Addis Ababa University
College of Developemnt Studies
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Harmonizing Indigenous and Scientific Seasonal Drought Forecasting Knowledge for Building Livelihood Resilience: The case of Borana Oromo Pastoral Households' of Southern Ethiopia

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DECLARATION

I, the undersigned, declare that this thesis entitled Harmonizing indigenous and scientific seasonal drought forecasting knowledge for livelihood resilience capacities: the case of Borana Oromo of Southern Ethiopia is my original work and has never been submitted at any University, for any degree or other purposes.

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This dissertation has submitted for examination with my approval as University supervisor. Supervisor name: Prof. Dr. Feyera Senbeta Wakjira

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This is to certify that the thesis prepared by Abera Bekele Dinsa: "Hamonizing indigenous and scientific seasonal drought forecasting knowledge for building livelihood resilience: the case of Borana Oromo of Southern Ethiopia" and submitted in partial fulfillments for the requirements for the Degree of Doctor of Philosophy (Environment and Development Studies) complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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List of Orignal papers

This PhD dissertation is based on the following five original papers

1. Dinsa AB, Wakjira FS, Demmesie ET and Negash TT, Neilson H, **Hamacher**. Indigenous astronomical knowledge based seasonal weather forecast: evidence from Borana Oromo pastoralists of Southern Ethiopia [version 1; peer review: 1 approved, 1 approved with reservations]F1000Research2022, 11:1217 https://doi.org/10.12688/f1000research.121926.1
2. Dinsa AB, Wakjira FS, Demmesie TE and Negash TT. Indigenous knowledge of astronomical star positions and temporal patterns for seasonal weather forecasting: the case of Borana Oromo Pastoralists of Southern Ethiopia [version 1; peer review: awaiting peer review] F1000Research 2023, 12:205 https://doi.org/10.12688/f1000research.128556.1
3. Dinsa AB, Wakjira FS, Demmiese ET, Negash TT (2023) Forecasting Seasonal Drought Using Spatio-SPI and Machine Learning Algorithm: The Case of Borana Plateau of Southern Oromia, Ethiopia. Journal of Earth Science and Climate Change 14: 713
4. Dinsa AB, Wakjira FS, Teferi Demmesie E and Negash TT. Alignment of Scientific and indigenous seasonal drought forecasting: the case of Borana pastoralists of Oromia region, Ethiopia
5. Dinsa AB, Wakjira FS, Teferi Demmesie E and Negash TT. Drought Disaster Resilience capacity of the Borana Pastoral Community of Southern Oromia Region, Ethiopia

Abbreviations

ANN	Artificial neural neuron
ASALs	Arid and Semi-Arid Low Land Areas
ASIK	Alignment of Indigenous and Scientific Weather Knowledge
DFID	Department of For International Development
FGD	Focus Group discussion
FAO	Food and Agriculture Organization of the United Nations
GCMs	General circulation models
GDP	Gross Domestic Product
GIS	Geographic Information System
GPS	Geographic Position System
GOs	Government Organizations
HHS	Household Survey
IPBES	International Policy on Biodiversity, Ecosystem and Social System
ICA	Individual and Collective Social action
IPCC	Intergovernmental Panel on Climate Change
IK	Indigenous Knowledge
ICT	Information Communication Technology
ISDR	International Strategy for disaster Risk Reduction
KII	Key informant interview
LMBP	Levenberg-Marquardt back propagation algorithm
MSE	Mean Square Error
NASA	National Aero-Space Admistration
NGOs	Non-Government Organizations
NAR	The nonlinear autoregressive neural neuron network
OPADC	Oromia Pastoral area Development commission
OBI	Oromia Bureau of Irrigation
PCA	Principal Component analysis
PA	Peasant Association
RPLRP	Regional Pastoral Livelihoods Resilience Project
SPI	Standard precipitation Index
SIK	Scientific and Indigenous weather knowledge
SK	Scientific weather knowledge
SPEI	Standard Precipitation Evapo-transpiration Index Package
UNDP	United Nations Developemnt Programme
USAID	United States Agency for International Development
UNESCO	United Nations Education, Social and Cultural Organization
WMO	World Meteorological Organization

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Harmonizing of Indigenous and Scientific Seasonal Drought Forecasting Knowledge in Building Pastoral Households Livelihood Resilience Capacities: The case of Borana Oromo of Southern Ethiopia

Abstract

This study examines pastoral households' livelihoods resilience capacities with especial insights on the driving role of the seasonal drought forecasting knowledge in livelihood decision making and implementation among the Borana Oromo pastoralists of southern Ethiopia. Thirteen districts of the Boran Zone were grouped into six clusters that consist of Yabello, Teltele, Gomole, Dirre, Moyale and Guchi based on the traditional rangeland resources divisions and the proximate of the area to each other for the purpose of this study. Primary data were collected using households survey, experimental groups, focus group discussions and key informant interviews. Historical rainfall data were retrieved from the website of national Aero-Space administration - predition of world energy resources / NASA POWER access project climate data/ and Ethiopian meteorological agency/NMA/. SPI and ANN based analysis methods were used in the actual and in the prediction of the historical seasonal drought forecasting of the study area. PCA based on the variability (%) and factor loadings methods of data analysis were used in the verification of the variation of the resilience process and resilience outcome before and after the severe drought of the 2016/17 in the study area. Regarding qualitative data, this study used thematic based qualitative data analysis techniques. The study findings revealed that the widely used practices of indigenous-based seasonal weather forecasting objects were observable external features of astronomic Moon and Stars in the study area. It was identified that the observation of the Moon and Stars features had been offering sufficient lapse time in a more than/within ahead of a season. This study showed that both astronomic moon and stars based temporal and spatial dimensions of the forecasting were happened in Hagayya dry season (January and Febuaruy), Ganna (March to May rainfall), Adolessa dry season (June to September) and Hgayya rainfall (October to November) seasons. This indigenous weather forecasting practices are still regularly used in every livelihood decision making process. Similarly, this study identified that, actual/observed and ANN based Ganna and Hagayya seasons SPI 3-months and SPI 6-months prediction value of 1981 – 2021 discovered that Borana Zone rainfall seasons on which communities rely for their entire life supporting systems were/ are drought prone seasons. In the study area, NASA POWER data were more promising in providing actual and predicted seasonal drought modeling when compared with the NMA data.The finding of this study also showed that there were alignments between indigenous and scientific seasonal drought forecasting knowledge in the study area. PCA output value retained the use of indigenous weather knowledge and its multidimensional overall impacts in making the establishment and maintenance of water sources, rangeland management, livestock mobility and social network/support out of 22 resilient preparedness variables. Cattle and sheep were less resilient while goats, camels and rangeland productivity were more resilient to 2016 drought out of 15 resilient outcome capacities. Integrated drought risk management/ knowledge based holistic development approach will sustainably minimize adverse effects of drought in the study area.

Keywords: drought, seasonal drought forecasting, drought preparedness, drought resilience, indigenous astronomic weather knowledge

CHAPTER ONE
Introduction

1.1. Background

Drought is a natural recurrent climate phenomenon of an environmental stress which occurs in all parts of the world in varying severity, temporal patterns and spatial coverage (Benassi, 2008;Wong, 2010). However, recently, an impact of climate change induced drought is becoming too severe in all dimensions; and has causing a far-reaching adverse impact across all sectors, especially on the resource-poor and vulnerable communities (Krakauer et al., 2019; Bevacqua, 2010). It has negative impacts on agriculture, domestic water use, hydrology, hydropower, economy, social systems, forestry, ecology and environment, trade, transport, healthy, education, turism and, etc, (Crossman, 2018;UNSDR, 2007). This human-induced climate change is already affecting weather patterns, as evidenced by frequent occurrences of drought and heatwaves. Hence, drought has become one of the most severe climate events that need to be mitigated to reduce its negative impacts (WMO, 2006;De Sherbinin, 2016).

In this case, weather forecasting knowledge/information is the driver of appropriate livelihood decision making and implementation in the process of ensuring resilience building, especially, towards recurrent drought (Gelder & Decisions, 2018;Kumar et al., 2020; Agyekum et al., 2022). This implies that lack of access and/or failure to use of the seasonal weather/drought forecasting knowledge in timely and efficient manner is deteoriated livelihood resilience capacities (Prasad & Ganesan, 2020; Prasad & Ganesan, 2020;Crochemore et al., 2021). This is mainly attributed by the climate change and variability induced drought that is disturbing accustomed seasonal patterns of drought in a given environmental setting (Oyekale, 2015; Singh et al., 2021). Hence climate change induced drought is becoming a major serious causes of various disasters in the arid and semi-arid low land (ASALs) areas and is continuously threatening the life, livelihood sources and livelihood system of pastoralists in an alarming trend.

According to IPCC, (2013); Kuwayama et al., (2019), drought affected over 1.5 billion people during 2008 – 2018, an average of 53 million people each year. In Africa recurrence of each drought episode in 2-3 years in different scale, location and time is resulting in aggregate damage of up to 25 per cent of each country's GDP (Richman et al., 2016). Similarly,Amsalu, (2009) ; and Ambelu, (2015) stated the increasing in frequency and severity of drought and (Eddie, 2017 ;Venton, 2018), argued as the drought is becoming, sporadically, cutting short any chance for resilience in the pastoral areas of Ethiopia. According to (Salifu, 2020) study Borana pastoralists have lost more than 70 per cent of their livestock during the severe drought of the 2011 and 2016. Apparently, unless proper measure is taken in to account such losses will continue to sap the resilience capacity of the pastoral sector to deal with drought (Ahmadalipour et al., 2017).

In the rural areas; indigenous drought/weather forecasting knowledge is the basis of the livelihood decision making and implementation (Chang et al., 2010a; Petzold et al., 2020 ;Dejene & Yetebarek, 2022). In addition, it is the primary driver in planning and management of resources in making a living in the process of ensuring drought resilience (Crane et al., 2010; Zounon et al., 2020). In this regard, rural communities observe clouds, wind, lightning, behavior of livestock, wildlife, local flora; Others watch and define features of the celestial objects/astronomy in the process of weather forecasting (Mbilinyi, 2020; Zounon et al., 2020). Mbewe et al., (2019) argued incorporating indigenous knowledge into scientific knowledge could lead to the development of effective resilience/adaptation strategies that are cost-effective, participatory and sustainable in reducing livelihoods/production risk such as drought.

Accordingly, since time immemorial; indigenous drought forecasting knowledge/information has been used to predict drought patterns and prepare Borana pastoralists for every daily livelihood decision making/ to prepare for either a good or bad season; and has invaluable input/ is the driver in ensuring resilience building towards drought. However, currently, when compared with the past: loss of biodiversity, lack of recording/documentation and ignorance by some of the younger educated generation/ are the factors that are challenging the use of the indigenous seasonal drought forecasting knowledge (Mugabe et al., 2011; Enock, 2013; RAJ, 2013).

In addition, Borana pastoralists put under questions reliability, applicability, accessibility and accuracy of the scientific weather forecasting. Furthermore, the differences in approach/myth and perception between the indigenous and scientific knowledge proponents are also in illusion/anti-parallel (Dube et al., 2016; Rishona, 2016). This has caused a barrier and hindrance to the use of the weather information and drought resilience at the grass root level (Neofotis et al., 2011; RAJ, 2013).

Indigenous seasonal drought forecasting knowledge of Borana pastoralists' are perfectly aligned with the seasonal scientific knowledge. In this regard, recently Borana pastoralists have started use of scientific drought forecasting information to complement IK based seasonal drought information in every day livelihood decision making; and in practices of their efforts in resilience building towards drought.

Being resilient can allows a given system to retain its own identity, integrity, core value, and/or core purpose in the ongoing responses to uncertainty (Danes, 2014; Brown, 2021). In this regard, despite the recent popularity of the concept of resilient in development studies the use of the concept in analytical frameworks has been started with in the general system theory (Holling, 1973; Decker & Redhorse, 1979; Argone, 2013; Bertalanffy, 2014;Pauley et al., 2019) . Little & Mcpeak, (2014) argued that the same as its importance in ecology the notion of thresholds is critical in understanding relevance's of resilience to pastoralism and development. Indeed, Lybbert et al., (2004) argued the two key thresholds in pastoralism 1) the subsistence constraints and 2) the herd size thresholds which played a key role in understanding pastoral systems and resilience. Pastoral scholars claim that the term resilience is synonyms with dominant empirical evidence in pastoralism like the model of bounce back in the boom/bust drought cycles, disequilibrium ecology paradigm which incorporates ideas of resilience with the notions of flexibility and mobility that have decisive in pastoralism (Nori & Scoones, 2019;Little & Mcpeak, 2020a).

Drought resilience is maintained through following proactive drought planning, preparedness and mitigation approach than focusing only on the crises management (Oktaviani, 2000 ; Lain, 2017; Kamara et al., 2019). In connection with this, understanding of the three major resilience/vulnerability factors such as exposure, sensitivity, and coping capacity of a given system, community, individuals and ecosystems are fundamental in the process of building resilience capacities (Kesik, 2017; Alary et al., 2022; Semplici et al., 2023a). In this regard, in most cases resilience is categorized in to outcome/absorptive capacity and resilience preparedness/process of livelihoods' decision making capacities such as anticipatory, preparedness/mitigation, absorptive, adaptive, and transformative capacity within individual and collective social actions (Almedom, 2013a).

Under ordinary pastoral mode of life resilience process/every livelihood activities: management of water and pasture land, mobility, herd splitting, herd diversification, social support, crop farming and livestock selling were undertaken depending on the indigenous weather/drought forecasting knowledge. This implies that lack and/or failure of using seasonal weather forecasting information could leads to the collapse/vulnerability of the livelihoods basis of Borana pastoralists to drought.

This desertation is divided in to seven major chapters. The first chapter describes the introductory part, objectives of the thesis, research questions, and significance of the study, conceptualframework and the description of the study area. Brief of research methods used and data analysis system is also discussed in this chapter. It is followed by the chapter two which presents interpretation and analysis of the indigenous astronomical knowledge based seasonal weather forecasting practices in the study area. It presents details of the seasonal weather indicating temporal and physical patterns of the IK astronomic Moon.

Chapter three deal with the presentation and analysis of the findings of the indigenous astronomical star knowledge based seasonal weather forecast. This chapter analyze temporal, positional and physical patterns of indigenous astronomical star in seasonal weather forecasting in the study area. Chapter four presents interpretation and analysis of the scientific knowledge based seasonal drought forecasting of the study area using historical rainfall data of 1981-2021. This chapter characterizes actual (SPI 3-months and SPI 6 months) and predicted (ANN-modeled) seasonal drought of 1981 to 2021 in the study area.

Chapter five presents findings of the livelihood resilience capacities of the study area towards drought. This chapter categorizes drought resilience in dimension with the resilience process/preparedness practices and resilience outcome. Chapter six deal with the aligment of indigenous and scientific seasonal drought forecasting in the study area. In the Chapter seven the author tries to conclude the findings of the study and finally forwards points of policy implications for future research and pastoral development endeavors.

1.2. Statement of the problem

Drought is a natural recurrent 'climate phenomenon' (Crossman, 2018;Wilhite, 1993) which occurs in all parts of the world throughout the course of human history (World Bank, 2019); with a varying frequency and magnitude. However, according to IPCC (2013); Biovitenskap, (2005) ISDR, (2007) currently and /or starting from the 1970s, globally, what is making new about the drought disaster is that climate change and variability is exacerbating drought in multi-dimensional ways i.e. drought is becoming too severe, prolonged, recurrent and increasing in spatial coverage. Drought has been a far-reaching adverse impacts on all sectors (Little et. al, 2017; Bartels, 2014;Jenkins et. al 2011). In Ethiopia in the past half a century new wave of drought is occurring before people/livelihood sources/systems are becoming resilient from the previous adverse drought without giving enough time for resilience (Nightingale et al, 1993; FAO, 2019; Keil, 2011; Mera, 2018). Pastoralists face adverse drought impacts such as degradation in rangelands, expansion of invasive species, water scarcity, and livestock diseases/death, negative terms of trade and food insecurity (Andy Catley, 2007; Blench et al., 1999).

Drought forecasting knowledge/ information is the basis of appropriate livelihood decisions making in the process of the improving resilient capacities of the pastoralists/farmers towards recurrent drought (RAJ, 2011) . Lack of access to seasonal scientific weather forecasts and failure in use of the seasonal indigenous weather foreasts have continuously threaten the resilient capacities of pastoralists (Masinde & Bagula, 2011; Mafongoya et al., 2021).

Recent studies have grown increasingly pessimistic about the viability of traditional drought forecasting mechanisms (Kettle et al., 2014; Ju et al., 2018 ; Makwara, 2013). Among other things, the declining popularity of traditional climate forecasting is explained by the extinction of some biotic species that were used for weather forecasting (Mbewe et al., 2019; Chikaire et al., 2013). The expansion of modern education and monotheistic religions is another factor undermining the claimed rationality of indigenous knowledge (Roan, 2017; Jiri et al., 2015). In many places, the precarious survival of indigenous drought forecasting skills is further undermined by poverty, lack of clear knowledge transfer mechanisms and poor documentation (Mbewe et al., 2019 ; Chang et al., 2010).

In connection with this, when relatively compared with the past Borana's indigenous drought risk spreading mechanisms which are mainly guided by the defining of the sets of the indigenous environmental knowledge are, currently, not effectively functional due to related external and internal aforementioned factors.There are related studies that are undertaken in East Africa (Radeny *et al*., 2019a); in Borana pastoralits of Southern Ethiopia *(*Itticha *et al*, 1999), in Afar pastoralists of North Eastern Ethiopia (Balehegn *et al*., 2019a); all are mainly focused on the identification of the indigenous drought/weather forecasting knowledge in that particular area. In addition, these all related studies were not addressed all types of indigenous drought forecasting objects and chronological order/cycle of IK objects which signals respective spatial and temporal patterns of drought that are commonly used in the Borana. In this case, (Lusenoa et al., 2002 ; Tesfaye *et al.*, 2018) examined the value of climate forecast information for pastoralists; and (Ayal et al., 2015) identified opportunities and challenges of indigenous biotic weather forecasting knowledge in southern Ethiopia (Borana pastoralists). Furthermore, these related studies were not taking in to account the role of the indigenous seasonal drought forecasting knowledge in maintaing pastoral household's drought resilience.

External stakeholders are still focusing on the scientific drought forecasting information as the sole drivers in making a living. However, Neofotis et al., (2011) disclose that, although scientific information is well organized, rural community could not understand, interpret and implement in livelihood decisions making. Mugabe et al., (2011) argued that lack of accuracy of scientific weather information make rural communities to stick up more with the use of the indigenous weather forecasting knowledge. In connection with this, (RAJ 2013) argued that, the capacity to generate and access to the location specific rainfall forecasting (Enock, 2013) which is mandatory for proper decision making at the grass root level is still very limited in Africa. Dube et al., (2016) and Rishona ,(2016) argued that the differences in approach/myth and perception between the indigenous and scientific knowledge proponents are also in illusion/anti-parallel, i.e. caused as a 'barrier and hindrance' to drought resilience at the grass root level. Although, in the last three decades; there is/was a tendency of using; simultaneously, indigenous and scientific climate information (SICK), Borana pastoralists put under question the credibility of the later in minimizing drought impacts. Related studies in Philippines by Hiwasaki et al., (2014) explored process for using local and indigenous knowledge with science for hydro-meteorological disaster risk reduction and climate change adaptation. Rengalakshmi (1999) , examined climate prediction and utilization through linking of traditional and scientific climate knowledge systems in India. Masinde(2012) work on the bridge between African indigenous knowledge and modern Science of drought prediction is experimental, and examined use of ICT, especially, mobile phone to disseminate available weather information of both sources for end users in Kenyan villages. These studies were context specific and are not directly related with the aspects of the objectives of this study which is mainly focusing on the exploration of the role of the seasonal drought forecasting information in minimizing drought impacts on pastoral households'.

The severity/devastating effects of droughts are not always directly related to the lack of rainfall (Cossins, 1983); but it is the result of multi-effects of policy, institution, cultural and individual capacity problem at all levels (Wario, 2015; Abebe, 2010). In Ethiopia until recently, disaster/drought management is re-active in process/focuses on crisis management/and more resources are mobilized for drought emergency (Echeverría et al., 2016) instead of/than focusing on pro-active long term development activities that enhancing resilience through planning, mitigation and drought preparedness (Mohamed, 2019; Tadesse, 2016). Even though Ethiopia's early warning system is one of the oldest in Africa poor management of early warning information is still a major obstacles to its proper functioning at all levels to process and use information; and to mobilize resources for ensuring drought resilience (UNDP, 2019; Debsu, 2013; Solomon et al., 2008; Andy Catley, 2007).

The increasingly worsening condition of resilience in pastoral areas is due partly to the government's lack of a clear understanding of local coping strategies (Salifu, 2020; UNDP, 2019). Public interventions that limit mobility, weakening social ties and disrupting of indigenous methods of resource management increase their vulnerability to drought (Schrijver, 2019 ; World Bank, 2019;Debsu, 2013). Drought could erode the resilience/adaptation capacity of not only the poor but also the better off, but the latter may not be able to get help because they are considered resilient (Little et al, 2020; Abebe, 2010). In addition, livelihood diversification is still poor in pastoral areas (Duguma, 2017). In the lowland areas lack of watering points and shrinkage of grazing areas during droughts are the Key challenges contributing to low resilience capacity (Debsu, 2013). Moreover (Ambelu, 2015) argued, pastoralists in Ethiopia are the most marginalized social groups in the country in terms of access to public services (UNDP, 2011). Further challenges include very low educational attainment, limited health and rural infrastructure services, including roads, access to markets, as well as the dearth of microfinance institutions for pastoralists, which makes it challenging to escape low-income, natural resource-dependent livelihoods in the lowlands (Echeverría et al. , 2016; Liao, 2014). Hence, in the last few decades, Borana pastoralists have become increasingly dependent on food aid, due to widespread loss of resilience (Hurst et al, 2014; Simone, 2017).

There are related studies in different parts of Ethiopia; study amongst in Pastoral Societies of Afar Region of Ethiopia (Mekuriya, 2017) on Understanding Resilience Pathways to Climate Change in a Changing Rangeland Environment; Tesfahun, (2017 explored the household resilient to food insecurity in the Tach-Gayint District, Amhara region of Ethiopia. There is also studies undertaken on (Boka, 2017a) measuring resilience to climate change in Ethiopia. In addition, Ferede, (2016) explored household drought resilience to green famine in Benishangul Gumuz region of Ethiopia. These studies are context and area specific and are difficult to directly use to the pastoralists in the semi-arid region of the Borana zone of Oromia region of souther Ethiopia.

1.3. Objective of the study

The general objective of this desertation is to examine livelihood resilience capacities with especial insights on the driving role of the seasonal drought forecasting knowledge in decision making and implementation within the Borana pastoral zone of Oromia region of Ethiopia.

The specific objectives of this study are:

1. To explore indigenous seasonal drought forecasting knowledge and practices that are based on astronomic moon among the Borana pastoralists of southern Oromia region of Ethiopia,
2. To explore indigenous seasonal drought forecasting knowledge and practices that are based on astronomic stars among the Borana pastoralists of southern Oromia region of Ethiopia,
3. To characterize actual and predicted historical SPI seasonal drought/SPI 3-months values/SPI 6-months values/ in the study area,
4. To analyze the agreement/aligment of scientific and indigenous seasonal drought forecasting knowledge in the study area,
5. To analyze Borana pastoralists'livelihoods resilience capacities towards 2016/17 drought.

1.4. Research questions

This study is the outcome of the following key leading research questions:

1. What are the indigenous seasonal drought forecasting knowledge and practices that are based upon the astronomic moon and stars in the study area?
2. What are the indigenous seasonal drought forecasting knowledge and practices that are based upon the astronomic stars in the study area?
3. What are the characterics of the SPI seasonal /SPI 3-months values and SPI 6-months values/based historical drought in the study area?
4. Is there an agreement/alignment among the indigenous and scientific seasonal drought forecasting knowledge that are in use by the Borana pastoral zone of Oromia region?
5. How are the livelihoods resilience capacities of the study areas pastoralists' towards 2016/17 drought?

1.5. Scope and limitation of the study

Constraints of time and financial resources were resulted in limiting the scope of this study. This study was only focused on the harmonizing of indigenous and scientific seasonal drought forecasting knowedge and its driving role on Borana pastoralists' ongoing preparedness process in building respective livelihood resilience capacities towards drought. In addition, it is limited to the analysis of the indigenous seasonal weather indicaing feaures of astronomic moon and stars in the study area. It is not addressed the broader aspects of the indigenous weather forecasting knowledge of atmospheric characteristics, astronomic objects, wind directions, water bodies, biotic objects, etc in the study area.

It is also limited in the analysis of the actutal and predicted historical SPI seasons/ SPI 3-months values and SPI 6-months values in the study area. In addition, it is also limited to the analysis of the aligment of the astronomic moon and stars based indigenous seasonal weather forecasting knowledge with the actual and predicted historical SPI seasonal based in the study area. Constraints of the historical quantitative IK weather data of astronomic moon and stars movements/events that could reveals the pulling effects with in the land-atmosphere-sea surface which will requires at least a decades of the start-up data were limited verification of the alignment of the historical seasonal indigenous and scientific drought forecasting of this study to the analysis of the only seasonal drought of the 2021.

Furthermore it is limited only to the 290 households' twice panel data in the analysis of the livelihood resilience capacities of Borana pastoralists' towards 2016/17 severe drought. Despite these limitations, this study has added invaluable input to the existring knowledge of IK weather forecasting, scientific weather forecasting, aligment of IK and scientific weather forecasting and overall impacts of these in building resilience capacities towards drought.

1.6. Conceptual framework

Resilience is about the (change) constructing of safe rational innovative capacities within the ongoing responses to the inevitable continuum of natural and social changes (Fleming & Ledogar, 2008; Giangrande et al., 2013; Boyd & Consultant, 2014). Resilience preparedness/process allows the system to retain its own identity, integrity, core value, and/or core purpose in the ongoing responses to the uncertainty within the existing experienced contexts of natural and social environmental system and beyond (Danes, 2014; Brown, 2021). Resilience is about to use the challenge as an opportunity for developing rational capacity in the process of dealing with the existing contexts of distorted experiences of complex system, and uncertainty caused by natural and man-made factors (Nelson et al., 2007; Folke, 2016). Being resilient requires a new way of thought, decisions, self-organization and self-reconfiguration with in the continuum of change to resist experienced uncertainty that is dominated with in the conventional orthodox thinking (Snell et al., 2016; Fraccascia et al., 2019). Experienced uncertainty is the existing dominant norms of actions that are caused by natural and social context within and beyond in which a given system/community is living.

In this regard, conceptual framework of this study was developed using the synthesis of the definitions of Holling ecological stability (1973), the DFID resilience framework (DFID, 2011, Frankenberger, 2014), human adaptive resilience (Almedom, 2013),United Nations international strategy for disaster reduction (2013), resilience concepts of the resilience alliance framework (Bots et al., 2015; van der Merwe et al., 2018), IPCC climate resilience framework (Shammin et al., 2022), and USAID resilience policy revision (USAID, 2022).

In this regard, this study contextualized and defined conceptual framework of drought resilience of Borana pastoralists in dimension with the importance of the cumulative evolving impacts of the ongoing community resiliene process against disturbance/ drought (Chapter1, 2, 3,4,5, Dinsa AB, 2023) as the function of the resilient outcome/absorptive capacity/vulnerability within and beyond the existing contexts of natural and social environment (Chapter 5, Dinsa AB,2023). Here resilience is defined as the outcome /absorptive capacity/ of a system or a community to resist shock and/or, recover, reorganize, reconfigure and re-stabilized from the effects of a drought in a timely and efficient manner while retaining the same core and basic structure and ways of functioning in the continuum of change using cumulative flexibility of the process of knowledge including anticipatory, mitigation, absorptive, adaptive, and transformative knowledge under both scientific and indigenous that drive preparedness/mitigation practices of individual and collective actions.

Although different disciplines use various definitions of resilience all have embedded three main core interconnected concepts in common. These interconnected concepts includes 1) absorptive/persistent capacity to shocks/disturbances, 2) capacity to recovery/ to return to its original/previous/ functioning state after shock, 3) capacity to learn/anticipate, adapt and transform/shift to new way of thought to resist shock and/ or to retain original identity, integrity and core values through individual and collective social action in the system (Thulstrup, 2015; Folke, 2016; Ungar, 2018). Hence, conceptual framework of this study was analyzed mainly in accordance with the resilience concept which comprises context, disturbance, capacity, vulnerability and resilience pathways reflecting the reality in the study area. Contexts are existing dominant experienced realities of social, natural, economy, political, policy, infrastructures, technology, education, healthy, etc. Disturbance includes experienced natural and man made disasters. Vulnarability is lack of capacity/asset. Capacicitis are a wide range of livelihood asset. Livelihood resilience is defined as the persistence capacity of all people across all generations to sustain and improve their livelihood opportunities within wide scale disturbances in the continuum of change (Tanner et al., 2015; Zhou et al., 2021). A livelihood comprises capabilities, assets and activities that are basic/needed for means of living (Hodge, 2011; Rudiarto et al., 2019;Luo et al., 2022) . In this case, within the field of development studies, the concept of livelihoods has drawn from multidisciplinary backgrounds into a more logical set of ideas (Pain & Levine, 2012; Hou et al., 2021;Bauer et al., 2022). Therefore in development studies livelihood resilience comprise capacities, assets, activities, strategies, human agency; individual and collective capacity to respond to stressors (Thulstrup, 2015; VSF , 2018).

A livelihood viewpoint pushes further to situate local thresholds as influencing and influenced by wider development transformations as a processes of pro-poor and poverty reduction, food security, rule of law, non-violence, democratization, inclusion, balancing existing distorted dominant norms of action, globalization, social and political movements, urbanization, green growth, high diversity, fair competition, research, diffusion of information and technology, etc (Christopher B. Barrett et al., 2016; Binns & Bateman, 2022).

In social-ecological system very minor changes within one of an interacting sub-system of political, financial, cultural, physical and socio-natural components with in the continuum of multi-complex adaptive social system could cause the whole system unstable or make vulnerable to loss of livelihoods (Nelson et al., 2007; Almedom, 2013; Holling, 2013; Brown, 2021). This implies the development of negative/maladaptive behavior in complex social system may precipitate vulnerability/chronic misery and human suffering (Almedom, 2013b). However, complex systems are held together by local knowledge and interactions only. In a complex local social system, because of the deep and extended webs of interactions and interconnections of the local community, any agent's action without local participation could controls very little (Almedom, 2013). Hence, in the process of resilience building any activities without in-depth knowledge/emotional based damaging response could leads to the long vicious cycle of the scenario and continuous failure of the system (Mehran et al., 2015; Yao et al., 2022; Chiroro, 2023). However, wrong responses could not completely impede continuum of constructive rational positive change of local people (resilience) in the long run (Kapalla, 2021; Nuvey et al., 2021). In this regard (Almedom, 2013) argued that when the behaviors of people, institutions, or nature violate the norms; command-and-control system is often sought as the primary solution in an effort to move human or ecosystem behaviors to a predetermined, predictable state.

In this regard, as it is seen in figure 1, conceptual framework of this study was categorized drought resilience in to the interconnected continuous cycles of resilience process/responses which are influencing/ influenced by the continuous cycles of the decision making capacity/knowledge/ of the Borana community against drought (chapter, one, two, three and four) within the experienced existing environmental context as a function of resilience outcome/absorptive capacity and vulnerability (Chapter four).

Weather/drought knowledge is the driver of all livelihoods decision making in Borana pastoral zone of Oromia region (Chapter one, two, three and four). Under ordinary pastoral mode of life drought resilience process/every livelihood activities: establishment and management of water and pasture land, livestock mobility, herd splitting, herd diversification, social support and social network, crop farming and livestock selling were undertaken depending on the weather/drought forecasting knowledge. This implies that lack and/or failure of using drought forecasting knowledge could leads to the collapse/vulnerability of the livelihoods basis such as livestock, water, productive rangeland, etc, (chapter five). Drought resilience outcome (absorptive capacity) is ensured through the proper preparedness/drought resilience process (Chapter five).

In this regard, using aforementioned definition as the base; this study constructed visual representation of the cause and effects/conceptual framework of the implications of the seasonal drought forecasting knowledge towards building pastoralists drought resilience capacities of the study area. The figure has three sections. The Whole section is embedded within the existing experience of dominant norms of action that are continuously influencing/influenced by the multidimensional natural and social contexts including disturbances with in and beyond the system. The resilient and vulnerability dimensions of the study area were the function of the ongoing drought prepardnes practices that are drived and are driven in general by the knowledge, especially, weather knowledge which constitutes indigenous and scientific weather knowledge. Objectives of this study were to identify indigenous and scientific seasonal drought forecasting knowledge, identified alignment of indigenous and scientific drought forecasting knowledge and implications of drought forecasting in building drought resilience capacities in the study area.

An ongoing innovative process of resilience practices could result in resilience outcome/improve absorptive capacity of a given entity/system's original value (Hoiling, 1973; Ungar, 2018). Scholars argued that a process based resilience do have a capacity to develop a new way of thought which is termed as an emergent behavior in natural system and transformative resilience capacity of a social system's in the continuum of change) (Rutter, 2006; Woods, 2011;Folke, 2016). In this case, resilience is achieved by what the system perform and endowed/retained in the process of ongoing preparedness measures at all cross-scales (Almedom, 2013; Bots *et al*., 2015).

As it can be seen in figure 1, consciously/unconsciously the dynamics in the process of resilience building in response to the continuum of change allows a complex system of Borana communities and/or individuals to undergo simultaneously/distinctly interconnected resilience process of drought preparedness practices within the existing experienced context of the environment/natural and socio-economic environment (Chapter five). In this case, K-knowledge (comprising IWK- indigenous weather knowledge and SWK- scientific weather knowledge/ ASIWK-alignment of both are the key driver in the livelihood resilience preparedness practices/process to produce resilient absorptive capacity towards drought in the study area.

This implies that the effectiveness of an innovative ongoing drought preparedness in producing absorptive capacity is depending upon the interconnected decision making capacities which are continuously developed through combined anticipatory capacity, mitigation, absorpative, adaptive capacity knowledge /incremental knowledge/, and transformative capacity knowledge/re-organization of knowledge in new ways or paradigm shift in thought and decision making of Borana community (Rai, 2006; Folke et al., 2010;Woods, 2011;Van Breda, 2018b; Brown, 2021; Veloz et al., 2022;Akamani, 2023).

As it can be seen in figure 1, there is a situation when existing anticipatory capacity/-knowledge is challenged/vulnerable in the process (mitigation/preparedness) of producing required absorptive resilient capacity within the process of existing norm of action/response to the dynamic continuum of environmental context/change due to natural and manmade factors (Folke et al., 2010; Veloz et al., 2022). In this case, individuals, communities, systems, organization are forced to continuously develop means of resisting disturbance and /or to maintaining resilience within the context of the dynamism of environmental change (Tanner et al., 2015; Fedele et al., 2019). This implies that, both natural and social systems forced to undertake adaptive capacities (adjustments/modification of dominant norms of action) which help to increase the range and use of existing available knowledge as a means of response to the continuum of environmental change (Hodgson, 2010;Folke, 2016; Snell et al., 2016;Ungar, 2018).

Furthermore, when a given natural and social systems are challenged /vulnerable to resist shock and /or to maintaining resilience using existing adaptive/incremental capacity; again systems subjected to produce new behavior (Folke, 2016; Van Breda, 2018b; Asadzadeh et al., 2022 .

This shift of behavior is termed as emergent behaviors under ecological/natural system and T-transformative behavior under social system, economic, … using inherent potential to resist shock and/or to maintain resilience in a process of response to/within the continuum of environmental change (Holling, 2013; Veloz et al., 2022). In this case, transformability is about shifting existing norms of action/dominant experience of norm of action that are accustomed due to natural and mam made factors/ into new innovative orientations of process and actions to produce absorptive capacity (Ungar, 2018; Fedele et al., 2019; Nyamwanza et al., 2023). This process of knowledge development is cyclical either simultaneously/distinctly depending on the magnitude of the disturbances within and beyond the system/ in the natural and social environment.

Conceptual framework of this study is depicted in Figure 1.

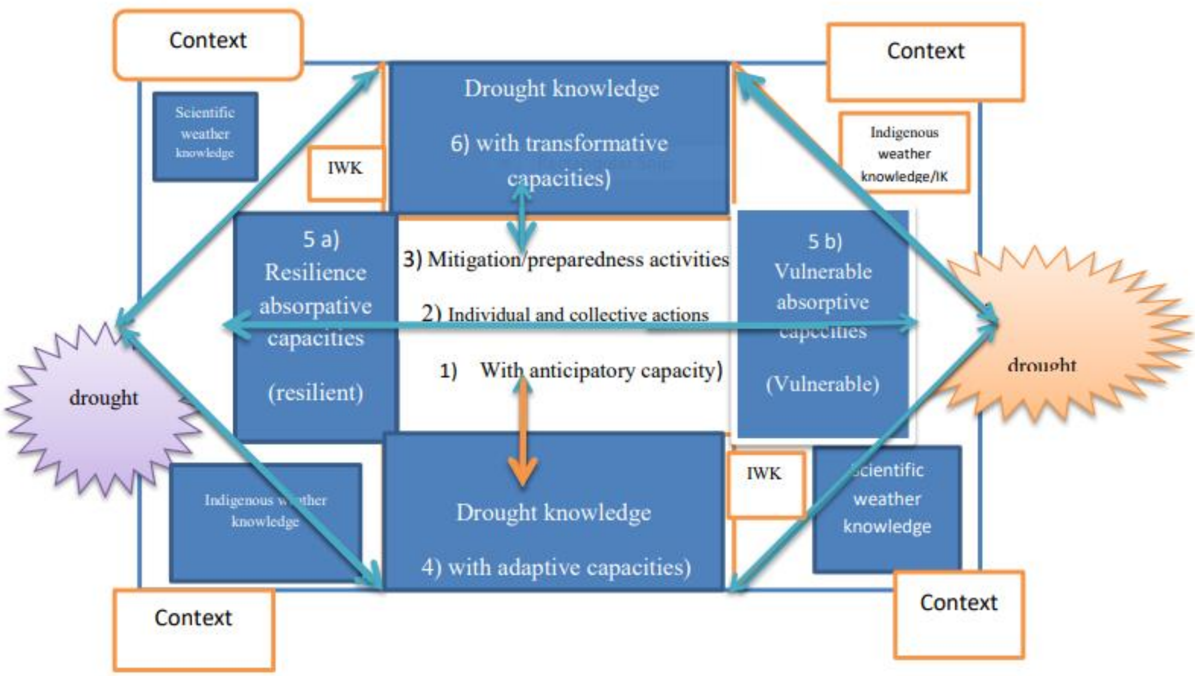

Figure1. Conceptual framework of this study

Source: own work, 2022

Remark: The whole picture /context/ represent issues like policy, environment, education, infrastructures, livelihood asset, population, investment, technology, market, politics, economy, institutions. In addition, the arrow indicate the continuous cycles of the resilience building knowledge of the study areas' anticipatory, preparedness/mitigation, absorptive, adaptive and transformative knowledge that drive individual and collective actions in the process of building resilience towards drought.

Transformative capacity is about having the capacity to shift accustomed dominant experiences caused by natural and man-made factors in to a new ways of rational thought, process and action/ unknown development trajectories to resist shock and / or to maintain constructive positive change (resilience) in response to the internal/external environmental context (Almedom, 2013; Asadzadeh et al., 2022; Nyamwanza et al., 2023). These resilience capacities can sustainable only/ could undertake proper function only under the inclusive strategies (ICA-individual and collective social action) to maintain the well-being of the individuals in the social system and beyond the domain (Folke et al., 2010; Almedom, 2013;Bruno 2015).This implies that the concept of resilience is holistic in approach. It is to secure the well-being of all in inclusive way (Hodgson, 2010;Tanner et al., 2015).

1.7. Description of the study area

Astronomically, Borana zone is located between 3º 31' 31 '' to 6º 35' 37'' latitude and 36º 42' 38" to 39º 45 '15 '' E longitudes. Location of the zone is depicted in Figure 2. It is located in the southern part of Oromia regional state of Ethiopia (Reflection et al., 2000; Berhanu, 2011). Yabello the capital town of Borana Zone is 570 km South of the capital city, Addis Ababa (Tura and Reddy, 2015). It borders Kenya in the South, Somali Regional State and Gudji Zone in the East, and the Sidama Region, Southern Nations, Nationalities, and Peoples Region (SNNPR) in the north and west (Godana, 2016). The projected population of Borana Zone is 1,626,930 (Male 821,733 and Female 805,197) with the majority (97%) living in rural areas; Borana Oromo is the largest community in the area with interconnected Oromo groups of Garba and Burdji (Desta, 2006; Homann et al., 2008; Berhanu and Beyene, 2015).

The land area is 63,939 km2 (Dirriba et al., 2020 ; Dalle, 2014). The landscape of the zone is mainly lowlands with slightly undulating peaks up to 2000 meters above sea level in some areas (Berhanu and Beyene, 2015). Agro-ecologically large areas of the Borana zone (more than 60% is below 1500 altitude) are categorized as arid and semi-arid low lands (Kena, 2021; Hurst & Pedersen, 2014). North central and southern parts such as Yabello and central parts of Dirre districts are elevated up to 2000 M abs (Homann et al., 2008; Dalle, 2014).

It is semi-arid lowlands and are frequently prone to severe drought within a year to year increasing trends in causing damage on the livelihoods (Ambelu, 2015). There are four locally defined seasons in which annual rainfall distribution and the dry period patterns of the study area are bimodal in character. Mean annual rainfall of the area is between 400 to 700 mm. The long/main rain season (*Ganna* rain) is between March and May; and the short rain season (*Hagayya* rain) is between September and November.

The onset and cessation of both rainfall seasons are often irregular in duration; and are scattered in spatial coverage (Bule, 2021). The warm dry seasons (*Bona Hagayya*) is between December and February with a high evapo-transpiration rate (Dalle, 2014); and the cool dry season (*Bona Adoolessa*) is between June and August (Lemenih et al,. 2011). The average annual temperature of the area is $24.5^{0\ C}$. The average amounts of maximum and minimum temperatures are 26.83^{0C} and 20.4^{0c} , respectively (Kamara, 2003; Duba et al., 2021).

Traditionally, all economic and social life revolves around the traditional wells of water sources and rangelands (Kamara et al., 2003; Doyo et al., 2018). Ecologically, in the past Borana rangeland was known as the highest east African belt of productive rangelands' and administered by groups of traditional elders who define decision making rules and implementation under abba madda/economic affairs issues heads of the Gada system (Kopock, 1993, Kamara, 2003;Worku, 2022). Periodical livestock mobility strategy is the common drought risk spreading mechanisms which allow Borana pastoralists to use ecologically/seasonally variable scarce communal natural resources (Mengistu, 2016).

Except few areas that were converted to crop farming and other land use; large proportion of the Borana grazing area, especially land and water are administered and used under common use at the community level (Hurst & Pedersen, 2014b). Under this system rangelands are categorized in to different common property use of forra (grazing of bulls and non-lactating cows), warra (for lactating cows) and calf enclosures (calves, sick and weak animals) (Homann et al., 2008; Chang et al., 2010b). Water resource consists of traditional deep wells. In addition, in the last three decades ponds with different size were constructed by different stakeholders (Godana G, 2016).

The main important sources of livelihoods are pastoralism and /or extensive livestock production, under semi-sedentary basis unlike in the past which was based on the indigenous transhumance (Hogg, 1997;Tadicha, 2015). Historically, Borana pastoralists are known by the husbandry of the world famous type of Boran cattle breeds. As a trend of recurrence and magnitude of drought is increasing; currently, herd diversification which includes husbandry of large number of small ruminants and camel is highly adapted by the Borana pastoralists (Coppock, 1993). Despite, the increasing livelihood challenges which are caused by the climate change induced drought; Borana's indigenous knowledge based of livestock production system is cited as the model of successful pastoralism in sub-Saharan Africa (Coppock, 1993; Chewaka, 2000; Kamara, 2003).

Extensive pastoral production system and seasonal mobility is the key means of livelihood systems and strategies of Borana pastoralists towards drought (Homann et al., 2008). Currently, unlike in the past extremely shortening of drought cycles have been increased livelihood risks and damages (Homann et al., 2008; Bahal'Okwibale, 2018). These are resulted in decreasing of per capita livestock holding size due to the livestock death and poor reproductive performance that have been caused by the drought (Agyekum et al., 2022). Currently, drought occurs every 1-2 years unlike in the past which was every 6-8 years. These have challenged recovery and resilience capacities of livestock size before the next cycles of the drought is occurring (Hurst & Pedersen, 2014b).

