrix (also referred to as the monitoring format) gauges the magnitude and availability of each indicator using locally defined measurements and culturally grounded symbols. These symbols are socially meaningful and allow communities to communicate environmental and livelihood conditions more effectively to external stakeholders and humanitarian actors (Dhiba, 2024). The use of indigenous symbols in monitoring and communication aligns with broader scholarship emphasizing that locally embedded early warning systems enhance risk communication, community ownership, and the legitimacy of disaster information among vulnerable populations (Hiwasaki et al., 2022; Wondim et al., 2023). Community-based monitoring systems rooted in local knowledge are increasingly recognized as critical tools for translating environmental observations into practical and timely disaster preparedness actions.

The measurements of change in each indicator are classified into four categories that correspond to varying levels of livelihood security and disaster risk. These include *very good*, symbolized by a full milk container denoting abundance and livelihood stability; *good*, represented by a half-full milk container indicating declining but manageable conditions—comparable to the alert stage in disaster risk reduction (DRR) terminology; *poor condition*, symbolized by a nearly empty milk

container indicating scarcity and heightened vulnerability; and finally an *empty milk container*, which signifies an emergency condition where communities anticipate external assistance, including food aid, water rationing, and livestock feed support. Such locally defined classifications facilitate prioritization of interventions based on the severity and progression of hazards. Similar graduated warning systems have been documented among pastoral communities elsewhere in eastern Africa, where indigenous classifications help bridge local observations with formal disaster management frameworks and improve response targeting (Karnoto et al., 2025; Alemayehu et al., 2025).

In the study area, based on these indicators, the Peasant Association (PA) Early Warning Committee (EWC) conducts monitoring on a monthly basis using a format endorsed by all stakeholders. The PA and district EWCs jointly analyze reports to develop a shared understanding of prevailing conditions and corresponding response needs. This collaborative approach reflects increasing recognition that co-produced early warning systems—combining indigenous monitoring with institutional analysis—enhance the credibility, accuracy, and usability of disaster information (Baertlein et al., 2024). Studies from pastoral Ethiopia similarly demonstrate that participatory early warning systems improve coordination among communities, local governments, and humanitarian actors, thereby strengthening planning and implementation of disaster risk reduction interventions (Alemayehu et al., 2025). Such synergized monitoring has created greater harmony in planning and executing DRR programs by establishing common interpretations of risk conditions and response priorities.

Table 4: Early Warning Monitoring Matrix

Indicator	Magnitude			
				
		✓		
		✓		
		✓		
		✓		
		✓		



✓



✓



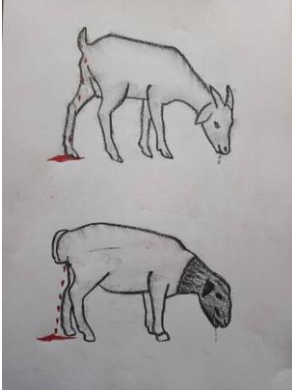
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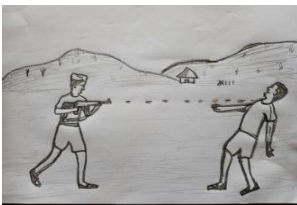
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✓



✓



✓

Source: FGD results, Dec. 2024

According to community-based early warning monitoring conducted in December 2024, rainfall, pasture, crops, and food sources were all categorized as *very good*, indicating normal and favorable conditions (Table 4). Other stress indicators, including livestock body condition, child nutritional status, and conflict, were marked as empty, signifying a *no-stress* situation during that month. This unusually favorable condition during the normally dry month of December 2024 resulted from exceptionally strong rainfall performance during the preceding rainy seasons. Climate and rangeland studies in southern Ethiopia support this interpretation, showing that above-average