The customary structure of social organization and traditional governance system of resource use and management in Borana has survived for centuries independent of the formal organization (Copack, 1993; Homann et al., 2008). Societies are categorized in to age grade (Tache, 2008; Berhanu & Fayissa, 2009). The holistic Oromo traditional administration/the Geda system/ is still mainly functional among the Borana Oromo community of Southern Ethiopia (Ahmed, 2006;D. Belayneh, 2016).

According to FAO/UNESCO classification, the soil resources of Borena zone are classified into Vertisols, Cambisols, Luvisols, Nitosols, Calcisol, Gypsisol, Paeozems, Ferralsols, Solonetz, and Fluvisoil (Godana, 2016; Fenetahun & Fentahun, 2020). High forest, broad leafed forests, wood land, bush and shrub land, grass land and plantations trees are found in the zone (Dalle, 2014, Godana, 2016; Fenetahun & Fentahun, 2020). Acacia woodland and savanna region is found in the larger areas of the zone including in districts of Moyale, Taltale, Arero, Dire, Dillo, Dhas, Miyo and Yabello (Dalle, 2014; Fenetahun & Fentahun, 2020). Nickel, cobalt, rare metals (columbines tantalite), kaolin, feldspar and quartz, talc, graphite muscovite, asbestos, lime stone, gypsums, olivine and garnet are found in Dire, Arero, Dillo,Yabelo, Taltale and Dhas (Fenetahun & Fentahun, 2020).

In line with this, traditionally, in Borana zone of Southern Ethiopia indigenous weather forecasting knowledge practices and information are the basis of livelihood decision making and implementation. Drought, scarcity of water, rangeland degradation, poor market system, lack of infrastructure, weak disaster preparation, weak service delivery system/lack of strong institution, weakening of the customary indigenous system and lack of appropriate pastoral oriented development policy exacerbated the adverse effects of the drought in the area (Godana, 2016; Mohamed, 2019; Dirriba et al., 2020; Dinsa AB et al., 2022). In this case, more than 95% of the rural communities have not access to basic services especially, like telephone, quality water, and banking (Ahmed, 2006; Fenetahun & Fentahun, 2020). Location map of Borana zone is displayed in Figure 1.

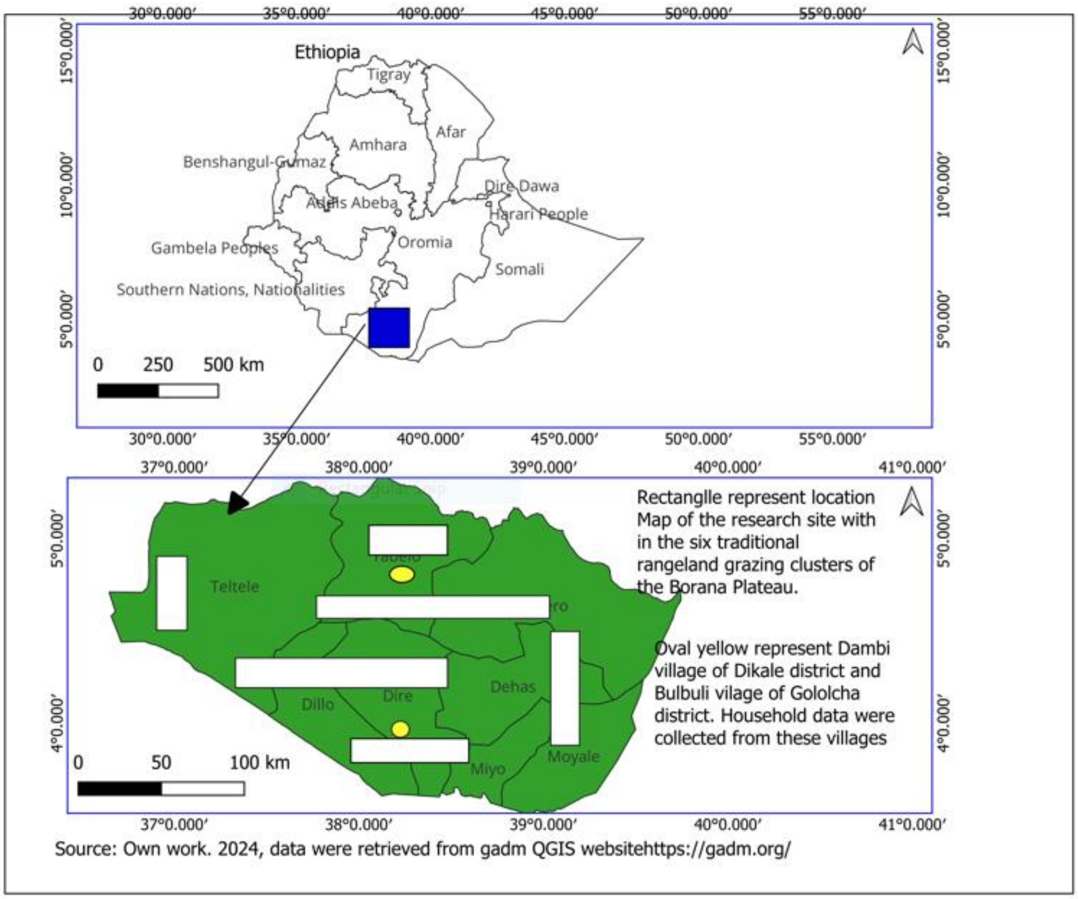

Figure 2. Location Map of the Study area

1.8. Research methodology

1.8.1. Philosophical view of the research

World view is a basic set of beliefs which guide an action (Guba, 1990). In this case, Creswell (2014) stated four commonly used philosophical world views or beliefs: 1) the post-positivist, 2) constructivism, 3) transformative, 3) and the Pragmatic world views. These philosophical world views are selected based on disciplines orientation, objective and/or research questions, students' advisors/mentors inclination and past research experiences. Therefore, based on these aforementioned domains/ factors and the intended problems to be addressed; a researchers employ a qualitative, quantitative, or mixed method approaches in their research.

According to (Oshagbemi, 2017), World views are seeing as a general philosophical orientation about the World and the nature of the research that a researcher brings to a study. Cognizant, with this dynamic sphere of influence, pragmatic worldview was used to frame all the process in this particular research. Rossman and Willson, (1985) explored that instead of focusing on single methods; pragmatism allow to use multiple methods, different World views and different assumption to understand the problem as well as it opens the door to use different data collection and analysis methods.

1.8.2. Research approach

There are three advanced research approaches: Qualitative, Quantitative and Mixed methods (Creswell, 2014). The three approaches are not as discrete as they appear. Qualitative and quantitative approaches should not view as rigid, distinct categories, polar opposites, or dichotomies. Instead, they represent different ends on a continuum (Newman & Benz, 1998). A study tends to be more qualitative than quantitative or vice versa. Mixed research methods reside in the middle of the continuum because it incorporates elements of both quantitative and qualitative approaches. The broad research approach is the plan or proposal to conduct a research which involves the intersection of philosophy, research designs and specific methods (Cresswell, 2014).

In this particular study a mixed methods of research approach was employed. Mixed methods approach involves combining or integration of qualitative and quantitative research and data in the study. Qualitative data tends to be open-ended without predetermined responses while quantitative data usually includes closed-ended responses such as found on questionnaires or perception instruments.

1.8.3. Research design

Research designs are type of inquiry with in qualitative, quantitative and mixed method approaches that provide specific direction for procedures in a research design (Akhtar, 2016). Others have called them strategies of inquiry (Denzin and Lincolin, 2011). Although, many designs exist in the mixed methods field, Creswell (2014) identified the three primary models in the social sciences today: convergent parallel mixed methods, explanatory sequential mixed methods and exploratory sequential mixed methods.

Mixed methods designs (Convergent parallel mixed methods), which combines both quantitative and qualitative methods across the stages of the research, will used to comprehend the interrelated objectives of the study. Convergent parallel mixed methods are a form of mixed methods design in which the researcher converges or merges quantitative and qualitative data in order to provide a comprehensive analysis of the research problem. In this design, the investigator collected both forms of data at roughly the same time and then integrates the information in the interpretation of the overall results. Contradictions or incongruent findings explained or further probed in this design. Even though it was the mixed method approach, the quantitative research methodology was formed the basis of this study. The two approaches are complementary, providing different perspectives and answering different specific questions within any one broad area (RDSU, 2003; Bryman, 1988).

Furthermore, in this research, both experimental and non-experimental research design was employed to understand indigenous and scientific seasonal drought forecasting and its driving role on livelihoods resilience capacities of Borana pastoralists. The details are herebelow in the sampling techniques and in the data collection sections.

1.8.4. Sampling design

Different sampling design/ techniques were employed for qualitative and quantitative data sets. In this study, region, zone and districts were selected using purposive sampling techniques. In addition, experimental groups, FGD and KII participants were selected through non probability sampling techniques. PA and respective villages were selected through lottery methods of sampling techniques.

1.8.5. **Sampling techniques**

In this study, non probability and probability sampling techniques were used to identify the sample unit for both qualitative and quantitative data. In this regard, region, zone and districts were selected using purposive/non probability samplinig techniques. PA/Ganda and villages were selected using probability/lottery methods of sampling techniques.

At the first stage, Oromia national regional state, specifically Oromia pastoral area is purposively selected for this study. The dreadful conditions/ continuously intimidation of the livelihood basis such as environment, economy and social/cultural fabrics on which the community entirely depends by the increasing trends of drought in multidimensional ways were the fundamental reason for the selection of Borana pastoral zone for this specific study.

In connection with this, from the time immemorial Borana Oromo pastoral communities do have uses their own indigenous knowledge, specifically, indigenous weather forecasting knowledge in the making of every daily livelihood decisions and implementation. In addition, in the past three decades; distortion of the occurrence /cycle of the drought from its regular accustomed patterns have made the study area pastoralists to the use of meagerly available scientific drought forecasting information. Furthermore, regardless of the importance of both sources of scientific and indigenous seasonal drought forecasting knowledge/information in ensuring drought resilience; studies on seasonal drought forecasting that are alining both sources of knowledge were not undertaken in the study area. In general, lack of information on the resilience dimension; and lack of appropriate information of the weather/seasonal drought forecasting and its impacts in making appropriate livelihoods decisions are the main underlying causes for the selection of the Borana pastoral zone for this particular study.

In the second stage: for this study, 13 districts of the zone were grouped in to six clusters that were consists of Teltele, Yabello, Gomole, Dirre, Guchi and Moyale which were based on the proximate of the district to each other for the purpose of this study. Recurrences/challenges of drought disaster, degradation of livelihood sources by drought, persistence modes/way of pastoral livelihoods/life, availability of the bulk of the functional indigenous knowledge, specifically, indigenous weather knowledge were among the main factors for the grouping of these districts in to the same clusters. In addition, accessibility to roads, representativeness in agro-ecological and/or geographical location; and in economic/socio-cultural fabrics of these districts were also the other reasons for their selection/grouping in to the same clusters for this particular study. In this regard, experimental groups, FGD and KII were selected purposively from these clusters. Regarding the quantitatives historical rainfall data; representative districts of these clusters such as Yabello, Dillo, Dirre, Moyale and Guchi were purposively selected by the researcher.

In the third stage (Selection of the Kebeles and Villages): Regarding household survey data, the most two (2) pastoral and agro-pastoral representative PAs such as Dikale of Yabello district and Gololcha of Dirre district were selected using lottery methods for the exploration of the variables of households' livelihoods resilience capacities in the study area. Similarly, Bulbulli villages of Gololcha and Dambi villages of Dikale were selected through lottery methods.

Households' quantitative livelihoods resilience data were collected through household survey from all 290 households reside/available within the villages during the period of data collection.

1.8.6. Methods of data collection

This particular research used the mixed method approach which was followed the pragmatism World view of convergent parallel mixed methods design and collection of both quantitative and qualitative data roughly at the same time in the design. This type of design is popular in fields with a strong quantitative orientation that augments the result with qualitative research methods (Creswell, 2014). The quantitative data were generated from household survey, experimental groups and secondary sources (satellite image, historical rainfall data, and websiteetc.). In this regard, for household survey instruments like the structured questionnaire and semi-structured questionnaires were used for collection and administration of the data. The qualitative data of this study largely depends on information obtained through focus group discussion, key informant interview; experimental groups and direct observation.

Household survey: Babbie (1998) stated that a household survey has logical, deterministic, general, parsimonious, and specific characteristics. In this research, data/verbal consent were collected from all accessable households/household heads residing in the two selected villages; one pastoral villages (Gololcha of Dire district) and in one agro-pastoral villages (Dikale of the Yabello district) during the time of the data collection. Cognizant to this, households in the villages were surveyed to collect the necessary data which assist to identify their knowledge of the sets of indigenous and scientific seasonal drought forecasting knowledge from the easily accessible environment/biosphere and/or up to the hardly accessible atmosphere/Universe, level/extent of the use of the types/sets of the seasonal drought forecasting knowledge, drought disaster risk reduction planning; and finally the data of the contribution of the use of the drought forecasting knowledge in ensuring households' drought resilience capacities.

In connection with this, simultaneously, household survey questionnaires were designed to collect a range of data which help to identify the vulnerability/vulnerability factors like exposure, sensitivity, and coping capacity and dimensions of resilience capacities like anticipatory, mitigation, adaptive, absorptive, transformative capacity, individual and collective social actions in the process of building resilience towards drought. In this regard, the survey questionnaires were designed for calculating 22 variables of resilience process and 15 resilience absorptive capacities of the Borana pastoralists. It includes inquiries on socio-economic and environmental attributes as well as their observations regarding rainfall over the past 41 years. Identifying/information recorded were limited to the name of the HHs and the questionnaires number.

Focus Group Discussions (FGDs): it is a qualitative research method where semi structured discussions are held with a small group of persons sharing a common feature. Specifically, old men and women were incorporated into the group discussions in order to capture information related : to historical drought, knowledge of seasonal drought forecasting, the mechanisms/ use of the drought information of seasonal drought forecasting and extent/level of drought disaster risk reduction planning, and its overall impact in drought resilience. A shortlist of open-ended questions was employed to guide the discussion. Accordingly, six focus group discussions; each consists of 12 participants (8 males and 4 females) were participated in data generation.

Key informant interviews (KIIs): KIIs are effective methods of collecting information when investigators are interested in understanding the perceptions of participants to phenomena or events. It was used to generate in-depth information pertinent to climate trends over time, drought disaster risk, IK drought forecasting objects, drought resilient strategies, change in rangeland productivity trends, and livestock production and productivity. In addition to pastoralists/agro-pastoralists and development agents working in the Kebeles; KIIs were conducted with representatives of different Zonal and District sectoral offices of the study area. Interview guide was used as an instrument. In this regard, 12 key knowledgeable informants (6 males and 4 Females) were interviewed.

Experimental groups: In this research, experimental groups were used to read/define astronomic objects/ variables of seasonal drought forecasting objects in the near biosphere; and in the hardily accessible seas surface and atmosphere/Universe which could help to identify the magnitude, temporal and spatial patterns of seasonal drought in the study area. Indigenous seasonal drought forecasing data which were drived through expermental practices that were consists of indigenous experimental groups who do have in-depth knowledge in defining/reading astronomic objects.were gathered ahead of the three months in four seasons of 2021 were used in this study. In connection with this, five experimental groups/practices in which each consists of 5 (a total of 25 participants) well experienced traditional astronomical weather forecasters who do have in-depth knowledge in defining/reading astronomic objects.were used for data gathering. In addition, MATLAB/ANN was used to drive seasonal quantitative historical scientifc drought forecasting data of the study area in the last 41 years. Historical rainfall data were retrived from NASA POWER access project climate data website. The grid reference system is WGS84 https://power.larc.nasa.gov/data-access-viewer/. Furthermore, local station data of Yabello and Moyale districts were used to compare its actual and ANN output with the NASA POWER project climate data.

In this research, IK astronomic/atmospheric seasonal drought forecasting data were gathered from celestial objects of mainly astronomic moon and the stars. The detail of indigenous seasonal drought forecasting data were collected from periodically/spatially/varied multidimensional outlooks of these celestial objects: alignment/defect of the alignment/, direction, group formation, color/physical features, size, ray, partial or full eclipse (death), type, and duration of the observation of the stars in the sky; and inclination and date of the born of each new moon of the month, etc.

Observation: Direct observation of the study sites were undertaken to look at the environmental outlooks of natural resources situation. In addition, it includes a set of the IK weather forecasting objects, features and chronological order /cycles of IK objects in the near biosphere and hardly accessible Universe/atmosphere, livelihoods sources status, socio-economic and institutional contexts of the study area were examined through direct observation. Such methods of data collection were employed in this study as it help to approaches reality in its natural setting, and offers first-hand information without relying on the reports of others. Moreover, it can offer data when respondents are unable and/or unwilling to cooperate or to offer information (Robson1993; Kothari, 2004; Sarantakos, 2005). Checklists were also used as an instrument to manage all components of the variables which were required in the process of this research. Different types of information such as the biophysical characteristics of the study areas, ground truth data collected from the field, the household's resilience strategies and practices used in response to drought were observed and collected at their original setting. In line with this, this study used field research approach in the whole process of data collection. The essential idea is that the researcher goes into the field to observe the phenomenon in its natural state (Micheal,2015; Van de Ven, 2017). In the field research approach researcher typically takes continuous extensive field notes which are subsequently coded and analyzed in a variety of ways (Genkova, 2020; Whitney, 2008).

Secondary data: This includes information on the livelihoods, rain fall data, crop and livestock production data, population data, satellite image maps and other relevant issues related to the study objectives. Generally, data on biophysical environment, socio-economic and institutional contexts of the study areas were collected from secondary sources. Furthermore, research conducted in the area, government strategy and policy documents, and non-governmental organizations and government reports were reviewed in the process of the data collection of this study.

1.8.7. Methods of data analysis

Currently, under ordinary pastoral mode of life; every livelihood decision making and implementation among Borana Oromo pastoralists are mainly guided through the use of the indigenous seasonal drought forecasting knwoledge/information. In this case, pastoral livelihood activities/means of making a living: rangeland and water sources management, mobility in search of pasture and water during severe drought, herd diversification, herd splitting and social network and supports are reconfigured /decided periodically depending on the seasonal weather/drought forecasting information in the process of building resilience towards drought. Hence, from time immemorial weather information is part and parcel of life in the non-equilibrium environments of the Borana pastoral zone of Oromia region of Ethiopia. FAO (2011; 2017) found that due to lack/faulty of accuracy of weather information with accompanied distorted decisions making of livelihood strategies undertaken at all levels; in the recent severe drought pastoralists in the horn of Africa has lost up to 70 per cent of their livestock.

In connection with this, this study gave emphasis on the seasonal drought forecasting knowledge/information in paving the way/ in its driving role/ in the process of decision making undertaken towards building pastoral livelihood resilience towards drought. In this regard, driving role of weather knowledge in livelihoods decision making was analyzed along within the 22 resilience prepardnes practices and 15 types of resources that were endowed by the pastoral households in the study area. In connection with this, this study was employed both quantitative and qualitative data analysis techniques. The qualitative data set were used in the analysis of the functionality and accuracy of the IK seasonal drought forecasting variables through following the

Bazeley (2009) ideas of thematic data analysis. The three key strategies of, Bazeley (2009), including description of data, classification of data, and seeing how concepts are interconnected were applied to scientifically analyze, synthesize, triangulate and report the findings of this study.

Quantitative historical rainfall data of this study were annalyzed using standard precipitation index (SPI), McKee et al (1993), artificial neural neuron networks (ANN) (McCulloch and Pitts, 1943), the mean square error (Bolen, 2021) and pearson correlation cofficent (Mukaka, 2012). In addition, principal component analysis (PCA) was used in the process of analysing household quantitative data in dimension within the use of the weather knowledge in livelihood decision making and implementation. In this regard, RStudio software and SPEI packages with in R software were used in the quantification of historical rainfall data of the 41 years of the study area in to SPI months values. In this regard, ANN deep learning/toolbox in MATLAB software were used in the process of forecasting actual and predicted seasonal drought in the study area. In connection with this, Rstudio and XLSTAT software tools were used in the identifying of PCA in the process of analysising of the driving role of the weather knowledge in the livelihood decison making process and resource endowment of the resilience absorptive capacities in the study area. Mendeley desktop was used in managing the reference cited in this study. GIS and GPS were used in maping of the location of the study area. Furthermore, grammery software and plagrasim software were used in the process of checking readability and overlapping of words of this study with other authors, respectively.

Chapter Two

Indigenous Astronomical Moon Knowledge based Seasonal Climate forecast: Evidence from Borana Oromo Pastoralists of Southern Ethiopia

Abstract

Indigenous knowledge is still widely used by communities around the world to overcome social-ecological challenges. Borana Oromo pastoralists of Southern Ethiopia have been searching for future climate phenomena using their indigenous knowledge. This study examines indigenous knowledge-based seasonal climate forecasts using observable physical and temporal patterns of astronomic moon. Data were generated through using focus group discussion, experimental knowledgeable groups and direct observation in the year 2021. The finding reveals that Borana Oromo pastoralists commonly define physical and temporal outlooks of the Moon that are changed and/ or displayed periodically within a range of varying contexts. The observation of the Moon features has been offering sufficient lapse time in a more than/within ahead of a season/ and is relatively more accurate than the other traditional forecasting objects. The study showed that both temporal and spatial dimensions of the forecasting were actually happened in Ganna (March to May rainfall), Adolessa dry season (June to September) and Hgayya rainfall (October to November) seasons of 2021. This indigenous climate forecasting practices are still regularly used in every livelihood decision making process. However, this indigenous climate knowledge of Borana Oromo pastoralists of Southern Ethiopia is not yet mainstreamed in the formal institutional structures. Curtailments of mobility, severity of drought, weakening of traditional institution, leaving of traditional lifestyle and death of the knowledgeable elders are the major factors that are challenging the potential effects of the indigenous weather forecasting indicators of the features of moon in the study area.

Key Words: Astronomic Moon, Borana Oromo, Ethiopia, Weather Forecast, Indigenous Knowledge,

1. Introduction

Indigenous Knowledge (IK) is not a new concept (UNFCCC, 2013; Chand et al., 2014; Ibrahimm, 2020). It has been in existence 'since humankind' (Sillitoe and Sillitoe 2006; Bruchac, 2020). However, (World Bank, 2009; Tang, 2012) noted that IK is a wisdom that is unique to a given culture/society with in a given geographical area. In line with this, (Ssettee, 2007; Fernandez, 2015) argued that IK is an essential survival mechanism; is the sum total of knowledge and practices based on people's accumulated experience in dealing with the problems related to all aspects of life system. In this regard, IK practices are not static traditions (Langill, 1999; Ssettee, 2007; Moste, 2015) it is rather complex, holistic, dynamic/changing through adaptive responses to external and internal changes/shocks and have evolved throughout the generations from wisdom distilled in trial and error (Eyong, 2001; Mandaluyong & Donato-kinomis, 2016; Rahman & Rusli, 2017; Ibrahimm, 2020). These characteristics of IK are the driver in formulating cost-effective and participatory adaptation measures/to prepare and respond better to disaster risks (Theodory, 2016; Berkes et al., 2021). The logic behind this is that 'intrinsic resilience' is the outcome of indigenous adaptation practices (Kirmayer et al., 2011; Hiwasaki, 2014; Commonwealth, 2015).

In connection with this, ancient human civilization, technology and practices are distilled through millennia of experimentations (Fernandez, 2015; Moste, 2015; Mafongoya et al., 2017; Nakashima et al., 2018) . Even, in the age of the current modernization period IK is functional in all fields of humanity and sustainability science in the forms of literary knowledge, languages, belief, arts, music, science, agriculture, ecological knowledge, engineering and governance etc (Eyong, 2001; Mandaluyong & Donato-kinomis, 2016 ; Lambert & Scott, 2019).

Study asserts that IK has value, not only for the culture in which it evolves, but also for those who are striving to improve conditions in rural livelihoods (Apgar & Apgar, 2010; Nakashima et al., 2018; Panampitiya, 2019). Hence, IK cannot be separated into discrete disciplinary departments and time. However, according to Puffer & Associate, (1995), Mauro et al., (2010),Lunga, (2014) marginalization of IKs' worldview was underway since the 12 th century with the increasing dominance of the modernization values/cultures. In addition, lack of documentation, influence of modernization, departing of IK based life style and / or death are among the factors that are challenging IK (Saskato, 2002; Apgar & Apgar, 2010; IASG, 2014).

However, recently, the role of IK in development is more recognized at all levels in response to increasing multi-hazard/disaster, climate variability and change and as a response to failure of the blue print development planning (UNFCCC, 2013; MoSTE, 2015; Theodory, 2016; David-Chavez, 2019).

Historically, prediction of seasonal weather and impending disasters have been an integral part of indigenous peoples' adaptation and resilient strategies which are used to interpret observed natural signals to predict future weather patterns (Rahman & Rusli, 2017; Mosime, 2018; Nyadzi et al., 2021). Still today indigenous communities in different parts of the world have relied on IK weather forecasting in making agricultural practices, environmental conservation, governance, in disaster risk reduction measures; and to deal with continuum of dynamic aspects of social, political, economic, environmental and technological change in resilience process (Tang, 2012; Ibañez, 2014; Mandaluyong et al., 2016; Nakashima, et al., 2018).

Indigenous astronomy is about peoples relationships with the sky, not just about the sky (Willis & Ii, 2011; Lawrence, 2021). Important aspect of indigenous astronomy is how knowledge about the sky is culturally encoded weather in every daily livelihood decision making (Scofield, 2010; Ruggles, 2015; Lee et al., 2020). Studies posited that still today, use of indigenous astronomical seasonal weather forecasting information is functional in Africa (Angchok et al., 2006; Holbrook, 2016; Mafongoya et al., 2017; Chang et al., 2019). In Uganda, Karamoja communities used star relationship with the moon to forecast future weather events (Okonya et al,, 2013; Oruru et al., 2020). Holbrook, (2016) stated that in South Africa indigenous Knowledge of changing seasons, lunar cycle, shape, location of the Moon and the Stars are used to predict drought. In Zimbabwe a set of the biotic and a-biotic weather forecasting objects are used for agricultural practices (Jiri et., 2015). Studies in Burkina Faso and Lesotho quoted in (Ifejika et al., 2009) examined that local forecasting knowledge seems to be less widely used than in the past.

Likewise, in rural areas of Ethiopia indigenous knowledge practices are still sustained/ dominated in all aspects of life and livelihoods making (Workineh et al., 2010; Ibinarriaga, 2020). In this regard, Borana pastoralists define outlooks of astronomic objects, observe atmospheric characteristics, read physical condition of biotic objects and rememorize the unique and known weather events in each Geda cycles; periodically in the process of future weather forecasting. However, studies and proper documentation is not yet undertaken to preserve this invaluable indigenous weather indicating knowledge and practices of the Borana Oromo pastoralists. In addition, still yet no area specific study is undertaken on practical experiences of community-based approaches vis-à-vis of weather indicating features of the astronomic Moon.

Hence, objective of this paper is to examine indigenous astronomic seasonal weather forecasting knowledge and practices of Borana Oromo pastoralists of southern Ethiopia with insights on the weather indicating features of the Moon. This study is tried to answer three interrelated questions. 1) What is the future weather indicating features of the Moon in the study area?, 2) Is there sufficient lapse time between forecasting and occurrence of the weather events?, 3) Is, currently, indigenous weather forecasting practices are used by the study community in the process of the livelihood decision making?,

1.1. Concept and definition of indigenous knowledge

In cognizant with above narratives, several scholars have developed definitions of indigenous knowledge in respect of the aspect/contexts of the indigeneity matters in consistent with the premise of the disciplines under concern. Owing to the fact that a given IK is embedded/ is the reflection of a society within a given specific environmental/geographical area (Tang, 2012); it is better to highlight the definition of the phrase indigenous science and indigenous peoples separately before articulating the definition of the IK. It is believed that indigenous science and indigenous peoples are the subset of the indigenous knowledge (Eyong, 2001; Lunga, 2014; Lambert & Scott, 2019).

Existing literatures classify indigenous sciences definition in to individual and social/cultural level definition. This study highlight on the social/cultural level definition which define indigenous science/ ethno science as a culture/society dependent collective rational perceiving of a reality (Theodory, 2016; David-Chavez, 2019). Indigenous science classifies the objects, activities, and events within a given Universe. Indigenous science interprets the local world cultural perspective of indigenous agriculture, astronomy, navigation, mathematics, medical practices, mining, engineering, military science, architecture, governance, and ecology, etc (Scofield, 2010 ; Siseho, 3013; MoSTE, 2015; Holbrook, 2016; Panampitiya, 2019; Ibinarriaga, 2020). In addition, processes of science that include rational observation of natural events, classification, and problem solving are woven into all aspects of indigenous science (Langill, 1999; Rahman & Rusli, 2017).

It is beyond the scope of this research to deliver the details of the social science disciplines perspectives scholars' debate on the issues of the indigenous peoples. In line with this study, it is more appropriate to use/adapt the development perspectives definition of the (World Bank, 2010; UNPFII, 2012; UNFCCC, 2013; Rahman & Rusli, 2017; Šakić, 2020 Eyong, 2001; Burgos-Ayala et al., 2020) that defines, indigenous peoples are groups of native inhabitants having their own territory, languages, political system and self-rule. They have historical continuity with their neighbors' pre-settlers societies, with distinct social and cultural identity; resolve to maintain and reproduce their ancestral environments which are vulnerable/ disadvantaged in the development process aftermath of the intrusion of the external cultures/actors. Worldwide indigenous peoples speak 'two-thirds of humankinds' more than 7,000 known spoken languages and many of these languages are, currently, under use and /or spoken by very few peoples. It is expected that unless protection is maintained 70 up to 90 per cent of these languages will be lost up to the coming 2115 (Rajasekaran, 1993; Panampitiya, 2019 ; Bruchac, 2020).

Whereas knowledge embraces knowledge of tools and techniques for assessment, acquisition, transformation, and utilization of resources in the locality (Tang, 2012; IASG, 2014; Ibañez, 2014; Theodory, 2016; Aderemi, 2017; Mafongoya and Ajayi, 2017). It is indigenous because it differs from known forms of formal knowledge (scientific, Western, modern) in the contextual sense (as IK is deeply rooted in its environment, history, and new experiences) and the epistemological nature of IK is holistic (Ssettee, 2007; Ibañez, 2014; Fernandez, 2015; Mandaluyong & Donato-kinomis, 2016; Ajagbe, 2018; Williams & Sikutshwa, 2020). This kind of knowledge remains the information base for a society, which facilitates communication and livelihood decision-making.

Studies of (Apgar & Apgar, 2010; Nakashima et al, 2018; David-Chavez, 2019 reveals that indigenous knowledge bears both scientific and technological threads but in its creation and use it is simply practical/pragmatic knowledge and not ordinarily identified as a science. Thus, understanding and analysis of indigenous science tends to be done with reference to the well-established Western Modern Science (WMS), which people are already familiar with (Ssettee, 2007; Fernandez, 2015; Mandaluyong & Donato-kinomis, 2016).

In synopsis with this, this study adapted, aggregated and synthesize IK definition of mainly

World Bank (2010), UNPFII (2013) and IPBES (2014) which stated that IK is a multi-faceted array of area specific knowledge; know how, practices, representation of identity and survival strategy, adaptive/dynamic with change and holistic in nature, intergenerational, which guides societies in their interactions with their surrounding environment. Indigenous knowledge can help build resilience in three ways: increasing the range of available knowledge; providing the basis for adaptations; and enabling social practice and learning (Panampitiya, 2019; Berkes et al., 2021).

1.2. Research methodology

All research subjects and variables in this study were purposively selected to directly reach and explore representative samples. To easily manage the demeanor of this study, 13 districts of the zone were grouped in to six clusters that were consist of Yabello, Teltele, Gomole, Guchi, Dirre and Moyale which are based on the proximate of the district to each other for the purpose of this study. Primary data were generated through using focus group discussions, experimental groups, knowledgeable informants, and direct observation. In the present study, indigenous knowledge of astronomical seasonal weather representative variables of observable external physical features of the Moon were mainly explored using well experienced elders in the community.

Data were collected using focus group discussion participants, experimental groups and key informant interview participants that were held at the study area clusters. Accordingly, six focus group discussions; each consists of 12 participants (8 males and 4 females) were participated in data generation. Regarding the experimental groups, six groups (clusters) each consists of 4 (a total of 24 participants) well experienced traditional astronomical weather forecasters were used for gathering data. In addition, 10 key knowledgeable informants (6 males and 4 Females) were interviewed to more enrich the data. During data collection, four local enumerators who have in-depth knowledge of variable under the study were participated in all the steps and phases of the data collection after receiving training on the topic and issues of the study. The first author has more than eight years career experiences with the community in the study area. Selection of the participants and formation of the clusters were undertaken in collaboration with the relevant stakeholders/organizations including GOs, NGOs, organization and community representatives. Data were collected in three months lead time of each season.

The data were collected in four subsequent rounds/seasons; starting from the seasons of *Bona*

Hagaya (warm dry season of December to February), *Ganna* (main rainfall season of March to May), *Bona Addolessa* (cool dry season of June to August) and *Roba Hagayyaa* (small rainfall season of September to November) of 2021. According to the local calendar of the study area New Year is started on first day of December.

The details of the data were collected through reading physically/spatially and temporally varied multidimensional outlooks of the weather indicating features of the moon. In this regard, defining, reading and observation of the direction/inclination of the new Moon, cloud surrounding the moon/cloud not surrounding the moon and clour pattern of the moon were done in the data collection process to know the upcoming season's weather phenomena in the study area. In connection with this, Borana Oromo abstractly made sequential list of 27 traditional day patterns of the moon which are reconfigured/ varied in chronological order with in each of the 12 moon/months of the year, moon day/the day on which new moon is re-emerged in the night sky and rainfall patterns of the moon day, etc., were used in the data collection process of this research. In this research, during defining, reading and observation; ratification of the projection/forecast (mainly normal occurrence of rainfall/severe drought) was established by the experimental groups/experienced traditional weather forecasters upon the interpretation of the future weather indicating features of the moon.

Finally, verifications of the accuracy/occurrence of the future weather phenomena were done against the projection/established forecast of the future weather indicating features of the moon. In this study, only qualitative data were collected through using semi-structured questioners and open-ended interview guides. Finally, data were analysed through using Bazeley (2009) methods of qualitative data analysis techniques. The three key strategies including description of data, classification of data, and seeing how concepts are interconnected were applied in the analysis of qualitative data

2. Results and discussion

It is identified through this study that since time immemorial, indigenous weather forecasting knowledge is the fundamental deriver of the livelihood decision making among Borana Oromo pastoralists of the Southern Ethiopia. In this regard, in the process of making this into effects; traditionally, indigenous Borana Oromo community could define, read, and interprets all objects in the easily observable /biosphere/ and hardly accessible environment/Universe/ to forecast current particular and future weather events in the process of making /ensuring drought resilience.

2.1. Indigenous weather forecasting knowledge and practices of Borana Oromo Pastoralists

It is identified through this study that the commonly practiced indigenous based weather forecast indicating objects that are exhibit change naturally with in a continuum of varying temporal/seasonal contexts that are, currently, in use by the study area communities are mainly categorized into astronomic objects, atmospheric characteristics, biotic objects and the *Geda* cycles/historical experiences.

In the process of weather forecasting; Borana Oromo pastoralists could regularly define multidimensional outlooks of the astronomic/celestial objects which are displaying varied indicators/signs within a context of changing spatial and temporal patterns. In this regard, alignment/defect of the alignment/, direction, group formation, color/physical features, size, ray, type, and duration of the observation of the stars in the sky are used in weather forecasting. Borana pastoralists' abstract sequential list of day patterns of the emerging of new moon /moon day/, cloud formation/no cloud formation, inclination of each of the new emerging moon and colour pattern of the moon were defined and interpreted in the indigenous weather forecast process. In addition, ring formation, direction/position, size, partial or full eclipse (death) and color/physical features of the sun are regularly defined to indicate either of the fortune/wickedness of the forthcoming season. It is identified that they could make the prediction through defining characteristics/conditions of the biotic objects that are varying in alignment with temporal patterns and are influenced by the pulling effects of the tell-connections with in the Geo-space (wind circulation, cloud formation, temperatures and lightening with in the land, ocean and atmosphere) of the their environment.

Pastotalists of the study area were well accustomed in reading indicators such as Physical condition, physiological features, movement/flying patterns, rhythm/sound and smell of biotic objects; observing of cloud, wind, temperatures and lightening that are varying vis-a-vis with in the temporal and spatial contexts were used in the study area in weather forecasting. Weather forecasting was also undertaken through using *Geda* Cycle. There are seven cycles in *Geda* system. Each cycle is completed in eight years and each cycle of the *Geda* has its own distinctive name. Each *Geda* cycle is known by its usual and unique expected weather events which are greatly known in that cycle. Hence, it is possible to forecast weather condition of the coming 40 years through using *Geda* cycles.

This is consistent with the Study of Bruchac (2020) and Zounon et al.(2020) that noted indigenous community in Zambia and Benin use plant, animal, historical experiences and astronomical elements to forecast weather. In Nigeria (JU, 2018) argued IK indicators that are used to predict the severe drought are fruits drying/falling off from trees, increasing occurrence of termites, shedding of tree and appearance of rainbows.

In the study area, all members of the community have no skill of forecasting upcoming season of weather events from all objects at equal level. In this regard, one does the skill of forecasting upcoming season of weather events via defining of astronomic objects, others have observe/interprets atmospheric objects/or read physical and physiological condition of biotic objects, etc. Even though, all elders have shared/transfer/ their skill of weather forecasting to all their children, including women without any gender restriction; all the children of a given household/family/ do not have capacity, wish and interest to keep all the elements of forecasting signs equally at required level.

There are few individuals in the community who are qualified in making accurate forecasting via using a given specific objects in the environment. Individuals those who are qualified in reading internal intestinal structures of livestock are locally called *Uchu*; those who are qualified in defining physical and temporal features of the moon are locally called '*Ayyaantu*. Individuals those who are qualified in identifying the star moon-alignment are called *Hedduu* and those individuals who are qualified in rememorizing the known events in each *Geda* cycles are called *Arga-dhageti*. In this regard, in eacha village there was one trusted forecaster in each of the the field; and an aggregate of total experienced forecasters might range up to 1% (one per cent) of the community in the study area. Although it is the driver of the livelihood decision making at the local level; IK weather forecasting of Borana pastoralists were not mainstreamed in the formal institutional structures.

2.1.1.Weather indicating features of the Moon

It is identified through this study that, it is a widely common/ accustomed/ ordinary traditional practice that any pastoralists in the study areas have regularly searching future outlooks of the seasonal weather phenomena, since time immemorial. In line with this, in the study area; one of the widely used practice of indigenous based weather indicating objects that are exhibit change naturally with in a continuum of varying temporal and /or seasonal and spatial contexts are observable external physical features of the moon. It is identified that Borana Oromo pastoralists regularly define/read physical and temporal outlooks of the moon that are changed and/ or displayed periodically with in a range of varying contexts.

This is consistent with the study in Botswana quoted in Lorreta, (2014) which posited that it was customary for the ancient people to align their sacred monuments with precise solar, lunar and stellar positions. Lee et al., (2020) noted that Weather forecasting has been a tool of decision making since millennia. In connection with this Lawrence, (2021) also found that until about 350 years ago scientists and natural philosophers thought that the Sun, Moon and planets play an important role in modulating the weather on Earth.

The prediction that is set up via the observation of the moon would offer sufficient lapse time in a more than/within ahead of the three months lead time and is more accurate than the other traditional forecasting objects that are, currently, under use in the study area. In addition, this future seasonal weather indicating features of the moon would provide specific spatial dimensions of the weather events within and beyond the Borana zone area in all direction. Especially, future phenomena of the severity and physical distribution of drought; and location specific amount of rainfall in the Borana zone and its surrounding area is easily predicted by using seasonal weather indicating features of the moon. This is agreed with the finding of the Lawrence, (2021) which noted that many village level Astrologers (Pandits) are still predicting highly accurate weather with planet movements in advance of the occurrences of the events which allow people to prepare in disaster risk management.

These outlooks of the weather indicating features of the moon which are used for making seasonal weather forecasting by Borana pastoralists are categorized in to two major sets of the multidimensional distinctive interrelated patterns. These outlooks of the Moon includes: 1) weather indicating temporal patterns of the moon/ patterns of the days of the emerging of the new Moon Locally called *ayyaana Ji'aa*)[1], 2) Weather indicating physical pattern of the moon. In line with this, a physical pattern of the Moon entails four observable indicators during the dry

[1]. The first day on which each new moon is emerging in the night sky is locally called ayyaana ji'aa.

season of *Bona Adolessa* and *Bona Hagaya* to make the probable clue of the upcoming rainfall season: Moon with tiny synthesized cloud, Moon with partially synthesized cloud, Moon without synthesized cloud and; the Color patterns of the observable external physical quality/dirtiness of the outlooks of the moon which are changed periodically.

The weather phenomena indicating temporal patterns of the moon are categorized into two interrelated patterns: 1) Day Patterns of the Moon, and 2) rainfall patterns of the day of the new moon. Study of Oruru et al., (2020) explored that indigenous people in Uganda observe moon and stars to predict weather changes.

2.2. Weather indicating temporal patterns of the Moon

In line with this, future weather indicating temporal patterns of the moon are categorized in to two interrelated patterns: 1) Day Patterns of the Moon (Tables 1-12), and 2) rainfall patterns of the moon.

Day patterns of the Moon: According to local calendar there are abstractly made 27 distinctive day patterns of a moon which are locally called *Ayyaana*. The main legends of the temporal patterns of the moon days are to ratify the days on which each new moon is emerging/re-emerging in the night sky. In the study area; each moon has distinctive temporal patterns. This study discover that Borana Oromo abstractly created astronomic based sequential list of 27 traditional temporal patterns of the moon is reconfigured/varied in chronological order with in each of the 12 moon/months of the year.This day/temporal patterns/ of a new moon have great influence on the upcoming season weather phenomena and livelihood decision making process.

Table 1: Indigenous knowledge based twenty seven days of the moon of the year

SN	Names of the 27 days of the Moon	Name of the Moon which is emerging on each Month of the year
1	*Gardaduma*	September (*Birraa*)
2	*Sonsa*	
3	*Ruruma*	October (*Ciqaawaa*)
4	*Lumasa*	
5	*Gidada*	November (*Sadaasa*)
6	*Ruda*	
7	*Areeri duraa*	December (*Arfaasa*)
8	*Areeri bal'aa*	
9	*Adula duraa*	January (*Amaajji*)
10	*Adula bal'aa*	
11	*Garba duraa*	February (*Guraandhala*)
12	*Garba bal'aa*	
13	*Garba dullacha*	
14	*Bita duraa*	March (*Bitotessa*)
15	*Bita bal'aa*	
16	*Sorsa*	April (*Caamsaa*)
17	*Algajim*	
18	*Arba*	May (*Buufaa*)
19	*Walla*	
20	*Basa dura*	June (*Wacabaji*)
21	*Basa bal'aa*	
22	*Maganata duraa (Carraa)*	July (*obora* Guddaa)
23	*Maganata Jarraa*	
24	*Maganata biritii*	
25	*Salban duraa*	August (*Oboraxiqqaa*)
26	*Salbaan bal'aa*	
27	*Salbaan dullacha*	

Source: Synthesized idea of research participants, 2021

This is consistent with the, Baki study in Botswana quoted in (Loretta, 2014) posited that celestial bodies are used for practical purposes such as timekeeping and in creating accurate calendar; is therefore fundamental in relation to the daily cycle of work as well as the annual round of agricultural activities. In similar with this, study in ancient weather forecasting de-signs (Beardmore, 2013) noted that astronomy, weather and calendars are the main methods of weather prediction in the ancient world.

Table 1, discloses sequential lists of the days of a month which are the benchmark/point of a reference for the description of the next 12 Tables. Generation old knowledge of Borana Oromo abstractly created sequential list of 27 traditional day patterns that are derived /developed/ based on the lunar cycles of the light and dark nights of the moon in the sky are depicted in the Table 1.

These 27 days of a month that are traditionally derived from the lunar cycles of the moon which are reconfigured/ varied in chronological order with in each of the 12 moon of the year are used for weather forecasting since time immemorial, in the study area (see all 12 Tables).

Remark 1, first day of the new moon: As depicted in the table 1, in the study area; the start/commence of the first day of each moon (in the column 3 of Table 1) begin from the first probable day /as listed in the column 2 of Table 1) on which each particular new moon is expected to re-emerge in the night sky. Out of 12 moons of the year; nine of them have nature driven two probable emerging days as listed in the column 2 of Table 1(which makes them 30 days per month) and three of them have three probable emerging days (which makes them 31 days per month). In this regard, in the study area; for the purpose of annual/monthly calendar; commencements of the first date of the new born moon are begin from the first probable day of their re-observation in the night sky. However, for the purpose of the seasonal calendar; commencements of the first date of the new moon are beginning from the first actual emerging day of their re-observation in the night sky. The study area community believes that the exact actual first date of the emergence of the new moon has great impact on the upcoming season weather phenomena.

Remark 2, Full dark night of the Moon /End date of each Moon /: each moon of a year has one full dark night day. In this regard, there is no observable sign of moon in the night sky on full dark night sky day. This full dark night day is locally called *Luwoo* which is between the *Diba* of the current moon and the crescent of the next new moon. Traditionally, this day is expected as the driver of the terrifying events. Hence, it is not listed within the nature driven locally created abstract sequence of the 27 dates of a moon; and it is silently over passed by the community in the study area. It is the end date of each moon; it is the 30 th date for those of the moon having two probable emerging day; and 31 st date for those of the moon having three probable emerging day.

Remark 3, double count dates: As stated in the remark one and two of this section; each 12 moons of a year have two/three probable emerging days. Local community believes that each moon of a year has emerging phase (1 st to 15 th dates) and hidden phase (16 th to 30/31 st dates) as depicted in the Tables 1-12. In this case, they believed that the first date of the emerging phase of each moon in column 3 of Table 1 begin from the first probable emerging date that are listed orderly in the column two of Table 1. Similarly, the 30 th/31 st date of the final hidden phase of each moon is/was completed on the *Luwoo* day of each moon that was represented by the serial number 30/31 in the column 4 of the Tables 1 -12 in this section.

This implies that, 1 st, 2 nd and 3rd dates are re-counted/double counted in the IK based calendar of the study area. Hence, this study constructed two columns of serial number in all 1-12 Tables that was derived from the benchmark Table 1, in this section. The serial numbers 1 to 27 were listed in the first column of the Tables to orderly count 1 st to 27 th dates in the emerging phase of the moon. The serial number 28, 29, 30/31were listed in the column 4 of all 1-12 Tables to re-count/double count hidden phase of the moon. This was due to the fact that the two/three probable emerging dates (represented by serial number 1 to 3) of the new moon in the column 2 of 1-12 Tables were recounted in the hidden phase of the dates (represented by the serial number 28 to 30/31) of the end of each moon.

As depicted here below; all the 12 Tables in this section/ seasonal weather indicating temporal patterns of the moon/ were derived from the Table 1.

Table 2. January's Moon WI Temporal Patterns

SN	Dates of the January Moon/Emerging phase	lunar cycles	SN	abstract cycles /hidden phase
1	*Adula duraa*	*Light month of the moon*	*28*	*Full dark night*
2	*Adula bal'aa*		*29*	
			30	
3	*Garba duraa*			
4	*Garba bal'aa*			
5	*Garba dullacha*			
6	*Bita duraa*			
7	*Bita bal'aa*			
8	*Sorsa*			
9	*Algajim*			
10	*Arba*			
11	*Walla*			
12	*Basa dura*			
13	*Basa bal'aa*			
14	*Maganata duraa (Carraa)*			
15	*Maganata jarraa*			
16	*Maganata biritii*	*Dark month of the moon*		
17	*Salban duraa*			
18	*Salbaan bal'aa*			
19	*Salbaan dullacha*			
20	*Gardaduma*			
21	*Sonsa*			
22	*Ruruma*			
23	*Lumasa*			
24	*Gidada*			
25	*Ruda*			
26	*Areeri duraa*			
27	*Areeri bal'aa*			

Source: RP, 2021

As it is seen from table 2, January moon is emerged on the day *of Adula duraa*. Lunar cycle of 1^{st} up to 15^{th}dates of the January moon (*Adula duraa up to Maganata jarraa)* are locally called the light/bright moon nights of the January Month[2]. Lunar cycle of the 16^{th} up to 30^{st} dates of the January moon (*Maganata biritii* up to *Adula bal'aa*) are locally called the dark moon nights of the January Month. When it is seen, literally January moon has only 29 days. However, it had 30 days. In this case, next to the *day* of *Adula bal'aa/ next to serial number 29* in the hidden phase of the double counting/ there was one full dark night without no sign of moon in the night sky which is locally called *Luwoo* of January moon/30^{st} date of January month. In line with this, because of the January Moon has two probable emerging days which consists of *Adula duraa* and *Adula bal'aa*/serial number 1 to 2 in the emerging phase of the moon/ the total dates of the January moon are/were 30. The *Diba* (final hardly observable decreased margin in the hidden phase of the moon) of the January moon was observed on the date of the *Adula bal'aa which was represented by the serial number 29 of the column 4 in the Table 2*. The probability of the emerging of the January moon is on the day of *Adula duraa (serial number 1) or Adula bal'aa (serial number 2).* In this case, there is a common belief that when the January moon is emerged on the day of

[2]. see remarks on the start and end of the counting of the moon dates of a month in this section

Adula duraa; the upcoming Ganna rain season (March to May) would be very little/the probability of severe drought would be very high. In the 2021, January moon was emerged on the day of *Adula bal'aa instead of Adulaa duraa*.Hence, the study community believed that severe and devastating drought of 2021/2022 was mainly caused by the nature driven anomalous of the emerging of the January Moon of 2021 on the day of *Adulaa duraa*.

This is agreed with the study of Lee et al. (2020) which noted that, the regularity of the motions of celestial objects enabled peoples around the world to create worldviews that is culturally organized systems of knowledge and generations of sky watchers, carefully tracking the positions of the heavenly bodies in order to understand how to conduct the human life on the earth. In addition, study quoted in Loretta, (2014) noted that the perspective of the Mapuche people of Chile belief as natural forces govern and regulate the universe. It also stated that there is a very strong connection with nature and the environment in which one lives.

Table 3. February's Moon WI Temporal Patterns

SN	Dates of the February Moon/emerging phase	lunar cycles
1	*Garba duraa*	Light month of the moon
2	*Garba bal'aa*	
3	*Garba dullacha*	
4	*Bita duraa*	
5	*Bita bal'aa*	
6	*Sorsa*	
7	*Algajim*	
8	*Arba*	
9	*Walla*	
10	*Basa dura*	
11	*Basa bal'aa*	
12	*Maganata duraa*	
13	*Maganata Jarraa*	
14	*Maganata biritii*	
15	*Salban duraa*	
16	*Salbaan bal'aa*	
17	*Salbaan dullacha*	Dark month of the moon
18	*Gardaduma*	
19	*Sonsa*	
20	*Ruruma*	
21	*Lumasa*	
22	*Gidada*	
23	*Ruda*	
24	*Areeri duraa*	
25	*Areeri bal'aa*	
26	*Adula duraa*	
27	*Adula bal'aa*	

SN	abstract cycles/hidden phase
28	Full dark night
29	
30	
31	

Source: **RP**, 2021

As it is seen from table 3, February moon is emerged on the day *of Garba Duraa*. Lunar cycle of 1 st up to 15 th dates of the February moon (*Garba Duraa up to Salban Duraa*) are locally called the light/bright moon nights of the February Month[3]. Lunar cycle of the 16 th up to 31 st dates of the February moon (*SalbanBall'aa* up to *Garba Dullacha*) are locally called the dark moon nights of the February Month. When it is seen, literally February moon has only 30 days. However, it has 31 days. In this case, next to the *day* of *Garba dullacha/ next to serial number 30* in the hidden phase of the double counting with in the column 4 of the Table 3/ there was one full dark night without no sign of moon in the night sky which is locally called *Luwoo* of February moon/31 st date of February month. In line with this, because of the February Moon has three probable emerging days which consists of *Garba Duraa, Garba Bal'aa* and *Garba Dullacha* /serial number 1 to 3 in the emerging phase of the moon/ the total dates of the February moon are/were 31. The *Diba* (final hardly observable decreased margin in the hidden phase of the moon) of the February moon was on the day of the *Garba Dullachaa which was represented by the serial number 30 of the column 4 in the Table 3*. Finally, there was one full dark night on which there was completely no moon which is locally called *Luwoo* of the February moon or the 31 st day of the February month. The probability of the emerging of the February moon is on the day of *Garba Duraa*,

3

Garba Bal'aa and *Garba Dullacha*. In this case, when the February moon is emerged on the day of *Garba Duraa* the upcoming Ganna rainfall (March to May) would be very little/the probability of prolonged and severe drought in the *Bona addolessa* (December to February) would be very high. In the 2021, February moon was emerged on the day of *Garba duraa instead of Garba Bal'aa*. Furthermore, community believed that when the shower of rainfall is occurred on either days of *Gardaduma*, *Sonsa*, *Ruruma*, *Lumasa*, *Gidada*, *Arba*, *Walla*, *Sorsa*, *Algajim and Ruda* of the February month; the upcoming *Ganna* rainfall (March to May) would be very little. In this case, shower of rainfall was occurred on the day of *Sonsa in February* 2021. Hence, the study community believed that severe and devastating drought of 2021/2022 was mainly caused by the nature driven anomalous of the emerging of the February Moon of 2021 on the day of *Garba duraa* and occurrence of shower of rainfall on the day of *Sonsa*.

Table 4. March's Moon WI Temporal Patterns

SN	*Dates of the March Moon*	*lunar cycles*
1	*Bita duraa*	*Light month of the moon*
2	*Bita bal'aa*	
3	*Sorsa*	
4	*Algajim*	
5	*Arba*	
6	*Walla*	
7	*Basa dura*	
8	*Basa bal'aa*	
9	*Maganata duraa (Carraa)*	
10	*Maganata Jarraa*	
11	*Maganata biritii*	
12	*Salban duraa*	
13	*Salbaan bal'aa*	
14	*Salbaan dullacha*	
15	*Gardaduma*	
16	*Sonsa*	*Dark month of the moon*
17	*Ruruma*	
18	*Lumasa*	
19	*Gidada*	
20	*Ruda*	
21	*Areeri duraa*	
22	*Areeri bal'aa*	
23	*Adula duraa*	
24	*Adula bal'aa*	
25	*Garba duraa*	
26	*Garba bal'aa*	
27	*Garba dullacha*	

SN	*lunar abstract cycles*
28	*Full dark night*
29	
30	

Source:RP, 2021

As it is seen from table 4, March moon is emerged on the day *of Bita duraa*. Lunar cycle of 1 st up to 15 th dates of the March moon (*Bita duraa up to Gardaduma)* are locally called the light/bright moon nights of the March Month[4]. Lunar cycle of the 16 th up to 30 st dates of the March moon (*Sonsa* up to *Bita bal'aa*) are locally called the dark moon nights of the March Month. When it is seen, literally March moon has only 29 days. However, it had 30 days. In this case, next to the *day* of *Bita bal'aa/ next to serial number 29* in the hidden phase of the double counting/ there was one full dark night without no sign of moon in the night sky which is locally called *Luwoo* of March moon/30 st date of March month. In line with this, because of the March Moon have two probable emerging days which consists of *Bita duraa* and *Bita bal'aa*/serial number 1 to 2 in the emerging phase of the moon/ the total days of the March moon are/were 30. The *Diba* (final hardly observable decreased margin in the hidden phase of the moon) of the March moon was observed on the day of the *Bita bal'aa which was represented by the serial number 29 of the column 4 inthe Table 4*. The probability of the emerging of the March moon is on the day of *Bita duraa (serial number 1) or Bita bal'aa (serial number 2)*. In this case, there is a common belief that when the March moon is emerged on the day of *Bita duraa; upcoming Ganna* rain season (March to May) would be very little/the probability of prolonged and severe drought would be very high in the

[4]. see remarks on the start and end of the counting of the moon dates of a month in this section

Bona Hagayyaa (dry season of December to February). In the 2021, March moon was emerged on the day of *Bita duraa instead of Bita bal'aa*. Furthermore, community believed that when the first shower rainfall is occurred on either days of *Gardaduma, Sonsa, Ruruma, Lumasa, Gidada, Arba, Walla, Sorsa, Algajim and Ruda* of the March month; the *Ganna* rainfall (March to May) would be very little in its entire dimension. In this case, first shower of 2021 *Ganna* rainfall (March to May) was occurred on the day of *Gardaduma*. Hence, the study community believed that severe and devastating drought of 2021/2022 was mainly caused by the nature driven anomalous of the emerging of the March Moon of 2021 on the day of *Bita duraa*; and the occurrence of the first shower of 2021 Ganna rainfall (March to May) on the dates of *Gardaduma*.

This is consistant with the study of Scofield, (2010) in the ancient Greece weather forecasting de-signs. Hesiod used three counting traditions to describe the various points in the Moon's cycle that are favorable or unfavorable for one activity or another. He first counted the entire cycle, referring to the positive qualities of the first, fourth, and seventh days of the Moon for planting. The first day is being the day on which the crescent appears after the New Moon; about 1 to 15 days after the New Moon. He then shifted into another way of counting the cycle; stating that the sixteenth day of the mid-month is bad for plants. The second cycle is also the 16th day of the Moon/ the day after the full Moon. Study of Beardmore (2013) also supported this study which stated that Hesiod's good and bad days of the lunar month, appears to be a kind of indigenous Greek astrology that offered information for farmers. This justification illustrated as moon days are used for livelihood decision making in the ancient Greece, however, it is yet not stated the future temporal, spatial and features of the future/seasonal/ weather indicating outlooks of the moon.

Table 5. April's Moon WI Temporal Patterns

S N	Days of the Apriln Moon/ emerging phase	lunar cycles	SN	abstract cycles/ hidden phase
1	*Sorsa*	Light month of the moon	28	Full dark night
2	*Algajim*		29	
			30	
3	*Arba*			
4	*Walla*			
5	*Basa dura*			
6	*Basa bal'aa*			
7	*Maganata duraa (Carraa)*			
8	*Maganata Jarraa*			
9	*Maganata biritii*			
10	*Salban duraa*			
11	*Salbaan bal'aa*			
12	*Salbaan dullacha*			
13	*Gardaduma*			
14	*Sonsa*			
15	*Ruruma*			
16	*Lumasa*	Dark month of the moon		
17	*Gidada*			
18	*Ruda*			
19	*Areeri duraa*			
20	*Areeri bal'aa*			
21	*Adula duraa*			
22	*Adula bal'aa*			
23	*Garba duraa*			
24	*Garba bal'aa*			
25	*Garba dullacha*			
26	*Bita duraa*			
27	*Bita bal'aa*			

Source: RP, 2021

As it is seen from table 5, April moon is emerged on the day *of Sorsa*. Lunar cycle of 1 st up to 15 th dates of the March moon (*Sorsa up to Ruruma)* are locally called the light/bright moon nights of the April Month[5]. Lunar cycle of the 16 th up to 30 st dates of the April moon (*Lumasa* up to *Algajim*) are locally called the dark moon nights of the April Month. When it is seen, literally April moon has only 29 days. However, it had 30 days. In this case, next to the *day* of *Algajim/ next to serial number 29* in the hidden phase of the double counting/ there was one full dark night without no sign of moon in the night sky which is locally called *Luwoo* of April moon/30 st date of April month. In line with this, because of the April Moon has two probable emerging days which consists of *Sorsa* and *Algajim*/serial number 1 to 2 in the emerging phase of the moon/ the total days of the April moon are/were 30. The *Diba* (final hardly observable decreased margin in the hidden phase of the moon) of the April moon was observed on the day of the *Algajim which was represented by the serial number 29 of the column 4 in the Table 5*. The probability of the emerging of the April moon is on the days of *Sorsa (serial number 1) or Algajim (serial number 2)*. In this case, there is a common belief that when the April moon is emerged on the day of *Sorsa; Ganna* rain season (March to May) would be interupted/the probability of severe drought would be very high. In the 2021, April moon was emerged on the day of *Sorsa* instead of *Algajim.* Hence, the study community believed that severe and devastating drought of 2021/2022 was mainly caused by the nature driven anomalous of the emerging of the April Moon of 2021 on the day of *Sorsa.*

[5]. see remarks on the start and end of the counting of the moon dates of a month in this section

Table 6. May's Moon WI Temporal Patterns

SN	Dates of the May Moon/Emerging phase	lunar cycles	SN	abstract cycles/hidden phase
1	*Arba*	Light month of the moon	28	Full dark night
2	*Walla*		29	
			30	
3	*Basa dura*			
4	*Basa bal'aa*			
5	*Maganata duraa (Carraa)*			
6	*Maganata Jarraa*			
7	*Maganata biritii*			
8	*Salban duraa*			
9	*Salbaan bal'aa*			
10	*Salbaan dullacha*			
11	*Gardaduma*			
12	*Sonsa*			
13	*Ruruma*			
14	*Lumasa*			
15	*Gidada*			
16	*Ruda*	Dark month of the moon		
17	*Areeri duraa*			
18	*Areeri bal'aa*			
19	*Adula duraa*			
20	*Adula bal'aa*			
21	*Garba duraa*			
22	*Garba bal'aa*			
23	*Garba dullacha*			
24	*Bita duraa*			
25	*Bita bal'aa*			
26	*Sorsa*			
27	*Algajim*			

Source: RP, 2021

As it is seen from table 6, May moon is emerged on the day *of Arba*. Lunar cycle of 1^{st} up to 15^{th} dates of the May moon (*Arba up to Gidada)* are locally called the light/bright moon nights of the May Month[6]. Lunar cycle of the 16^{th} up to 30^{st} dates of the May moon (*Ruda* up to *Walla*) are locally called the dark moon nights of the May Month. When it is seen, literally May moon has only 29 days. However, it had 30 days. In this case, next to the *day* of *Walla/ next to serial number 29* in the hidden phase of the double counting/ there was one full dark night without no sign of moon in the night sky which is locally called *Luwoo* of May moon/30^{st} date of May month. In line with this, because of the May Moon has two probable emerging days which consists of *Arba* and *Walla*/serial number 1 to 2 in the emerging phase of the moon/ the total days of the May moon are/were 30. The *Diba* (final hardly observable decreased margin in the hidden phase of the moon) of the May moon was observed on the day of the *Walla which was represented by the serial number 29 of the column 4 in the Table 6*. The probability of the emerging of the May moon is on the dates of *Arba (serial number 1) or Walla (serial number 2)*. In this case, there is a common belief that when the May moon is

[6]. see remarks on the start and end of the counting of the moon dates of a month in this section

emerged on the day of *Sorsa; Ganna* rain season (March to May) would be interrupted /the probability of severe drought would be very high. Even though, May moon of the 2021was emerged on its right day on Walla; *Ganna* rainfall (March to May) was very poor.

Table 7. June's Moon WI Temporal Patterns

SN	Days of the June Moon/emerging phase	lunar cycles	SN	abstract cycles/ hidden phase
1	*Basa dura*	Light month of the moon	28	Full dark night
2	*Basa bal'aa*		29	
			30	
3	*Maganata duraa (Carraa)*			
4	*Maganata Jarraa*			
5	*Maganata biritii*			
6	*Salban duraa*			
7	*Salbaan bal'aa*			
8	*Salbaan dullacha*			
9	*Gardaduma*			
10	*Sonsa*			
11	*Ruruma*			
12	*Lumasa*			
13	*Gidada*			
14	*Ruda*			
15	*Areeri duraa*			
16	*Areeri bal'aa*	Dark month of the moon		
17	*Adula duraa*			
18	*Adula bal'aa*			
19	*Garba duraa*			
20	*Garba bal'aa*			
21	*Garba dullacha*			
22	*Bita duraa*			
23	*Bita bal'aa*			
24	*Sorsa*			
25	*Algajim*			
26	*Arba*			
27	*Walla*			

Source: RP, 2021

As it is seen from table 7, June moon is emerged on the Day *of Basa dura*. Lunar cycle of 1 st up to 15 th dates of the June moon (*Basa dura up to Areeri duraa)* are locally called the light/bright moon nights of the June Month Lunar cycle of the 16 th up to 30 st dates of the June moon (*Areeri bal'aa* up to *Basa bal'aa*) are locally called the dark moon nights of the June Month. When it is seen, literally June moon has only 29 days. However, it had 30 days. In this case, next to the *day* of *Basa bal'aa/ next to serial number 29* in the hidden phase of the double counting/ there was one full dark night without no sign of moon in the night sky which is locally called *Luwoo* of June moon/30 st date of June month. In line with this, because of the June Moon has two probable emerging days which consists of *Basa dura* and *Basa bal'aa*/serial number 1 to 2 in the emerging phase of the moon/ the total days of the June moon are/were 30. The *Diba* (final hardly observable decreased margin in the hidden phase of the moon) of the June moon was observed on the day of the *Basa bal'aa which was represented by the serial number 29 of the column 4 in the Table 7*. The probability of the emerging of the June moon is on the day of *Basa dura (serial number 1) or Basa bal'aa (serial number 2)*. In this case, there is a common belief that when the June moon is emerged on the day of *Basa dura; the upcoming Hagayyaa* rain season (September to October) would be very little/the probability of severe drought would be very high. In the 2021, June moon was emerged on the day of *Basa dura instead of Basa bal'aa.* Hence, the study community believed that lack of Hagayya rain /severe and devastating drought of 2021/2022 were mainly caused by the nature driven anomalous of the emerging of the June Moon of 2021 on the day of *Basa dura.*

Table 8. July's Moon WI Temporal Patterns

SN	Dates of the July Moon/ emerging phase	lunar cycles	SN	abstract cycles/hidden phase
1	*Maganata duraa (Carraa)*	Light month of the moon	28	Full dark night
2	*Maganata Jarraa*		29	
3	*Maganata biritii*		30	
			31	
4	*Salban duraa*			
5	*Salbaan bal'aa*			
6	*Salbaan dullacha*			
7	*Gardaduma*			
8	*Sonsa*			
9	*Ruruma*			
10	*Lumasa*			
11	*Gidada*			
12	*Ruda*			
13	*Areeri duraa*			
14	*Areeri bal'aa*			
15	*Adula duraa*			
16	*Adula bal'aa*	Dark month of the moon		
17	*Garba duraa*			
18	*Garba bal'aa*			
19	*Garba dullacha*			
20	*Bita duraa*			
21	*Bita bal'aa*			
22	*Sorsa*			
23	*Algajim*			
24	*Arba*			
25	*Walla*			
26	*Basa dura*			
27	*Basa bal'aa*			

Source:RP, 2021

As it is seen from table 8, July moon is emerged on the day *of Maganata duraa*. Lunar cycle of 1 st up to 15 th day of the July moon (*Maganata duraa up to Adula duraa)* are locally called the light/bright moon nights of the July Month Lunar cycle of the 16 th up to 31 st dates of the July moon (*Adula bal'aa* up to *Maganata biritii*) are locally called the dark moon nights of the July Month. When it is seen, literally July moon has only 30 days. However, it had 31 days. In this case, next to the *day* of *Maganata biritii/ next to serial number 30* in the hidden phase of the double counting/ there was one full dark night without no sign of moon in the night sky which is locally called *Luwoo* of July moon/31 st date of July month. In line with this, because of the July Moon has three probable emerging days which consists of *Maganata duraa*,*Maganata Jarraa* and *Maganata biritii* /serial number 1 to 3 in the emerging phase of the moon/ the total days of the July moon are/were 31. The *Diba* (final hardly observable decreased margin in the hidden phase of the moon) of the July moon was observed on the day of the *Maganata biritii which was represented by the serial number 30 of the column 4 in the Table 8*. The probability of the emerging of the July moon is on the day of *Maganata duraa (serial number 1) or Maganata Jarraa (serial number 2) or Maganata biritii*. In this case, there is a common belief that when the July moon is emerged on the day of *Maganata duraa; the upcoming Hagayyaa* rain season (September to October) would be very little/the probability of severe drought in the *Bona Hagayyaa* (December to February) would be very high. In the 2021, July moon was emerged on the day of *Maganata* *duraa instead of Maganata Jarraa.* Hence, the study community believed that severe and devastating drought of 2021/2022 was mainly caused by the nature driven anomalous of the emerging of the July Moon of 2021 on the day of *Maganata duraa.*

Table 9. August's Moon WI Temporal Patterns

SN	Dates of the August Moon/emerging phase	lunar cycles	SN	abstract cycles/hiddenphase
1	*Salban duraa*	Light month of the moon	28	dark Full night
2	*Salbaan bal'aa*		29	
3	*Salbaan dullacha*		30	
			31	
4	*Gardaduma*			
5	*Sonsa*			
6	*Ruruma*			
7	*Lumasa*			
8	*Gidada*			
9	*Ruda*			
10	*Areeri duraa*			
11	*Areeri bal'aa*			
12	*Adula duraa*			
13	*Adula bal'aa*			
14	*Garba duraa*			
15	*Garba bal'aa*			
16	*Garba dullacha*	Dark month of the moon		
17	*Bita duraa*			
18	*Bita bal'aa*			
19	*Sorsa*			
20	*Algajim*			
21	*Arba*			
22	*Walla*			
23	*Basa dura*			
24	*Basa bal'aa*			
25	*Maganata duraa (Carraa)*			
26	*Maganata Jarraa*			
27	*Maganata biritii*			

Source: synthesized idea of RP, 2021

As it is seen from table 9, August moon is emerged on the day of *Salban duraa*. Lunar cycle of 1 st up to 15 th dates of the August moon (*Salban duraa* up to *Garba bal'aa*) are locally called the light/bright moon nights of the August Month Lunar cycle of the 16 th up to 31 st dates of the August moon (*Garba dullacha* up to *Salbaan dullacha*) are locally called the dark moon nights of the August Month. When it is seen, literally August moon has only 30 days. However, it had 31 dates. In this case, next to the day of *Salbaan dullacha* / next to serial number 30 in the hidden phase of the double counting/ there was one full dark night without no sign of moon in the night sky which is locally called *Luwoo* of August moon/31 st date of August month. In line with this, because of the August Moon has three probable emerging days which consists of *Salban duraaSalbaan bal'aa,* and *Salbaan dullacha* /serial number 1 to 3 in the emerging phase of the moon with in the column 2/ the total days of the August moon are/were 31. The *Diba* (final hardly observable decreased margin in the hidden phase of the moon) of the August moon was observed on the day of the *Salbaan dullacha* which was represented by the serial number 30 of the column 4 in the Table 9. The probability of the emerging of the August moon is on the day of *Salban duraa* (serial number 1) or *Salbaan bal'aa* (serial number 2) or *Salbaandullacha (serial number 3)*. In this case, there is a common belief that when the August moon is emerged on the day of *Salbanduraa*; the upcoming *Hagayyaa* rainfall season (September to October) would be very little/the probability of severe drought would be very high. In the 2021, August moon was emerged on the day of *Salban duraa* instead of *Salbaan bal'aa*. Hence, the study community believed that severe and devastating drought of 2021/2022 was mainly caused by the nature driven anomalous of the emerging of the August Moon of 2021 on the dates of *Salban duraa*. This is suppoted by the study in India (Sankar et al., 2019) which posited that Many village level Astrologers (Pandits) are still predicting highly accurate weather with planet movements. It also stated that the daily rainfall forecast through astro-meteorology showed the highest forecast accuracy of 74-87 percent. Apparently study undertaken by (Lawrence, 2021) explore that the repeated cycles of the sun, moon, and stars helped to regulate human activity as people strove to make sense of their world and to keep their actions in harmony with the cosmos as they perceived it. Study of (Scofield, 2010c) found that early Greece use context of astrological features to best illustrate works and days, the cycle of the year, and the month in the process of agricultural activities.

Table 10. Septmber's Moon WI Temporal Patterns

SN	Days of the September Moon/emerging phase	lunar cycles	SN	abstract cycles/ hidden phase
1	*Gardaduma*	*Light month of the moon*	*28*	*Full dark night*
2	*Sonsa*		*29*	
3	*Ruruma*		*30*	
4	*Lumasa*			
5	*Gidada*			
6	*Ruda*			
7	*Areeri duraa*			
8	*Areeri bal'aa*			
9	*Adula duraa*			
10	*Adula bal'aa*			
11	*Garba duraa*			
12	*Garba bal'aa*			
13	*Garba dullacha*			
14	*Bita duraa*			
15	*Bita bal'aa*			
16	*Sorsa*	*Dark month of the moon*		
17	*Algajim*			
18	*Arba*			
19	*Walla*			
20	*Basa dura*			
21	*Basa bal'aa*			
22	*Maganata duraa (Carraa)*			
23	*Maganata Jarraa*			
24	*Maganata biritii*			
25	*Salban duraa*			
26	*Salbaan bal'aa*			
27	*Salbaan dullacha*			

Source:RP,2 021

As it is seen from table 10, September moon is emerged on the day *of Gardaduma*. Lunar cycle of 1 st up to 15 th dates of the September moon (*Gardaduma to Bita bal'aa)* are locally called the light/bright moon nights of the September Month Lunar cycle of the 16 th up to 30 st dates of the September moon (*Sorsa* up to *Sorsa*) are locally called the dark moon nights of the September Month. When it is seen, literally September moon has only 29 days. However, it had 30 days. In this case, next to the *day* of *Sonsa / next to serial number 29* in the hidden phase of the double counting/ there was one full dark night without no sign of moon in the night sky which is locally called *Luwoo* of September moon/30 st date of September month. In line with this, because of the September Moon has two probable emerging dates which consists of *Gardaduma* and *Sonsa* /serial number 1 to 2 in the emerging phase of the moon/ the total days of the September moon are/were 30. The *Diba* (final hardly observable decreased margin in the hidden phase of the moon) of the September moon was observed on the day of the *Sonsa which was represented by the serial number 29 of the column 4 in the Table 10*. The probability of the emerging of the September moon is on the day of *Gardaduma (serial number 1) or Sonsa (serial number 2).* In this case, there is a common belief that when the September moon is emerged on the daythe upcoming of*Gardaduma; Hagayyaa* rain season (September to October) would be very little/the probability of severe drought would be very high.

Table 11. October's Moon WI Temporal Patterns

S N	Days of the October Moon/emerging phase	lunar cycles	SN	abstract cycles/ hidden phase
1	*Ruruma*	Light month of the moon		
2	*Lumasa*			
3	*Gidada*			
4	*Ruda*			
5	*Areeri duraa*			
6	*Areeri bal'aa*			
7	*Adula duraa*			
8	*Adula bal'aa*			
9	*Garba duraa*			
10	*Garba bal'aa*			
11	*Garba dullacha*			
12	*Bita duraa*			
13	*Bita bal'aa*			
14	*Sorsa*			
15	*Algajim*			
16	*Arba*	Dark month of the moon		
17	*Walla*			
18	*Basa dura*			
19	*Basa bal'aa*			
20	*Maganata duraa (Carraa)*			
21	*Maganata Jarraa*			
22	*Maganata biritii*			
23	*Salban duraa*			
24	*Salbaan bal'aa*			
25	*Salbaan dullacha*			
26	*Gardaduma*			
27	*Sonsa*			
			28	Full dark night
			29	
			30	

Source:RP, 2021

As it is seen from table 11, October moon is emerged on the day *of Ruruma*. Lunar cycle of 1 st up to 15 th dates of the October moon (*Ruruma up to Algajim)* are locally called the light/bright moon nights of the October Month[7]. Lunar cycle of the 16 th up to 30 st dates of the October moon (*Arba* up to *Lumasa*) are locally called the dark moon nights of the October Month. When it is seen, literally October moon has only 29 days. However, it had 30 days. In this case, next to the *day* of *Lumasa/ next to serial number 29* in the hidden phase of the double counting/ there was one full dark night without no sign of moon in the night sky which is locally called *Luwoo* of October moon/30 th date of October month. In line with this, because of the October Moon has two probable emerging days which consists of *Ruruma* and *Lumasa/*serial number 1 to 2 in the emerging phase of the moon/ the total days of the October moon are/were 30. The *Diba* (final hardly observable decreased margin in the hidden phase of the moon) of the October moon was observed on the day of the *Lumasa which was represented by the serial number 29 of the column 4 in the Table 11*. The probability of the emerging of the October moon is on the day of *Ruruma (serial number 1) or Lumasa (serial number 2)*. In this case, there is a common belief that when the October moon is emerged on the day of *Ruruma; Hagaya* rain season (October to November) would be interrupted/the probability of severe

[7]. see remarks on the start and end of the counting of the moon dates of a month in this section

drought in the Bona Hagayyaa (December to February) would be very high. In the 2021, October moon was emerged on the day of *Ruruma instead of Lumasa*. Furthermore, community believed that when the first shower of rainfall is occurred on either day of *Gardaduma, Sonsa, Ruruma, Lumasa, Gidada, Arba, Walla, Sorsa, Algajim and Ruda* of the October month; the *Hagayyaa* rainfall would be very little/interrupted early. Similarly, first shower of 2021 *October* rainfall was occurred on the day of *Ruruma*. Hence, the study community believed that severe and devastating drought of 2021/2022 was mainly caused by the nature driven anomalous of the emerging of the October Moon of 2021 on the day of *Ruruma*; and the occurrence of the first shower of 2021 Hagayya rainfall on the day of *Arba*. Study of Allen quoted in (Loretta, 2014) posited that indigenous peoples observations of the celestial objects give future clue of the seasonal patterns. This is exactly still functional among the Borana Oromo of Southern Ethiopia.

Table 12. November's Moon WI Temporal Patterns

SN	Dates of the November Moon/emerging phase	lunar cycles	SN	abstract cycles/hidden phase
1	*Gidada*	Light month of the moon	28	Full dark night
2	*Ruda*		29	
			30	
3	*Areeri duraa*			
4	*Areeri bal'aa*			
5	*Adula duraa*			
6	*Adula bal'aa*			
7	*Garba duraa*			
8	*Garba bal'aa*			
9	*Garba dullacha*			
10	*Bita duraa*			
11	*Bita bal'aa*			
12	*Sorsa*			
13	*Algajim*			
14	*Arba*			
15	*Walla*			
16	*Basa dura*	Dark month of the moon		
17	*Basa bal'aa*			
18	*Maganata duraa (Carraa)*			
19	*Maganata Jarraa*			
20	*Maganata biritii*			
21	*Salban duraa*			
22	*Salbaan bal'aa*			
23	*Salbaan dullacha*			
24	*Gardaduma*			
25	*Sonsa*			
26	*Ruruma*			
27	*Lumasa*			

Source: RP, 2021

As it is seen from table 12, November moon is emerged on the day *of Gidada*. Lunar cycle of 1st up to 15th dates of the November moon (*Gidada up to Walla)* are locally called the light/bright moon nights of the November Month[8]. Lunar cycle of the 16th up to 30st dates of the November moon (*Basa dura* up to *Ruda*) are locally called the dark moon nights of the November Month. When it is seen, literally November moon has only 29 days. However, it had 30 days. In this case, next to the *day* of *Ruda / next to serial number 29* in the hidden phase of the double counting/ there was one full dark night without no sign of moon in the night sky which is locally called *Luwoo* of November moon/30th date of November month. In line with this, because of the November Moon has two probable emerging days which consists of *Gidada* and *Ruda /*serial number 1 to 2 in the emerging phase of the moon/ the total days of the November moon are/were 30. The *Diba* (final hardly observable decreased margin in the hidden phase of the moon) of the November moon was observed on the day of the *Ruda which was represented by the serial number 29 of the column 4 in the Table 12*. The probability of the emerging of the October moon is on the day of *Gidada (serial number 1) or Ruda (serial number 2)*. In this case, there is a common belief that when the November moon is emerged on the day of *Gidada* the probability of prolonged/severe drought in the *Bona Hagayyaa* (December to February) and the scarcity/interruption of rainfall in the upcoming Ganna season (March to May) would be very high in the study area. Hence, the study community believed that the devastating drought of the 2021/202 drought was caused by the anomalous of the emergence of the November moon on the

[8]. see remarks on the start and end of the counting of the moon dates of a month in this section

day of *Gidada.* Similarly (Lehoux, 2021) found that in ancient Greek new and full moons were used to determine general weather conditions. Study of Mcmillan quoted in (L0rettaa, 2014) revealed that Batswana communities have prominent phonological markers of cultural astronomy that signal the change of the seasons; predict droughts as well as weather related diseases by watching the movements of celestial bodies.

Table 13. December's Moon WI Temporal Patterns

SN	Days of the December Moon/emerging phase	lunar cycles	SN	Hidden phase /abstract cycle
1	*Areeri duraa*	Light month of the moon	28	Full dark night
2	*Areeri bal'aa*		29	
			30	
3	*Adula duraa*			
4	*Adula bal'aa*			
5	*Garba duraa*			
6	*Garba bal'aa*			
7	*Garba dullacha*			
8	*Bita duraa*			
9	*Bita bal'aa*			
10	*Sorsa*			
11	*Algajim*			
12	*Arba*			
13	*Walla*			
14	*Basa dura*			
15	*Basa bal'aa*			
16	*Maganata duraa*	Dark month of the moon		
17	*Maganata Jarraa*			
18	*Maganata biritii*			
19	*Salban duraa*			
20	*Salbaan bal'aa*			
21	*Salbaan dullacha*			
22	*Gardaduma*			
23	*Sonsa*			
24	*Ruruma*			
25	*Lumasa*			
26	*Gidada*			
27	*Ruda*			

Source:RP,2021

As it is seen from table 13, December moon is emerged on the day *of Areeri duraa*. Lunar cycle of 1 st up to 15 th dates of the December moon (*Areeri duraa up to Basa bal'aa)* are locally called the light/bright moon nights of the December Month[9]. Lunar cycle of the 16 th up to 30 st dates of the December moon (*Maganata duraa* up to *Areeri bal'aa*) are locally called the dark moon nights of the December Month. When it is seen, literally December moon has only 29 days. However, it had 30 days. In this case, next to the *days* of *Areeri bal'aa / next to serial number 29* in the hidden phase of the double counting/ there was one full dark night without no sign of moon in the night sky which is locally called *Luwoo* of December moon/30 th days of December month. In line with this, because of the December Moon has two probable emerging days which consists of *Areeri duraa* and *Areeri bal'aa /*serial number 1 to 2 in the emerging phase of the moon/ the total days of the December moon are/were 30. The *Diba* (final hardly observable decreased margin in the hidden phase of the moon) of the December moon was observed on the day of the *Areeri bal'aa which was represented by the serial number 29 of the column 4 in the Table 13*. The probability of the emerging of the October moon is on the day of *Areeri duraa (serial number 1) or Areeri bal'aa (serial number 2)*. In this case, there is a common belief that when the December moon is emerged on the day of *Areeri duraa* the probability of prolonged and severe drought would be very high in the *Hagayya* drought season (December to February) and scarcity of rainfall in the upcoming Ganna season (March to May).

[9]. see remarks on the start and end of the counting of the moon dates of a month in this section

Hence, the study community believed that the devastating drought of the 2021/202 drought was mainly caused by the anomaly of the emerging of the December moon on the day of *Areeri dura.*

Rainfall patterns of the day of new Moon: In the study area it is believed that day of a new moon has decisive factors on the amount and distribution of rainfall. In this case, when the first shower of rainfall is occurrs on the day of *Salbaan duraa;* high rainfall will be expected in that whole season (see tables 1-12). Similarly, when the first shower of rainfall occurrs on the day of *Salban bal'aa, salban dullacha, Basa bal'aa, Areeri dura, Areeri bal'aa and Bitaa bal'aa*; sufficient rainfall is expected in that whole season. Similarly, when the first shower is occurred on the day of *Basaa duraa;* there is no equal physical distribution of rainfall in that season for all area of Borana zone. Similarly, when the first shower occurrs on the days of *sorsa, algajim, arba, walla, gardaduma, sonsa, ruruma, lumasa, gidada* and ruda; rainfall is not sufficient in amount and physical distributions, in the study area.

Study in Botswana quoted in Loretta, (2014) support this current study, disclosed that the moon controlled the tides and regulate annual agricultural activities and production. It further stated that months are divided up according to the phases of the moon. The author of the ancient Greece de signs of weather study quoted in (Beardmore, 2013) did sketch out a basic time-reckoning system/seasonal calendar that were based on a mixture of stellar, lunar and solar patterns. Astronomical time-reckoning which is tied to a seasonal structure, has been argued and demonstrated in works of (Scofield, 2010c). It stated that the first method, used to describe the weather for each quarter of the year, utilizes horoscopes calculated for the new or full Moon that most closely precedes the equinoxes and solstices.

2.3. Weather indicating physical features of the Moon

It is identified through this study that future weather indicating physical features of the Moon are categorized in to three distinctive interrelated features: 1) probable inclination/direction of the first date new moon and, 2) formation of the ring / cloud surrounding the moon, 3) Colour patterns of the moon.

Probable directions/inclinations of the first date new moon: In connection with this there are three predetermined probable direction of the first date new moon. In this case, 1) when the probable inclination of the first date new moon of December, January and February dry periods are towards south direction; the condition of the upcoming rainfall season is comparatively more favorable to the area in the South direction than elsewhere. In this regard, according to the local community; the benchmark/the reference area of the probable south ward inclination of the first day new moon is Dire district. The upcoming season rainfall will be more favorable for the *Dire* district including the area towards south of *Dire* such as *Moyale* and *Miyo* than the districts of the Borana zone in the other three direction.

The inclination of the first day new moon to this direction is mainly to signals *Ganna* rainfalls (March to May). During such inclination of the moon/ towards *Dire* direction; *Finna*/condition is more very suitable for cattle in all the dry land areas of Borena. In this regard, in the last *Bona Hagaya* (December to February) and *Bona Addolessa* (June to September) of 2021 the first date new moon is not inclined in to the southwards; as the result *Ganna March to May)*and *Hagayya* rainfall (October to November) of 2021 was very poor in the area south of *Dirre* district of the Borana zone. This is in consistent with the study of Lawrence, (2021) argued there is universal belief that the planets, solar system and their movements around the Earth affected atmospheric conditions and weather.

Similarly, 2) when the probable inclination of the first date new moon of June, July and August (during early period of the drought season known as *Bona Adolessa*) are inclined towards North direction; the condition of the upcoming rainfall season will comparatively more favorable to the area in the North direction than elsewhere. In this regard, according to the local community; the local benchmark/the reference area of the probable North ward inclination of the first date new moon is *Gomole* district. The upcoming season rainfall will be more favorable for the *Gomole* district including the area towards North of *Gomole* than the other districts of the Borana zone in three directions.

This phenomenon was happened in *Ganna* and *Hagayya* rainfall season of 2021. *Ganna* and *Hagayya* rainfall season of 2021 was more favorable to *Gomole* and area to the North of *Gomole* district of Borana zone. In the study area, the inclination of the first date new moon towards north direction is mostly used to signals *Hagaya* rainfall season. In this regard, when the inclination is made towards north direction the upcoming season/condition will be more suitable for Goat and camel than cattle in all the dry land areas of Borena zone. Contrary to this, 3) When the first new moon is emerged towards East direction/upwards during the dry season of bona *Adolessa/Bona Hagayya*; the upcoming season rainfall will delay or the probability of severe drought will be high. Study in Tanzania (Elia, 2014a) revealed that when a half moon is constantly appearing in north direction it signals rainfall, however, it did not identified the time lapse between observing the indicating features of the moon and the occurrence of rainfall which is very mandatory in making early preparedness.

Tiny clouds surrounding the Moon: This study identified six predetermined probable directions through which tiny clouds are surrounding the moon. First) Moon is surrounded with a tiny synthesized cloud; during the dry season of the *Bona Addolessa (June to September) and Bona Hagaya* (December to February). The tiny cloud surrounding the moon is formed on the seventh date of the new moon. This sign of the moon indicates that the upcoming rainfall season will be very promising in its entire dimension.

In addition, it is indicating that as there will be favorable weather condition in the upcoming season which is locally called *Finnaa* (enough water, pasture and milk). Furthermore, it is indicating that there will be no fear of risk of disease (both of human and livestock disease) outbreak and local conflict. The amount of rainfall in the upcoming season will be determined by the physical pattern /direction through which tiny clouds are formed around the moon in the night sky. In line with this, when the Moon is surrounded by tiny cloud while it is on the eastern, mid and western direction of the earth during the very early period of Bona *Adolessa*/*Bona Hagaya* it implies that the upcoming season rainfall will be high, medium and small, respectively.

This is similar with the study quoted in Beardmore, (2013) which stated that the seemingly celestial is explained by Aristotle as being firmly terrestrial. In addition, the temporal pattern of the *Danbala*/tiny cloud that is surrounding the moon has its own implication on the upcoming season rainfall. For example, when the moon is surrounded by tiny cloud in October and in April; the upcoming rainfall season of the *Ganna* (end of February up to May) and *Hagaya* (end of September up to November) would be very promising in its entire dimension, respectively. Second) when a tiny cloud that has a gap/a get/ is surrounding the moon during the dry period of Bona Adolessa (June to August) and Bona Hagaya (December to March) will indicating that the forthcoming season (rainfall season of October to November) and rainfall of (March to May) would be very promising, respectively.