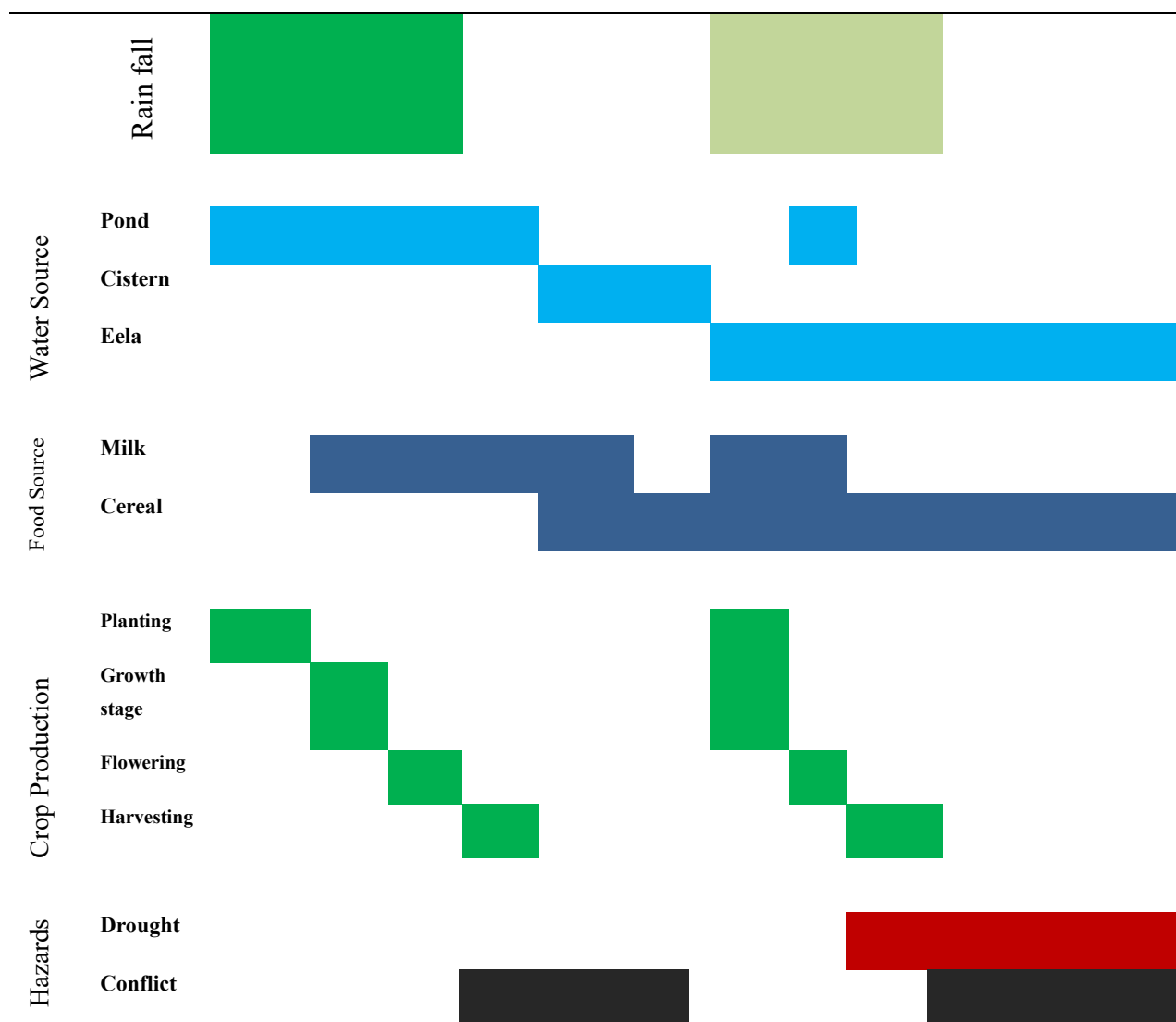
rainfall contributes significantly to pasture regeneration, water availability, and livestock productivity, thereby reducing vulnerability among pastoral households (Dejene et al., 2023). Tamirat et al. (2021) further underscore the importance of livestock body condition as a key indicator of resilience and food security, emphasizing that healthy livestock provide food, income, and an essential safety net during periods of environmental stress. Recent pastoral resilience research similarly confirms that livestock health serves as both an economic and nutritional buffer, strongly influencing household adaptive capacity and drought recovery (Mekonnen et al., 2024).

Furthermore, district-level analyses conducted jointly with communities and informed by seasonal calendars revealed similar conditions across all indicators and seasons. In all sample areas, the community seasonal calendar has been integrated into analytical formats used at both community and district levels. This integration reflects growing recognition that seasonal calendars constitute an essential analytical tool within indigenous early warning systems because they contextualize environmental variability and distinguish between expected seasonal patterns and genuine anomalies (Hiwasaki et al., 2022). The inclusion of seasonal knowledge enables decision-makers to avoid false alarms and interpret indicators in culturally and ecologically meaningful ways.