In contrary, Third) when a tiny cloud is not surrounding the moon during the dry season of *Bona Adolessa*/*Bona Hagaya*/it is indicating that the upcoming rainfall season is too little/the probability of the occurrence of the prolonged drought would be very high. In addition, the moon is stunted/shirked/ in physical appearance and looks like reddish in color. Fourth) when a tiny segment of cloud is observed inside the moon during the dry season it implies that there will be normal occurrence of rainfall in the upcoming season. Fifth), the direction on which cloud is constructed around the moon has decisive factors on the amount of rainfall of the upcoming season. When the moon is surrounded by (constructed) tiny cloud after 15 th dates of new moon while it is on the eastern, mid of the sky and western direction during the dry season it is indicating that the upcoming season rainfall will be very promising, medium and small, respectively.

Furthermore, Sixth) when the moon is surrounded by tiny clouds in October it indicates that the upcoming rainfall season of the *Ganna* (end of February/March up to May) will be very good in its entire dimension. Similarly, When moon is surrounded by tiny cloud while it is on the east, mid of the sky and west in April it is indicating that the upcoming rainfall season of the *Hagaya (October to November)* will be very good in its entire dimension. In contrary to this, study (Elia, 2014a) in Tanzania argued that When the moon is surrounded by clouds, the villagers believe that rainfall will be small quantities.

Color patterns of the Moon: In the study area it is believed that when the color of the moon looks white, big, shine, cloudy and shivering during the current particular period of the dry season; it is indicating that the upcoming rainfall season will promising in its all dimension. However, when the color of the moon is dirty and stunted during the current particular period of the dry season; it is indicating that the upcoming rainfall season will be very little. This phenomenon was actually happened in *Hagayya* and *Adolessa* dry season of 2021. Study in Tanzania (Lehoux, 2021a) revealed that the moon's brightness and its haloes, taken just before and after its significant phases, give weather predictions. Similar studies (Elia, 2014a) in Tanzania revealed that when farmers observe a halo of light around the moon, they believe as it signifies that the moon is surrounded by water and that this forecasts rain. Study (Oruru et al., 2020) in Uganda among the Baganda clan expect sunshine when the moon is bright red in color. However, both of these studies not identified the specified lapse time between the observations of the indicators and occurrence of the rainfall.

2.4. Input of indigenous weather indicating features of the Moon in livelihood decision making

In this study it is identified that since time immemorial local community in the study area has far-fetched trust in the role of indigenous weather forecasting practices, especially, in the role of seasonal weather indicating features of the moon in drought resilience. Every daily livelihood activity: management of water and pasture land, mobility, herd splitting, herd diversification, social support and livestock selling and opportunistic crop farming are undertaken depending on the indigenous weather/drought forecasting information that are especially found through defining of weather indicating features of the moon. In addition, they commonly use and believe in its role of prediction/in disaster risk reduction such as drought, flood, disease/pest outbreak and local conflict. In this regard, forecasting based on the weather indicating features of the moon are more accurate and trusted in livelihood decision making process than the other aspects of the astronomic features and/or than the other aspects of the indigenous weather forecasting objects currently, under use in the study area.

In line with this, although all members of the community (including children and women) could have basic skill of forecasting weather events; all have not equal capacity i.e., there are differences among individuals in accuracy of forecasting. In line with this, individuals who have mastered in defining physical and temporal patterns of the moon in the process of forecasting future events including weathers are locally known as *Ayyaantu*. Currently, curtailments of mobility, severity of drought, weakening of traditional institution, leaving of traditional lifestyle and death of the knowledgeable elders have challenged the potential effects of the indigenous weather forecasting indicators of the features of moon among Borana pastoralists.

Study of ancient Greece weather signs study (Beardmore, 2013) disclose that popular-practical astronomy originating far back beyond the beginnings of writing, and having gained particular traction in Babylonia, where known to have taken place in systematic observations of celestial and meteorological phenomena. It further stated that astro-meteorology as being connected to the weather; it began life bound up with time-reckoning and specific activities. In this regard (Beardmore, 2013) posited that regularities formed by the motions of celestial objects provided the necessary context upon which many structural symbolic patterns were built to regulate human activities on the earth.

3. Conclusion and recommendation

Conclusion: It is identified through this study that since time immemorial indigenous astronomic weather forecasting knowledge is the driver of livelihood decision making among Borana Oromo Pastoralists of Southern Ethiopia. In this regard, physical and temporal and /or probable predetermined day patterns of the emerging of new moon are the main features of the moon that are commonly used by the local community in the process of indicating future weather phenomena. Day patterns of the emerging of new moon are relatively more accurate and is relatively widely used than the other features of moon in weather forecasting in the study area. The prediction that is displayed via the observation of the moon would offer sufficient lapse time in a more than/within ahead of the three months lead time which is sufficient for making early preparedness in advance of the occurrence of the weather/adverse events.

Recommendation: Borana pastoralists have full trust in indigenous weather forecasting knowledge in leading vis-à-vis of their every daily livelihood activity. Hence, the following recommendations are mandatory in demonstrating the full potential of the indigenous knowledge weather forecasting knowledge:

1. It is better to strengthening traditional institutions in order to regain and rehabilitate the full functional capacity of the indigenous weather forecasting knowledge,
2. Borana pastoralists define outlooks of astronomic objects (sun, moon and stars), observe atmospheric characteristics (cloud, wind, temperature, rainfall and lightning), read physical condition of biotic objects (livestock, tree, wildlife, birds, social insects, Reptiles etc.) and rememorize the unique and known events in each Geda cycles periodically in the process of future weather forecasting. In this regard, it is advisable to undertake detail in-depth study; and making documentation of the findings of each object to preserve and use this body of knowledge in sustainable manner,
3. It is better to acknowledge and mainstreaming the indigenous weather knowledge into formal institutional structures and integrate with science to improve its applicability and role in drought resilience.

CHAPTER THREE

Indigenous Knowledge of the Astronomical Star Positions and Temporal Patterns of Borana Oromo Pastoralists for Seasonal Weather Forecasting

Abstract

Indigenous Knowledge-based (IK) prediction of weather is an activity as old as humanity. Objective of this study is to examine indigenous astronomic stars knowledge-based of seasonal Weather forecasting among Borana Oromo pastoralists of Southern Ethiopia. This study is based on primary data that were generated through using focus group discussion, key informant interviews, experimental groups, and direct observation.The findings revealed that indigenous-based weather indicating astronomic objects that exhibit change naturally with in a continuum of varying temporal and spatial contexts were observable external features of Stars. Temporal patterns of star-moon alignment/defect of star-moon alignment, position/direction of the stars and physical/colors of Stars were commonly used in seasonal weather forecasting. The indicators were displayed in a more than three months lead time ahead of the actual occurrence of weather events. The occurrence of the forecasting of the weather event was actually happened in 2021. The severe drought of 2021/2022 was mainly/caused by naturally driven defects of star-moon alignment. These practices are still regularly used in decision making. However, these practices are not yet mainstreamed into formal structures. Curtailments of mobility, severity of drought, weakening of traditional institution, leaving of traditional life-style and death of the knowledgeable elders are the major challenging factors to these practices.

Key Words: Borana Oromo, Ethiopia, Indigenous Knowledge, Astronomy, Stars, Weather Forecast

1. Introduction

People around the world throughout human history have developed indigenous knowledge systems (Romani, 1981; Sillitoe and Sillitoe, 2006 ; Apgar and Apgar, 2010) in an effort to improve livelihood decision making. IK guides and allows people to produce sustainable survival mechanisms. In this regard, IK is the driver in everyday lives/livelihoods; and provides early signals to the probable events within a continuum of a given environmental and social changes /contexts and helps people to undertake effective preparedness and response (Tang, 2012; Zounon *et al*., 2020; Ibinarriaga, 2020; Dinsa AB *et al*., 2022).

In this case, IK explains the origin of natural features, the dynamics of natural processes, and various natural phenomena through deduction, observation, experimentation, and experience (Rajasekaran, 1993; Sillitoe and Sillitoe, 2006; Ssettee, 2007; Loretta, 2014; Fernandez, 2015; Anju and Bonny, 2019 ; David-Chavez, 2019). Indigenous people across the globe use their indigenous knowledge to classify the objects, to interpret activities; and to identify events in the process of overcoming all aspects of natural and manmade problems (Apgar and Apgar, 2010; Rahman and Rusli, 2017; Kim, 2018; Bruchac, 2020) . The logic behind this is that intrinsic resilience is the outcome of indigenous knowledge adaptation practices (Rustomjee, 2015; Kirmayer *et al*., 2011). However, IK constitutes skill/knowledge systems that are dynamic, holistic; and designating/reflecting specific geographical area, distinct /original to a given society/culture and evolving with in the intergenerational transmission, since time immemorial (Ibañez, 2014; Sirima, 2015; Aderemi, 2017).

Hence, continuity, preservation, restoration and sustainability of IK systems have value not only for the communities in which it evolved and is practiced but also for scientists and planners striving to improve conditions in rural localities (Theodory, 2016; Sillitoe and Sillitoe, 2006 ; Kim, 2018). Likewise, in rural areas of Ethiopia indigenous knowledge practices/technologies are still prevalent in all aspects of life and livelihoods (Workineh *et al*., 2010; Mihertu, 2018; Dinsa AB *et al*., 2022). Indigenous weather forecasting knowledge, livestock mobility, traditional by-law in relation to water and rangeland use and management practices; prescribed firing, traditional Oromo administration system (Geda system[10]), and social support (rebuilding

[10] . Holistic Oromo indigenous administration system which is responsible for economic, environmental, social,

poor and/or disaster affected individuals in the community) locally known as *Busa gonofa*[11]) among the Borana Oromo of Southern Ethiopia are some of the examples of IK practices in Ethiopia (Jalata, 2012).

However, studies by (Cowley-Head, 2002; Mauro *et al*., 2010) explored that marginalization of IK systems was underway since the 12th century with increasing modernization. In recent years, anti-IK myths (such as primitivism, non-technical, backward, etc.,); lack of documentation, lack of autonomy and departing from IK based life style and death are some of the factors that are challenging functionality and sustainability of IK (Sirima, 2015; Aderemi, 2017; Ibinarriaga, 2020). Despite the fact that there are very few harmful traditional practices (Apgar and Apgar, 2010), it is argued that anti-IK views have negatively impacted community development processes, especially, over the last five decades.

Recently, however, the role of IK in the development discourse has been more rediscovered at all levels in response to increasing multi-hazard/disaster, climate change/ variability, environmental pressure, and its significance in resilience; and response to failure of blue print development planning (Apgar and Apgar, 2010; Šakić, 2020).

IK based Prediction of seasonal weather is an activity as old as humanity (Ginibre, 2009; Scofield, 2010a). Even still today indigenous communities in different parts of the world have relied on IK weather forecasting in making every livelihood practice; and to deal with continuum of dynamic aspects of environmental change in the process of making adaptation practices (Tang, 2012; Ibañez, 2014; Mandaluyong and Donato-kinomis, 2016; Nakashima *et.al*, 2018; Dinsa AB *et al*., 2022). Biotic and a-biotic objects, celestial bodies/astronomical features and atmospheric phenomena/ indicators that are varied within the context of the dynamics of the spatio-temporal patterns are routinely used in indigenous knowledge based weather forecasting practices (Baity *et al*., 1973; Clarke, 2009b; Loretta, 2014; Salite, 2019; Dinsa AB *et al*., 2022).

Astronomical knowledge is a significant component of the culture and cosmology of many indigenous peoples (Alacgac and Alisacan, 2003; Scofield, 2010b; Lee *et al*., 2020b ; Lehoux,

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cultural, political, military issues, etc.

[11] Busa Gonofa is Oromo indigenous social support system to reconstruct/rebuild poor and/or disaster affected individuals/households in the community.

2021b). An important aspect of indigenous astronomy is about peoples relationships with the sky (Willis and Ii, 2011; Lawrence, 2021) ; and how knowledge about the sky helps to identify weather and culturally encoded weather in the process of every-daily livelihood decision making (Ruggles, 2015). Indigenous people in Northern America (Romani, 1981; Norton-smith *et al*., 2016 ; Rawn *et. al.*, 2019 ; Steen, 2021; Cannon, 2022a), Aborginal people in Australia (Clarke, 2009b; Hamacher *et al*., 2015), central European Russian farmers (Rudnev, 2002), Japan Archipelago (Goto, 2018), Indian rural people (Rajasekaran,1993;Sivaprakasam and Kanakasabai, 2009; Anju and Bonny, 2019); indigenous peoples of South Africa (Romani, 1981; Zimu-Biyela, 2016), Botswana (Dare *et al*., 2014), Zimbabwe (Shoko and Shoko, 2017; Muguti, 2012), Uganda (Okonya and Kroschel, 2013a) and Ethiopia (Balehegn *et al.*, 2019; Radeny *et al.*, 2019; Dinsa AB *et al*., 2022) are still using celestial bodies of the sky in the making of the IK based weather forecast. In this regard, external physical features, positions and temporal patterns of the stars, Moon and the Sun are regularly used to found explanations of tides, eclipses; and prediction of the season, fertility, activities, production and disasters in the process of the livelihood decision making with in a given environmental context (Romani, 1981; Clarke, 2009; Norris and Harney, 2012 ; Hamacher *et al*., 2015; Dinsa AB *et al.*, 2022).

Borana Oromo pastoralists of Southern Ethiopia have continuously defined outlooks of astronomic object, observed atmospheric characteristics, read physical condition of biotic objects, and rememorized the unique and known weather events in each Geda[12] cycles in the process of forecasting future weather phenomena. Since time immemorial, indigenous knowledge based weather forecasting is the driver of livelihood decision making in the study area. However, studies and proper documentation have not yet been undertaken to preserve this invaluable body of the indigenous weather indicating knowledge and practices of the Borana Oromo pastoralists (Dinsa AB *et al*., 2022). Furthermore, no area-specific study has been conducted in the study area on the practical experiences of community-based approaches vis-à-vis weather indicating features of astronomic objects including stars that have continuously manifesting different physical and temporal patterns within a range of dynamic contexts (Dinsa AB *et al*., 2022).

[12] Holistic Oromo traditional administration/governance system

Hence, this study examined the indigenous knowledge based seasonal weather forecast using positional and temporal patterns/features of the stars and its role in livelihood decision making. In doing so, this study tried to answers three interrelated questions: 1) Is the IK based observation of positional, physical and temporal features/patterns of the stars used in the process of indicating future weather phenomena in the study area?, 2) Is there sufficient lapse time between forecasting and occurrence of the weather events?, 3) Are , indigenous weather forecasting practices currently used by the community in the process of the livelihood decision making?

1.1. Concept of indigenous knowledge

Relevant scholars' works/definitions were reviewed and were highlighted here within the context of the aforementioned view of the IK astronomic weather forecasting stars. In this regard, it is better to begin with the highlight phrases/terms of the cultural astronomy, archaeo-astronomy, ethno-astronomy, and ethno-meteorology instead of focusing only on the definition of IK.

The observation of the sky/astronomy is probably the earliest scientific activity ever performed by humankind (Willis and Ii, 2011; Belmonte, 2018; Gullberg, 2021). This highlights the culture based dimension of astronomy. Cultural astronomy is the study of the use of astronomical knowledge, beliefs, or theories to inspire, inform, or influence social forms and ideologies, or any aspect of human behavior (López, 2011; Mart, 2016; Clausen, 2016; Belmonte, 2018; Gullberg, 2021) . Since the theme of this research is to examine the importance of IK based weather indicating features of stars; this study adopted the definitions of Nicholas Campion (1997): cited in (Mart, 2016; Clausen, 2016; Belmonte, 2018) who stated that cultural astronomy is the study of humans and their relationship with the phenomena of the sky which includes timekeeping, weather prediction, seasonal calendars and artistic inspiration.

In addition, cultural astronomy describes metaphysical beliefs such as celestialism, astrology; as well as human relationships vis-à-vis with the scientific studies of astronomy, astrophysics, space sciences, atmospheric science, and planetary science (Explorers club, 2010; Youssefnia, 2014; Berg, 2018). It also deals with the study of the history and evolution of all of these beliefs within regions, cultures, and sub-groups which means it examines the astronomy used in ancient cultures, including orientations found at sites and structures of ancient peoples (Clausen, 2016 ; Zotti *et al*., 2020).

Cultural astronomy comprises the modern disciplines of archeo-astronomy and ethno-astronomy (Clarke, 2009b; Mart, 2016). Archaeo-astronomy is the branch of archaeology that deals with the study of the prehistoric civilizations and their astronomical techniques used to establish the seasons or the cycle of the year (Willis and Ii, 2011). Archaeo-astronomy is quite interdisciplinary. It employs astronomy, but also uses elements of archaeology and anthropology (Willis and Ii, 2011; Belmonte, 2018; Gullberg, 2021).

Ethno-astronomy is the branch of astronomy concerned with the astronomical beliefs and practices of specific cultures. It deals with the astronomical systems of living indigenous peoples (López, 2011; Garofalo, 2021). Ethno-meteorology is a scientific trend in studying the ethnic specificity of traditional ideas of different peoples of the world linked with the weather, in the context of modem ideas of natural science (Clarke, 2009a). In synopsis with this, this study adapted, aggregated and synthesized IK definitions from IPBES, World Bank and UNPFII cited in (Langill *et al*., 1999; SsetteeE, 2007; Sirima, 2015) which stated that IK is a multi-faceted array of area specific knowledge; know how, practices, distinct/original to particular society/culture, representation of identity and survival strategy, might be adopted/adapted by various societies, adaptive/dynamic with change and holistic in nature, intergenerational, which guides societies in their interactions with their surrounding environment. Indigenous knowledge can help build resilience in three ways: increasing the range of available knowledge; providing the basis for adaptations; and enabling social practice and learning (Panampitiya, 2019; Berkes *et al*., 2021) .

1.2. Research methodology

Research approach, sampling techniques, data collection and data analysis techniques were briefly highlighted here below.

1.2.1.Research approach

In this study all the steps and procedures of data collection process were adapted from the indigenous holistic theory. Indigenous peoples have unique means of relating to the world (Absolon, 2022). Indigenous peoples always have been engaged in research in relation to their environment. Indigenous holistic theory is multi-layered; earth-based, ecological, cyclical, relational and its methodologies derive from teaching experiences and relational storytelling about the land, sun, water, sky and all of creation (Mwinzi, 2015; Absolon, 2022). Indigenous research methods is mainly depend on the common principles of respect, relevance, reciprocity and responsibility to indigenous holism, collectivisms, indigenous identity and indigenous ethics (Pidgeon and Riley, 2021; Bruchac, 2022). Holistic theory includes an intermixing and consideration of time and space: the past, present, future and values that retain the balance and harmony of all (Champagne, 2008 ; Absolon, 2022).

Theoretically, indigenous holism values the interconnections of the self to the animate and inanimate, as well as the metaphysical relationships within and between the physical, emotional, cultural/social, and intellectual realms. It also focuses on the interrelationships of the individual to family, community/nation, and lands/waters and indigenous governance (Mwinzi, 2015; Coates *et al.*, 2022). Indigenous research practices are based on respect for indigenous ways of knowing and being, relevance to the community/nation, reciprocity in research processes, and responsibility in the relationships between researchers and the community. Additionally, indigenous research methods provide guiding principles on how one should be working with indigenous peoples, which include identity and respect for indigenous knowledge (Absolon, 2016 ; Pidgeon and Riley, 2021). In line with this, this study used field research approach in the whole process of data collection. The essential idea is that the researcher goes into the field to observe the phenomenon in its natural state (Micheal,2015; Van de Ven, 2017). In the field research approach researcher typically takes continuous extensive field notes which are subsequently coded and analyzed in a variety of ways (Genkova, 2020; Whitney, 2008).

1.2.1. Sampling techniques

Similarly, all research subjects and variables under the study were purposively selected to directly reach/explore the major representative samples and quality data in the study area. To easily manage the process of this study, 13 districts of the zone were grouped into six clusters that consist of *Yabello, Teltele, Gomole, Guchi, Dirre and Moyale* based on the proximate of the area to one other for the purpose of this study. Traditionally, Borana Oromo communities and their stakeholders know well experienced weather forecasting elders in the community; and could compare them with their varying capacity including anyone who is more specialized in stars based indigenous weather forecasting. Purposively, selection of the participants and formation of the clusters were undertaken in collaboration with the relevant stakeholders/organizations including GOs, NGOs, community based organization and community representatives at villages, districts and cluster levels, respectively. In this regard, stakeholders were participated in the selection and verification/ratification of research participants with in-depth knowledge of the variables under study.

1.2.2.Data collection

Data were collected through focus group discussions with FGD participants, experimental groups and key informant interview that were held at the aforementioned clusters. Accordingly, 5 focus group discussions, each consists of 12 participants (8 males and 4 females) were involved in data generation. Regarding the experimental groups, 5 groups (clusters) each consisted of 4 participants (a total of 24 participants) of well experienced traditional astronomical weather forecasters were used for gathering data. In addition, 10 key knowledgeable informants (6 males and 4 females) were interviewed. In this regard, in addition to aforementioned research groups; reserve participants including 4 males and 1 female of FGD participants, 5 males and 1 female of experimental groups' participants, and 3 male and 1 female of key informant interview participants were formed to use in case of a probable absenteeism of a given participant due to illness, mobility in search of pasture and water; overlapping duties and, etc.

Accordingly, in the first phase of the data collection 1 female FGD participant; and in the third and fourth phase of data collection 2 females FGD and 2 females experimental groups participants were informed us of their absenteeism ahead of the three days of the start of the data collection, Hence, they were replaced by the reserve participants that were already prepared for this purpose. During data collection, four enumerators who have in-depth knowledge of the variable under the study were participated in all the steps and phases of the data collection after receiving training on the topic of the study. In addition, indigenous ethics: greeting, introduction and up to-date scenario briefing were done at the beginning of the study. Next, opening of the discussion was held with almighty God respect based on blessing by three elders including one woman elder under the shade of the ever-green tree locally known as *oda*. Third, discussion was held with free, fair and equal participation. Finally, at the end of the daily discussion; brief thanks giving to the almighty God was held.

Data were collected in three months lead time of each seasons for three up to five days starting from 9:00 AM to 5:00 PM. The data were collected in four subsequent phases/rounds/seasons; starting from the seasons of *Bona Hagaya* (warm dry season of December to February), *Ganna* (main rainfall season of March to May), *Bona Addolessa* (cool dry season of June to August) and *Roba Hagayyaa* (small rainfall season of September to November) of 2021. According to the local calendar of the study area New Year begin on the first day of December.

FGD interview guides in this research mainly focused on identifying the types of stars, periodical based physical outlooks/color of stars, total number of dates of loss of visibility and (re) observation of stars in the year with in the observable dimension of the night sky in the study area. It also focused on the continuous varied direction of the stars, periodically varied temporal and positional patterns of the stars that are used for weather forecasting in the study area. In addition, alignments and the defects of the alignments of the stars with each Moon on their predetermined night that are counted from the first date of the new Moon and its effects on the future weather phenomena were used to guide the FGD. In connection with this, nature/new Moon emerging driven Borana Oromo's abstractly made 27 day patterns which are reconfigured and varied with in each month of a year and its effects on future weather phenomena were used as FGD guide during the data collection. Furthermore, time lapse between the forecasting, the probable occurrence of the weather events and its role in livelihood decision making process are among the major FGD guides that were used in the data collection of this research.

The details of the data were collected through defining, reading and observation of varied multidimensional outlooks of the weather indicating features of the stars that are continuously varying in their positional and temporal (star-Moon alignment) based reconfiguration patterns. Defining, reading, and observing of the three types of stars that were well-known in the area by the representation of: 1) *Bakkalcha Dheera* (toll star), 2) *Bakkalcha goofoo* (medium stars/venues) and 3) 12 groups of normal stars which are varied in their numbers and group formation patterns were used for main data collection. Abstractly made sequential list of 27 Borana Oromo traditional day patterns of the moon which are periodically reconfigured in chronological order within each of the 12 months of the year are used in the data collection.

In addition, moon day/the day on which each new moon is re-emerge in the night sky and day of the star-moon alignment/defect of the star-moon alignments that are counted from the first date of the new moon, etc., were used in the data collection process. During defining, reading and observing of the features of the stars; ratification of the projection/forecast (mainly normal occurrence of rainfall/severe drought) was established by the research participants upon the interpretation of the future weather indicating features of the moon/stars. Finally, verifications of the accuracy of the future weather phenomena were done against the projection/established forecast of the future weather indicating features of the stars. In this study, data were collected through using semi-structured questionnaires and open ended interview guides.

Ethical consideration: Ethical clearance letter of this study/No/002/2022 was signed and given by Teshome Tefesse (PhD) head of the institutional review board of the college of development studies of Addis Ababa University, Ethiopia. Letter of informed consent was obtained from the research participants who allow publishing and publicizing their data in any possible way without any limitation. It also stated that participants have the right to participate /where necessary not to participate/and to communicate in a language they could speak in the provision of data. In this regard, from the beginning participants know as the data were collected for the PhD dissertation of the correspondent author which could be published in any possible way.

1.2.3.Data analysis

Thematic based qualitative data analysis techniques were used in this research. According to (Bazeley, 2016a ; Nowell *et al.*, 2017; Sgier, 2017; Kiger and Varpio, 2020) thematic analysis allows researchers to undertake familiarization, identify a thematic framework, code, tabulate and interpretate data. In this regard, transcriptions of the data were conducted directly using a laptop computer in each of the four phases of the data collection. In each of the four phases/seasons of data recording similar sets of the enquiry were disclosed to capture new ideas as well as to verify compatibility of the records. Simultaneously, data familiarization, identification of themes and data coding were done to substantiate the classification of theme and patterns of ideas in the process of data interpretation and analysis.

2. Results and discussion

In the process of weather forecasting, Borana Oromo pastoralists regularly define multidimensional outlooks of the astronomic/celestial objects which are displaying varied indicators/signs within a context of changing spatial and temporal patterns. Particularly, alignment/defect of the alignment/, direction, group formation, color/physical features, size, ray, type, and duration of the observation of the stars in the sky are used in weather forecasting. The abstract sequential list of day patterns of the birth of a new moon , (not) ring formation, inclination of each of the new Moons and colour patterns of the Moons are defined and interpreted in the indigenous weather forecast process. Additionally, ring formation, direction/position, size, partial or full eclipse and color/physical features of the sun are regularly defined to indicate either the fortune/challenges of the forthcoming season (Dinsa AB, *et al*., 2022). These are consistent with the studies by Bruchac (2020); Zounon *et al*. (2020) which noted that the indigenous community in Zambia and Benin use plant, animal, historical experiences and astronomical elements to forecast weather. As mentioned earlier this study is focused on the weather indicating features of the stars.

This study discovered that while all members of the community are aware of the types of stars used to forecast weather events and have basic forecasting skills, there are only a few experienced individuals who are qualified to make accurate forecasts. Individuals who are experienced in making accurate forecasts through observing physical and temporal patterns of the stars are locally known as *Heddu* that account for around 1% of the community in the study area. This is consistent with the Hamacher's study (Hamacher, 2014; Hamacher *et al*., 2015) in Australia which posited that a person's ability to accurately read the various changes in the properties of stars can assist them in predicting weather and seasonal change. It also stated that it has application in navigation, time reckoning, food economics, and predicting animal behavior.

According to the current study; three types of stars were used for weather forecasting among Borana Oromo pastoralists of Southern Ethiopia. The local names of these stars were 1) *Bakkalcha dheera* (toll star), 2) *Bakkalcha goofoo* (medium stars/venues) and 12 normal stars which are varied in their quantity or in their group formation from each other. The Borana Oromo communities regularly observe/read weather indicating outlooks of the stars in the sky. This was consistent with the related study undertaken by Explorersclub (2010) on Easter Island's indigenous community that identified 26 different types of stars that are predicting weather phenomena.

This study discovered that these weather indicating stars were classified into three major distinguishing features. These include 1) temporal patterns of the star-moon alignment/defect of the star moon alignment in the night sky; 2) position/direction of the stars in the sky; and 3) physical/colors of the stars. These indicators that were displayed via the features of the stars could reveal a time lapse that were more than/ up to three months lead time ahead of the actual occurrence of the weather and other catastrophic events.

In 2020 and 2021, the Lammi star's alignment with the moon deviated from its predetermined day of November 9th and aligned on November 10th. (Table 3). As a result, the local community believed that the severe prolonged devastating drought that occurred in the study area/the Horn of Africa region in 2021/2022 was mainly caused by flaws in the November 2020/2021 star-moon alignments. Indigenous knowledge-based future weather forecasting, specifically future weather indicating features of the stars, are still used on a daily basis in the study area's livelihood decision making. This is consistent with the study by Elia, (2014) in Tanzania that found the position and number of visible stars were used to foretell phenomena of future season.

Similarly, Aboriginal Australians carefully observe the properties and positions of stars, including both overt and subtle changes in their brightness, for subsistence and social application (Gantevoort *et al.*, 2016). I n addition, according to Gantevoort *et al.,* (2016) ancient Georgian astronomical heritage identified five types of the weather indicating stars in which 1) Tsultokhebi/five stars rise in summer at midnight, 2) Mravalai follows Tsultokhebi as a cluster, 3) Tsiskari/one star rises in summer before sunrise and sets at dawn, 4) Mejoge/ one star/ big star rises after midnight 5) Irmebis Nakhtomi a symbol of an ox and a deer competing with each other. It also stated that in spring Tsiskari, Gutneuli, Jaraebi and Tsultokhebi stars follow Mravalai at a definite distance.

2.1. Weather indicating temporal patterns of the star-moon alignment

This study discovered that the Borana Oromo community of Southern Ethiopia has been reading/defining 12 distinct normal stars that are naturally align in temporal predetermined patterns with the moon in the process of forecasting the magnitude of the upcoming *Hagayyaa* rainfall (September to October) and *Ganna* rainfall season since time immemorial (March to May).These stars are locally called *Lammii, Busaan, Sorsa, Algajim, Arba Gaddu, Walla, Lammii Basaa, Torbaan, Wajjinoo, Angofii, Mataan Gohii* and *Korma Maddo*. The local community revealed that the names of these stars were derived/given in respect to the size/numbers and group formation patterns of the stars. These stars were categorized in to *Ganna (March to May rainfall season)* and *Hagayya* (September to November) rainfall indicating stars.

***Ganna* rainfall indicating temporal patterns of the Star-Moon alignment:** *Lammi, Busaan, Sorsa, Algajim, Arba Gaddu, Walla* and *Lammii Basaa*[13] stars were used for forecasting of the

[13] Lammii and Lammii basaa stars are different stars

magnitude of the *Hagaya* dry season (December to February) and the condition of the upcoming *Ganna* rainfall season (March to May). In this regard, for forecasting of the magnitude of the *Ganna* rainfall season (March to May); star-moon alignment was started in the month of November and ended in the month of March. As shown in Table 3, when the nature based driven star-moon alignments were defected from their predetermined date it will result in severe prolonged drought of *Hagaya* dry period (December to February) and the occurrence of the rainfall anomalies of the upcoming *Ganna* rainfall season (March to May).

Table 14 presents lists of the days of the moon/months which are the benchmark/point of reference for the description of Table 16, which displays the date of the star-moon alignment/defects of the star-moon alignments in the process of weather forecasting in the study area. Even though it is not the primary focus of this study, Borana Oromo abstractly created sequential list of 27 traditional day patterns of the moon that are reconfigured in chronological order within each of the 12 months of the years are also used for weather forecasting (Table 14) . Tables 14 and 15 clarify the Table 16; which presented naturally driven temporal patterns of star-moon alignment which has great impact on the rainfall phenomena of the Ganna season (March to May) in the study area (Dinsa AB *et al*., 2022).

Counting of the first date of the moon/ month: As depicted in Table 14; the counting of the first day for each month/moon in column 3 begin from the first probable day on which each particular moon of that particular month is expected to emerge. Out of 12 moons of the month (Table 14 column 3) nine of them have two probable emerging days which makes them 30 days per month and three of them have three probable bearing days which makes them 31 days per month. In this regard, as depicted in Table 15; for all moon, counting begins from the first probable of their emerging day (Dinsa AB *et al*., 2022). In this regard, see as an example the Table 15 which was derived from Table 14.

Counting of the end day of the Moon/ month: Counting of the days of each particular moon of the month ends on the second probable emerging/born day of the Moon for those of the Moon having two probable day to born/to emerge; and end on the third probable day for those of the Moon having three probable day to emerge (Dinsa AB *et al*., 2022). In this regard, for example November moon/month which was derived from the referee Table 14 is depicted in Table 15.

Table 14. Twenty - seven *Ayyaana*/day/ of the Moon of the year

SN	Name of the 27 *ayyaana*/date of the Moon on whicheach Moon of the month is born	Name of the Moon which is emerge on each month of the year
1	*Gardaduma*	September (*Birraa*)
2	*Sonsa*	
3	*Ruruma*	October (*Ciqawaa*)
4	*Lumasa*	
5	*Gidada*	November (*Sadaasa*)
6	*Ruda*	
7	*Areeri duraa*	December (*Arfaasa*)
8	*Areeri bal'aa*	
9	*Adula duraa*	January (*Amaajji*)
10	*Adula bal'aa*	
11	*Garba duraa*	February (*Guraandhala*)
12	*Garba bal'aa*	
13	*Garba dullacha*	
14	*Bita duraa*	March (*Bitotessa*)
15	*Bita bal'aa*	
16	*Sorsa*	April (*Caamsaa*)
17	*Algajim*	
18	*Arba*	May (*Buufaa*)
19	*Walla*	
20	*Basa dura*	June (*Wacabaji*)
21	*Basa bal'aa*	
22	*Maganata duraa (Carraa)*	July (*Obora Guddaa*)
23	*Maganata jarraa*	
24	*Maganata biritii*	
25	*Salban duraa*	August (*Obora xiqqaa*)
26	*Salbaan bal'aa*	
27	*Salbaan dullacha*	

Source: FGDs, 2021

It can be seen from Table 15 that the November moon emerged on the day *of the Gidada*. The lunar cycle of 1^{st} up to 15^{th} dates of the November Moon (*Gidada up to Walla)* are locally called the light/bright Moon nights of the November Month[14]. The lunar cycle of the 16^{th} up to 30^{th} dates of the November Moon (*Basa dura* up to *Ruda*) are locally called the dark Moon nights of the November month. When it is seen, November moon has only 29 days. However, it has 30 days. In this case, next to the *day* of *Ruda / next to serial number 29* in the hidden phase of the double counting/ there was one full dark night without the Moon visible in the night sky which is

[14]. See remarks on the start and end of the counting dates of the moon a month in this section

locally called *Luwoo*[15] of November Moon/30th date of November. In line with this, because of the November moon has two probable emerging days which consist of *Gidada* and *Ruda /*serial number 1 to 2 in the emerging phase of the Moon/ the total days of the November Moon are 30. The *Diba*[16] (final hardly observable decreased margin in the hidden phase of the moon) of the November Moon was observed on the day of the *Ruda which was represented by the serial number 29 of the column 4 in the Table 15*. The probability of the emergence of the October moon is on the day of *Gidada (serial number 1) or Ruda (serial number 2)*.

In this case, there is a common belief that when the November Moon has emerged on the day of *Gidada* the probability of severe drought in the *Bona Hagayyaa* (December to February) and the scarcity of rainfall in the upcoming Ganna season (March to May) would be very high in the study area. Hence, the study community believed that the devastating drought of 2021/2022 was caused by the anomalous emergence of the November Moon on the day of *Gidada.* Similarly (Lehoux, 2021) found that in ancient Greek new and full moons were used to determine general weather conditions. Mcmillan quoted in (Lorettaa, 2014) revealed that Botswana communities have prominent phonological markers of cultural astronomy that signal the change of the seasons; predict droughts as well as weather related diseases by watching the movements of celestial bodies (Dinsa AB *et al*., 2022).

[15] Full dark night; the night in which there is no moon light
[16] Hardly observable very minimized signs of the moon

Table 15 . Weather indicating temporal patterns of the November Moon

<table>
<tr><th>SN</th><th>Days of the November Moon/emerging phase</th><th>Lunar cycles</th><th>SN</th><th>Abstract cycles/hidden phase</th></tr>
<tr><td>1</td><td>Gidada</td><td rowspan="16">Light month of the moon</td><td>28</td><td rowspan="3">Full dark night</td></tr>
<tr><td rowspan="2">2</td><td rowspan="2">Ruda</td><td>29</td></tr>
<tr><td>30</td></tr>
<tr><td>3</td><td>Areeri duraa</td></tr>
<tr><td>4</td><td>Areeri bal’aa</td></tr>
<tr><td>5</td><td>Adula duraa</td></tr>
<tr><td>6</td><td>Adula bal’aa</td></tr>
<tr><td>7</td><td>Garba duraa</td></tr>
<tr><td>8</td><td>Garba bal’aa</td></tr>
<tr><td>9</td><td>Garba dullacha</td></tr>
<tr><td>10</td><td>Bita qaraa</td></tr>
<tr><td>11</td><td>Bita bal’aa</td></tr>
<tr><td>12</td><td>Sorsa</td></tr>
<tr><td>13</td><td>Algajim</td></tr>
<tr><td>14</td><td>Arba</td></tr>
<tr><td>15</td><td>Walla</td></tr>
<tr><td>16</td><td>Basa dura</td><td rowspan="11">Dark month of the moon</td></tr>
<tr><td>17</td><td>Basa bal’aa</td></tr>
<tr><td>18</td><td>Maganata duraa (Carraa)</td></tr>
<tr><td>19</td><td>Maganata Jarraa</td></tr>
<tr><td>20</td><td>Maganata biritii</td></tr>
<tr><td>21</td><td>Salban duraa</td></tr>
<tr><td>22</td><td>Salbaan bal’aa</td></tr>
<tr><td>23</td><td>Salbaan dullacha</td></tr>
<tr><td>24</td><td>Gardaduma</td></tr>
<tr><td>25</td><td>Sonsa</td></tr>
<tr><td>26</td><td>Ruruma</td></tr>
<tr><td>27</td><td>Lumasa</td><td></td></tr>
</table>

Source: FGDs, 2021

There is a sequential alignment between the Moon and stars on predetermined date which was counted from the re-observation of the very beginning of the first day of that particular moon in the sky (see Table 16). Each moon of the year has its own predetermined date on which it has to align directly with the stars. In this regard, when the alignment of the Moon and the stars are defected from its naturally predetermined date; there will be high probability of the occurrence of the severe drought in the upcoming season. Similarly, in a Kamaroja/Uganda study of Mulegna cited in (Ibrahimm, 2020) argued that the occurrence of clusters of the stars' relationship with the Moon indicate the challenges in the coming season; however, it was not identified the type of stars in relation with the temporal patterns of the Moon.

As shown in Table 16, the nature driven predetermined day on which the Moon was aligned sequentially with the star which was locally called *Lammi was* on 15th September (*Bira*), 12th October (*Ciqawaa*), 9th November (*Sadaasa*), 7th December (*Arfasa*), 5th January (*Amaji*), 3rd February (*Guraandhala*) and 1st March (*Bitotesa*) for indicating the normal occurrence of upcoming *Ganna* rainfall season (March up to May).

The others stars which were locally called *Busan, Sorsa, Algajim, Arba, Walla,* and *Basaa* were aligned on their own predetermined days sequentially with the Moon as depicted in the Table 14. In this regard, if the alignment of the Moon and *Lammii* star; and other stars following *Lammii* on their own day deviated from this nature-driven predetermined date that was counted from the very beginning of the first day of the new Moon, it would result in a postponement of the start of the *Ganna* rainfall (March to May) season, i.e. there would be severe drought in the *Bona Hagaya* (December to February). In this case, from all the stars the one which was making first alignment with Moon was *Lammii* and the other stars were sequentially aligned turn by turn in their nature based pre-determined temporal patterns as displayed (Table 14).

Table 16: Temporal patterns of the star-moon alignment

Name of the late probable day on which the new Moon	Name of the Moon/month	Name of the stars	Date of the alignment of the stars and Moon which was counted from the first probable day of the emerging of the	Days of the Moon on which alignment would be undertaken
Ruuda	November	*Lammii*	9	*Bita qara*
		Busaan	10	*Bita bal'aa*
		Sorsa	11	*Sorsa*
		Algajim	12	*Algajim*
		Walla	13	*walla*
		Arba	14	*Arba*
		Basaa	15	*Basaa*
		Carraa	16	*Carraa*
Areerri Bal'oo	December	*Lammii*	7	*Bita qara*
		Busaan	8	*Bita bal'aa*
		Sorsa	9	*Sorsa*
		Algajim	10	*Algajim*
		Walla	11	*Walla*
		Arba	12	*Arba*
		Basaa	13	*Basaa*
		Carraa	14	*Carraa*
Adula bal'aa	January	*Lammii*	5	*Bita qara*
		Busaan	6	*Bita bal'aa*
		sorsa	7	*sorsa*
		algajim	8	*algajim*
		walla	9	*walla*
		arba	10	*arba*
		basaa	11	*basaa*
		carraa	12	*carraa*
Garba bal'oo	February	*Lammii*	3	*Bita qara*
		Busaan	4	*Bita bal'aa*
		Sorsa	5	*Sorsa*
		Algajim	6	*Algajim*
		Walla	7	*Walla*
		Arba	8	*Arba*
		basaa	9	*Basaa*
		Carraa	10	*Carraa*
Bita Bal''aa	March	*Lammii*	1	*Bita qara*
		Busaan	2	*Bita bal'aa*
		Sorsa	3	*Sorsa*
		Algajim	4	*Algajim*
		Walla	5	*Walla*
		Arba	6	*Arba*
		Basaa	7	*Basaa*
		Carraa	8	*Carraa*

Source: FGDs, 2021

If the November moon was aligned with the *Lammii* stars on the 10th November instead of the 9th November; it would result indelay of *Ganna* rainfall by one month. In order to get *Ganna* rain, lately by one mouth, the Moon of November has to be aligned with *Lammii* stars in the next Moon of literally December 9th; but on a nature dependent normal moon counting basis it was on Moon/month of 9th November (which means a delay of one month).

In this regard, when such defects/events of the star-moon alignment was happening; in the normal Moon counting basis both November and December Moons becomes only one month; the previous November Moon defect was adjusted or aligned on the literally next December Moon/month. This is due to the fact that the November Moon was not aligned with the *Lammii* star on its previous predetermined day. Hence, it will have to adjust or will align on the literally December month; however, in vis-à-vis star- moon alignment and on the sequence of moon counting basis it was November Moon. Star-Moon alignment of November was waiting for the re-adjustment of the November Moon alignment with the *Lammii* star in the next coming December Moon; this situation resulted in little/total failure of 2021*Ganna* rainfall in the study area.

Even if it was known that in normal counting cycle a year has only 12 months, nature based adjustments of the defects of the star-moon alignment could make months of a year 13 or more months. Hence, in order to get rain it is mandatory to wait for the nature based re-adjustments of the star-moon alignments. This causes lack of rain in both *Ganna* (March to May) and *Hagayya* (September to October) rainfall seasons of 2020 and 2021 in the study area. Despite the fact that the concern of the star moon alignment was not raised, similar studies conducted in Australia (Gantevoort *et al.*, 2015; Hamacher *et al*., 2015) posited that indigenous peoples observe the motions and positions of stars to develop seasonal calendars; it also stated that changing properties of stars, such as their brightness and color, were also used for weather prediction.

***Hagaya* rainfall indicating temporal patterns of the stars**: *Torban, Korma Maddo and Wajjinoo: These* stars are used for the forecasting of the *Hagaya* rainfall season (September to October). However, these stars did not align with the Moon like the above stars used for the forecasting of the *Ganna* rainfall season (March to May). In indicating the close of the *Hagaya* rainfall season *Torbaa* star was hidden in the moon of July (*Obbora Guddaa*). In contrast, when this star was not yet hidden in the Moon of July; the upcoming *Hagaya* rainfall (September to

October) would not occur in its normal time or delayed from its usual time. The *Torbii* star was observable in the night sky through the Southeastern direction of Borana; it emerged in the southeast, traveled some distance towards the middle of the sky and set through the north eastern direction of Borana areas. The *Torbi* star was also used for the forecasting of the closing of *Hagaya* and Ganna rainfall season. It was identified through this study that during dusk at 8 – 9:00 PM (in the month of July and August) the *Torbi* star was used/observed for the forecastin of the *Hagaya* rainfall season. Similar studies (Clarke, 2009b; Beardmore, 2013; Hamacher *et al*., 2015) with ethnographic fieldwork in Australias Indigenous peoples; explored the various ways that they utilize stellar scintillation (twinkling) as an indicator for predicting weather and seasonal change.