Table 5 presents the seasonality of events against which early warning indicators are monitored. For example, the absence of rainfall during June, July, August, and the prolonged dry season months of December, January, and February should not automatically be interpreted as a warning sign but rather as a normal climatic condition because rainfall is not ordinarily expected during these periods. This distinction between seasonal normality and abnormal stress is fundamental to effective early warning systems. Contemporary climate adaptation and early warning literature stresses that monitoring frameworks must incorporate historical and seasonal baselines to differentiate routine variability from emerging hazards and thereby improve anticipatory decision-making (WMO, 2023; FAO, 2024). The integration of seasonal calendars into local monitoring systems therefore strengthens contextual interpretation of indicators and enhances the reliability of early warning information.

Table 5: Seasonal calendar of events

Description of	<i>Ganna</i> (LRS)			<i>Adoolesa</i> (SDS)			<i>Hagayya</i> (SRS)			<i>Bona</i> (LDS)		
Events	March	April	May	June	July	August	Sept	Oct	Nov	Dec	Jan	Feb



Note: LRS = Long rainy season, SDS = Short dry season, SRS = Short rainy season, LDS = Long dry season

Source: FGD results, Dec. 2024.

3.5. Indictors of imminent crisis

The chart in Table 6 illustrates the principal indicators associated with the build-up of a crisis, beginning with the failure of the major rains during March, April, and May. Under normal climatic conditions in Borana, rainfall is expected to commence by mid-March, initiating regeneration of pasture, replenishment of water resources, and improvement in livestock productivity and milk production. Consequently, delayed onset of rainfall represents the first warning signal of potential drought. When delayed onset is compounded by early cessation and inadequate rainfall amounts, the consequences for pastoral and agro-pastoral livelihoods become increasingly severe (Tamirat et al., 2021; Girma, 2023; Mosisa, 2024; Worku, 2024). Recent climate studies in southern Ethiopia

further demonstrate that increasing rainfall variability, erratic onset and cessation patterns, and prolonged dry spells have intensified drought frequency and undermined livelihood stability in pastoral systems (Dejene et al., 2023; Mekonnen et al., 2024). Such climatic irregularities disrupt seasonal production cycles and diminish the predictive reliability upon which local livelihood planning traditionally depends.

According to KII, within indigenous early warning systems, rainfall timing is particularly significant because seasonal rains trigger a cascade of ecological and socio-economic responses. Pastoral communities closely monitor rainfall onset not merely as a climatic event but as a determinant of pasture recovery, livestock body condition, and household food availability. Studies among pastoral societies in Ethiopia confirm that delayed rainfall onset is commonly interpreted as an early signal of declining livelihood security and heightened drought risk (Guye et al., 2022). The disruption of rainfall schedules affects forage production and water access, thereby reducing milk availability and weakening livestock, which are central to household nutrition, income, and social security (Alemayehu et al., 2025).

If standing crops wilt by late April, this signifies below-average rainfall during the main rainy season and signals deterioration in livelihood conditions, particularly among poor households that depend on some level of harvest by late May or early June. Crop failure in such circumstances represents more than agricultural loss; it signifies erosion of household coping capacity and increased vulnerability to food insecurity. Climate vulnerability literature emphasizes that early-season crop stress serves as a reliable proxy for emerging food crises because it reflects cumulative deficiencies in rainfall, soil moisture, and agricultural productivity (FAO, 2024). In Borana, expectations of harvest during late May or early June are crucial to bridging seasonal food gaps, and failure to realize these expectations may force households into deeper food deficits and reliance on external assistance.

This situation also influences local and regional market systems, producing unfavorable terms of trade between livestock and staple foods imported from surplus-producing regions. During drought periods, livestock prices often decline because weakened animals attract lower market demand, while grain prices rise owing to scarcity and transport costs. Such deteriorating livestock-to-grain exchange ratios reduce household purchasing power and deepen livelihood insecurity. Recent drought and pastoral market studies in Ethiopia indicate that market disruptions and adverse price

dynamics frequently emerge before full humanitarian crises become visible, making them critical indicators within integrated early warning systems (FEWS NET, 2024; Alemayehu et al., 2025). Consequently, monitoring market trends alongside ecological indicators strengthens anticipatory action and supports more timely interventions.