Wajino and *Korma Maddo* stars were observed in the sky through the western direction; and were used for the forecasting of the *Hagayya* rainfall (September to October). It is common that the *Korma Maddoo* star was slightly covered by cloud in the *Adolessa* dry season (July to August) between 8-9:00 PM. *Furmata* light shower of rainfall (before *Hagayya* rain) would be expected in the*Adolessa* dry season (in July and August) only when this cloud is covering the *Korma Maddo* star from 11: 00 up to 12:00 PM. In this case, it was believed that when the cloud stayed in the full night by covering the *Korma Maddo* star there would be high rainfall in the upcoming *Hagaya* rainfall season (September and October).

In addition, when cloud was covering the *Korma Maddo* star in the month/Moon of June (*wacabaji*) and July (*Obora guddaa*) there would be promising rainfall in the upcoming *Hagaya* rainfall season (September to October). Contrary to this, when the cloud was not covering the *Korma Mado* star in the month/Moon of June and July there will be little rainfall /severe drought in the upcoming *Hagaya* rainfall season (September to October). FGD participants stated that there was no cloud in this mentioned season on the *Korma Maddo* star in 2021 and this resulted in severe prolonged drought/failure of *Hagayyaa* rainfall season (September to October). Directionally, the *Wajinoo* star was located behind the *Korma Maddo* star. In this regard, when more cloud was densely covering the *Wajjino* star than the *Korma Maddo* star; more rainfall will be expected on the direction of the *Wajjino* star than on the *Korma Maddo* star. This was consistent with the studies which argued that the Australians observe the stars to determine the changing of seasons and plan when to fish, plant and harvest accordingly (Clarke, 2009b; Hamacher *et al*., 2015).

2.2. Weather indicating positional/directional patterns of the stars

According to the findings of this study, directional/positional patterns of the stars that vary in location on a regular basis were commonly used in the process of predicting future weather phenomena. These stars are locally called 1) *Bakkalcha Gofoo*, and 2) *Bakkalcha Dheeraa*.

Bakkalcha Gofoo (toll stars): Despite the fact that the study area communities were unaware of it, every aspect of this star defined by the community shares characteristics with Venus . *Gofo* star was observed in the night sky in the western direction during the *Hagaya* rainfall season (September up to October), set directly through the western and hidden from observation for seven days and rose in the east at the eve of the next Ganna rainfall season (March to May). This implies that during such an occasion, the upcoming *Ganna* rainfall season (March to May) was very sufficient. However, when it was hidden for more than seven days without rising in the east, after setting/being hidden through the west direction; it implies that the upcoming *Ganna* rainfall (March to April) will be very little/may not occur at all.

Similarly, when the *Gofo* star (Venus) was visible in the east sky throughout the *Ganna* rainfall season (March to May), it set directly through the east and was hidden from the observable sphere of the night sky in the study area for 30/60/100 days[17] before emerging/rising in the west on the eve of the next *Hagayya* rainfall season (September to October).In this regard, when the *Gofo* star is not emerging /observed in the night sky of the western direction for 100 successive days after setting through the east; implies that the upcoming *Hagayya* rainfall season (September to October) will be poor/ the probability of the occurrence of severe drought is very high. In connection with this, when such events are occurring (when the stars are not observed for 100 successive days in the sky without rising) rain may not sag completely during the forthcoming *Hagayya* rainfall season (September to October). This phenomenon actually happened in the Hagayya rainfall season (September to October) of 2021 which resulted in the devastating Horn of Africa drought of 2021/2022. In contrast to this, when the star is risen in the 60

[17] . Probable duration of dates in which *Gofoo* stars is hidden from observation of the night sky after setting through the eastern direction of the study area in the end of the *Ganna* rainfall season (March to May). When the *Gofo* star is rise/observed in Western direction with in 30, 60 and 100 days after hidden from observation in the east the upcoming *Hagaya* rainfall season will be high, medium and small, respectively.

and 30 days after it was hidden from the observation; this implies that the coming *Hagaya* rainfall season (September to October) will be very promising.

This was consistent with the Ryan, (2013) and Hamacher *et al*., (2015) study that pointed out, observational and positional astronomy were an important and integral component of many indigenous knowledge systems in Australia. Other Similar studies undertaken by Teichelmann and Schürmann , (1840) cited in Hamacher, (2015) supported this current study which revealed that, periodic appearance of particular stars in the night sky was governing seasons in Kaurna traditions. For example, autumn was signaled by the morning appearance of the star *Parna*. The hot season was governed by the Wolta wild turkey constellation and Spring was under the influence of Wilto eagle star. Winter rainy season was not associated with any particular star in the record. This study was also consistent with Scofield, (2010b) and Fuller (2020) which stated that the full synodic cycle of Venus, the cycle of the relationship between Venus and the Sun consists of two primary phases that we know as the morning and evening star. This current study is also supported by the studies of Simonia *et al*., (2008), Scofield (2010b) and Hamacher (2019) on Gregorian Mesopotamian and the Mayan astrologers which confirmed that these celestial phases have influences on terrestrial phenomena such as rainfall, food supply, outcome of wars, and on all human affairs.

Borana Oromo community has a belief that all aspects of the favorable conditions locally called *Finnaa* which include success of fertility, timely occurrence of rainfall, and availability of pasture, etc. were promising when the *Gofo* star was observable in the night sky than compared to when it was hidden. This was consistent with the study of Norton-Smith and Star, (2013) undertaken on Minnesota American red Indian indigenous communities which pointed out the cyclical positional patterns of the Venus star that reside in the east at sunrise for nine months and then in the west at sunset for the following nine months. It also stated that Venus was associated with abundance, fertility, growth, death and rebirth. The pattern repeats in a nine-month cycle. In addition Norton-smith *et al*. (2016) found that Mayan and American indigenous communities associated Venus with abundance, fertility, growth, death andrebirth.

In contrast to this, when the *Gofo* star set and rose in the west/east in the epoch ofthe rainfall that particular rainfall season was believed to be very promising in all dimensions. While when the Gofo star was set and rose in west/east during the dry period; there would be an occurrence of severe drought in that particular dry season. When the *Gofoo* star is sets through the eastern in the months of January, February and April there will be occurrence of drought in the *Ganna* rainfall season (March to May). When the *Gofoo* star was risen in the brown cloud through both directions there will be an occurrence of drought which will result in mass death of livestock. This was consistent with the Hamacher *et al*., (2015) who state that particular asterisms or bright stars that rise or set at dusk or dawn foretell changing seasons and are often portrayed as important ancestral figures in indigenous creation stories.

The length of the normal July dry season (June up to August/September) which was locally known as *Bona Adolessa* was three months and the length of the winter dry season (end of November up to early February) which was locally known as *Bona Hagaya* was three month. *Hagaya* rainfall started to sag after the emergence of the Moon of the *Obora Xiqqaa*. When the *Gofo* star had emerged and disappeared from observation in the month of *Obora xiqqaa* (Augst), *Hagaya* rainfall was not sufficient and resulted in shortage of the water and pasture. When the *Gofo* star emerged in the month of the *Birra* (September) and disappeared from observation in the month of the *Onkololessa* (October) or in the month of *Sadaasa* (November); it was indicated that the *Hagaya* rainfall (March to October) would be good; and no drought problem.

2.3. Weather indicating physical/colour patterns of the star

Bakkalcha Dheeraa: It provides very little indication about weather forecasting. It rises and also sets through the western direction. Prior to a week or before two weeks of rainfall the physical colour of this star is looks shine, bulged, shivering, and whiting, however, when rainfall is not close to occur it appeared shrinking, full of dust/not shining. This is consistent with the studies of Clarke (2009b) and Hamacher *et al*. (2015) who found that the visible properties of stars, such as their color, brightness, changes in brightness, and relative positions with respect to the horizon all have special significance and applications to seasonal and traditional law and social structure.

2.4. Seasonal weather indicating features and its implications on livelihood decision making

In this study, it was discovered that the local community in the study area has long trusted indigenous weather forecasting practices, particularly in the role of seasonal weather indicating features of the stars in drought resilience. The study discovered that in the ordinary pastoral mode of life, daily livelihood activities such as water and pasture land management, mobility, herd splitting, herd diversification, social support, livestock selling, and opportunistic crop farming are carried out based on indigenous weather/drought forecasting information, which is found particularly through the definition of weather indicating features of the stars. Furthermore, they frequently use and believe in its role in disaster risk reduction, such as drought, flood, disease/pest outbreak, and local conflict. In this regard, forecasting based on weather indicating features of the stars is accurate and trusted in the study area's livelihood decision making process.

Similarly, Studies in Zimbabwe (Shoko and Shoko, 2017) revealed that livestock numbers, water resources and pasture management all depend on indigenous weather forecasts and in particular, rainfall forecasts. A Study in Benin (Zounon *et al*., 2020) pointed out that, populations in the arid region have adapted to extreme climatic events, especially severe drought through their indigenous knowledge systems. In addition, this is consistent with the study in Canada which revealed that indigenous people use the sensitivity of celestial change to read critical signs from the environment that something unusual was happening. It also stated that indigenous knowledge includes processes that allow knowledge holders to adjust and modify their actions in response to environmental change (UNESCO, 2009).

This study also identified/confirmed that when a given Borana household/community lacks/fails to use indigenous drought information, they may fail to implement appropriate drought risk reduction measures such as feed, food, and water preparation for a severe prolonged drought period. Furthermore, if a particular household does not mobile to safe area and/or sell their livestock prior to the occurrence of severe drought by using IK drought forecast information (due to a failure to use IK weather information), they will lose all or some of their livestock.

Although all members of the community (including children and women) may have basic forecasting skills, they do not have equal capacity, i.e. there are differences in forecasting accuracy among individuals. Individuals who have mastered defining physical and temporal patterns of the stars in the process of forecasting future events such as weathers are locally known as "Heddu." Currently, mobility, restrictions, severity of the drought, weakening of traditional institutions, abandonment of traditional lifestyles, and the death of knowledgeable elders have put into question the potential effects of indigenous weather forecasting indicators of the stars among Borana pastoralists.

Studies of ancient Greek weather signs (Beardmore, 2013) disclose that popular-practical astronomy originates before the beginnings of writing, and gained particular traction in Babylonia, where it is known to have taken place in systematic observations of celestial and meteorological phenomena. It further stated that astro-meteorology as connected to the weather, began life bound up with time-reckoning and specific activities. In this regard Clarke (2009b) and Beardmore (2013) posited that regularities formed by the motions of celestial objects provided the necessary context upon which many structural symbolic patterns were built to regulate human activities on the earth.

3. Conclusion and recommendation

Conclusion: It is identified through this study that since time immemorial indigenous astronomic based weather forecasting knowledge is the driver of livelihood decision making among Borana Oromo Pastoralists of Southern Ethiopia. Three are types of stars which are used for weather forecasting among Borana Oromo pastoralists of Southern Ethiopia. The local names of these stars are 1) Bakkalcha dheera (toll star), 2) Bakkalcha goofoo (Medium stars/venues) and 12 normal stars which are varied in direction, temporal patterns, quantity or in their group formation from each other's with in a continuum of environmental contexts. These future weather indicating outlooks of the stars are categorized into three major distinctive features/dimensions. These include 1) temporal patterns of the star-moon alignment/defect of the star moon alignment in the sky; 2) position/direction of the stars in the sky; and 3) physical/colors of the stars.

The indicators that are displayed via the features of the stars could reveal time lapses that are more than/ up to three months lead time ahead of the actual occurrence of the weather and other catastrophic events. Indigenous knowledge based future weather indicating features of the stars are still regularly used in every day livelihood decision making in the study area. The study showed that both temporal and spatial dimensions of the forecasting actually happened in Ganna (March to May rainfall), Adolessa dry season (June to September) and Hgayya rainfall (October to November) seasons of 2021 which caused the devastating eastern African drought of 2021/2022.

This study identified that all members of the community could know the type of stars that are used to forecast weather events and have basic skills of forecasting, however, there are few experienced individuals who are qualified in making accurate forecasting. In this case, individuals who are experienced in making accurate forecast through observing physical and temporal patterns of the stars are locally known as ‘Heddu’. Currently, curtailments of mobility, severity of drought, weakening of traditional institution, leaving traditional life style and death of knowledgeable elders have challenged the potential effects of the indigenous weather forecasting indicators of the features of stars among Borana pastoralists.

Recommendation: The following recommendations are drawn from the study for future improvement of IK management related to seasonal weather forecasting in Borana and beyond: strengthening traditional institutions in order to regain and rehabilitate the full functional capacity of the indigenous weather forecasting knowledge. Acknowledging and mainstreaming the indigenous weather knowledge into formal institutional structures and integrating with science to improve its applicability and role in drought resilience. Undertaking detailed in-depth studies, and documenting the findings of each objects in order to preserve and use this body of knowledge in a sustainable manner.

CHAPTER FOUR

Forecasting Seasonal Drought using Spatio-SPI and Machine Learning Algorithm: The case of Borana plateau of Southern Oromia, Ethiopia

Abstract

Drought is a natural phenomenon that occurs in all parts of the World. Hence, drought monitoring and forecasting have been fundamental issue for developing and implementing a proactive drought mitigation plan. In the process of monitoring and forecasting drought occurences; the major decisive factors are drought identification/quantification and selection of appropriate forecasting models. This study modeled seasonal drought forecasting using the Spatio-Standardized Precipitation Index (SPI) data in the Borana plateau of Southern Oromia region of Ethiopia with the techniques of machine learning algorithm. Adjusted native resolution based historical rainfall data of 1981 to 2021 of the study area were used from NASA POWER project climate data repository website in the January 2022. In addition, local meteorological data of Moyale and Yabello districts were collected from Ethiopian national meteorological agency to compare actual and predicted forecast with NASA POWER project climate data. Quantifications of SPI seasonal drought were done using SPEI package with in the RStudio software. The nonlinear outoregressive neural neuron network (NAR network) based Levenberg-Marquardt back propagation algorithm (LMBP) was used to model Spatio-SPI seasonal drought forecasting of some sites in the study area using MATLAB software. The findings of this study within both NASA POWER project climate data and local station data showed SPI 3-months and SPI 6-months ANN based seasonal drought prediction model performance evaluation value of MSE ranged between 0.0022 and 5.5752 which were in the excellent acceptable range of validation. SPI 3-months and SPI 6-months model performance evaluation value of correlation coefficient (R) of all the study sites were above 0.9034 which was also in the excellent range of validation. The study results revealed that ANN modeling could works effectively for forecasting seasonal drought /SPI 3-months and SPI 6-months/ ahead of two months and five months lead times, respectively, in all the districts in the study area. However, unlike NASA data; local station based ANN outputs of the seasonal prediction were not provided same values for each months within in all the historical years under the study i.e, all ANN prediction values of each months in all the years under the study were diferent. This study identified that, actual/observed and ANN based Ganna and Hagayya seasons SPI 3-months and SPI 6-months prediction value of 1981 – 2021 discovered that Borana's zone rainfall seasons on which communities rely for their entire life supporting systems were/ are drought prone seasons.

Key words: SPI Seasonal, RStudio, ANN, Matlab, drought forecast, Borana, Oromia, Ethiopia

1. Introduction

Drought is an environmental stress that originates from a deficiency in precipitation over an extended period of time (Bhuiyan 2000; M. J. Hayes *et al*., 2012). It is a natural recurrent 'climate phenomenon' which occurs in all parts of the world (Wilhite, 2000 ; Wilhite *et al.* , 2007; Deo *et al.*, 2017; Crossman, 2018; Nabipour et al., 2020). However, drought is becoming too severe in all dimensions; and has causing a far-reaching adverse impact across all sectors (Jenkins, 2011; IPCC, 2013; Shad *et al*, 2017). It has negative impacts on agriculture, domestic water use, hydrology, hydropower, economy, social systems, ecology and environment, trade, transport, healthy, education, transport and, etc., (Mariotti *et al.*, 2013; Krakauer *et al* ., 2019) . Drought has become one of the most severe climate events that need to be mitigated to reduce its negative impacts (Dyn *et al.,* 2007; Achour *et al.* 2020).

Hence, drought monitoring and forecasts are becoming fundamental for developing and implementing a proactive drought mitigation plan (WMO 2006; Deo *et al*., 2017; Nabipour *et al*., 2020). Furthermore, probabilistic and risk-based drought monitoring and prediction information is not only useful for mitigation, but is also vital for successful drought relief management during an extreme event (Santos *et al*., 2009; Brust *et al.*, 2021)

Drought prediction has been a challenging techniques owing to its complexity with diverse origins and occurrence at different temporal and spatial scales (Karavitis *et al.*, 2011; Shad *et al.*,2017; Kaimkhani *et al.*, 2021). In the process of drought monitoring and forecasting, the first and the most deceive factors are drought identification and quantification (WMO 2006; Nabipour *et al.*, 2020). Among the available drought indices; standardized precipitation index (SPI) developed by (Mckee *et al* ., 1993) are widely used, especially, for meteorological drought quantification across the world (Parvaze *et al*., 2016) [5]. Standardized Precipitation Index (SPI) expresses the actual rainfall as a standardized departure with respect to rainfall probability distribution function and permitted comparisons across space and time (*WMO, 2006*; Di and Bonaccorso, 2007).

The computation of SPI requires long term data on precipitation to determine the probability distribution function which is then transformed to a normal distribution with mean zero and standard deviation of one (Bhuiyan, 2000 ; Parvaze *et al.*, 2016; Peña *et al.*, 2020). Thus, the values of SPI are expressed in standard deviations, positive SPI indicating greater than median precipitation and negative values indicating less than median precipitation (McKee, 1997). However, at different locations; SPI could not correspond to the same deficits or surplus of precipitation (Guttman, 1999a; Di and Bonaccorso 2007). This means that SPI is site-dependent and an absolute drought comparison among sites can be done through a deepened spatial analysis that takes the evolution of the characteristics of drought, namely: duration, severity and intensity into account (WMO, 2012 ; Koem *et al*., 2019; EDO, 2020).

The most fundamental factor in drought forecasting is the selection of appropriate forecasting methods/ model (Nabipour *et al*., 2020; Gallardo *et al.*, 2021; Yaseen *et al.*, 2021). Generally, three methods have been used for drought prediction: statistical, dynamical, and composite/hybrid methods (Singh, 2011; Hao *et al.*, 2018; Bolen *et al.*, 2021)). The statistical prediction method uses empirical relationships of historical records which is difficult for solving practical application issues in non-leaner time series data for prediction (Santos *et al*.,2009; Alawsi *et al*., 2022). Hence, the complex character and non-linearity of the drought/ rainfall data require methods that can simulate non-linear time series data (Hassanzadeh *et al.*, 2014; Arnone *et al*. 2020 ; Yaseen *et al.*, 2021). In this regard, with the increased computational capability and improved understanding of climate, drought prediction has been tackled more with state-of-the-art general circulation models (GCMs), which provide drought prediction based on the physical processes of the atmosphere, ocean, and land surface (Hao *et al.*, 2018; Kasahara and Washington, 1967; Fajardo *et al.*, 2020). The past decade has also witnessed the development of conceptual prediction methods that combine forecast from both statistical and dynamical methods (Emine, 2021; Hamarash *et al*., 2022).

Drought forecasting systems use models fed by climatic and atmospheric data to predict the probability of a drought occurance in a region or area of interest (UNEP, 2017; Hao *et al.*, 2018; Doshi, *et al*., 2022). Machine learning algorithms/hybrid methods/ for example, artificial neural networks (ANNs) (Shad *et al.*, 2017; Iván *et al.,* 2018) are used to predict drought using drought indicators such as the Index (SPI) as input data (Bordi *et al*., 2005; Arnone *et al.*, 2020). ANN is a mathematical model based on biological neural neuron networks (Moller 1990; Kuo and Huang, 2018; Lv *et al*., 2018; Farizawani *et al.*, 2020). In most cases, an ANN is an adaptive system that changes its structure based on external or internal information which flows through the network during the learning phase (Shad *et al.*, 2017; Yotov *et al.*, 2020).

In more practical terms, neural networks are nonlinear statistical data modeling tools *(Babani et al.*, 2017; Yaseen et al., 2021). Thus, they can be used to model complex relationships between inputs and outputs (Anshuka, 2019). ANN based drought prediction is one of the most well-known method (Deo et al., 2017). Its Parallel processing and its ability to learn the patterns are the main factors that make it popular in drought modeling (Yadu and Shrivastava, 2019; Pregowska and Osial 2021; *Doshi et al.*, 2022). In this study, the SPI, the most widely used drought indicator which is recommended by the World Meteorological Organization was used as an input data for predicting SPI seasonal drought using machine learning algorithm NAR-neural network (WMO, 2006).

Drought is an environmental stress mostly originates from precipitation deficit over an extended period of time; while in certain cases it may result from the anomaly of other variables, such as temperature or evapotranspiration (Kane *et al.*, 2016; Zhong et al., 2020; Nasir *et al.*, 2021; Ayugi *et al.*, 2022). Meteorological drought is measured in terms of days, weeks, months, seasons, years, or decades of precipitation deficit (Salehnia *et al.*, 2017). Mainly, it is the cause of the other three forms of drought and is derived by the pulling effects of the teleconnection with in land, atmosphere and sea surface (M. Hayes *et al.*, 2011; Vicente-Serrano *et al.*, 2022). Hence, definition of meteorological drought is region specific; and is depend on the precipitation anomaly that is deviated from the historical average with in a given geographic area (Palmer 1965; Boustani and Ulke, 2020). This study was focused on the characterization and prediction of the SPI seasonal precipitation deficit/meteorological drought using SPI and machine learning algorithm, respectively.

Drought may occur with multiple processes driving its onset, persistence or recovery, happening at a wide range of time scales (subseasonal/weekly, seasonal, multiyear, or decadal) and across different spatial scales of local, regional, continental, and global (An *et al.*, 2020; Fuentes *et al.*, 2022). Drought is commonly characterized at the seasonal time scale (Karavitis *et al.*, 2014; Gidey *et al.*, 2018).

As mentioned there are several research and operational models that provide drought monitoring and/or prediction information depending on the priority of the forms/types of the drought under concern with in a given area. In this regard, prediction of drought with machine learning algorithms through using SPI based drought characterization as input data were done in America

(Xu and Mo, 2019; Bolen *et al.*, 2021; Brust *et al*., 2021) Iran (Hassanzadeh et al., 2014; Dastorani and Afkhami 2015), Algeria (Bhuiyan, 2000; Chour *et al.*, 2020), Brazil (Celso, 2009) , Pakistan (Ali *et al.* , 2017), Kenya (Raphael et al., 2014), Awash basin of Ethiopia (Belayneh and Jan Adamowski, 2013), upper blue Nile basin of Ethiopia (Mulualem and Liou, 2020), Botswana (Byakatonda *et al.*, 2016), etc.

According to (IPCC, 2013; De Sherbinin; 2016 Kuwayama *et al.*, 2019), drought affected an average of 53 million people each year. Each year, the United States suffers losses of six to eight billion dollars as a result of droughts (Santos *et al.*, 2009; Jenkins, 2011) . Lin et al. (2013) and Yu et al. (2018) mentioned that drought is also a major natural disaster in China, with its frequency reaching 70% in certain places during the summer and with enormous socioeconomic losses.

In Africa recurrence of each drought episode in 2-3 years in different scale, location and time was resulting in aggregate damage of up to 25 per cent of each country's GDP (AU, 2015; Richman *et al*., 2016). In Ethiopia in the past half a century new wave of drought was occurring before people/livelihood sources/systems were becoming recovered from the previous adverse impacts of drought (Magarsa *et al.*, 2020; Muche 2022; Haile *et al*. 2022). According to study by (Salifu, 2020) Borana pastoralists lost more than 70 per cent of their livestock during the severe drought of the 2011 and 2016. Drought has also agrvated rangeland degradation, expansion of invasive species, water scarcity, and negative terms of trade, and food insecurity. The adverse impacts of drought in the study area has exacerbated by the lack of area specific appropriate drought forecasting information which allow early preparedness to minimize its negative impacts in advance. Hence, objective of this study was to model Spatio-SPI seasonal drought forecasting using machine learning algorithm in the Borana plateau of southern Oromia region of Ethiopia.

1.2. Research methodology

This study used standard precipitation index (SPI) and Artificial neural network (ANN) to characterize and forecast SPI seasonal drought in the study area, respectively, by using historical rainfall data from 1981 up to 2021.

In this regard, this study used native resolution based NASA POWER project climate data. In this study, NASA power project climate data were preferred due to the fact that the data/parameters in POWER Release 901 are provided on a global grid with native resolutions equal to the input data/it provides original insitu agrometeorological data which are not synthetic second hand data/. Prediction of world energy resources (POWER 901 Release) is also not only builds upon the data portal established with Release 8, but it also adds more recent data releases from NASA's GEWEX SRB Release 4, CERES SYN 1^0, and FLASHFlux Version 4A. The spatial resolution is 1.0° latitude by 1.0° longitude for the radiation data sets and ½° latitude by ⅝° longitude for the meteorological data sets. The grid reference system is WGS84 https://power.larc.nasa.gov/data-access-viewer/.

In this regard, monthly rainfall data of Yabello ($4^0$91'60'' N latitude and 38^0 12' 52'' E longitude, at an elevation of 1549.25 meters), Dirre ($4^0$10'01'' N latitude and $33^0$27'62'' E longitude at elevation of 1174.4 meters), Dilloo ($4^0$13' 84''N latitude and $37^0$47'15''E longitude at elevation of 772.1 meters), Guchi ($4^0$33'97''N latitude and $39^0$58'77'' E longitude at elevation of 1053.85) and Moyale ($3^0$53'83'' N latitude and 39^0 09'20'' E longitude at elevation of 903.8) were retrieved from Native resolution NASA power project climate data with adjusted missed data/the value for missing source data that cannot be computed or is outside of the sources availability range is -999 https://power.larc.nasa.gov/data-access-viewer/. NASA/POWER CERES/MERRA2 Native temporal Resolution are available in hourly, daily, weekly, monthly, annual and climatology basis (month/day/year): 01/01/1981 up to now/https://power.larc.nasa.gov/data-access-viewer/).

1.2.1. Standard precipitation index (SPI)

The SPI based drought classification was used in this study to characterize seasonal drought phenomena and to model ANN based SPI seasonal drought prediction in the study area. SPI was computed at multiple timescales. It was developed by Mckee et al. (1993) and Edwards and McKee (1997) to quantify precipitation anomaly with respect to long-term normal conditions for multiple time scales. It uses monthly precipitation aggregates and has been widely applied in many studies (Vicente-serrano, 2006 ; Vicente-Serrano et al. 2010). Mckee *et al*. (1993) defined the Standardized Precipitation Index (SPI) often called the z score as the number of standard deviations that cumulative rainfall differs from the historical climatological average and has been used as a tool for monitoring and defining drought. SPI can be calculated at various time scales on which precipitation deficits/ surpluses/ can affect different aspects of the hydrologic cycles (drought and flooding) (Edwards and McKee, 1997; Kumar et al. 2009. Positive and negative SPI values indicate wet and dry conditions, respectively (Mckee et al.,1993; Guttman 1999b). A drought event starts when SPI value reaches negative and ends when SPI becomes positive again (Mckee *et al.*, 1993). SPI reflect the natural lags in response to different water sources, such as river discharge, underground and reservoirs storage, snow pack and to precipitation anomalies (M. Naresh *et al*., 2015; Mehdi et al., 2019).

As an illustration of the procedure, for a 3-month time scale, the precipitation accumulation from month j-2 to month j is summed and attributed to month j . At this time scale, the first two months of the data time series are missing (Edwards and McKee, 1997; IES - CRM Unit, 2013). Next follows the normalization procedure, in which an appropriate probability density function is first fitted to the long-term time series of aggregated precipitation (Guttman, 1999a ; WMO, 2012; IES - CRM Unit, 2013). Then the fitted function is used to calculate the cumulative distribution of the data points, which are finally transformed into standardized normal varieties. This procedure is repeated for all needed time scales. The most commonly used distribution for SPI calculation is the two-parameter gamma distribution with a shape and scale parameter ((Angelidis et al., 2012; Pieper *et al.*, 2020; Zhang and Li 2020). Gamma distribution is used to fit to the frequency distribution of precipitation summed over individual month (for various time scales), which is defined by its probability density function:

$$g(x) = \frac{1}{\beta^{\partial}\Gamma(\partial)}\ \chi^{\partial} e^{-1_e} \quad \frac{\chi}{\beta} \qquad for\ \times > 0 \qquad (1)$$

Where the probability density function is given by $g(x)$, ∂ is the shape parameter (β>0) β is a scale parameter and (σ > 0), and

$$\Gamma(\partial) = \int_0^{\partial} y^{\partial-1_e}{}^{-}1_{dy}\ - 1_{dy} \qquad (2)$$

$$\Gamma(\partial)\ is\ the\ gamma\ function$$

The parameters σ and β are assessed as follows:

$$\partial = \frac{1}{1\,A} + (\ x = 1 + \frac{\sqrt{1+4A}}{3}\ ) \qquad (3)$$

$$\beta = \frac{\times}{\partial} \quad (4)$$

$$A = \mathrm{ln}(\dot{x}) - \frac{\sum \mathrm{ln}(\ddot{X})}{n} \quad (5)$$

Where n is the number of precipitation observations and x is the arithmetic mean over the analyzed time scale. A cumulative probability G(x) of an observed quantity of rainfall in each month and time scale (if α and β estimators were used to integrate the probability density function with respect to x) is computed as follows:

$$G(X) = \int_0^{\chi} g(\chi)d\chi = \frac{1}{\beta\text{-}\acute{\sigma}}\Gamma(\tilde{O}) \int_0^{\chi} \chi_e^{\acute{\sigma}} \frac{\dot{x}}{\beta} dx \quad (6)$$

The incomplete gamma function is obtained when substituting t for $\frac{\dot{x}}{\beta}$ in the previous equation. However, the gamma distribution function is undefined for x = 0 and q = P(x = 0) > 0; where P(x = 0) is the probability of zero precipitation. Therefore, the actual probability of non-exceedance H(x) should be computed as follows

$$H(x) = q + (1 - q)G(x) \quad (7)$$

where q is the probability of x = 0. If m is zero in a sample of size n, then q is calculated as

$$q = \frac{m}{n} \quad (8)$$

Finally, to compute the SPI, the cumulative probability distribution H(x) is standardized to a normal variable Z ~ N(0,1). Taking into account the SPI yielded results, the classification of wet or drought periods is shown in Table 17 as stated by (Mckee *et al.*, 1993)

Table 17. Classification of standardized precipitation index values.

SPI Value	Class
≥2.0	Extremely wet
1.5 to 1.99	Severely wet
1.0 to 1.49	Moderately wet
−0.99 to 0.99	Near normal
−1.49 to −0.99	Moderately dry
−1.99 to −1.49	Severely dry
≤2.0	Extremely dry

Source: Mckee *et al.*, 1993

Since changes in precipitation have influence in many aspects of the hydrologic cycle, several time scales are used for SPI computation. The 3-month SPI value describes short- and medium-term moisture, the 6-month SPI value describes droughts that affect agriculture, and the 12-month SPI describes droughts affecting water supply reservoir levels.

In this study, *Ganna* (March to May) and *Hagayya* (October to November) seasons SPI (SPI 3-months and SPI 6-months) were computed to characterize drought phenomena in the Borana plateau of Southern Oromia region of Ethiopia to prepare SPI based input data for machine learning algorithm based drought forecasting.

This study set up an input file containing precipitation data tabulated with 3-column format: Year, Month, and Monthly Precipitation Value. In this regard, due to the difficulty of manually calculating SPI values, various computer programs have been developed for this purpose. This study used the 'SPEI' package for SPI computation. The 'SPEI' package is a library of R system 4.1.1 (Beguería *et al*., 2017). In this, regard, both system and packages are available at the Comprehensive R Archive Network (https: //www.cran.r-project.org/ accessed on 30 January 2022). Next to this, SPEI package in RStudio software was used to calculate the SPI 3-months and SPI 6-months to characterize drought situation in the study area.

1.2.2. Artificial neural networks (ANN)

In the majority of cases, time series applications are characterized by high variations and fleeting transient periods (Santos *et al.*, 2009 ; Alawsi *et al.*, 2022). This fact makes it difficult to model time series data using a linear model, especially, the complex interaction in the hydroclimatic system cannot be characterized by linear models (Hassanzadeh *et al*., 2014; Arnone *et al*. 2020 ; Yaseen *et al*., 2021) . Hence, artificial Neural Networks (ANN) was initially proposed by McCulloch and Pitts (1943) to analyze problems with variables of a non-linear or stochastic nature. ANN is a computation paradigm of complex networking system that attempts to mimic the neural connections in the brain (Deo *et al*., 2016 ; E Surmaini1 *et al.*, 2019;Deo, *et al.*, 2016; Das et al. 2016).

Artificial neural networks helps to understand the brain, human cognition, and perception and have been proven to be successful for solving different problems in pattern classification, decision making, and predicting (Gonzaga *et al.* 2016; S.Sapna *et al.*, 2012; Celso *et a., l* 2009;Hassanzadeh, Ghazvinian, and Abdi 2014). In this regard, ANN Network has been frequently used for predicting and modeling nonlinear time series data, especially, in modeling climatological and/ or hydrological, ecological, weather pollution, energy and water consumption, wind speed, marketing price data, stock data, health data, and etc. (Sundararajan *et al.*, 2021 ; Wambua *et al.*, 2014; Gonzaga *et al*., 2016).

Through time, many algorithms have been proposed to find optimum structure of the network, but none of these methods guaranteed the optimal solution of the parameters for all types of forecasting problems (Yotov *et al.*, 2020 ; Katip, 2018) . There are no hard and fast rules prevailing the correct structure of a neural network (Yadu and Shirivastava, 2019, ; Pregowska and Osial 2021 ; Doshi, Shanmugam, and Akib, 2022). Important factors such as the number of inputs, the number of hidden units, and the arrangement of these units into layers are often determined using trial and error methods or fixed in advance according to the subjective opinion of each individual designer(Bazrkar & Chu, 2022).

The procedure for MLPNN consists of four parts: (i) Variable selection, (ii) formulations of training, testing, and validation; (iii) Architecture and (iv) Model verification and forecasting (Z. Liu *et al.*, 2018; Anshuka, 2019 ; Yadu and Shrivastava, 2019). This emplies that choosing variable for training, testing, and validation is done by software itself (Moller, 1990; *Nawi et al.,* 2013 ; Lv *et al.*, 2018; Xu and Mo, 2019)

Hence, this research used non-linear autoregressive neural networks (NAR), which are to forecast samples framed in a one-dimensional time series. A nonlinear autoregressive neural network applied to time series forecasting, describes a discrete, non-linear, autoregressive model that can be written as follows (Sapna, 2012; Nawi *et al.*, 2013; Gonzaga *et al*., 2016) :

$$(y(t) = h(y(t-1),(y(t-2), \dots ,(t-p))t \,\epsilon\, (t) \tag{9}$$

This formula describes how a NAR network is used to predict the value of a data series y at time t, y(t), using the p past values of the series. The function h(·) is unknown in advance, and the training of the neural network aims to approximate the function by means of the optimization of the network weights and neuron bias. Finally, the term ϵ (t) stands for the error of the approximation of the series y at time t. The topology of a NAR network is shown in Figure 1a and b. The p features y(t−1), y(t−2), . . . , y(t−p), are called feedback delays (Sapna, 2012 ; Trifonov *et al.*, 2017 ; Kuo and Huang , 2018). The number of hidden layers and neurons per layer are completely flexible, and are optimized through a trial-and-error procedure to obtain the network topology that can provide the best performance (Sapna, 2012). Nevertheless, it is important to bear in mind that increasing the number of neurons makes the system more complex, while a low number of neurons may restrict the generalization capabilities and computing power of the network (Nawi *et al.*, 2013; Lv *et al.*, 2018). Schematic structures of NAR neural network is depicted in figure 3 (a and b).

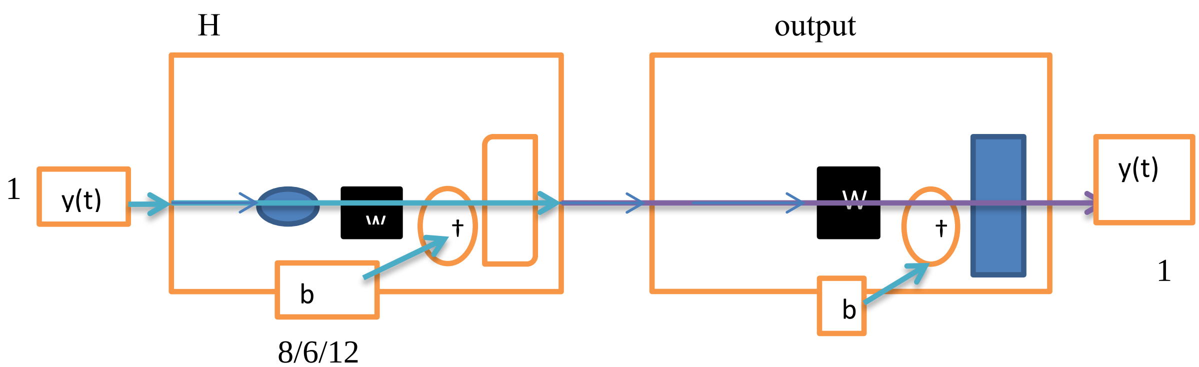


Figure 3 (a). Schematic structures of NAR neural network (Benrhmach *et al.*, 2020). H stands for hidden layers

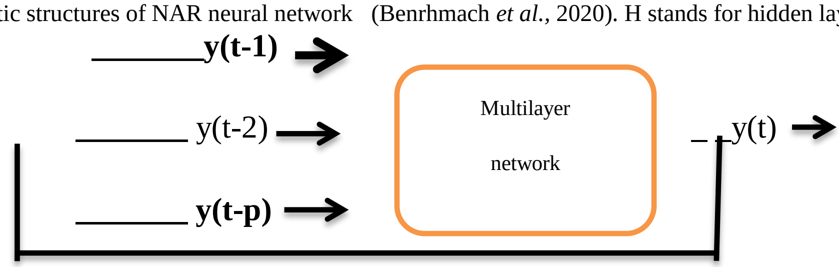


Figure 3(b). Schematic structures of NAR neural network (Lv *et al.*, 2018)

In this study, NAR neural networks were used to model drought forecasting as follows: the network structures contains one input (SPI seasons/SPI 3-months and SPI 6-months) at time t−1, y(t−1), and one output (the next value of the time series, y(t), to be predicte d). The number of delays is set experimentally after a data pre-processing and analysis stage. In this regard, this study used and compared three different combinations of ANN-NAR networking structures in which each represent 1 input layer, 8/6/12 hidden layers and 1 output layer that were constitutes (1,8,1); (1,6,1) and (1,12,1) to identify the model output/ forecast/ that meet the best validation criteria in seasonal drought prediction using input data /SPI 3-months and SPI 6-months/ of the study area which was retrieved and computed from NASA raw climate data at native resolution.

This study used the most common learning rule for the NAR network which is the Levenberg-Marquardt back propagation algorithm (LMBP) (Nawi *et al.*, 2013; Lv et al. 2018). This training function is often the fastest back propagation-type algorithm. The division of the historical time series data in this study was 70% for the training, 15% for the validation, and 15% for the testing. Randomly, 490 data samples were divided into 342 data for the training, 74 data for the validation, and 74 data for the testing.

Finally, this study used two criteria to evaluate the performance of the neural network forecast model. The Mean Square Error (Bolen, 2021) calculated as:

$$MSE = \frac{\sum_{i}^{n} (y_{i} - \acute{y}_{i})^{2}}{N} \tag{10}$$

Where, N is the number of times, y_i and $\acute{y}_i$ are the observed and predicted SPI i th, respectively. The best MSE value is 0 which is mostly unlikely.

The performance of the forecasts from the data-driven models was evaluated. The Pearson correlation coefficient is one of the most commonly used performance in selecting proper inputs for the ANN (Saccenti et al., 2020; Waldmann, 2019; Mukaka, 2012). Correlation coefficient is described as the degree of correlation between the empirical and modeled values (Eq. 10):

$$R = \frac{\sum_{1}^{N} (y_{i} - \acute{y}_{i})^{2} (y_{mi} - \acute{y}_{m})^{2}}{\sqrt{\sum_{1}^{N} (y_{i} - \acute{y}_{i})^{2} \quad \sum_{1}^{N} (y_{mi} - \acute{y}_{m})^{2}}} \tag{11}$$

Where y_i and y_{mi} enounce the network output and measured value from the ith element; $\bar{y}$ and $\bar{y}_m$ conceive their average respectively, and N describes the number of times. The best R value is 1 . In this study, all the ANN drought forecasting model was done with in the MATLAB ANN toolbox.

2.Results and discussion

Historical Rainfall data (1981 – 2021) was subjected to SPI 3-months and SPI 6-months departure analysis for identification of drought and the extent of moisture deficit. Actual/observed and ANN based *Ganna* and *Hagayya* seasons SPI 3-months and SPI 6-months forecasting value of 1981 – 2021 discovered that Borana zone was/ is drought prone area. These revealed that there were extreme meteorological and agricultural drought in the aforementioned years during *Ganna* and *Hagayya* rainfall seasons in the study area. Actual/observed and predicted seasonal SPI 3-months and SPI 6-months values of 1981 – 2021 were displayed in

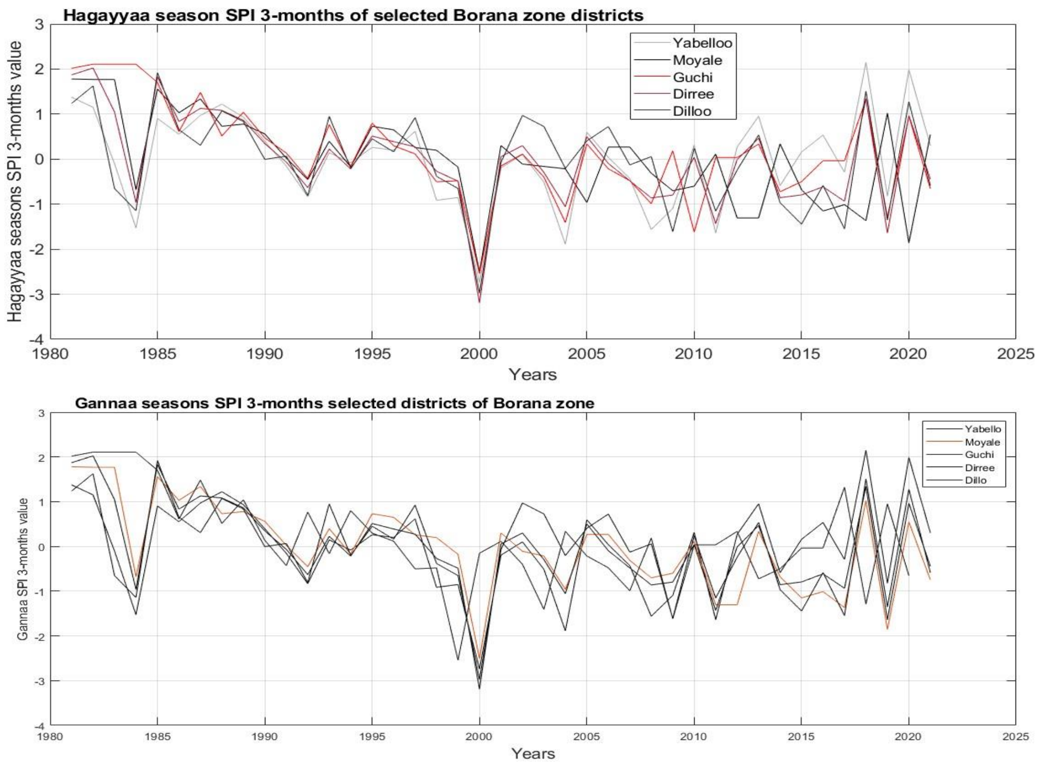
Figures 4, 5, 6 and Tables 18 and 19. Table 18 might used as a reference for making future drought prediction in the study area.

In all study districts with different combinations of ANN architectures/structures which constitutes (1,8,1); (1,6,1) and (1,12,1) in seasonal prediction (SPI 3-months and SPI 6-months) there were no significant differences in values of MSE and R. In this regard, SPI 3-months and SPI 6-months ANN based seasonal drought prediction model performance evaluation value of MSE was between 0.0022 and 5.5752 which were in the best acceptable range of validation. Hence, this current study results show that ANN modeling was works best for forecasting seasonal drought /SPI 3-months and SPI 6-months ahead of two months and five months lead times, respectively, in all the districts.

2.1. Characterization of drought in the study area

Seasonal SPI 3-months and SPI 6-months value of drought characterization finding of this study revealed that there were moderate, severe, and extreme drought in the *Ganna* and *Hagayya* rainfall period in the years between 1981 – 2021 in the study area. *Ganna* and *Hagayya* seasons SPI 3-months and SPI 6-months drought classifications values of Dilloo, Dirree, Guchi, Moyale and Yabello districts of Borana zone are displayed in Figures 4 and 5.

Accordingly, in all the districts in the period between 1981 to 2021 only 1 to 2 out of 41 *Ganna* and *Hagayya* rainfall seasons had received 1.5 up to 2.12 (wet and extreme wet) SPI 3-months and SPI 6-months value. In addition in this study period (1981 to 2021); in all the districts 13 up to 23 out of 41 *Ganna* and *Hagayya* seasons had received -1.49 up to-0.99 (Moderate drought class) SPI 3- month value in the last 41 years. According to *Ganna* and *Hagayya* seasons SPI 3-months and SPI 6-months of this study; drought, severe drought and extreme drought were occurred in *Ganna* and *Hagayya* rainfall seasons of 2000, 2004, 2005, 2007, 2008, 2009, 2010, 2011, 2013, 2016, 2017, 2019 and 2021 with in SPI 3-months and SPI 6-months value of -3.19 to -1.5. Model output showed that major extreme drought was recorded during *Ganna* and *Hagayya* seasons in Dirre in 2000 (SPI 3-months value of -3.19), Dillo in 2000 (SPI 3-months value of -2.97), Yabello in 2000 (SPI 3-months value -2.74), Guchi 1999 (SPI 3-months value -2.54) and Moyale in 2000 (SPI 3-months value -2.51).

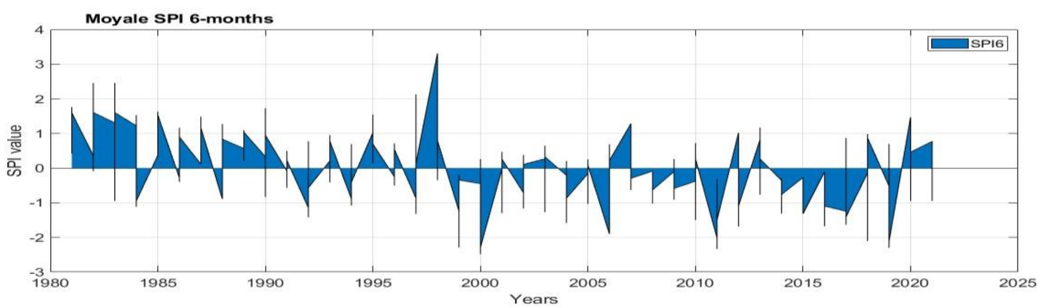


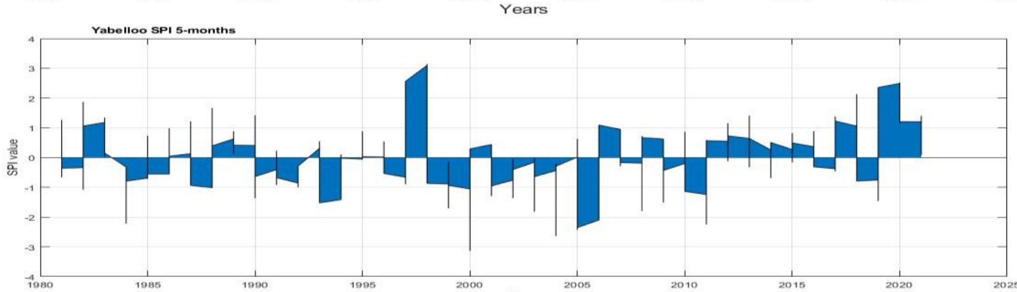
Figures 4. *Gannaa* and *Hagayyaa* Seasons SPI 3-months
Source: own work, data was retrieved from power access project climate data

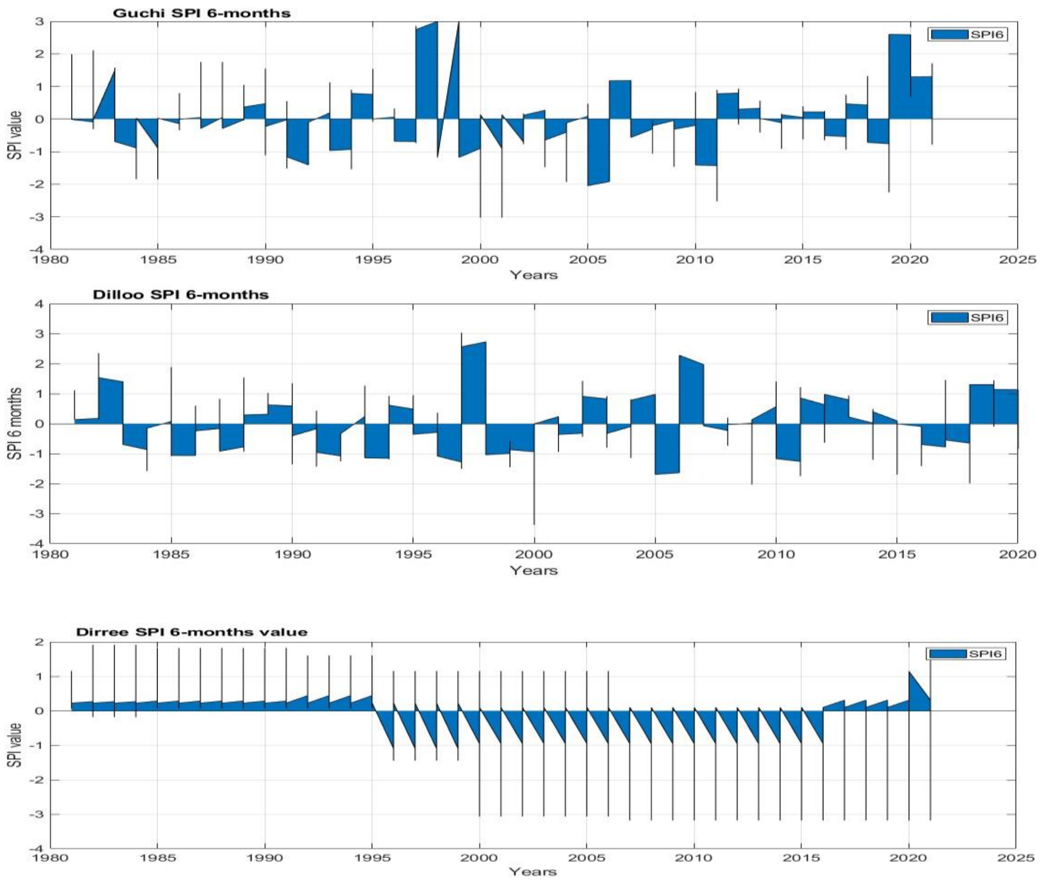
In addition, in this period (1981 to 2021) ; in all the study districts 8 up to 16 out of 41 *Ganna* and *Hagayya* rainfall seasons had received 0.113 to 0.972 (near normal) SPI 3-months value in the last 41 years. The SPI 3-months and SPI 6-months value revealed that 23 *Ganna* seasons SPI 3-months and SPI 6-months (out of 41) in the study area were categorized under moderate, severe and extreme drought. In addition, as it can be seen in figures 3, in all the districts between 1981 to 2021; SPI 6-months drought magnitude was very high when compared with SPI-3 months.

There was drought, severe drought and extreme drought in Ganna and *Hagayya* rainfall seasons of 2000, 2004, 2005, 2007, 2008, 2009, 2010, 2011, 2013, 2016, 2017, 2019 and 2021 with in SPI 6-months value of -4 to -1.5. In general, according to seasonal SPI 3-months and SPI 6-months drought characterization finding of this study both *Ganna* and *Hagayya* rainfall seasons were drought prone seasons in the years between 1981 –2021. These revealed that there were extreme meteorological and agricultural drought in the aforementioned years during *Ganna* and *Hagayya* rainfall seasons in the study area. Hence, designing of multidimensional, interconnected/integrated, and implementation of area specific drought risk management activities are mandatory to minimize the adverse effects of drought on the socio-economy and over all development of the study area.

This is consistent with the study of the (Palmer, 1965 ; WMO 2008 ; Karavitis *et a*l., 2011) that stated 3-month SPI index provides an indication of short- and medium-term moisture conditions, precipitation estimates over a season which is appropriate in agricultural areas to highlight the nature of soil moisture. The 6-month SPI provides an indication of precipitation trends over a season (Kumar and Murthy, 2009; Khan et al., 2008). Study by Guttman (1999a) and Vicente-serrano (2006) found that 3-month SPI specifies short-term as well as medium-term moisture conditions and offers an estimate of seasonal precipitation. A 3-month SPI is more helpful in emphasizing existing moisture conditions of major agricultural regions than many other hydrological indices. Similarly, (*Ahmad et al.,* 2016) used SPI 3-months for the period 1985-2015 to characterize seasonal precipitation in Shalimar, India. Figure 5, depicted the SPI 6-months of the Borana plateau of southern Oromia region of Ethiopia.







Figures 5. SPI 6-months of the study area
Source: Own work, data was retrieved from NASA from power project climate data

2.2. ANN based seasonal drought forecasting

Model results of the seasonal/ANN based SPI 3-months and SPI 6-months drought prediction of two months and five months lead times, respectively of the selected Borana zone districts between 1981 and 2021were displayed in table 2 and figures 4. Table 2, show that the seasonal/the SPI 3-months forecasts output value of medium years SPI 3-months and SPI 6-months input data (10 – 15 years SPI 3-months ANN input data value) were more close to seasonal observed SPI 3-months and SPI 6-months value than the results of long years SPI 3-months and SPI 6-months data (more than 30 years SPI 3-months ANN input data value) . predicted seasonal SPI 3-months and SPI 6-months (ANN based prediction) value showed that the study area was in drought class of extreme, severe, moderate drought, near normal drought and wet in *Ganna* and *Hagayya* rainfall seasons during 1981 - 2021.

Apparently, ANN model output of the SPI 3-months and SPI 6-months seasonal drought prediction were properly signaled observed value of SPI 3-months and SPI 6-months in Dirre, Guchi and Moyale districts than Yabello and Dillo.Yabello and Dillo results demonstrated the differences between the seasonal forecasted value of (SPI 3-months and SPI 6-months) ANN output and seasonal observed value of (SPI 3-months and SPI 6-months) that were derived from historical rainfall data. The differences were resulted from two reasons: 1) as the years from where the ANN input/ SPI months ANN input data were derived is longer; it causes the increase in accumulation of error between seasonal observed SPI 3-months value and seasonal forecasted value which is inevitable, 2) continuous variation in historical seasonal precipitation data hinder the ANN model to simulate it in the predicted SPI 3-months and SPI 6-months value.

This is consistent with the study of (Dastorani and Afkhami, 2015) which found that ANN represent a non-linear system to the nearest possible approximation. In addition, similar studies in USA (Brust et al., 2021) argued that ANN has the capacity to capture different drought types occurring across diverse climate regimes. Furthermore, it is also consistent with similar study in Algeria (Achour et al., 2020) which stated that the best model ANN design results was found to vary from one plain to another and from one-time scale to another. In general, finding of this study discovered that the ANN model based seasonal drought forecast of (SPI 3-months and SPI 6-months) could signals/identify occurrence of drought in two months and five months lead time in the study area.

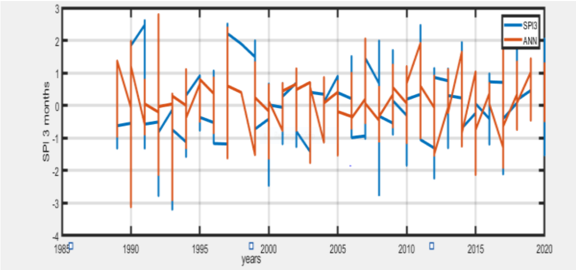
Figure 6. observed and predicted SPI 3-months of 1980 to 2021
Source: Own work/raw data was retrieved from NASA power access project climate

Table 18. ANN output value of modeled seasonal drought, 1981-2021

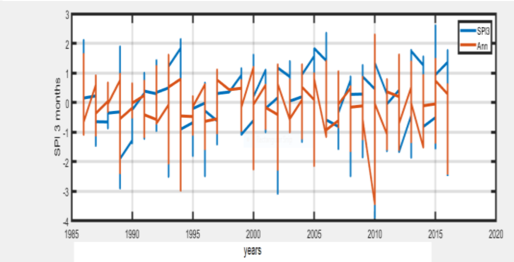
		Period	Jan	Feb	March	Apr	May	Jun	July	Agust	Sep	OcT	Nov	Dec
SPI3	Dilloo	1981 - 2021	-0.013	0.013	0.027	-0.037	-0.021	0.059	-0.057	0.04	-0.017	0.01	-0.002	0.0035
		2008-2021	-1.998	-0.161	-0.971	-1.236	-0.151	0.512	0.525	0.581	-0.342	2.473	-3.902	-0.1246
SPI6		1981 - 2021	0.011	-0.011	-0.015	-0.036	0.035	0.059	-0.108	0.131	-0.101	0.055	-0.025	-0.0011
		2008-2021	-1.902	-0.552	0.897	1.611	0.948	0.737	1.324	0.129	0.412	2.015	-8.887	1.65712
SPI3	Dirree	1981-2021	0.096	-0.185	0.101	0.112	-0.263	-0.032	0.472	0.301	-0.903	0.449	-0.167	-0.0589
		2008-2021	-0.216	0.23	-0.183	0.066	-0.002	-0.168	0.386	0.035	-0.867	0.545	-0.186	-0.0819
SPI6		1981 - 2021	0.004	-0.024	0.057	-0.06	-0.015	0.088	-0.077	0.024	-0.007	0.009	7E-04	-0.001
		2008-2021	0.017	-0.05	0.057	0.054	-0.015	-0.126	-0.035	0.193	-0.22	0.176	-0.065	-0.0111
SPI3	Guchi	1981-2021	-0.013	0.037	-0.079	0.089	-0.052	0.099	-0.177	0.146	-0.048	0.027	-0.006	-0.0023
		2008-2021	0.162	0.479	-0.265	-0.78	-0.337	0.11	-0.01	0.636	2.702	3.98	-7.03	-0.5447
SPI6		1981 - 2021	-0.012	0.025	-0.017	0.009	0.016	-0.052	-0.014	0.108	-0.09	0.025	0.007	3.84E-04
		2008-2021	0.095	-0.541	-0.264	0.082	-0.151	0.033	0.24	-0.969	-0.236	3.87	-1.93	0.68919
SPI3	Moyale	1981-2021	-0.573	0.195	0.378	0.336	-0.613	-0.472	0.895	-0.751	-1.074	1.829	-0.599	0.07129
		2008-2021	-0.041	0.041	0.1	0.033	-0.06	-0.223	0.139	0.294	-0.382	0.181	-0.077	0.0026
SPI6		1981 - 2021	-0.133	0.181	0.008	-0.113	0.088	-0.013	-0.039	0.104	-0.142	0.081	-0.022	0.0094
		2008-2021	0.73	-0.348	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.06114
SPI3	Yabelloo	1981-2021	0.028	0.021	0.038	0.038	-0.051	-0.227	0.023	0.253	-0.173	0.157	-0.044	0.00866
		2008-2021	-0.044	0.089	-0.062	-0.095	0.14	-0.055	-0.012	0.092	-0.141	0.138	-0.063	0.01846
SPI6		1981-2021	-0.039	-0.227	-0.066	0.202	0.08	-0.198	0.297	0.199	-0.63	0.138	0.015	-0.0452
		2008-2021	0.301	-0.299	-0.186	0.305	0.14	-0.852	-0.105	0.616	-0.675	0.442	-0.184	0.00632

Source: Own work, 2022 / data was retrieved from power access climate data

This study also tried to model and compare seassonal drought using local station data of the Moyale and Yabello districts. However, unlike NASA data; local station based ANN outputs of the seasonal prediction were not provided same values for each months within in all the years under the study i.e, all ANN prediction values of each months in all the years under the study were diferent. For example, ANN prediction values of the January months in all the years under the study were different. Hence, this reason made challenge/difficult to model seasonal drought using of the study area local station data. The variation of the ANN model output within the each same month values of the years under the study could be mainly due to the majority of the local station monthly data were with missed data and also with the zero data values. This implies that quality of the data is a decisive factor in modeling seasonl drought.



Figures 6 a : Moyale station data based actual and predicted SPI 3 months/seasonal drought forecast



Figures 6 b : Yabelloo local station based data actual and predicted SPI 3 months/ Sseasonal drought forecast

Source: Own work/data were retrieved from the NMA, 2022.

Apparently, as showed in the figures 6 a and 6 b and also as revealed in the table 20; the same as NASA data ANN could predict local station data with acceptable validation performance.

2.3. Model performance evaluation

In all the studied districts with different combinations of ANN architectures/structures which constitutes of (1,8,1); (1,6,1) and (1,12,1) seasonal prediction (SPI 3-months and SPI 6-months) had no significant differences in values of MSE and R (Table. 2). The SPI 3-months and SPI 6-months ANN based seasonal drought prediction model performance evaluation value of MSE were between 0.0022 and 5.5752 with in the very acceptable range of validation. Dirre site had 5.0456 and 5.5752 values of MSE for long years and middle years SPI 3-months ANN input data, respectively which was in great acceptable range of validation. In line with this, SPI 3-months and SPI 6-months model performance evaluation value of correlation coefficient (R) of all the districts were above 0.9034.

This showed that the model output value mean square error (variation between observed SPI value and ANN based SPI 3-months and 6-months predicted value) was very law and the relation between (R) seasonal input/observed SPI value and seasonal output/predicted SPI value of the model was equally strong for both SPI 3 months and SPI 6-months in all the districts. This implies that variation in precipitation and elevation has no impacts on the forecast performance of the ANN model in the study area. The current study results showed that ANN modeling was works well for forecasting seasonal drought /SPI 3-months and SPI 6-months ahead of two months and five months lead times, respectively, in all the districts. In this study there was no significant difference in forecast effectiveness vis-à-vis of SPI 3-months and SPI 6-months.

This study was not consistent with the study of Belayneh and Adamowski (2013) in Awash valley of Ethiopia which found that forecast effectiveness was increased as the SPI months lead times are increasing. It is also not consistent with the study in Sri Lanka which stated that (Illeperuma & Sonnadara, 2014), when the lead time was increased, model predictions were degraded at each time step into the future. Similar studies in Algeria (Achour et al., 2020) confirmed that the effectiveness of ANN models for predicting monthly SPI and an accurate drought warning system with 2 months lead-time based on meteorological drought information.

Table 19. NAR –ANN model forecast performance validation

SPI	Years	ANN structures	Dillo		Dirre		Guchi		Moyale		Yabello	
			MSE	**R**	**MSE**	**R**	**MSE**	**R**	**MSE**	**R**	**MSE**	**R**
SPI 3	1981 - 2021	1,8,1	0.2159	0.2147	1.38	1.000	0.0066	0.9997	0.0010	0.9999	2.9463	0.9034
		1,6,1	0.4691	0.7513	0.714	0.9971	0.0501	0.9978	0.0365	0.9984	0.0413	0.9994
		1,12,1	0.0760	0.9969	**5.5752**	1.0000	0.0023	0.9999	0.0098	0.9996	0.5214	0,99998
	2008 – 2021	1,8,1	0.0165	0.9997	2.63	1.000	0.0145	0.9995	0.0100	0.9996	0.0016	0.9999
		1,6,1,	**1.9992**	0.9000	5.0456	0,8094	0.0034	0.9999	2.0703	0.9209	0.2182	0.9899
		1,12,1	0.0022	0.9999	0.0251	0.9990	3.3959	1.0000	0.1986	0.9878	4.3271	1.0000
SPI 6	19981 - 2021	1,8,1	0.0043	0.9998	0.0030	0.9999	5.0851	0.9983	1.7085	0.9588	0.0452	0.9980
		1,6,1	0.125	0.9994	0.0424	0.9900	0.0151	0.9993	0.545	0.9980	0.0606	0.9981
		1,12,1	3.0115	1.0000	1.7977	1.0000	4.7756	1.0000	2.0878	1.0000	0.0554	0.9975
	2008- 2021	1,8,1	0.0083	0.9996	0.0110	0.9996	0.0127	0,9995	0.0441	0.9977	0.0098	0.9998
		1,6,1	0.0080	0.9997	0.0080	0.9996	2.3633	0.9334	4.0124	0.9002	0.0093	0.9996
		1,12,1	0.1842	0.9919	0.4592	0.9760	0.0019	0.9999	8.5612	1.0000	0.0013	0.9999

Remark: the three ANN structures represent input, hidden and output layers

Source: own work, 2022 /data was from NASA native resolution power project climate data

This study also compared ANN model performance output of the local meteorological station data of the Moyale and Yabello districts with the NASA POWER project climate data. As it can be seen from the figures 6 a and 6 b and table 20, unlike NASA POWER (prediction of world energy resources) project climate data which had strong correlation; ANN model output performance evaluation showed that there were low correlation between actual and predicted forecast of SPI 3 months of seasonal drought. However, as it is seen from table 20, regarding MSE; there were no significant differences between the ANN model output of the NASA climate data and local station meteorological data.

Table 20. NAR –ANN model forecast performance validation of Yabello and Moyale

SPI	years	ANN structures	Moyale		Yabello	
			MSE	**R**	**MSE**	**R**
SPI3 months	1989 –2020	1-8-1	0.6073	0.6243	0.6519	0.6083
		1-6-1	1.0083	0.443	0.5534	0.7712
		1-12-1	0.8649	0.5759	1.2639	0.4861
SPI 6 months		1-8-1	0.3102	0.8524	0.3701	0.8125
		1-6-1	0.1782	0.8804	0.2647	0.7887
		1-12-1	0.2624	0.8792	0.2334	0.8614

Source: Own work, data were obtained from NMA, 2021

2.3. Conclusion and recommendation

Conclusion: Actual/observed and ANN model based predicted seasonal SPI 3-months and SPI 6-months drought characterization showed that both *Ganna* and *Hagayya* rainfall seasons were drought prone seasons in the years between 1981 –2021 in the study area. Especially, there was extreme drought in *Ganna* and *Hagayya* seasons (SPI 3-months and SPI 6-months) of 2000, 2004, 2005, 2007, 2008, 2009, 2010, 2011, 2013, 2016, 2017, 2019 and 2021 with in SPI 3-months and SPI 6-months value of -4 to -1.5. These revealed that there were extreme meteorological and agricultural drought in the aforementioned years during *Ganna* and *Hagayya* rainfall seasons in the study area.

In addition, finding of this study discovered that the ANN model based seasonal drought forecast (SPI 3-months and SPI 6-months) could signals/identify occurrence of drought in two months and five months lead time, respectively, in the study area. Hence, this current study results show that ANN modeling works well for forecasting seasonal drought /SPI 3-months and SPI 6-months/ ahead of two months and five months lead times, respectively, in all the districts in the study area.

Recommendation: Actual/observed and predicted seasonal SPI 3-months and SPI 6-months drought characterization finding of this study showed that both *Ganna* and *Hagayya* rainfall seasons were drought prone seasons in the years between 1981 –2021. In the study area, there was extreme meteorological drought which is mainly the driver of agricultural, hydrological and economic drought. Hence, in order to minimize adverse effects of drought on the lives and livelihoods of the community in the study area in the future following recommendations are mandatory:

- Providing up to date drought early warning information through continuous drought monitoring and prediction will minimize the adverse effects of drought on the livelihood sources' of the community in the study area.
- Integrated drought risk management/ knowledge based holistic development approach will sustainably minimize the adverse effects of drought in the study area. This includes improving decision making capacity of the local community through provision of information, technology, data, training and extension service concerning rangeland management and development; livestock husbandry and crop farming; expansion of water, irrigation and other infrastructures, social and economic service delivery, fiancé and market, etc.,
- linking local community to production enhancing technologies and digital economies will help to reduce the adverse effects of drought. Hence, designing of multidimensional, interconnected/integrated, and implementation of area specific drought risk management activities are mandatory to minimize the adverse effects of drought on the socio-economy and over all development of the study area, etc.

CHAPTER FIVE

Analyzing Livelihood Resilience Capacities towards Drought Disaster: the case of Borana Pastoral households' of Southern Oromia Region, Ethiopia

Abstract

Resilience is becoming a commonly driver of multifaceted catch-all agenda in all the sustainability and humanity sciences; in science policy interphase and in the formulation and implementation of development polices/program across all level, especially, in response to climate change. Objective of this study was to analyze the livelihood resilience capacity of the Borana pastoralists of Southern Oromia, Ethiopia towards drought of 2016. Data were collected from 290 households of Bulbuli villages/Gololcha of Dirree district and Dambi villages/Dikale of Yabello district in 2020. In the process, districts were purposely selected while villages/Gandas were selected through lottery methods of sampling techniques. In this study, principal component analysis (PCA) method was used to analyze the data in RStudio tools/software. Unlike other many resilience studies; this study was categorized drought resilience in to the resilience process/drought preparedness practices and resilience outcome/resource endowment/absorptive capacities of the household in all the data collection process and analysis. The findings of this study showed that use of indigenous weather knowledge, establishment and maintenance of water sources, rangeland management, livestock mobility and social support are among the drought resilience determinant practices that are employed by the Borana pastoral households'. Similarly, cattle, sheep, goats, camels, water and rangeland resources productivity were among the very important asset/absorptive capacity endowed by the pastoral households'. The values of the PCA factor loadings revealed that cattle and sheep were less resilient while goats, camels and rangeland productivity were more resilient to 2016 drought. Hence, drought resilience should be derived with safe innovative SMART preparedness/response and livelihood diversification to ensure productivity and sustainability of pastoral livelihoods.

Keywords: **drought preparedness, resilient capacity, drought resilience, resilient community, Borana pastoralists, Oromia, Ethiopia**

1. Introduction

Resilience is becoming a commonly driver of multifaceted catch-all agenda at all cross-scale phenomena (Constas et al., 2017 ; Cai et al., 2018). It was developed from the Latin word resilio which is to jump back to its previous state (Pezzoli & Ponte, 2014;Kleinet al., 2003). Recently, it is widely used across all disciplines to denote the ability of a given system to resist and /or other wise to bounce back to its previous (and good) condition without losing its major elements and function after a disturbance/shock (Alraggad et al., 2017;Ganji, 2019) . Despite, the recent popularity of the concept of resilient in development; the use of resilience in analytical frameworks were begin with in the general theory of systems and later on widely used in ecology, engineering, psychology and epidemiology, etc. (Holling, 1973; Argone, 2013; Pauley et al., 2019).

In this regard, currently, the term resilience/resilient is the major crucial aspects of the studies within all disciplines of sustainability and humanity sciences and within the development practices and studies (of science-policy interphase) of the nations, systems, institutions, policies, programming and interventions and within the study of corporate/enterprises, community and individuals (Pezzoli & Ponte, 2014;Pauley et al., 2019). In addition, it is becoming the priority area of development partners, Governments, society and individuals in policy/strategy formulation and designing of development projects, especially, through associating all cross-scale issues of development and sectors with the aspects of disaster risk management and development (Kamara et al., 2020). This study was mainly focused on the drought disaster resilience capacity of the Borana pastoral community of Southern Oromia, Ethiopia.

In this case, resilience theory proposes an ongoing preparedness practices to strengthen the system through using continuum of innovative capacities in multidimensional circumstances to resist shocks and/or to return to its appropriate original function/ state after shocks (Fu, 2013;Meng et al., 2018). In this regard, innovative capacity is mainly focused in the making of the paradigm shift in decision/thought that are supported with the practices of improving known traditional six resilience capacities (Mehran et al., 2015). Traditional resilience capacities includes anticipatory/knowledge, mitigation/preparedness measures, absorptive (resource/asset endowment), adaptive (adjusting the practices with the continuum of change) and *advocating/working for transformative* capacity (production system modification/examples to market oriented pastoralism) through collective social action capacities and or/ through performing alternative state-development-society-environment relations to sustainably strengthen the well-being of the structures of the system (Basiago, 1998; Little, 2017; Kafle, 2017; Ihunov et al., 2018;Purvis et al., 2019; Nuvey et al., 2021; Shayan et al., 2022).

This implies that resilience is about change within the continuum of the change through the rational thought of innovative capacity without causing damage in the process of making response to keep and / or to maintain the original structures and proper functioning of a given system with in the domain and beyond in all dimension (Schmidt & Garland, 2012; OXFAMGB, 2013). In the process of resilience building any activities without in-depth knowledge/emotional based damaging response could leads to the long vicious cycle of the scenario and continuous failure of the system (Mehran et al., 2015; Yao et al., 2022; Chiroro, 2023). However, wrong responses could not completely impede continuum of constructive rational change (resilience) in the long run (Kapalla, 2021; Nuvey et al., 2021).

In this case, it is possible to say that resilience is sonorous with sustainability and accountability (Haugum, 2021). Contrary, vulnerability to disaster is the results of the lack of capacity to sustain the system and lack of accountability for/of the sets within and beyond the domain of the system; and the resilience capacity denotes the recovering/re-functioning capacity of a given system after disturbances (Eun et al., 2021; Yu et al., 2021) in claim to the maintenances of the prototype of the original state of the entity/structures with in the process of ensuring resilience. This implies that vulnerability to drought disaster is a function of susceptibility and sensitivity (Semplici et al., 2023b). In connection with this, understanding of the three major traditional resilience/vulnerability factors such as exposure, sensitivity, and adaptive capacity are mandatory in the process of designing successful drought/disaster preparedness and mitigation measures to ensure resilience with in the continuum of change (Umetsu et al., 2007; Kamara et al., 2020; Bahta, 2022).

Existing literature confirmed that drought resilience is maintained through well-articulated, multi-dimensional knowledge based, inclusive framework and proactive area specific drought risk reduction planning, preparedness, mitigation and collective social action approach than focusing only on the crises management/emotional based damaging and emergency responses (Fu, 2013; McPeak & Little, 2017; Dyer & Mcguinness, 2018). This indicates that resilience is mainly rest upon the rational and functional flexible decision making capacity of a given community through associating the real issues on the ground with the dynamic contexts of external and internal factors which could help to reduce shocks/impacts of drought risk /disaster and then hasten the bouncing back of the system after occurrence of a probable given disturbance/drought (Ihunov et al., 2018; Pazoki, 2022).

The first steps in understanding the resilience level of the systems are beginning with the identification of the potential risk/ hazard threatening the system; susceptibility/vulnerability of the system to the probable occurrence of the risk, and resource endowment/copying capacity of the system to resist the adverse effects of the disaster/ capacity to proper re-functioning/bounce back of the system (Gayle, 2018;Bahta & Myeki, 2021b). Threat/risk includes natural hazards such as drought, flood, disease outbreak; social/economical hazards such as market shock, conflict, etc.; and technological hazards, etc, (Muricho *et al*., 2017; Bahta, 2022). Susceptibility/vulnerability includes mainly lack of six traditional resilience capacities and lack of accountability to resist/to mitigate the risk and to recover from the disaster/disturbance. Capacity includes the endowment of the traditional six resilience capacities by a given system (Ranjan, 2011; Muricho et al., 2017) .

The next steps requires, reducing the vulnerability of the system through designing appropriate inclusive emergency, mitigation, development policy; strategy, programme, projects, plan and activities to improve sustainability of the six traditional capacities such as the anticipatory, mitigation, absorptive, adaptive and transformative capacity, collective social network capacity and well-being of the entities/structures within and beyond the system (Muricho et al., 2017;Dyer & Mcguinness, 2018; Gayle, 2018; Bahta & Myeki, 2021b).

Resilience of a community is the outcome of the cumulative effects of six capacities of the system (Rai, 2006;Boka, 2017; TANGO International, 2018;Mung et al., 2019). In this case, characteristics of resilience mode of anticipatory capacity includes the use of knowledge, technology, innovation, invention, SMART development planning and physical planning, input; good governance and strong institution, rational attitude/non-violent mind set, equity and just, capacity to adapt to the continuum of uncertainty and change, participation, appropriation of indigenous knowledge and values, production value add chains, high diversity, scaling up and scaling out, dynamism, social learning/practices, accountability and transparency, rule of law, etc

(Rhodes, 2009; Jones, 2019 ;Schaefer et al., 2020; Bega et al., 2020;Wienroth et al., 2021; Muñoz-Erickson et al., 2021).

Absorptive capacity is about the resource endowment/ fair access to main five or more livelihood capitals: natural, social, financial, physical capital, political capital, technology, and etc (Ranjan, 2011; Kafle, 2017; Kafle, 2017; Sancho-Zamora et al., 2021). Mitigation/development measure implies appropriate designing of short to long term development proposal and operation of activities with in the six capacities (Abel et al., 2016)Subiyanto & Boer, 2020). Adaptive capacity implies modification of existing norm/modalities to make more re-functioning the system with in the continuum of change (Grigg et al., 2019). Adaptive capacity is the flexibility of a given system to undergo re-configuration to make more sustain its structures and functions within the dynamic continuum of external and internal environmental change and /or within the extent of adverse contexts (Mung et al., 2019). Transformative capacity implies shifting existing dominant process of norm of action /modalities in dimension with the prevailing continuum of change/condition, for example shifting to market oriented pastoralism, livelihood diversification, asset protection, financial protection, rural insurance, improved trade and finance, micro-enterprise, innovation, irrigation/infrastructures, green-economy, discovery, exploration, value add chains, use of technology, innovation and invention, etc (Kafle, 2017;Busch et al., 2021)(Kafle, 2017)(Kafle, 2017). In addition, transformative capacity includes using the principles of research-society-practices/production measures linkage, farmers-research-extension linkage and research and development linkage in all the aspects of measures and levels.. –etc (Schmidt & Garland, 2012;Meng et al., 2018;Habte et al., 2022). A social network based resilience capacity implies the process of ongoing collective action to ensure well-being among all the sets/structures within/beyond the system within inclusive mind set (Fu, 2013;Ohlsson, 2017).

Furthermore, in the third steps cross-scale based holistic development based approach of operational methods have decisive factors in the ongoing livelihoods decision making related to the elements of the resilience indicators: anticipatory, mitigation, absorptive, adaptive, and transformative capacity, collective social actions capacity and well-being of the sets of the system (Boka, 2017; Pauley et al., 2019; Pauley et al., 2019 ;Kamara et al., 2020). Resilience is a function of adaptive capacity and vulnerability. Resilience is the outcome of the subsequent drought preparedness of six traditional resilience capacities practices which are resulting in resisting the adverse effects of the shocks and/or speeding up the normal re-functioning of the system aftershocks (Cai et al., 2018; Ganji, 2019; UNDP, 2022). Drought preparedness is not static; it is performed and/or revised periodically through associating variability of influential risk/threat/ hazard factors with the dynamic continuum of livelihood resources/capitals in a given specific environment (Fu, 2013; Gayle, 2018;Mihunov et al., 2019).

In this regard, endowing/access to basic service and livelihood asset such as social, economic, human, political capital, physical and natural capitals are the basis in the process of ensuring resilience (Simelton et al., 2009; Pazoki, 2022). In this regard, realization of resilient systems have demonstrated more through proper functioning of multidimensional attributes including reduced rate of poverty, effective governance and institution, balancing/addressing existing distorted dominant norms of action/process, collective local action, use of the recent international multilateralism model in all the aspects, stability, performance of pro-poor inclusive development policy, justice and equity, participation , etc, through taking in to account specific dynamics in local reality (Neves, 2018;Nhamo & Mabhaudhi, 2019; Kamara et al., 2020; Normandin, 2023).

Collective capacity/climax might including multilateralism in this case is the level of resilience that could maintain the well-being of the sets of its structures is the stage of flexibility of a given system to undergo re-configuration to make more sustain its structures and functions within the dynamic continuum of external and internal environmental change (Nitoiu & Pasatoiu, 2021 Park, 2022). Although there are many definition of resilience in the literature this study tried to synthesis/ defines drought resilience using the Hollinig definition as the base. Here, this study is conceptualized resilience as the persistent ability of a system to reconfigure its capacity to respond better to the inevitable continuum of the dynamics of a change/ to adapt to environmental shocks and re-continue proper functioning without a major change to its original features in timely and in effective manner after stress/shock (Walker, 2003; Folke, 2006;Holling, 2013;Dakos & Kéfi, 2022).

Since time immemorial, the context of the term resilience is accustomed among pastoralism (Semplici et al., 2023b). Pastoral scholars claim that the term resilience is synonyms with dominant literatures in pastoralism like the model of bounce back in the boom/bust drought cycles, disequilibrium ecology paradigm which incorporates ideas of resilience with the notions of flexibility and mobility that have decisive in pastoralism (Nori & Scoones, 2019;Little & Mcpeak, 2020a).

As a theory, resilience of a given system is maintained through designing of area specific holistic development approach (Ambelu et al., 2017; Little, 2017 ; Little & Mcpeak, 2020a). In non-equilibrium environment, under poor technology and poor capital pastoralism is a viable livelihood/production system than other land use system (Little, 2017;Little & Mcpeak, 2020a). Among pastoralism, resilience is the outcome of the relationships, interconnections, networks and practices using decision making based on indigenous knowledge and cultures (Brüntrup *et al*., 2017;Catley, 2017;Kemboi et al., 2018 ; Debela et al., 2019).

In this case, (Little & Mcpeak, 2014; Little & Mcpeak, 2020b) argued that as the notion of thresholds is critical to understanding the relevance's of resilience to pastoralism and development. Indeed, Lybbert et al., (2004) argued the two key thresholds in pastoralism 1) the subsistence constraints and 2) the herd size thresholds which played a key role in understanding pastoral systems and resilience. Recently, especially, starting from 2011 the term resilience is contextualized with in the development agenda of the Horn of African dry lands to build resilient community towards drought that is exacerbated by the adverse effects of climate change as an option to the dominant paradigm of humanitarian emergency response (Little, 2017;Degen, 2020).

In this regard, increasing herd size to minimize total loss by drought, periodically mobility, indigenous governance, social network and support, drought/weather forecast, traditional by-law based rangeland and water point management and allocation, etc. are some of the traditional resilient strategies of Borana pastoralists towards drought (Arjjumend, 2018) Sandi et al., 2020). Hence, Objective of this study was focused on the investigation of the 2016/17 severe drought disaster resilience capacity of the livelihoods' of the Borana pastoral communities' of Southern Oromia region, Ethiopia.

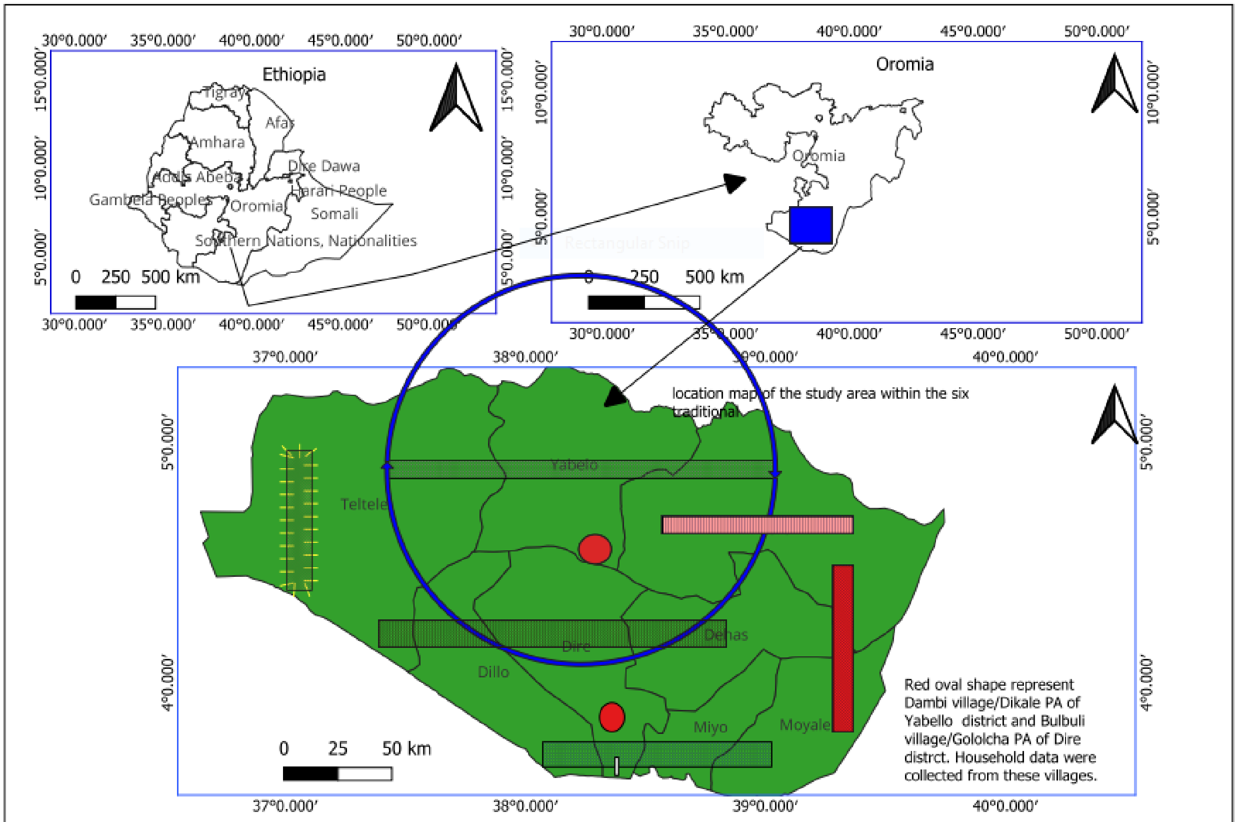
1.1. Research methodology

This study used quantitative data derived through household survey. In this case, purposive and lottery methods/ sampling techniques were used to select the research subjects. In this regard, Borana zone and respective districts were purposively selected due to their vulnerability to recurrences/challenges of drought disaster, degradation of livelihood sources by drought and persistence modes/way of pastoral livelihoods/life. Next, lottery methods were used to select respective Kebeles and villages.

In this case, Bulbuli village of Gololcha Kebele and Dambi village of Dikale kebele were selected to collect the required data through household survey. In Gololchaa village and Dikale vilage 87 and 95 households had resided, respectively; however, during the data collection period in April 2020 this study accessed only 75 and 70 households (total of 145 households) for data collection from both villages, respectively. The absenteeism was mainly due to social reason and mobility with livestock in search of pasture and water. Hence, panel data of 290 observations were collected from 145 households using closed ended survey questionnaires.

Data were collected from 145 (9 females and 136 males) households. In this case, closed ended household survey questioners which were focused on the variables/type of activities that were employed in the villages in the process of making ongoing recovery from the 2016/17 severe drought were used during data collection. In principle analyzing resilience level of a given system/an entity required panel data that constitute data of the same variables before and after the occurrence of the disaster. However, in all developing economies availability of panel data at the household level is very rare. Hence, this study used simultaneously, to collect 2016/before drought and 2020/after drought/ households data using closed ended questionnaires constituted of the same variables.

To minimize the loss of data, especially, with regard to the data of 2016 enough times were allocated while collecting the data from individual households. In addition, during the data collection, four local enumerators were participated in the data collection after receiving training on each variables of the study. Furthermore, traditionally, Borana pastoral community could make attention to (eager to memorize) the number of livestock an individual household had held before drought, number died by the drought and number of its livestock that were escaped the drought which were made an opportunity in the process of capturing necessary data required for this study. Hence, panel data of 290 observations were collected from 145 households using closed ended survey questionnaires. In this case, 145 observations were represented data before drought and 145 observations were represented data after drought of 2016 with respective data of different variables (22 drought preparedness variables and 15 resource endowment variables) from each of the 290 observations. Location map of the study village/districts depicted in the figure below.



Source: Own work, 2022/data were retrived from gadm QGIS data websitehttps://gadm.org/

In this regard use of indigenous weather and scientific weather information, indigenous social network and social support, mobility, household asset endowment, Water harvesting and natural resource management, access to infrastructures, perception on policy and institution, access to social and economic services, access to finance and credit service, use of input supply and technology were among the variables on which the data were collected to identify the 2016/17 drought resilience level of the households livelihoods in the study are. In addition, data were collected on the dimension of livelihood diversification, on the extent of livestock production for market oriented pastoralism, and on food security, etc. The details of the variables used for data collection can be seen from the Table 21.