Tschakert et al. (2019) emphasize that marginalized communities are often disproportionately vulnerable to climate variability because they possess fewer assets, weaker adaptive capacity, and limited access to alternative livelihoods. This observation is particularly relevant in Borana, where poorer households depend heavily on seasonal crop production and livestock products to meet basic food needs. Failure of anticipated harvests can therefore trigger rapid transitions from food stress to acute hunger and dependence on relief support. Recent resilience studies similarly reveal that wealth status, herd size, social capital, and access to institutional support strongly determine household ability to absorb climatic shocks and recover from production failures (Mekonnen et al., 2024; Baertlein et al., 2024, Boru et al., 2026b).

Conversely, relatively advantaged households may diversify their livelihood strategies or adopt more secure adaptation pathways, including livestock diversification, market engagement, mobility, petty trade, or migration. Tamou et al. (2018) note that livelihood diversification can buffer climate risks and enhance resilience among pastoral households. However, such adaptive responses are frequently inaccessible to poorer households because of financial constraints, limited productive assets, and restricted access to information and markets. Contemporary adaptation scholarship confirms that unequal access to resources often reproduces differentiated vulnerability, whereby better-off households capitalize on adaptive opportunities while poorer households remain trapped in cycles of climate-induced poverty and dependency (IPCC, 2023; FAO, 2024). Therefore, early warning systems must not only identify environmental deterioration but also capture socio-economic inequalities that shape differential exposure, sensitivity, and adaptive capacity among households.

Table 6: Indictors of imminent crisis by season and month

Seasons	Month		Indicator
Ganna			
		March	The main causes of drought are late on-set, shortage and absence of rain

Adoolesa	April	Reduction in surface water sources (eg ponds), constrained access to distant wet season grazing areas; reduction in the size of farmlands ploughed
	May	Early cessation of rain, with a serious implication for availability of resources
	June	Wilting of crops at flowering stage
	July	Evident harvest failure
Hagayya	August	People resorting to utilizing water wells (<i>eela</i>)
	September	Inadequate precipitation received, pasture and water scarcity
	October	Reduction in herd watering frequency
	November	Distress-induced cattle sale
Bona	December	Poor animal body condition observed, calve mortality reported
	January	Massive herd migration occur
	February	Human body condition deteriorates

Source: FGD results, Dec. 2024

4. Early warning response actions

As discussed above, early warning data inform preparedness and timely action at both community and district levels. The integrated early warning system was designed with this intention, linking locally generated information with graduated response mechanisms. Accordingly, when early warning information indicates normal conditions, preparedness measures and preventive actions are emphasized to sustain livelihood stability and maintain resilience capacities. Conversely, when the data signal alert conditions, mitigation mechanisms become necessary to minimize potential losses and reduce exposure to hazards. Where monitoring reveals deterioration beyond the alert stage, emergency intervention becomes paramount to prevent livelihood collapse and humanitarian crises. Such staged response systems reflect the broader disaster risk reduction principle that early

warning should not merely predict hazards but should trigger timely and proportional action (UNDRR, 2022; WMO, 2023).

Recent literature emphasizes that the effectiveness of Early Warning Systems (EWS) depends not only on forecasting accuracy but also on the extent to which warning information is translated into anticipatory action. Oliver et al. (2021) argue that effective EWS significantly reduce vulnerability among pastoralists by enabling preventive measures before shocks intensify. Similarly, contemporary anticipatory action frameworks highlight that early action based on warning information is often more cost-effective and socially beneficial than post-disaster humanitarian response (FAO, 2024). In pastoral systems, anticipatory measures may include strategic livestock mobility, water and pasture management, livestock destocking, supplementary feeding, vaccination campaigns, and livelihood diversification, all of which reduce the severity of drought impacts and enhance recovery potential (Alemayehu et al., 2025).