	Table 21. List of households' drought resilience variables		
No	Description of variables	Unitt	DS
1	Use of indigenous weather information - IWI	extent	HH
2	use of scientific weather information – SWI	extent	
3	Mobility during drought - Mobility	extent	HH
4	HH asset/communal asset: Cattle, Sheep, Goat, Camel, poultry, equine, Crop productivity, Water, Rangeland and farm land – HH asset	numb	HH
5	Functionality of indigenous ways of life/living, Social /cultural network, IK based asset/livelihood governance, risk management and social support- IK	Ext	HH
6	Natural resource, water harvesting, and rangeland management -WNRLM	extent	HH
7	Social and economic infrastructures– infrastructures	% C	HH
8	Grassroots level/community centered inclusive policy, improved local level decision making capacity through sound full public and stakeholder participation, functional legal framework; accountability, transparency, effectiveness, efficiency, democracy, good governance, impartiality and extent of institution at all level, - policy & Institution	Exten t	HH
9	Access of the community to social and economic service delivery; water, healthy, extension service, irrigation, market, trade, cooperatives/union, input supply service, etc.)- Services	% age	HH
10	Access to bank, micro-finance, credit, insurance – Finance service and financial protection	Exten	HH
11	Access to primary, secondary and tertiary education, research center, etc, - Education	cover	HH
12	Access to production enhancing input, technology, information and communication, TV, radio, internet, data, capacity building, etc, - Technology	Exten t	HH
13	Attitude of local communities towards livelihood diversification, agro-industry (sugar-cane, beverage crop production, etc,) -	Exten	HH
14	Local level market oriented production (mining, gum, commercial crop farming, horticulture, commercial fodder production, livestock selling and market oriented pastoralism – production for Market and trade	Exten t	HH
15	Status of multidimensional-innovation, Structural change in economy; settlement, well land use plan, local based planned urban development, industry, technology, agriculture, trade, social protection, community based organization, expansion of local producers based enterprise and company, improved means of production, natural and man made disaster manegment,etc, -Innovation	Exten t	HH
16	Informal daily labor,charcoal and firewood selling - destitution	Exten	HH
17	Vulnerability to drought, flood, market shock, disease outbreak, violence, conflict, war, etc. – peace and stability	Exten	HH
18	Food security - FS	Exten	HH

Source:Ownsynthesis,2021

2021

1.1.1. Data analysis

This study used Principal component analysis (PCA) data analysis technique. Principal component analysis (PCA) is a multivariate type of data analysis technique (Abson et al., 2012;Haugum, 2021;) . It is applied in all disciplines. In this regard, PCA transforms data; identify patterns, similarities and differences in the data set and help to predict/project phenomena,(Eun *et al*., 2021; Khanna et al., 2022). It is among the old type of adaptive data analysis techniques used to minimize large data with many observations and variables in to small manageable representative new data with minimized dimensions (without losing its original features) in the components; and alongside increase its interpretability (Pearson K., 1901; Hotelling H., 1933; Jolliffe et al., 2016;Khanna et al., 2022;Eun et al., 2021).

However, its popularity grows in the recent later decades simultaneously with the beginning of the use of electronic computer which make ease the computational problem of large data (Jolliffe et al., 2016; Yu et al., 2021; Greenacre et al., 2022). In this process PCA reduces the complex large data set in to manageable dimension of small components of new data set without losing its statistical information in the original data (Smilde, 2014; Markos & Tuzhilina, 2022).

Analysis and interpretation is done using new and reduced data set (Yu et al., 2021; D'Enza, et al., 2022). This means that PCA 'preserving as much variability as possible' translates into finding new variables that are linear functions of those in the original dataset, that successively maximize variance which are uncorrelated with each other (Eun et al., 2021; Khanna et al., 2022). PCA is defined as an orthogonal linear transformation that re-expresses multivariate data (Jolliffe et al., 2016; Yu et al., 2021). It extracts and displays the greatest variance in a data on the first axis (called the first principal component), the second greatest variance on the second axis (which is orthogonal to the first) and so on (Reris & Brooks, 2015;Jolliffe et al., 2016).

In addition, PCA is mainly used for the analysis and prediction of descriptive statistics with large observations and variables (Smilde, 2014; Brleković, 2021; Bahta & Myeki, 2021a). In this case, PCA created new uncorrelated variables of data with descending order of maximum variance (Haugum, 2021;Jing et al., 2023). The variance explained the proportion of the percentage of the variation in the original data (Smilde, 2014). PCA can be based on either the covariance matrix or the correlation matrix. Finding of such new variables called the principal components (PCs), reduces to solving an eigenvalue/eigenvector problem. Its aim is to reduce a larger set of variables into a smaller set of 'new' variables, called 'principal components', which account for most of the variance in the original variables (Reris & Brooks, 2015;Jolliffe et al., 2016) . The PCA aims to combine various correlation indicators to include as much information as possible for each original dataset. In particular, it efficiently recognizes data patterns to minimize information loss while reducing the high dimensionality of the dataset (Jolliffe et al., 2016 ; Yu et al., 2021).

This study was only focused to amylase the recovery status/resilience capacity of the variables /livelihood sources of the study area after the severe drought of 2016/17 using PCA factor loadings and cumulative variability of PCA values in percentage. In the majority of the cases If the proportion of a given variable PCA factor loadings is below 0.5 (Abson et al., 2012;Smilde, 2014) it denotes that the concerned variable was not resilient to the aforementioned drought disaster of 2016/17. In addition, depending on the original total quantity of the given variables of data before and after the drought; individual researcher could decide the dimensions/interpretations of the values of the factor loadings (Smilde, 2014; Eun et al., 2021).

Resilience analysis required a long periods/continuous decades of household livelihoods data, especially, quantitative data of every and each disaster cycles of before and after the disaster of the concerned specific area. However, due to lack of long period of drought cycles data on the required resilience variables and observations/households socio-economic data/ this study subjected to undertake analysis of resilience capacity only based on the households' data of 2016/17 drought. Hence, the analysis was only reflecting the recovery/resilience capacity of the households' livelihoods towards 2016/17 drought depending only on the variation of household data of before and after 2016/17 drought in the study area.

In this regard, this study used PCA to analyze list of panel data collected from 290 observations/pastoral households (75 from Dirre woreda and 70 from Yabello woreda) to identify the resilience level of the households livelihoods against 2016/17 drought. The data were arranged in 290 observations/rows with respective data of 22 and 15 drought preparedness and resource endowment variables, respectively, in columns with excel format. The panel data constitute households' quantified information on drought resilience variables in two times intervals. Information on 145 observations were represented data before drought of 2016 and the rest 145 were represented data after drought/April 2020. This study used XLSTAT analytical solver software to analyze PCA based drought resilience status of the study area. In this regard, PCA were creating one index variable (or a few) from a set of variables. The index variable is a weighted average of the original variables (Reris & Brooks, 2015).

In this case, the standard framework for PCA as exploratory data analysis mechanisms includes a dataset with observations on p-numerical variables, for every one of n objects or entities. These data values describe an n × p-data matrix X, whose j^{th} column is the vector x_j of observations on the j^{th} variable. In this case, PCA seek a linear combination of the columns of matrix X with maximum variance. This linear combinations are given by equation:

$$\sum_{j=1}^{p} ajkj = xa \qquad (1)$$

where a is a vector of constants a_1, a_2, ... , a_p. The variance of any such linear combination is given by var(Xa) = a' Sa, where S is the sample covariance matrix associated with the dataset and ‘ denotes transpose. Hence, identifying the linear combination with maximum variance is equivalent to obtaining a p-dimensional vector a maximizes the matrix form a‘Sa. In this process, for this problem to have a well-defined solution an additional restriction is set.

One of such restriction includes identifying an Eigenvalues of the matrix. Eigenvalue can be termed as characteristic value, characteristic root, proper values or latent roots as well. Eigen values represent the total amount of variance that is explained by the PCA using a given original data. The dimension of Eigen value in a scree/scatter/biplot is positive or negative in theory. However, Eigenvalues with a value of greater than zero have a good sign of prediction (Reris & Brooks, 2015). Eigenvalue is a scale that is used to transform the eigenvector which is given by the equation:

$$Sa - \lambda a = 0 \Leftrightarrow Sa = \lambda a. \qquad (2)$$

Thus, a is eigenvector, and λ is the corresponding eigenvalue, of the covariance matrix S.

The best n-point approximation to the scatterplot, in a q-dimensional subspace is where the sum of squared distances between corresponding points in each scatterplot is minimized, as in the original approach by Pearson (Reris & Brooks, 2015). This property of singular value decomposition implies interesting geometric interpretations of a PCA. Given any rank r matrix Y of size n × p, the matrix Yq of the same size, but of rank q < r, whose elements minimize the sum of squared differences with corresponding elements of Y is given (Reris & Brooks, 2015) by

$$Yq=U_qL_qA_q \tag{3}$$

where L_q is the q × q diagonal matrix with the first (largest) q diagonal elements of L and U_q, $A'_{q'}$ are the n × q and p × q matrices obtained by retaining the q corresponding columns in U and A.

In this case, the quality of any q-dimensional approximation can be measured by the variability associated with the set of retained PCAs (Jolliffe et al., 2016). Hence, the standard measure of quality of a given PCA is the proportion of total variance that it accounts for (Reris & Brooks, 2015), which is represented by the equation:

$$\pi = \frac{\lambda j}{\sum_{j=1}^{p} \lambda j} = \frac{\lambda j}{tr(S)} \tag{4}$$

where tr(S) denotes the trace of S. The incremental nature of PCs also means that we can speak of a proportion of total variance explained by a set S of PCs (usually, but not necessarily, the first q PCs), (Jolliffe et al., 2016) which is often expressed as a percentage of total variance accounted for:

$$\sum_{j\epsilon S} \pi j * 100\% \tag{5}$$

In this case, it is common practices to use some predefined percentage of total variance explained to decide how many PCs should be retained (70% of total variability is a common), although the requirements of graphical representation often lead to the use of the first two or three PCs. Even in such situations, the percentage of total variance accounted for is a fundamental tool to assess the quality of these low-dimensional graphical representations of the dataset. The emphasis in PCA is almost always on the first few PCs, but there are circumstances in which the last few may be of interest, such as in outlier detection or some applications of image analysis.

2. Results and discussion

This study tried to identify the determinants of resilience and the resilience capacities of the resources endowed/asset endowed/ by the pastoral households in the study area. As it is seen in tables 23 and 25; and figures 7 and 9, out of the 22 original variables loaded in to PCA; PCA output retained only values of five very important variables of the determinants of resilience in a linear based decreasing/increasing order that were employed by the study area pastoralists.

In principles, PCA outputs have retained only the variables with significant values of variance among observation before and after a given disaster. This implies that those of the PCA output of the retained five determinants of resilience/preparedness/ activities that were traditionally used in the study area have multidimensional cumulative impacts on the other activities that were employed by the households in the study area. These five determinants of resilience that were retained in PCA output in linear based decreasing/increasing/ order were includes indigenous weather forecasting, maintenances and establishment of traditional water points, rangeland management with its periodical allocation along livestock categories, livestock mobility, social networks and social support.

Similarly, as it can be seen from tables 24 and 26 and figures 8 and 10; out of 15 absorptive capacities/resources endowed/ by the households that were loaded to the PCA only five very important variables that have cumulative impacts on the other variables and with high variability value among the observations before and after the drought of 2016 were retained by the PCA. Those of the variables with high variability before and after the drought were cattle, sheep, goats, camels and rangeland productivity. Although Gololcha and Dikale villages cattle holdings were not resilient to the drought of 2016 with PCA factor loadings of -0.42 and -0.57, respectively, its cumulative PCA output with variability value of 87% and 54% still showed that its importance and its multidimensional impacts over the other variables in the components. In this study PCA output values showed that cattle and sheep were not resilient to drought of 2016 where as goats, camels and rangeland productivity were resilient to the drought of 2016.

2.1. Drought preparedness practices

This section was focused on the analysis of the determinants of the resilience capacities/preparedness activities/ of the households in the study area. In this case, HH responses on the 22 variables/drought preparedness practices such as use of indigenous weather forecasting knowledge in the process of livelihood decision making, establishment and maintenance of water points, rangeland management, livestock mobility, social support and social networks, production for market oriented pastoralism, pity trade, micro and small enterprise, saving cash in bank, crop farming, access to and use of production enhancing input and technology, access to health, education, market, cooperatives, extension service, transport, credit service, rural insurance, irrigation, communication service/information, use of scientific weather information, good governance and justice were loaded in to PCA. As it can be seen from tables 22, 23 and 25; and figures 7 and 9; PCA output of Gololcha village retained 9 and Dikale village PCA output retained 8 very important drought preparedness livelihood activities/variables/ out of the 22 original variables which were routinely performed in the study area in the process of building resilience towards drought.

In this case, as it can be seen from tables 22, 23, 24, 25, 25; and figures 7,8, 9, 10; from the total 22 drought preparedness practices; PCA output retained very important drought preparedness variables which were only 9 in Gololcha and 8 in Dikale such as use of indigenous knowledge (F1), establishment and maintenance of water points (F2), rangeland management (F3), livestock husbandry (F4), livestock mobility (F5), social support and social networks (F6), crop farming (F7), trade (F8), access to basic services (F9) such as health, education, agricultural extension, cooperatives, market, transport, information and communication and access to use of production enhancing input and technology.

In this case, PCA output retained only those variables/livelihood activities which their values revealed significant variation before and after the drought among the observation. In addition, as it can be seen from figure 7 and 9; PCA output retained very important variables with in linear order variance values in descending /ascending order. In this case, drought preparedness activities that were highly performed at the eve /before 2016/ and after the drought of 2016 with high cumulative impact over the other variables with in the component were represented by high variance values in the PCA output. As it can be seen in figure 7; indigenous weather forecasting knowledge which was represented by F1 in PCA has eigenvalues of 131 with the cumulative variability of 87%. This implies that its cumulative role over the other activities/variables/ with in the component and use of IK weather knowledge for livelihood decision making role was decreased by 13% in 2020 after the previous drought. However, still IK based weather forecasting has cumulative leading role with 87% variability in livelihood decision making over the other activities undertaken by the household with in the component in the process of building resilience towards drought. This implies that to make decisions of timely mobility in escaping from drought, in the management of traditional water points and rangeland management, sell of livestock, reservation of dry season grazing /seasonal based resource allocation for different livestock categories, in making social support and for making of opportunistic farming, etc., still now Borana pastoralists use indigenous weather forecasting knowledge in decision making process.

Traditionally, based on weather information decision making; the first important livelihood activities that were employed by the Gololcha and Dikale villages pastoral households were establishment and maintenances of water points (traditional eela or ponds) which was represented in figure 7 and 9 by F2 in PCA with eigenvalues of 12 and 2 and variability of 8% and 2%, respectively. This implies that extent of water points and rangeland management, establishment of new water points; and livestock mobility for search of water and pasture were increased by 8% and 2% after drought of 2016 in the villages, respectively. The next activities that were undertaken by Gololcha and Dikale villages' pastoralists were rangeland and natural resource management which was represented in figure 7 and 9 by F3 with eigenvalues of 2 and 0.5 and with variability of 1% and 0.3%, respectively. Livestock mobility and social networks/social supports are the next most important activities employed by the study area pastoralists that are retained by the PCA output. Access to education, health, agricultural extension, crop farming and market oriented pastoralism and others variables/practices/ were revealed below eigenvalues values of 1and variability of below 0.3 % in both villages. PCA output was not retained values of households cash saving in bank, access to rural finance, trade, use of scientific weather information, rural insurance, irrigation, etc . This is due to the fact that PCA do not predict values of the variables with very law variance/with continuous values in the original variables/ with similar variance values among the observations in the list.

Table 22. PCA factor loadings value of the drought resilience data set of the study area

Resource endowment/asset						Drought preparedness practices				
Golocha (Dirre)	Cattle	sheep	goats	camels	RP	IWK	MOB	SNS	RM	ABS
	-0.429	-0.571	0.286	0.286	0.286	-0.286	0.200	0.200	0.300	0.300
Dikale (Yabello)	-0.571	-0.286 -	0.143	0.143	0.286	-0.333	0.333	0.111	0.222	0.444

Source: own work/HHS data, 2021

As it can be seen from the table 22; PCA output factor loadings retained only five very important activities/variables (in linear orders that arranged from high to law or low to high) employed by the households in the study area out of 22 original variables. In this regard, Gololcha and Dikale villages PCA factor loadings values vis-à-vis of the use of indigenous weather knowledge showed -0.28 and -0.33 which implies that correlation of the use of IK weather forecast before and after the drought of 2016 was decreased from 1 to about 0.72 and 0.67, respectively. In both villages SNS (Indigenous social support and cash transfer based on public work) was declined after the drought of 2016 up to 2020. In addition, PCA factor loadings values of both villages regarding access to basic services were 0.300 and 0.444, respectively. This designates that as the quality and coverage of basic services such as healthy, credit, transport, insurance, irrigation, access to water, livestock market information and cooperatives, etc, were very poor in the study area both before and after the drought of the 2016/17.

2.2. Resource endowment/absorptive capacity

This section was focused on the analysis of the resilience capacity of the household assets/resources towards 2016 drought. In this case a total of 15 variables such as size of household cattle, sheep, goat, camels, annual rangeland productivity, annual income from sell of livestock and livestock product, household farm land size in hectares, annual household crop productivity, annual income from trade, annual income from remittance, annual income from permanent crop and horticulture farming, income from traditional mining, income from gum, charcoal and wood selling, income from poultry, income from equine total annual expenditures and annual net cash saving and annual food security status of the households were loaded in to the PCA.

In this regard, in Golocha and Dikale villages from the total original 15 variables; PCA output values retained only eight very important variables with high variance (in linear order from the high to low or low to high) that were endowed by the household of the study area before and after the drought of the 2016. In principle, the first three to five variables with high variance in the components of PCA output are the variables with high score in the original variables and have cumulative multidimensional impacts on the entire of the variables in the components.

In this case as it is seen from tables, 22, 24, 26; and figures 8 and 10 from the total of 15 absorptive variables; PCA output retained only five very important variables such as size of household cattle (F1), sheep (F2), goats (F3), camels (F4), and annual rangeland productivity (F5). This implies that those of the first to three or five PCA output based retained variables are the very important livelihood resources that were employed by the household of the study area. In this case, as it can be seen from table 24 and 6;and figures 8 and 10 PCA output values of cattle of Gololcha and Dikale were represented by F1 with eigenvalues of 106.5 and 74 and with variability of 71% and 57%, respectively. This implies that in 2020 households in Gololcha and Dikale villages had endowed only 71% and 57% of the proportion of their 2016 cattle size. However, still cattle were the main dominant livelihood sources with high variance/high variability with high multidimensional cumulative impact on the other variables in all the component of the PCA output in the study area. The second variables with high variability/variance was sheep with declining proportion in percentage in 2020. Contrary to this, as it can be seen from tables 22, 23, 25 and figures 8 and 10; PCA output values of Gololcha and Dikale villages goats were retained with eigenvalues of 14 and 11 and with variability of 9.5% and 8%, respectively. This implies that in Gololcha and Dikale; size of goats were increased by 9.5% and 8% respectively, in 2020 against its size before 2016. Similarly, size of camels was increased by 9.5% and 3% in Gololcha and Dikale, respectively. The fifth variable retained by the PCA output value was rangeland productivity. The rest variables such as annual income from sell of livestock and livestock product, household farm land in hectares, annual household crop productivity, annual income from trade, annual income from remittance, annual income from off-farm activities, total annual expenditures and annual net cash saving and annual food security status were not retained by the PCA output. In principles PCA retained variables that are revealed significant variation in values among the observation before and after the specified period. This indicates that those of the variables had more or less had continuous in their values before the 2016 drought and during the data collection in 2020.

Similarly, PCA factor loadings were retained only values of the five variables such as cattle, sheep, goats, camels and rangeland productivity in both villages. In this regard, as can be seen from table 22 PCA factor loadings value of Gololcha and Dikale cattle endowment were -0.429 and -0.571, respectively. This implies that cattle were more resilient in Gololcha of Dire district while it is not resilient in Dikale of Yabello districts. In contrary, goats had showed increment by 0.286 and 0.144 in Gololcha and Dikale, respectively. In both villages, goats and camels were more resilient to drought of 2016 when compared to cattle and sheep.

Table 23 .Gololcha drought preparedness practices PCA output values

	F1	F2	F3	F4	F5	F6	F7	F8	F9
Eigenvalue	131.332	12.653	1.856	1.190	0.952	0.834	0.672	0.397	0.114
Variability (%)	87.554	8.435	1.237	0.794	0.635	0.556	0.448	0.265	0.076
Cumulative %	87.554	95.990	97.227	98.020	98.655	99.211	99.659	99.924	100.000

Source: own work, HHS data, 2021

Screeplot of PCA output cumulative variability (%) and Eigenvalue of Gololcha drought preparedness is displayed in Figure 7.

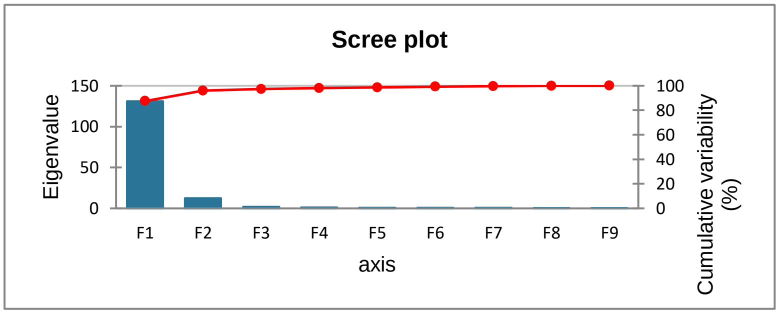


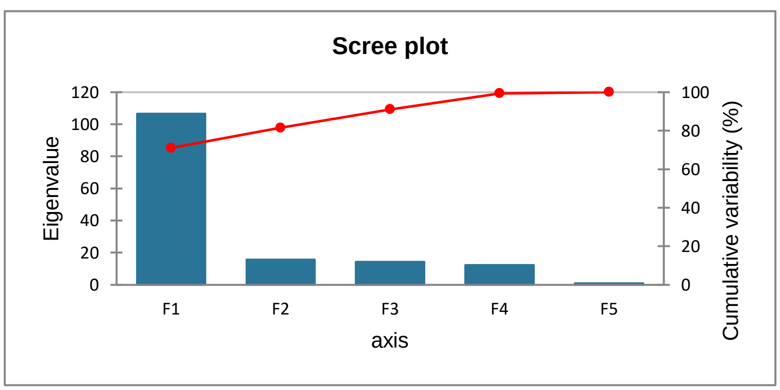
Figure7: Scree plot of PCA outputcumulative variability (%) of Gololcha drought preparedness
Source: Own work, HHS, 2021

Tables 24. Gololcha household resource endowment/assets PCA output value

	F1	F2	F3	F4	F5
Eigenvalue	106.534	15.720	14.378	12.356	1.012
Variability(%)	71.023	10.480	9.585	8.237	0.675
Cumulative (%)	71.023	81.503	91.088	99.325	100.000

Source: own work, HHS data, 2021

Screeplot of PCA outputcumulative variability (%) and Eigenvalue of Gololcha HH resource endoment is displayed in Figure 8.



Figurev 8: Screeplot of HH resource endoment
Source: Own work, HHS data, 2021

Table 25. Dikale drought PP PCA output value

	F1	F2	F3	F4	F5	F6	F7	F8
Eigenvalue	136.293	3.036	0.519	0.402	0.320	0.256	0.124	0.051
Variability (%)	96.662	2.153	0.368	0.285	0.227	0.182	0.088	0.036
Cumulative %	96.662	98.814	99.183	99.468	99.694	99.876	99.964	100.000

Source: own work, HH data, 2021

Screeplot of PCA output cumulative variability (%) and Eigenvalue of Dikale HH drought PP is displayed in Figure 9.

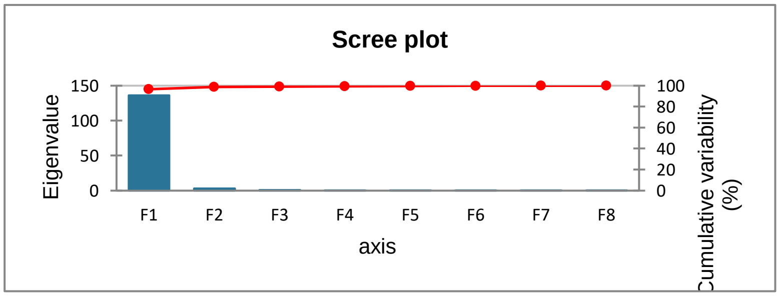


Figure 9: Dikale preparedness practices PCA output value
Source: Own work, HHS, 20201

Table 26. Dikale household resource endowment PCA output value

	F1	F2	F3	F4	F5
Eigenvalue	77.156	46.107	11.434	5.006	1.297
Variability (%)	54.720	32.700	8.109	3.550	0.920
Cumulative %	54.720	87.420	95.529	99.080	100.000

Source: own work, HH data, 2021

Screeplot of PCA outputcumulative variability (%) and Eigenvalue of Dikale HH resource endowment is displayed in Figure 10.

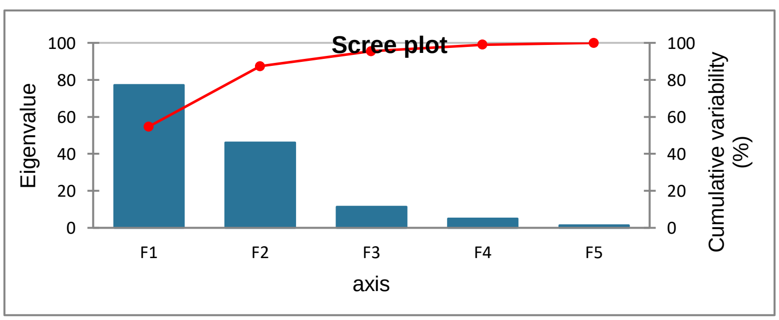


Figure 10. Dikale resource endowment PCA output value
Source: Own work, HHS, 2021

2.3. Quality/performance of the PCA output values

PCA literatures argued that if the first three to five variables in the component have cumulative variance of 70% and more values it revealed that the PCA output values illustrated a promising potential of predicting the variable under concern among the observation in the list. In this regard all the PCA output values of the resource endowment and drought preparedness variables of both villages showed more than 70% cumulative variability/variance in the first three to five variables. This implies that the first five variables had cumulative multidimensional impacts on the rest of the other variables within the components.

2.4. Conclusion and recommendation

Conclusion: This study identified that although cattle were not resilient to 2016 drought it has still high cumulative multidimensional impacts on the rest of the variables in the components. Goats and camels were more resilient to 2016 drought in the study area. Cattle, sheep, goats, camels, water and rangeland resources productivity are among the very important pastoral households' asset/absorptive capacity and their variability revealed significant variation after the drought of the 2016 with multidimensional cumulative impacts on the other variables in the components. The other pastoral household variables/asset showed low variability/variance in the PCA output according to their importance in ensuring drought resilience in decreasing order were not retained in the PCA output. However, all the 15 variables loaded in the components were mandatory for the households in the study area. This implies that resilience is the outcome of collective action in all the components. In this case, variance of the asset/variables not retained in the PCA output (those out of the five variables with in linear order and having cumulative impacts on the variables not retained) were explained/pulled in to the first five very important variables/asset with high variation among the observation/households.

Similarly, PCA output revealed that drought preparedness activities such as indigenous weather forecasting, traditional water maintenance and establishment, rangeland management and allocation of livestock category according to pasture availability and accessibility, mobility and social network/support are the determinants of drought/drought preparedness activities that were employed by the households of the study area with high multidimensional cumulative impacts over the rest of the preparedness practices.

Recommendation: Resilience is about making positive/constructive change within the inevitable continuum of all multidimensional nature and manmade based change (in our case drought exacerbated by anthropogenic effect) to ensure the sustainability of a given livelihoods/entity /system. Hence, drought resilience should be derived with safe innovative livelihood diversification and has to be guided by the SMART planning and holistic preparedness/response and should be without causing any shock to any entity in the process. However, any wrong emotional short term based emergency response could leads to the vicious cycle of the scenario, however, wrong action do not completely impede continuum of required change (resilience) in the very long run. Hence, any process in drought resilience preparedness taken towards drought should be multidimensional and inclusive to strengthen the resilience in sustainable manner. Continuous and further study will also required to have an up-to-date information on the resilience dimension of the study area.

Specifically, this study forwarded the following recommendation for future action with regard to drought resilience in the study area.

- Being resilient is an outcome of multidisciplinary efforts and actions. Hence, mainstreaming drought resilience planning and its implementation among all sectors/stakeholders in the study area can strengthen the livelihood resilience of the Borana community,
- Working for innovative drought preparedness practices and livelihood diversification will strengthen the drought resilience capacities of the community in the study area in sustainable basis instead of focusing on emergency response,
- Making structural changes on the dominant norms of action through market oriented pastoralism, index/weather based livestock insurance (IBLI), expansion of rural credit and rural finance, enhancing producer/pastoralist based livestock trade and export, micro and small enterprise, cooperatives, improving access to basic service, enhancing culture of selling livestock and saving cash in Bank, collective social action and social support, etc can improve the transformative resilience capacity of the Borana pastoralists. Inline with this establishment and maintenance of water sources, rangeland management, herd diversification, opportunistic crop farming will enhance the resilience capacity of pastoral community,

- Strengthening social network and support; and enhancing livestock mobility during severe drought Etc., could improve the resilient capacity of the community.

CHAPTER SIX

Alignment of Scientific and Indigenous Seasonal Drought Forecasting: the case of Borana pastoralists of Oromia region, Ethiopia

Abstract

Drought forecasting knowledge/ information is the basis of making appropriate livelihood decisions in the process of improving resilient capacities of the pastoralists/farmers to drought. Objective of this study was to identify alignment/agreement of scientific and indigenous seasonal drought forecasting knowledge in the study area. This study used quantitative and qualitative data to identify the alignment of scientific and indigenous seasonal drought forecasting in the study area. Quantitative historical rainfall data of 1981 to 1941 were retrieved from power acess project climate data website archive; and qualitative data were collected in 2021 using focus group discussions, experimental groups and key informant interview. Qualitative data of this study were analyzed using thematic data analysis techniques. Quantitative data were analyzed using standard precipitation index (SPI) and artificial neural neurons (ANN). The finding of this study showed that there were alignments between 2021 seasonal indigenous and scientific drought forecasting knowledge in the study area. Constraints of the historical quantitative IK weather data of atronomic moon and stars movements/events that could reveals the pulling effects of the general circulation with in the land-atmosphere-sea surface which will requires an independen projects were limited verification of the aligment of the historical seasonal indigenous and scientific drought forcasting of this study to the analysis of the only seasonal drought of the 2021. Hence, fully aligning of easily applicable scientific and indigenous weather forecasting knowledge (SIWFK) of the study area will require planting of sensor and software development. This will help to quantify scales of the temporal and spatial dimensions of the astronomic objects in some representatives' site/benchmarks. Then, it will detect a continuous practical follow-up of the IK weather indicating natural events of the astronomic moon and stars movements data of up to 10 years in the study area. These processes will be used as a base and start-up data for the future AI based forcasting of the IK weather knowledge that complement FGD based IK qualitative weather data to align with the scientific weather knowledge of the study area.

Keywords: Aligning, Scientific seasonal drought forecasting, indigenous seasonal drought forecasting, SPI, Borana, Oromia, Ethiopia.

1. Introduction

Drought forecasting knowledge/ information is the basis of appropriate livelihood decisions making in the process of the improving resilient capacities of the pastoralists/farmers towards drought (RAJ, 2011). Integrating climate/weather concerns into rural development policy, planning and implementation can speed-up the process of resilience building towards increased climate variability induced drought (Basdew et al., 2017). In the majority of cases, external actors/stakeholders are still focusing on the scientific drought forecasting information as the sole drivers in making a livelihood decision making (Mahoo et al., 2015). However, rural community claims the poor acessability and the credibility of the scientific weather forecasting problems in the process of the livelihood decision making (Masinde & Bagula, 2011). Seasonal indigenous drought forecasts differ from the seasonal scientific weather forecasts in scales/ temporal and spatial patterns/, types of variables used by the pastoralists which includes biological, meteorological, and astronomical indicators (RAJ, 2011) and in the methods of information flow (Masinde & Bagula, 2011; Mafongoya et al., 2021).

Neofotis et al., (2011) disclose that, although scientific information is well organized, rural community could not understand, interpret and implement in livelihood decisions making. Mugabe et al., (2011) argued that lack of accuracy of scientific weather information make rural communities to stick up more with the use of the indigenous weather forecasting knowledge. RAJ(2011) argued scientific weather forecasts have until recently provided information on seasonal rainfall and weather only at a regional scale, which is generally too coarse to help decision making at the farm level. In connection with this, (RAJ 2013) argued that, the capacity to generate and access to the location specific rainfall forecasting (Enock, 2013) which is mandatory for proper decision making at the grass root level is still very limited in Africa.

Scolars such as RAJ (2011) argued that such dichotomy between indigenous and modern scientific knowledge is increasingly seen as a cause for underdevelopment, especially, in the rural areas. Dube et al., (2016) and Rishona, (2016) argued that the differences in approach/myth and perception between the indigenous and scientific knowledge proponents are also in illusion/anti-parallel i.e., caused as a ‘barrier and hindrance’ to drought resilience at the grass root level. Hence, there is an urgent quest from a different discplines to align these two systems of knowledge (Mahoo et al., 2015;Basdew et al., 2017). However, the challenge is how to align seasonal indigenous and scientific drought forecasting knowledge without substituting one for the other and while respecting these two sets of values and building on their respective strengths (Basdew et al., 2017; Mafongoya et al., 2021).

Related studies in Philippines, Hiwasaki et al., (2014) explored process for using local and indigenous knowledge with science for hydro-meteorological disaster risk reduction and climate change adaptation. Rengalakshmi , (1999) examined climate prediction and utilization through linking of traditional and scientific climate knowledge systems in India. Masinde(2012) work on the bridge between African indigenous knowledge and modern science of drought prediction was experimental, and examined use of ICT, especially, mobile phone to disseminate available weather information of both sources for end users in Kenyan villages. Hence, objective of this study was to identify wether or not the scientific and IK seasonal drought forecasting of Borana pastoralists of Southern Oromia, Ethiopia are alingned to each other.

1.1. Research methodology

This study used both quantitative and qualitative data. To collect the qualitative data 13 districts of the zone were grouped in to six clusters that were consist of Yabello, Teltele, Gomole, Dirre Guchi and Moyale based on the proximate of the district to each other for the purpose of this study. In this regard, qualitative data were collected through using focus group discussion participants, experimental groups and key informant interview participants that were held at the aforementioned clusters. Accordingly, six focus group discussions; each consists of 12 participants (8 males and 4 females) were participated in data generation. Regarding the experimental groups, six groups (clusters) each consists of 4 (a total of 20 participants) well experienced traditional astronomical weather forecasters were used for gathering data.

In addition, 10 key knowledgeable informants (6 males and 4 females) were interviewed. During data collection, four local enumerators who have in-depth knowledge of variable under the study were participated in all the steps and phases of the qualitative data collection after receiving training on the topic and issues of the study. The first author has more than eight years career experiences and native of the same community in different geographical area. Selection of the participants and formation of the clusters were undertaken in collaboration with the relevant stakeholders/ organizations including GOs, NGOs, and community based organization and community representatives.

Regarding the scientific weather forecasting; data were retrieved from NASA power project climate data. In this study, *Ganna* (March to May) and *Hagayya* (October to November) seasons SPI (SPI 3-months and SPI 6-months) were computed to characterize drought phenomena in the Borana plateau of Southern Oromia region of Ethiopia to verify the alignment of scientific and indigenous weather forecasting knowledge. In this regard, this study used native resolution based NASA POWER project climate data. POWER (represent predicting of world energy resources).

In this study, NASA POWER project climate data were preferred due to the fact that the data/parameters in POWER Release 901 are provided on a global grid with native resolutions equal to the input data/it provides original incitu agrometeorological data which are not synthetic second hand data/. POWER 901 Release is also not only builds upon the data portal established with Release 8, but it also adds more recent data releases from NASA's GEWEX SRB Release 4, CERES SYN 1^{0}, and FLASHFlux Version 4A. The spatial resolution is 1.0° latitude by 1.0° longitude for the radiation data sets and ½° latitude by ⅝° longitude for the meteorological data sets. The grid reference system is WGS84 https://power.larc.nasa.gov/data-access-viewer/.

In this regard, monthly rainfall data of Yabello (4^{0}91’60’’ N latitude and 38^{0} 12’ 52’’ E longitude, at elevation of 1549.25 meters), Dirre (4^{0}10’01’’ N latitude and 33^{0}27’62’’ E longitude at elevation of 1174.4 meters), Dilloo (4^{0}13’ 84’’N latitude and 37^{0}47’15’’E longitude at elevation of 772.1 meters), Guchi (4^{0}33’97’’N latitude and 39^{0}58’77’’ E longitude at elevation of 1053.85) and Moyale (3^{0}53’83’’ N latitude and 39^{0} 09’20’’ E longitude at elevation of 903.8) were retrieved from Native resolution NASA power project climate data with adjusted missed data/the value for missing source data that cannot be computed or is outside of the sources availability range is -999 https://power.larc.nasa.gov/data-access-viewer/.

NASA/POWER CERES/MERRA2 Native temporal Resolution are available in hourly, daily, weekly, monthly, annual and climatology basis (month/day/year): 01/01/1981 up to now/https://power.larc.nasa.gov/data-access-viewer/). This study set up an input file containing precipitation data tabulated with 3-column format: Year, Month, and Monthly Precipitation Value. In this regard, due to the difficulty of manually calculating SPI values, various computer programs have been developed for this purpose. This study used the ‘SPEI’ package for SPI computation. The ‘SPEI’ package is a library of R system 4.1.1 (Beguería *et al*., 2017). In this, regard, both system and packages are available at the Comprehensive R Archive Network (https: //www.cran.r-project.org/ accessed on 30 January 2022). Next to this, SPEI package in RStudio software was used to calculate the SPI 3-months and SPI 6-months to characterize drought situation in the study area. Location map of the study area is depicted herebelow. Location map of the study area is depcted herebelow.

1.2.1. Data analysis

Thematic based qualitative data analysis techniques were used in the analysis of qualitative data of this research. According to Bazeley (2016) and Nowell et al. (2017), thematic analysis allows researchers to undertake familiarization, identify a thematic framework, code, tabulate and interpretate data. In this regard, transcriptions of the data were conducted directly using a laptop computer in each of the four phases of the data collection. In each of the four phases/seasons of data recording similar sets of the enquiry were disclosed to capture new ideas as well as to verify compatibility of the records. Simultaneously, data familiarization, identification of themes and data coding were done to substantiate the classification of themes and patterns of ideas in the process of data interpretation and analysis. Quantitative data were analyzed using standard precipitation index (SPI) and artificial neural neuron networks (ANN).

2. Results and discussion

This study revealed that seasonal indigenous and scientific drought forecasting of the 2021 *Ganna* season of the study area was aligned to each others. There was severe drought in the *Ganna* season of the 2021 in the study area. This was happened due to the anomalous of the emerging of the January Moon that was occurred on the day of the *Adula bal'aa* instead of *Adulaa duraa*. In addition, it was believed by the study area community that the defects of the star-moon aligment of the 2021 November Moon which was occurred on the 10 th November instead of the 9th November 2021 that was resulted in severe drought of the 2021 *Ganna* seasosn.

Likewise, actual and predicted/modeled seasonal drought output of the historical seasonal SPI 3-months and SPI 6-months of the study area revealed that out of the 41 *Ganna* seasosns more than 23 were hited by the severe drought. Hence, the finding of this study revealed that indigenous experimental groups based astronomical moon and Stars forecasts; and scientific historical rain fall based seasonal drought forecasting results of *Ganna* 2021 were alingned to each other.

Althogh, unlike many other indigenous knwolegde weather forecasting which can only forecasting temporal patterns of drought occurrence, Borana's indigenous weather knowledge could quantify seasonal rainfall and drought magnitude in terms of the mainly bounded ranges such as high ranfall/high drought, normal rainfall/normal drought, low rainfall/ drought, etc. However, these indigenous based distinctions of the all historical weather events and the data of Ik weather forecasting of the study area were mainly found only in the elders mind set in qualitative terms i.e, it was not framed in document form.

Establishment of the sensors/detectors that read and record weather indicating events of the natural events of the astronomic objetcs with their temporal and spatial patterns which reveals/signals the pulling effects of the land-atmosphere-sea surface are the entry point for the aligning of the both knowledge in a single manegable model. However, the process required at least a decades of the consequative weather indicating natural events of astronomic objets data. These factors are cause limit to the establishment of the framework/ easily applicable aligning models that constitute seasonal indigenous and scientific drought forecasting variables. Hence, this study subjected to limit the aligment of the seasonal and scientific weather knowledge of the study area to only Ganna season of the 2021.

2.1.Aligment of seasonal indigenous and scientific drought forecasting knowledge

The analysis of this section was undertaken to identify whether the indigenous and scientific drought forecasting in the study area were aligned/ not/ to each other. This study used the probable emerging day of the January, Moon of the 2021 and the defects/not defects of the star-moon aligment of the Novemebr, Moon of the 2021 as a benchmark.

This study identified that the probability of the emerging of the January moon is on the day of Adula duraa. In this case, as it is seen in Table, 2 of chapter 2; there is a common belief that when the January moon is emerged on the day of Adula duraa; the upcoming Ganna rain season (March to May) would be very little/the probability of severe drought would be very high. In this case, in the 2021, January moon was emerged on the day of Adula bal'aa instead of Adulaa duraa. Hence, the study community believed that severe and devastating drought of 2021/2022 was mainly caused by the nature driven anomalous of the emerging of the January Moon of 2021 on the day of Adulaa duraa.

In addition, the nature driven predetermined day on which the Moon was aligned sequentially with the star which was locally called Lammi was on 15th September (Bira), 12th October (Ciqawaa), 9th November (Sadaasa), 7th December (Arfasa), 5th January (Amaji), 3rd February (Guraandhala) and 1st March (Bitotesa) for indicating of the normal occurrence of upcoming Ganna rainfall season (March up to May).

In this regard, when the November moon was aligned with the Lammii stars on the 10th November instead of the 9th November; it would result in delay of *Ganna* rainfall by one month. In order to get *Ganna* rain, lately by one month, the Moon of November has to be aligned with Lammii stars in the next Moon of literally December 9th; but on a nature dependent normal moon counting basis it was on the Moon/month of 9th November (which means by a delay of one month).

In this regard, when such defects/events of the star-moon alignment was happening; in the normal Moon counting basis both November and December Moons become only one month; the previous November Moon defect was adjusted or aligned on the next December Moon/month. This is due to the fact that the November Moon was not aligned with the Lammii star on its previous predetermined day. Hence, it will have to adjust or will align on the December month; however, in vis-à-vis star-moon alignment and on the sequence of moon counting basis it was November Moon. Star-moon alignment of November was waiting for the re-adjustment of the November Moon alignment with the Lammii star in the next coming December Moon; this situation resulted in little/total failure of 2021Ganna rainfall in the study area.

This study identified that maintenances and establishment of traditional water points, rangeland management with its periodical allocation along livestock categories, mobility and social networks and support were undertaken using decision making based on indigenous weather forecasting knowledge.

In addition, it was identified that study area communities were not accessed to scientific seasonal drought forecasting. Although, recently, there is some improvement; regarding scientific seasonal drought forecasting it was identified that radio/TV broad casting news provided information after drought was occurred and caused adverse effects on the livelihood sources of the community in the study area. However, it was confirmed that indigenous weather information was forecasted occurrence of drought ahead of a season up to more than 40 years.

Similarly, May month is in the main rainfall seasons of the *Ganna* season (March to May). However, as it can be seen from table 21. ANN model output of the seasonal drought prediction revealed that majority of the SPI-3 May months values of 1981-2021 were negative SPI 3-months values. This implies that majority of the *Ganna* rainfall seasons from 1981 to 2021 of the study area were drought prone seasons. Hence, the finding of this study revealed that there was alignment/agreement between indigenous and scientific seasonal drought forecasting knowledge in the study area.