The integrated nature of the system observed in this study aligns with growing recognition that participatory and locally grounded EWS are more likely to produce actionable information and stronger community engagement. Alemayehu and Doda (2020) emphasize that involving pastoralists in the design and implementation of EWS enhances contextual relevance and responsiveness to local needs. This participatory approach increases trust in the warning process and improves the likelihood that communities will act upon information, whether indicating normalcy or signaling emerging risks. Similar findings from pastoral regions of Ethiopia demonstrate that indigenous knowledge-based monitoring systems enhance local ownership and strengthen communication between communities and formal institutions (Guye et al., 2022; Wondim et al., 2023). Such co-production of risk information is increasingly viewed as essential for effective climate adaptation and disaster governance.

In the study area, the *Community Managed Disaster Risk Reduction (CMDRR) Committee*—a multi-stakeholder body comprising community-level experts and relevant governmental and non-governmental actors—coordinates the design, implementation, and monitoring of CMDRR plans at district level. The relationship between the *Peasant Association (PA)-level Early Warning Committee* and the CMDRR Committee is fundamentally collaborative, whereby the former generates grassroots-level information and the latter makes decisions following joint evaluation and interpretation of reports. This partnership reflects contemporary models of decentralized

disaster governance that emphasize shared responsibility, participatory decision-making, and institutional coordination (UNDRR, 2022).

Field observations in all four PAs confirmed that CMDRR Committees had received training intended to clarify their mandate and strengthen their working relationship with PA-level EW Committees. Capacity-building and institutional learning are widely recognized as essential components of functional early warning systems because warning information alone cannot guarantee effective action unless supported by institutional preparedness and clear operational roles (WMO, 2023). Studies in Ethiopia and other drought-prone pastoral regions similarly demonstrate that trained local committees improve information flow, strengthen accountability, and facilitate timely mobilization of resources during crises (Zenebe et al., 2021; Baertlein et al., 2024).

The collaborative arrangement observed in the study area improves efficiency in drought response by enabling adaptive measures before conditions deteriorate further. Zenebe et al. (2021) report that coordinated local institutions can shorten response times and improve effectiveness of preparedness interventions, thereby minimizing livelihood losses. This finding resonates with recent evaluations of community-based early warning systems in pastoral Ethiopia, which reveal that integrated systems combining local monitoring with institutional support enhance both anticipatory action and resilience outcomes (Baertlein et al., 2024; Alemayehu et al., 2025). Such arrangements enable communities to move beyond reactive coping and toward proactive risk management.

The need for context-specific adaptation of EWS has also been emphasized beyond Ethiopia. Fernandez-Gimenez et al.(2017), in a study of pastoral systems in Mongolia, highlights that early warning systems are most effective when adapted to local ecological conditions, livelihood patterns, and governance structures. Similar conclusions are echoed in recent global resilience literature, which stresses that one-size-fits-all early warning approaches often fail to account for cultural knowledge, mobility systems, and locally specific hazard dynamics (IPCC, 2023; WMO, 2023). For pastoral communities, where livelihoods are highly climate-sensitive and mobility remains a key adaptation strategy, locally tailored and participatory EWS are therefore indispensable.

Overall, the integrated early warning and CMDRR framework observed in the study area illustrates an important transition from hazard prediction alone toward action-oriented and participatory disaster governance(See table 7). By linking community-generated monitoring, institutional analysis, and staged response planning, the system enhances preparedness, facilitates coordinated mitigation, and supports timely emergency intervention when required. This integrated approach corresponds with emerging global frameworks advocating people-centered, multi-hazard, and anticipatory early warning systems as central pillars of climate resilience and disaster risk reduction (UNDRR, 2022; WMO, 2023; FAO, 2024).

Table 7: Early warning and response actions

Indicators and responses													
Scenario													
	Mar	Apr	May	June	July	August	Sept	Oct	Nov	Dec	Jan	Feb	
Scenario 1 Normal amount of rain received in both rainy seasons				Livestock									
				<i>Kaloo</i> (enclosure)			Marketing						
				Management			Re-arrangement of			<i>Kaloo</i> Management			
				Bush Clearing			settlement patterns			Bush Clearing			Pond Construction
				Peace Building			Pond			Peace Building			<i>Eela</i> Rehabilitation
							Rehabilitation			Livestock Market			Pond Rehabilitation
							Peace Building						Cistern Construction
							Hay Making						

Scenario 2	Below normal or no rain received in both rainy seasons	Preferential grazing	Awareness creation		
		Destocking through market	Preferential grazing		Mobility to other areas
		Grain purchase and storage	Destocking through market	Reducing herd watering frequency	Destocking through slaughtering
		Mobility of <i>foora</i> herds	Grain purchase and storage	Administering <i>kaloo</i>	Emergency food sharing (qulaammoo ¹)
		Peace dialogue	Mobility of <i>foora</i> herds	Peace building	Reporting to relevant departments
		Peace building		Commercial destocking	
		Early warning report	Peace dialogue	Early warning report	Food aid
			Early warning report		Animal Feed
					Early warning report

Source: FGD results, Dec. 2024

5. Conclusion and recommendations

5.1 Conclusion

This study examined indigenous weather forecasting, early warning indicators, monitoring systems, and response mechanisms among Borana pastoral communities in southern Ethiopia. The findings show that indigenous early warning systems remain highly relevant and operational in disaster risk management despite increasing climate variability and socio-economic change. Borana communities maintain sophisticated forecasting systems rooted in ecological observation, astronomical interpretation, animal behaviour, and specialized indigenous expertise. Indigenous forecasters, particularly *ayyaantuu* and *uuchuu*, use indicators such as stars, moon conditions, solar movements, animal intestines, and livestock behaviour to anticipate drought, conflict, disease, and seasonal variability.

Drought emerged as the dominant hazard affecting livelihoods, with impacts intensified by shrinking rangelands, reduced mobility, and growing vulnerability. The study demonstrates that

¹Qulaammoo is a customary life-saving support traditional of Borana Oromo through which immediate neighbours or clan members share food and other resources. It is an instant gesture that precedes an impact-making formal support from the clan of the affect person or family.

indigenous forecasting systems are structured knowledge systems developed through long-term interaction with local environments and transmitted through customary institutions. A key finding is the institutionalization of indigenous knowledge through prediction matrices and monitoring formats jointly developed by communities and government institutions. The inclusion of indigenous experts within Pastoralist Association-level Early Warning Committees represents an emerging hybrid governance model where indigenous and scientific knowledge complement one another. Prediction matrices and seasonal calendars generated approximately six months of lead time for monitoring ecological stress and planning interventions.

The Borana early warning system extends beyond climatic monitoring to include environmental, livelihood, and socio-economic indicators such as rainfall, pasture, water, livestock condition, milk availability, market dynamics, migration, conflict, and child nutritional status. Community-developed monitoring matrices and culturally meaningful symbols strengthened communication and local ownership of monitoring processes. Joint monitoring by community and district institutions improved analytical accuracy and coordinated response planning.

The study further identified progressive indicators of imminent crisis, including delayed rainfall, crop failure, pasture depletion, livestock deterioration, market stress, and migration. Through the CMDRR framework, these warning signals triggered staged responses ranging from preparedness and mitigation to emergency action. Overall, the Borana system represents a mature, participatory, and action-oriented disaster governance model that strengthens resilience through co-production of indigenous and scientific knowledge.

5.2 Recommendations

The key findings from this study suggest salient recommendations pertinent to improving weather forecasting and preparedness in drought-prone areas like Borana that contiguously face vagaries of climate change. To begin with, integration of indigenous and scientific knowledge systems is highly recommended in order to aid better environmental monitoring and timely response with synergy. To this effect, regular joint risk assessment would benefit an endeavor to obtain a more comprehensive view about all the major hazards and risks facing the community. While the

centralized early warning system has enabled comprehensive coverage and synergy, caution in efficiency in reporting, feedback and timely interventions (when necessary) is imperative.

Moreover, creating a communication channel and ensuring community's access to early warning messages is paramount. Among other things, the information dissemination format must incorporate authentic interpretations of the early warning data given by the community, along with the key lessons drawn from the joint assessments conducted by the CMDRRC and the grassroots early warning committee. This would enhance harmonized learning and action. Preparing hazard and vulnerability maps will render an important tool that facilitates formulation of visualized district-level disaster management plan. Besides, records of the monthly EW monitoring should be kept properly for reference, to monitor trends of change in the indicators. As the magnitude of each change corresponds with different stages of a disaster, activity plans should also correspond with each stage. Finally, further research is required to uncover more community innate capacities to inform policy and pastoral development initiatives that enhance food security through reduced livelihood risks to climate change.

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