Table 27. ANN output value of modeled seasonal drought, 1981-2021

		Period	Jan	Feb	March	Apr	May	Jun	July	Agust	Sep	Oct	Nov	Dece
SPI3	Dilloo	1981 - 2021	-0.013	0.013	0.027	-0.037	-0.021	0.059	-0.057	0.04	-0.017	0.01	-0.002	0.0035
		2008-2021	-1.998	-0.161	-0.971	-1.236	-0.151	0.512	0.525	0.581	-0.342	2.473	-3.902	-0.1246
SPI6		1981 - 2021	0.011	-0.011	-0.015	-0.036	0.035	0.059	-0.108	0.131	-0.101	0.055	-0.025	-0.0011
		2008-2021	-1.902	-0.552	0.897	1.611	0.948	0.737	1.324	0.129	0.412	2.015	-8.887	1.65712
SPI3	Dirree	1981-2021	0.096	-0.185	0.101	0.112	-0.263	-0.032	0.472	0.301	-0.903	0.449	-0.167	-0.0589
		2008-2021	-0.216	0.23	-0.183	0.066	-0.002	-0.168	0.386	0.035	-0.867	0.545	-0.186	-0.0819
SPI6		1981 - 2021	0.004	-0.024	0.057	-0.06	-0.015	0.088	-0.077	0.024	-0.007	0.009	7E-04	-0.001
		2008-2021	0.017	-0.05	0.057	0.054	-0.015	-0.126	-0.035	0.193	-0.22	0.176	-0.065	-0.0111
SPI3	Guchi	1981-2021	-0.013	0.037	-0.079	0.089	-0.052	0.099	-0.177	0.146	-0.048	0.027	-0.006	-0.0023
		2008-2021	0.162	0.479	-0.265	-0.78	-0.337	0.11	-0.01	0.636	2.702	3.98	-7.03	-0.5447
SPI6		1981 - 2021	-0.012	0.025	-0.017	0.009	0.016	-0.052	-0.014	0.108	-0.09	0.025	0.007	3.84E-04
		2008-2021	0.095	-0.541	-0.264	0.082	-0.151	0.033	0.24	-0.969	-0.236	3.87	-1.93	0.68919
SPI3	Moyale	1981-2021	-0.573	0.195	0.378	0.336	-0.613	-0.472	0.895	-0.751	-1.074	1.829	-0.599	0.07129
		2008-2021	-0.041	0.041	0.1	0.033	-0.06	-0.223	0.139	0.294	-0.382	0.181	-0.077	0.0026
SPI6		1981 - 2021	-0.133	0.181	0.008	-0.113	0.088	-0.013	-0.039	0.104	-0.142	0.081	-0.022	0.0094
		2008-2021	0.73	-0.348	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.06114
SPI3	Yabelloo	1981-2021	0.028	0.021	0.038	0.038	-0.051	-0.227	0.023	0.253	-0.173	0.157	-0.044	0.00866
		2008-2021	-0.044	0.089	-0.062	-0.095	0.14	-0.055	-0.012	0.092	-0.141	0.138	-0.063	0.01846
SPI6		1981-2021	-0.039	-0.227	-0.066	0.202	0.08	-0.198	0.297	0.199	-0.63	0.138	0.015	-0.0452
		2008-2021	0.301	-0.299	-0.186	0.305	0.14	-0.852	-0.105	0.616	-0.675	0.442	-0.184	0.00632

Source: Own work. Data were retrived from NASAPOWER project clmate data, 2021

2.2.Limits of aligning seasonal indigenous and scientific drought forecasting knowledge

Unlike many other indigenous knwolegd, Borana's indigenous weather knowledge quantify seasonal rainfall and drought magnitude in terms of the mainly bounded ranges such as high ranfall/high drought, normal rainfall/normal drought, low rainfall/ drought, etc. However, these indigenous based distinctions of the all historical weather events and the data of Ik weather forecasting were mainly known by elders in oral forms i.e, it was not framed in document form. The current practical based study recorded only one season forecasting output of IK weather indicating of the natural events of the astronomic moon and stars which are not sufficient for making start-up of AI based IK weather data. Start-up of the AI based IK weather data might requires at least a collection of consequative 10 years data which can be used as a base for a future aligning in the process of the forecast of both knowledge.

Establishment of the sensors/detectors that read and record weather indicating events of the natural events of the astronomic objetcs with their temporal and spatial patterns which reveals/signals the pulling effects of the land-atmosphere-sea surface are the entry point for the aligning of the both knowledge in a single manegable model. These factors caused limit to the establishment of the framework/ easily applicable aligning models that constitute seasonal indigenous and scientific drought forecasting variables.

2.3.Conclusion and recommendation

This study tried to identify the alignment/agreement of indigenous seasonal drought forecasting and scientific seasonal drought forecasting of the study area. In this regard, this study used as a reference the findings of the 2021 indigenous seasonal drought forecasting knowledge of *Ganna* rainfall season (March to May) of this study (chapter two and three) and the SPI 3-May months of 1980 to 2021 to verify the alignment of the drought forecasting of both knowledge. The findings revealed that scientific and indigenous weather forecasting knowledge of the study area were aligned to each other.

Under ordinary pastoral mode of life indigenous weather information is the driver of livelihood decision making in the study area. Maintenances and establishment of traditional water points, rangeland management with its periodical allocation along livestock categories, mobility and social networks and support were undertaken using decision making based on indigenous weather forecasting knowledge. It was identified that still accessibility and use of scientific weather information was very limited in the study area. In this regard, continuous study and having up to date information on the alignment of both weather information will be mandatory to minimize adverse effects of drought on the livelihoods of the community. In addition, provision of timely and area specific scientific seasonal drought forecasting information will improve the livelihood decision making capacity of the community. Integration and mainstreaming of both indigenous and scientific seasonal drought forecasting information could minimize adverse effects of drought in the study area. Start-up of the AI based IK weather data might requires at least a collection of consequative 10 years data which can be used as a base for a future aligning in the process of the forecast of both knowledge.

CHAPTER SEVEN
Synthesis and Policy Implication

This chapter synthesis the main findings; and highlight important policy recommendations. Drought is a natural recurrent climate phenomenon. However, recently, across the Globe drought is becoming too severe in all dimensions; and has causing a far-reaching adverse impact among all sectors (Jenkins, 2011; IPCC, 2013; Shad *et al*, 2017). Especially, these losses have continued to deteriorate the resilient capacity of the resource poor and vulnerable pastoralists to deal with drought. Hence, drought monitoring and forecasts are fundamental for developing and implementing a proactive drought mitigation plan (WMO 2006; Deo *et al*., 2017; Nabipour *et al*., 2020).

7.1. Major findings of the study

Since time immemorial indigenous weather forecasting knowledge is the driver of the livelihood decision making and implementation among the Borana pastoralists of Southern Oromia, Ethiopia. In this regard, this study first analyzed indigenous knowledge based drought/weather indicating physical and temporal patterns of the astronomic moon (in chapter two). The finding of this study disclose that; one of the widely used practice of indigenous based seasonal weather indicating astronomic objects that are exhibit change naturally with in a continuum of varying temporal and /or seasonal and spatial contexts are observable external physical features of the moon. This study also identfied that weather indicating patterns of the moon which are used for making seasonal weather forecasting by Borana pastoralists are categorized in to two major sets of the multidimensional distinctive interrelated patterns. These outlooks of the moon includes: 1) weather indicating temporal patterns of the moon/ patterns of the days of the emerging of the new moon Locally called *ayyaana Ji'aa*)[18], 2) Weather indicating physical pattern of the moon.

Likewise, this study identified that, since time immemorial Borana Oromo's nature driven based abstractly made sequential list of 27 traditional temporal patterns /day patterns of the moon which are reconfigured/varied in chronological order with in each of the 12 moon/months of the year are the future weather indicating temporal patterns of the moon and has multidimensional influence in livelihood decision making and implementation process. In this regard, defining, reading and observation of the direction/inclination of the new born moon, (not) cloud

[18]. The first day on which each new moon is emerging in the night sky is locally called ayyaana ji'aa.

surrounding the moon and clour patterns of the moon are the physical weather indicating features of the moon.

The prediction which is set up via the observation of the moon would offer sufficient lapse time in a more than/within ahead of one season/ which is sufficient for making disaster risk management and is also relatively more accurate than the other traditional forecasting objects that are, currently, under use in the study area.

In addition, it is identified that this seasonal weather indicating features of the moon would provide specified temporal and spatial dimensions of the weather events within and beyond the Borana zone area. In this regard, both temporal and spatial dimensions of the IK astronomic moon based weather forecasting were actually happened in Hagayya dry season (January to Febuary), Ganna rainfall (March to May rainfall), Adolessa dry season (June to September) and Hgayya rainfall (October to November) seasons of 2021. Currently, this indigenous astronomic moon based weather forecasting knowledge and practices are still regularly used in every livelihood decision making and implementation.

The result of the findings showed that even though, all fathers have shared/transfer/ their IK based astronomic moon weather forecasting skill to all their children, including women without any gender restriction; all the children of a given household/family/ do not have capacity, wish and interest to keep all the elements of forecasting signs equally at required level. In connection with this, there are few individuals in the community who are qualified in making accurate forecasting via using a given specific objects in the environment. Those individuals who are qualified in defining physical and temporal features of the astronomic moon are locally called *Ayyaantu*.

Similarly, chapter three of this study analyzed indigenous knowledge based seasonal weather indicating positional and temporal patterns of the astronomic stars that are employed by the Borana Oromo pastoralists of the Southern Ethiopia. The finding of this study revealed that since time time immemorial Borana Oromo pastoralists' indigenous based weather knowledge define/read observable physical and temporal patterns of the astronomic stars in the process of making every-day llivelihood decision making, since time immemorial. The result of this study showed that alignment/defect of the star-moon alignment/, direction, group formation, color/physical features, size, ray, type, and duration of the observation of the stars in the sky are used in IK based weather forecasting in the study area.

These future weather indicating outlooks of the stars are categorized in to three major distinctive features: 1) temporal patterns of the star-moon alignment/defect of the star-moon alignment in the night sky; 2) direction of the stars in the sky; and 3) colors of the stars. The indicators that are displayed via the features of the stars could reveal a time lapses that are more than/ up to three months lead time ahead of the actual occurrence of the weather and other catastrophic events. This implies that there is suffiecient time between observation of future weather indicating features of stars and occurence of the events which allow undertaking of drought risk reduction measures.

The finding of this study also showed that both temporal and positional dimensions of the forecasting were actually and accurately happened in Hagayya dry season (January to Febuary), Ganna rainfall (March to May rainfall), Adolessa dry season (June to September) and Hgayya rainfall (October to November) seasons of 2021. Especially, the study area community confirmed that the severe devastating drought of the 2021/2022 was mainly caused by the naturally driven defects of the star-moon alignment of Lami star with the 2021 November moon. This indigenous weather forecasting practices are still regularly used in every livelihood decision making process. However, it is not yet mainstreamed in to the formal institutional structures.

This study discovered that while all members of the community are aware of the types of stars used to forecast weather events and have basic forecasting skills, there are only a few experienced individuals who are qualified to make accurate forecasts. Individuals who are experienced in making accurate forecasts through observing physical and temporal patterns of the stars are locally known as *Heddu* that account for around 1% of the community in the study area.

However, the findings of this study showed that this indigenous weather knowledge of Borana Oromo pastoralists of Southern Ethiopia is not yet acknowledged and not mainstreamed in the formal institutional structures. Curtailments of mobility, severity of drought, weakening of traditional institution, leaving of traditional life style and death of the knowledgeable elders are the major factors that are challenging the potential effects of the indigenous weather forecasting indicators of the features of astronomic moon and stars in the study area.

This study analyzed seasonal drought forecasting using machine learning approach (chapter four). In this regard, historical rainfall data (1981 – 2021) was subjected to SPI 3-months and SPI 6-months departure analysis for identification of drought and the extent of moisture deficit. The findings showed SPI 3-months and SPI 6-months ANN based seasonal drought prediction model performance evaluation value of MSE ranged between 0.0022 and 5.5752 which were in the excellent acceptable range of validation. SPI 3-months and SPI 6-months model performance evaluation value of correlation coefficient (R) of all the study sites were above 0.9034 which was also in the excellent range of validation. The study results revealed that ANN modeling could works effectively for forecasting seasonal drought /SPI 3-months and SPI 6-months/ ahead of two months and five months lead times, respectively, in all the districts in the study area.

According to *Ganna* and *Hagayya* seasons SPI 3-months and SPI 6-months of this study; drought, severe drought and extreme drought were occurred in *Ganna* and *Hagayya* rainfall seasons of 2000, 2004, 2005, 2007, 2008, 2009, 2010, 2011, 2013, 2016, 2017, 2019 and 2021 with in SPI 3-months and SPI 6-months value of -3.19 to -1.5. Model output showed that major extreme droughts were recorded during *Ganna* and *Hagayya* seasons in Dirre in 2000 (SPI 3-months value of -3.19), Dillo in 2000 (SPI 3-months value of -2.97), Yabello in 2000 (SPI 3-months value -2.74), Guchi in 1999 (SPI 3-months value -2.54) and Moyale in 2000 (SPI 3-months value -2.51).

Actual/observed and ANN based *Ganna* and *Hagayya* seasons SPI 3-months and SPI 6-months prediction value of 1981 – 2021 discovered that Borana's zone rainfall seasons on which communities rely for their entire life supporting systems were/ are drought prone seasons. Out of 41 (1981 – 2021) Ganna rain fall seasosns 23 of the ganna seasons were hit by severe drought. This revealed that there were extreme meteorological and agricultural droughts in the aforementioned years during Ganna and *Hagayya* rainfall seasons in the study area.

In chapter five this study analyzed drought disaster livelihood resilience capacities of Borana pastoral communities' towards drought disaster. Unlike other many resilience studies; this study was categorized drought resilience in to the resilience process/drought preparedness practices and resilience outcome/resource endowment/absorptive capacities of the household in all the data collection process and analysis.

The result showed that out of the major 22 drought preparedness practices that were employed by the Borana pastoral households'; PCA output value retained five very important practices/variables with significant PCA output variability values and with proportion of significant PCA factor loadings values before and after the droughts of 2016. The variables were includes the use of indigenous weather knowledge, establishment and maintenance of water sources, rangeland management, livestock mobility and social support. This implies that the variances of the rest of the variables among the observations were explained linearly in these PCA retained practices with significant variability and factor loadings vis-a-vis before and after the drought of 2016.

Similarly, in line with the resource endowment/absorptive capacity the result of this study showed that out of 15 major variables; PCA output retained five very important practices/variables with significant PCA output variability values and with proportion of significant PCA factor loadings values before and after the droughts of 2016.

In this regard, findings of this study showed cattle, sheep, goats, camels, water and rangeland resources productivity were among the very important pastoral households' asset/absorptive capacity with multidimensional cumulative impacts of 99% over the other 10 variables/resources which were not retained in the components of PCA output. The values of the PCA factor loadings revealed that cattle and sheep were less resilient while goats, camels and rangeland productivity were more resilient to 2016 drought. In principle PCA output showed/retained variables with significant variance in panel data among observations (in our case before drought/ 2016 data and after the drought/2020 data were used).

In Chapter six this study analyzed wether or not scientific and indigenous seasonal drought forecasting of the study area have alignment with each other. The results showed that the probability of the emerging of the January moon is on the day of Adula duraa. In this case, there is a common belief that when the January moon is emerged on the day of Adula duraa; the upcoming Ganna rainfall season (March to May) would be very little and the probability of severe drought would be very high. In the 2021, January moon was emerged on the day of Adula bal'aa instead of Adulaa duraa. Hence, the study community believed that severe and devastating drought of 2021/2022 was mainly caused by the nature driven anomalous of the emerging of the January Moon of 2021 on the day of Adulaa duraa.

Actual and predicted seasonal drought prediction revealed that the SPI-3 May months (Ganna rainfall season) values of 2021 were recorded negative SPI 3-months values/drought seoson. Hence, it showed that there were alignments between indigenous and scientific drought forecasting knowledge in the study area. Constraints of the historical quantitative IK weather data of astronomic moon and stars movements/events that could reveals the pulling effects with in the land-atmosphere-sea surface which will requires an independent study were limited verification of the alignment of the historical seasonal indigenous and scientific drought forecasting of this study to the analysis of the only seasonal drought of the 2021.

7.2. Conclusion

Weather forecasting knowledge is the driver of appropriate livelihood decision making and implementation in the process of making a living. Since time immemorial indigenous astronomic moon and stars based weather forecasting knowledge are the driver of livelihood decision making among Borana Oromo Pastoralists of Southern Ethiopia. In this regard, every daily livelihood activities: establishment and management of water sources and rangeland, livestock mobility, herd splitting, herd diversification, social support and social network, livestock selling and crop farming, etc, were undertaken depending on the indigenous weather/drought forecasting knowledge that are especially found through defining of weather indicating features of the astronomic moon and stars.

All members of the community have basic skills of indigenous weather forecasting knowledge of astronomic moon and stars, however, there are few experienced individuals who are qualified in making accurate forecasting. In this case, individuals who are experienced in making accurate forecast through observing physical and temporal patterns of the moon and stars are locally known as *Ayyantu* and *Heddu*, respectively.

In this regard, physical patterns and temporal emerging/ day patterns of new moon are commonly used by the local community in the process of indicating future weather phenomena for making informed decision making and livelihood implementation. Added to this, Borana pastoralists used future weather indicating outlooks of the stars which are including 1) temporal patterns of the star-moon alignment/defect of the star moon alignment in the sky; 2) position/direction of the stars in the sky; and 3) physical/colors of the stars. The prediction that is displayed via the observation of the astronomic moon and a groups of stars would offer sufficient lapse time in a more than/within ahead of the three months lead time which is sufficient for making early preparedness in advance of the occurrence of the weather/adverse events.

In this regard, temporal and spatial dimensions of the indigenous knowledge based seasonal weather forecasting output were actually happened in *Ganna* (March to May rainfall), *Adolessa* dry (June to September), *Hgayya* rainfall (October to November) and Hgayya dry (December to Febuary) seasons of 2021. Similarly, actual and predicted SPI 3-months and SPI 6-months drought forecasting output showed there was extreme drought event in *Ganna* and *Hagayya* rainfall seasons of 2000, 2004, 2005, 2007, 2008, 2009, 2010, 2011, 2013, 2016, 2017, 2019 and 2021 with in SPI 3-months and SPI 6-months value of -4 to -1.5. This implies that scientific and indigenous weather forecasting knowledge of the study area was aligned to each other.

In this regard, indigenous weather knowledge, establishment and maintenance of water sources, rangeland management, livestock mobility and social support, crop farming etc, are the major drought preparedness practices which were employed by the Borana pastoralists in the process of building resilience capacities towards drought. It was identified that cattle and sheep were less resilient while goats, camels and rangeland productivity were more resilient to 2016 drought.

7.3. Contribution of the study, policy implications, and future research areas

Conceptually, theoretically, methodologically and empirically; this particular study can provide a significant contribution for future action.

Conceptually: The study was more contextualized and refined the flow of the concept of disaster resilience framework. It was also more refined the confusion within the concepts of the terminology of resilience capacities. In this regard, the conceptual framework of this study categorized resilience in to resilience process and resilience outcome which are determining/determined by the interconnected capacities of anticipatory, absorptive, mitigation, adaptive and transformative knowledge. Resilient process comprises continuum of the holistic drought mitigation/preparedness practices under the individual and collective action. Resilience outcome is about the households' resource endowment/absorptive capacity and vulnerability. This study witnessed that resilience process and resilience outcome are the function of the use of the available components of knowledge. In this regard, vulnerability was mainly the result of the distorted experiances of the dominant norms of actions/knowledge. This knowledge is used cyclically (through combining/distinctly) and are influencing/influenced within the existing external and internal dominant experiences of natural and social scenario/context.

These components of knowledge comprise simultinously indigenous and scientific knowledge of anticipatory, absorpive, mitigation, adaptive and transformative capacities knowledge. Today's indigenous knowledge was sometimes a go's new innovative knowledge. Hence, this study brought in to a board the importance of seasonal indigenous and scientific weather forecasting knowledge in building resilience capacities of pastoralists towards drought.This study also contextualized that it is the magnitude of the production and use of the components of these knowledge which determines the resilience preparedness process (short to long term mitigation activities) and resilience outcome (resilience absorptive capacity and non-absorptive resilience capacity/vulnerability) of a given system under individual and collective social action/setting.

Hence, unlike all resilience conceptual frameworks, this study classified resilience capacities in to resilience knowledge: anticipatory, mitigation, absorptive, adaptive, transformative capacities knowledge which drives preparedness practices; in to resilience capacity process under individual and collective action/drought preparedness activities; and in to the resilience capacity outcome of absorptive resilience capacity and non-resilience absorptive capacity/vulnerability.

Theoretically: In this regard, theory of this study was developed using the synthesis of the theory of Holling ecological stability, the DFID disaster resilience theory, human adaptive resilience theory, IPCC climate resilience theory, and USAID resilience theory which theorize disaster/drought resilience as the function of the exposure, vulnerability and adaptive capacity. In addition, this study synthesized and used theory of the indigenous knowledge of mainly IPBES, World Bank and UNPFII. In this regard, theory of the components of applied knowledge (indigenous and scientific) that are including anticipatory, absorptive, mitigation, adaptive and transformative capacities knowledge were more refined, synthesized and adapted in to this study. On top of this, this study contextualized theory of drought resilience as the function of the multidimensional cumulative evolving impacts of the ongoing community resilient process/mitigation practices and resilient outcome/absorptive capacity/vulnerability which are determined by the use of the principles of knowledge in decision making and practices. These resilience functions are determining/determined by the production and use of the interconnected knowledge of anticipatory, absorptive, mitigation, adaptive and transformative capacities of indigenous and scientific knowledge within the existing contexts of external and internal natural and social environment.

Methodologically: The use and the application of indigenous and scientific seasonal weather forecasting methods and the verification of their alignment in the process of seasonal drought forecasting is generally the new development at all scales. Identification of indigenous and scientific seasonal weather forecasting knowledge and its driving role in building Borana pastoralists's livelihoods resilience capacities towards drought can be regarded as a new insight of integrative methods in drought risk management in the study area and in Ethiopia in general. Hence, this study was the first of its kind in Ethiopia in aligning and using of the scientific and indigenous weather knowledge parameters in the process of making seasonal drought projection.

In this regard, in 2021 experimental groups, FGDs and KII methods based data were derived using /within heightened debate and discussions supported with the practical applications through defining/reading and interpretation of physical, spatial and temporal patterns of astronomic moon and stars. Next, based on the interpretation; establishment of consensus on indigenous seasonal drought forecasting phenomena were done ahead of three months of next seasons. In addition, ratification/verification of actual occurrences of the weather events of all the four seasons of the 2021 were also done within each seasons in the process of making exhaustive cross-checking of the accuracy and applicability of the already established projection of indigenous seasonal weather knowledge in livelihoods decision making and implementation in the study area. In addition, the establishment of applicable methods of local level seasonal drought projection calendar through defining/reading, observation and interpretation of physical, spatial and temporal patterns of astronomic stars and moon is the first of its kind in Ethiopia.

In the process of scientific seasonal drought forecasting, this study used native resolution based power access project climate data. In this regard, power access project climate data were preferred due to the fact that the data/parameters in POWER Release 901 are provided on a global grid with native resolutions equal to the input data. Unlike others data; power access project climate data provides original in-situ agro meteorological data that are not manipulated synthetic second hand data. In addition, the spatial resolution of power access project climate data is ½° latitude by ⅝° longitude. Then historical rainfall data (1981 – 2021) was subjected to seasonal drought forecasting /SPI 3-months and SPI 6-months/ departure analysis for identification of drought and the extent of moisture deficit using SPEI package in the RStudio software. Unlike other many computers programming R software is used SPEI packages in the process of computing SPI. Hence, R is more relevant in providing promising SPI values.

In this study, ANN-NAR neural networks were used to model drought forecasting that was based on SPI 3-months and SPI 6-months ahead of two and five months, respectively. In this regard, this study used an advance combination of ANN structures unlike many other studies which used only one combination of hidden layers. In connection with this, this study used and compared three different combinations of ANN-NAR networking structures in which each represent 1 input layer, 8/6/12 hidden layers and 1 output layer that were constitutes (1,8,1); (1,6,1) and (1,12,1) to identify the model output/ forecast/ that meet the best validation criteria in seasonal drought prediction ahead of two and five months using input data /SPI 3-months/SPI 6-months/ with in the fastest NAR network Levenberg-Marquardt back propagation algorithm (LMBP). In this regard, using of ANN based SPI seasonal for drought forecasting is the new insights in the study area and general in Ethiopia. On top of this, alignment of indigenous and scientific seasonal weather forecasting methods were made through cross-checking of the qualitative based findings of the IK and quantitative based findings of the ANN-NAR model output values.

Unlike many resilience studies which used only after the disaster data; this study was used household based panel data of before and after the drought of the 2016 in investigating the variability of livelihood resilience capacities of the Borana pastoralists' towards severe drought of 2016/17. On top of this, unlike other many resilience studies; this study was categorized drought resilience in to the resilience process/drought preparedness practices and resilience outcome/resource endowment/absorptive capacities of the household in all the data collection process and analysis. In this study, principal component analysis (PCA) method was used to analyze the data in Rsoftware.

In this case, PCA analyzed variances (% variability values) and proportion of the significant PCA factor loadings values of the panel data (before and after 2016 drought) of resilience process and drought resilience absorptive capacities of the Borana pastoralists. PCA is preferred in this study over FAO-RIMA and LRI model due to its provision of variances (% variability values) in the panel data. On top of this, FAO-RIMA and LRI model use only current data (after drought data) of household status of access to basic service, asset endowment, absorptive capacity, adaptive capacity, social safety net, etc.

Empirically: establishing of practically applicable local/indigenous seasonal drought forecasting models and developing of ANN based SPI 3-months/SPI 6-months scientific seasonal drought forecasting models; and capturing of the alignment of both methods/ practical applicability of the actual occurrence of weather/drought events are a significant empirical contribution of this study. In addition, implications of the driving role of the drought/weather knowledge in building resilience capacities towards drought through weather information based informed decision making and livelihood implementation can be significant empirical contribution of this study. The use of the panel data and analysis of the variance (% cumulative variability) and factor loadings in the verification of the resilience capacities of before and after the drought of the 2016/17 using PCA can also be the significant empirical contribution of this study.

7.4. Policy recommendations

This PhD study has forwarded the following policy recommendations for future actions with regard to the role of seasonal drought forecasting in building pastoralists resilience capacities towards drought.

- ✓ It is better to strengthening traditional institutions in order to regain and rehabilitate the full functional capacity of the indigenous weather forecasting knowledge,
- ✓ Borana pastoralists define outlooks of astronomic objects (sun, moon and stars), observe atmospheric characteristics (cloud, wind, temperature, rainfall and lightning), read physical condition of biotic objects (livestock, tree, wild life, birds, social insects, Reptiles etc.) and rememorize the unique and known events in each Geda cycles periodically in the process of future weather forecasting. In this regard, it is advisable to undertake detail in-depth study; and making documentation of the findings of each objects in order to preserve and use this body of knowledge in sustainable manner,
- ✓ It is better to acknowledge and mainstreaming the indigenous weather knowledge in to formal institutional structures and integrate with science to improve its applicability and

role in drought resilience.In this regard, since this current study is only focused on the seasonal drought prediction (mainly of meteorological droughts) and its data were derived from point data ; continuous and detail specific studies will be also required on the long SPI months to have full information on the agricultural, hydrological including reservoir/water storage, snow pack, stream flow, underground water balance; and socio-economic droughts in the study area,

- ✓ The finding of this study showed that there were alignments between 2021 seasonal indigenous and scientific drought forecasting knowledge in the study area. However, fully aligning of easily applicable scientific and indigenous weather forecasting knowledge (SIWFK) of the study area will require a decades of IK quantitative data. These processes will be help to obtain a base and start-up data for the future AI based forecasting of the IK weather knowledge that complement FGD based IK qualitative weather data to align with the scientific weather knowledge of the study area,
- ✓ Integrated drought risk management/ knowledge based holistic development approach will sustainably minimize adverse effects of drought in the study area. This includes improving decision making capacity of the local community through provision of information, technology, data, training and extension service concerning natural resources management (soil and water conservation, water harvesting, forest management and development, rangeland management and development); livestock husbandry and crop farming; expansion of water, irrigation and other infrastructures, social and economic service delivery, finance and market, etc.,
- ✓ In general, linking local community to production enhancing technologies and digital economies will help to spread the adverse effects of drought in sustainable manner. Hence, designing of multidimensional, interconnected/integrated, and implementation of area specific drought risk management activities are mandatory to minimize the adverse effects of drought on the socio-economy and over all development of the study area. Provision of timely and area specific scientific seasonal drought forecasting information will improve the livelihood decision making capacity of the study area community,
- ✓ Being resilient is an outcome of multidisciplinary efforts and actions. Hence, mainstreaming drought resilience planning and its implementation among all sectors/stakeholders in the study area can strengthen the livelihood resilience of the

Borana community. Working for innovative drought preparedness practices and livelihood diversification will strengthen the drought resilience capacities of the community in the study area in sustainable basis instead of focusing on emergency response,

- ✓ Making structural changes on the dominant norms of action through market oriented pastoralism, index/weather based livestock insurance (IBLI), agricultural mechanization, expansion of rural credit and rural finance, enhancing producer/pastoralist based livestock trade and export, micro and small enterprise, cooperatives, improving access to basic service, enhancing culture of selling livestock and saving cash in Bank, tourism, collective social action and social support, etc. can improve the transformative resilience capacity of the Borana pastoralists. Inline with this establishment and maintenance of water sources, rangeland management, herd diversification, opportunistic crop farming will enhance the resilience capacity of pastoral community,
- ✓ Strengthening social network and support; and enhancing livestock mobility during severe drought, etc, could improve the resilient capacity of the community.

8. References

Abdul Kamara, Brent Swallow, M. K. (2003). *Role of policies and developemnt interventions in pastoral resource management: The Borana rangelands in Southern Ethiopia*. https://doi.org/https://publications.iwmi.org/pdf/H032442.pdf

Abebe, M. (2010). *Disaster Management in Ethiopia : A Review of Its Checkered History , Its Transformation and Some Implications for a Vibrant Disaster Management System , 1975-2008*. *12*(4), 237–254.

Abel, N., Wise, R. M., Colloff, M. J., Walker, B. H., Butler, J. R. A., Ryan, P., & Norman, C. (2016). *Building resilient pathways to transformation when " no one is in charge ": insights from Australia ' s Murray-Darling Basin*. *21*(2).

Absolon, K. (2022). *Indigenous Wholistic Theory : A Knowledge Set for Practice First Peoples Child & Family Review Indigenous Wholistic Theory : A Knowledge Set for Practice*. *Volume 5*, Document généré le 18 août 2022 05:31 First. https://doi.org/https://doi.org/10.7202/1068933ar

Absolon, K. E. (2016). *Wholistic and Ethical : Social Inclusion with Indigenous Peoples*. *4*(1), 44–56. https://doi.org/10.17645/si.v4i1.444

Achour, K., Meddi, M., Zeroual, A., Bouabdelli, S., Maccioni, P., & Moramarco, T. (2020). Spatio-temporal analysis and forecasting of drought in the plains of northwestern Algeria using the standardized precipitation index. *Journal of Earth System Science*, *129*(1). https://doi.org/10.1007/s12040-019-1306-3

Aderemi, A. (2017). *DOCUMENTATION AND DISSEMINATION OF INDIGENOUS KNOWLEDGE BY LIBRARY PERSONNEL IN SELECTED RESEARCH INSTITUTES IN NIGERIA.*

Agyekum, T. P., Antwi-agyei, P., & Dougill, A. J. (2022). The contribution of weather forecast information to agriculture , water , and energy sectors in East and West Africa : A systematic review. *Frontiers in Environmental Science*, *10.3389/fe*(August), 1–14. https://doi.org/10.3389/fenvs.2022.935696/https://www.frontiersin.org/articles/10.3389/fenvs.2022.935696

Ahmad, D., Majid, M., & Kanth, R. (2016). Analysis of Historical Rainfall Data for Drought Investigation Using Standard Precipitation Index (SPI) Under Temperate Conditions of Srinagar Kashmir Analysis of Historical Rainfall Data for Drought Investigation Using Standard Precipitation Index (SP. *Pakistan Journal of Meteorology*, *Vol. 13*, *I*(July). https://doi.org/Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir Shalimar (J&K) 190025.

Ahmadalipour, A., Ahmadalipour, A., & Nielsen-pincus, M. (2017). *Multi-Dimensional Drought Risk Assessment Based on Socio-Economic Vulnerabilities and Hydro- Climatological Factors*.

Ahmed, H. (2006). Household Food Security, Constraints and Strategies Among Borana Pastoral Communities of Ethiopia [College of Developemn tstudies, Addis Ababba University]. In *Cahiers d'études africaines* (Vol. 46, Issue 182). https://doi.org/10.4000/etudesafricaines.5928/http://etd.aau.edu.et/bitstream/handle/123456789/7287/Mekonnen%20W.Yesus.pdf?sequence=1&isAllowed=y

Ajagbe, E. F. S. (2018). *Indigenous Knowledge and the Development Debate in Africa Fidelis Ewane, EU Business School, Munich, Germany Samson Ajagbe, Catholic University of Applied Sciences Freiburg, Germany*. 64–81.

Akhtar, M. I. (2016). Research design Research design. In *Research in Social Science: Interdisciplinary Perspectives* (Issue September, pp. 68–84). Jamia Millia Islamia,. file:///E:/Documents/dosen/buku Metodologi/[John_W._Creswell]_Research_Design_Qualitative,_Q(Bookos.org).pdf

Al, Z. et. (2009). *Effects of climate change on livestock production and livelihood of pastoralists in selected pastoral areas of Borana , Ethiopia Effects of climate change on livestock production and livelihood of pastoralists in selected pastoral areas of Borana , Ethiop*. *January*. https://doi.org/10.13140/2.1.4475.9044

Alacgac, E. V. S. G., & Alisacan, C. R. M. B. (2003). *Traditional Weather Forecasting Methods*. *26*(March), 5–14.

Alawsi, M. A., Zubaidi, S. L., Al-Bdairi, N. S. S., Al-Ansari, N., & Hashim, K. (2022). Drought Forecasting: A Review and Assessment of the Hybrid Techniques and Data Pre-Processing. *Hydrology*, *9*(7), 1–23. https://doi.org/10.3390/hydrology9070115

Ali, Z., Hussain, I., Faisal, M., Nazir, H. M., Hussain, T., Shad, M. Y., Shoukry, A. M., & Gani, S. H. (2017). Artificial Neural Network Model. *Advances in Meteorology, Volume 201*. https://doi.org/https://doi.org/10.1155/2017/5681308

Almedom, A. M. (2013a). Resilience: Outcome, Process, Emergence, Narrative (OPEN) theory. *On the Horizon*, *21*(1), 15–23. https://doi.org/10.1108/10748121311297030/https://www.researchgate.net/publication/242429605_Resilience_Outcome_Process_Emergence_Narrative_OPEN_theory

Almedom, A. M. (2013b). Resilience: Outcome, Process, Emergence, Narrative (OPEN) theory. *On the Horizon*, *21*(1), 15–23. https://doi.org/10.1108/10748121311297030

Alraggad, M. (2017). Groundwater resilience to climate change in the Eastern Dead Sea Basin – Jordan. *Scientific Research and Essays*, *12*(3), 24–41. https://doi.org/10.5897/SRE2016.6459

Ambelu, A. (2015). *Rapid Appraisal of Resilience to the Effects of Recurrent Droughts in Borana Rapid Appraisal of Resilience to the Effects of Recurrent Droughts in Borana Zone , Southern Ethiopia Zewdie Birhanu Negalign Berhanu Argaw Ambelu Horn of Africa Resilience Innov*. *October*. https://doi.org/10.13140/RG.2.1.1873.9928

Ambelu, A., Birhanu, Z., Tesfaye, A., & Berhanu, N. (2017). Intervention pathways towards improving the resilience of pastoralists : A study from Borana communities , southern Ethiopia. *Weather and Climate Extremes Journal*, *17*(April), 16–18. https://doi.org/www.elsevier.com/locate/wace Intervention

An, Q., He, H., Gao, J., Nie, Q., Cui, Y., Wei, C., & Xie, X. (2020). Analysis of temporal-spatial variation characteristics of drought: A case study from Xinjiang, China. *Water (Switzerland)*, *12*(3), 1–20. https://doi.org/10.3390/w12030741

Andy Catley, Y. A. and B. A. (2007). *Impact Assessments of Livelihoods-based Drought Interventions in Moyale and Dire Woredas*.

Angchok, D., & Dubey, V. K. (2006). *Traditional method of rainfall prediction through Almanacs in Ladakh*. *5*(January), 145–150.

Angelidis, P., Maris, F., Kotsovinos, N., & Hrissanthou, V. (2012). Computation of Drought Index SPI with Alternative Distribution Functions. *Water Resources Management*, *26 no.4 Ma*(9), 2453–2473. https://doi.org/10.1007/s11269-012-0026-0

Anju, R., & Bonny, B. P. (2019). Indigenous knowledge based abiotic indicators used in weather prediction by farmers of Wayanad , Kerala , India. *Indian Journal of Traditional Knowledge*, *18*(Vol 18(3), July 2019, pp 565–572), 565–572.

Anshuka. (2019). *Forecasting Drought Indices using Machine learning and Spatial Modelling Approaches : An Application in Fiji*. The University of Sydney in 2019.

Apgar, J. M., & Apgar, J. M. (2010). *Adaptive Capacity for Endogenous Development of Kuna Yala , an Indigenous Biocultural System A thesis submitted in partial fulfilment of the requirements for the Degree of Doctor of Philosophy at by Abstract of a thesis submitted in partial fulfilment of*. A thesis submitted in partial fulfilment of the requirements for the Degree of Doctor of Philosophy at Lincoln University.

Argone. (2013). *Resilience Measurment Index: An indicator of Critical Infrastructure Resilience*. https://doi.org/www.osti.gov/bridge

Arjjumend, H. (2018). Review of Pastoralists ' Resilience and Adaptation to Climate Change : Can Technology Help Pastoralists Mitigate The Risks ? *International Journal of Bio-Resource and Stress Management*, *Internatio*(1), 118–128. https://doi.org/.ORG/10.23910/IJBSM/2018.9.1.1833a Review

Arnone, E., Cucchi, M., Gesso, S. D., Petitta, M., & Calmanti, S. (2020). Droughts Prediction: a Methodology Based on Climate Seasonal Forecasts. *Water Resources Management*, *34*(14), 4313–4328. https://doi.org/10.1007/s11269-020-02623-3

Asadzadeh, A., Khavarian-Garmsir, A. R., Sharifi, A., Salehi, P., & Kötter, T. (2022). Transformative Resilience: An Overview of Its Structure, Evolution, and Trends. *Sustainability (Switzerland)*, *14*(22). https://doi.org/10.3390/su142215267;https://www.mdpi.com/2071-1050/14/22/15267

Ayal, D. Y., Desta, S., Gebru, G., Kinyangi, J., Recha, J., & Radeny, M. (2015). Opportunities and challenges of indigenous biotic weather forecasting among the Borena herders of southern Ethiopia. *SpringerPlus*. https://doi.org/10.1186/s40064-015-1416-6

Ayugi, B., Eresanya, E. O., Onyango, A. O., Ogou, F. K., Okoro, E. C., Okoye, C. O., Anoruo, C. M., Dike, V. N., Ashiru, O. R., Daramola, M. T., Mumo, R., & Ongoma, V. (2022). Review of Meteorological Drought in Africa: Historical Trends, Impacts, Mitigation Measures, and Prospects. *Pure and Applied Geophysics*, *179*(4), 1365–1386. https://doi.org/10.1007/s00024-022-02988-z

Babani, L., Jadhav, S., Chaudhari, B., Conjugate, S., Based, G., Babani, L., Jadhav, S., & Chaudhari, B. (2017). Scaled Conjugate Gradient Based Adaptive ANN Control for SVM-DTC Induction Motor Drive To cite this version : HAL Id : hal-01557626 Scaled Conjugate Gradient based Adaptive ANN Control for SVM-DTC Induction Motor Drive. *HAL Id: Hal-01557626*, *Lochan Bab*. https://doi.org/https://hal.inria.fr/hal-01557626

Bahal'Okwibale, P. M. (2018). Mainstreaming Climate-Related Disaster Risk Reduction in Agriculture and Food Sectors in Eastern Africa. In *Mainstreaming Climate-Related Disaster Risk Reduction in Agriculture and Food Sectors in Eastern Africa*. https://doi.org/10.18356/72315af5-en

Bahta, Y. T. (2022). Nexus between Coping Strategies and Households ' Agricultural Drought Resilience to Food Insecurity in South Africa. *Land 2022, 11, 893. Https://Doi.Org/10.3390/Land11060893 Https://Www.Mdpi.Com/Journal/Land*, *Land 2022,*. https://doi.org/Land 2022, 11, 893. https://doi.org/10.3390/land11060893

Bahta, Y. T., & Myeki, V. A. (2021a). Adaptation, coping strategies and resilience of agricultural drought in South Africa: implication for the sustainability of livestock sector. *Heliyon*, *7*(11), e08280. https://doi.org/10.1016/j.heliyon.2021.e08280

Bahta, Y. T., & Myeki, V. A. (2021b). Heliyon Adaptation , coping strategies and resilience of agricultural drought in South Africa : implication for the sustainability of livestock sector. *Heliyon*, *7*(August), e08280. https://doi.org/10.1016/j.heliyon.2021.e08280

Baity, E. C., Aveni, A. F., Berger, R., Bretternitz, D. A., Geoffrey, A., Dow, J. W., Giot, P., Kelley, D. H., Klejn, L. S., Loops, H. H. E., Muller, R., Pittioni, R., Pleslova-stikova, E., Pohorecky, Z. S., Reyman, J. E., Roy, S. B., Smiley, C. H., Snow, D. R., Swauger, J. L., & Vermeersch, P. M. (1973). Archaeoastronomy and Ethnoastronomy SO Far1. *Current Anthropologypublished by The University of Chicago Press.*, *Vol. 14*, *N*, 62.

Balehegn, M., Balehey, S., Fu, C., & Liang, W. (2019a). *Indigenous weather and climate forecasting knowledge among Afar pastoralists of north eastern Ethiopia : Role in adaptation to weather and climate variability*.

Balehegn, M., Balehey, S., Fu, C., & Liang, W. (2019b). Indigenous weather and climate forecasting knowledge among Afar pastoralists of north eastern Ethiopia : Role in adaptation to weather and climate variability. *Pastoralism: Research, Policy and Practice, Spinger Open Acess*, *(2019) 9:8*, 15. https://doi.org/https://doi.org/10.1186/s13570-019-0143-y

Bank, T. W. (2019). Assessing Drought Hazard and Risk. *Assessing Drought Hazard and Risk*.

https://doi.org/10.1596/33805

Basdew, M., Jiri, O., & Mafongoya, P. L. (2017). *Integration of indigenous and scientific knowledge in climate adaptation in KwaZulu- Natal , South Africa*. 56–67. https://doi.org/10.1515/cass-2017-0006

Basiago, A. D. (1998). Economic, social, and environmental sustainability in development theory and urban planning practice. *Environmentalist*, *19*(2), 145–161. https://doi.org/10.1023/A:1006697118620

Bauer, T., de Jong, W., Ingram, V., Arts, B., & Pacheco, P. (2022). Thriving in turbulent times: Livelihood resilience and vulnerability assessment of Bolivian Indigenous forest households. *Land Use Policy*, *119*(September 2020), 106146. https://doi.org/10.1016/j.landusepol.2022.106146

Bazeley, P. (2016). *Analysing Qualitative Data : More Than ' Identifying Themes .' January 2009*.

Bazrkar, M. H., & Chu, X. (2022). *Development of category-based scoring support vector regression (CBS-SVR) for drought prediction Mohammad Hadi Bazrkar*. *24*(1), 202–222. https://doi.org/10.2166/hydro.2022.104

Beardmore, M. I. (2013). *Ancient Weather Signs : Texts , Science and Tradition.* [A Thesis Submitted for the Degree of PhD at the University of St Andrews]. https://doi.org/http://research-repository.st-andrews.ac.uk/ Please

Bega, D., Gramaglia, M., Fiore, M., Banchs, A., & Costa-Perez, X. (2020). AZTEC: Anticipatory Capacity Allocation for Zero-Touch Network Slicing. *Proceedings - IEEE INFOCOM*, *2020-July*, 794–803. https://doi.org/10.1109/INFOCOM41043.2020.9155299

Beguería, S. B. and S. M. V.-S. M. S. (2017). SPEI package, CRAN. *Drought Indices*, *http://sac*(Datasets for illustrating the functions in the SPEI package). https://doi.org/10.1175/2009JCLI2909.1.http

Belayneh, A., & Adamowski, J. (2013). Drought forecasting using new machine learning methods. *JJournal of Water and Land Development*, *J. Water L*. https://doi.org/10.2478/jwld-2013-0001

Belayneh, A., & Jan Adamowski. (2013). *Drought forecasting using new machine learning methods*. https://doi.org/10.2478/jwld-2013-0001

Belayneh, D. (2016). State Development Interventions versus Indigenous Resource management institutions : Whose Reality Count ? Evidence from Borana Pastoral system of Southern Ethiopia. *Munich Personal RePEc Archive*, *70780*. https://doi.org/https://mpra.ub.uni-muenchen.de/70780/1/MPRA_paper_70780.pdf

Benassi, M. (2008). Drought and climate change in Morocco . Analysis of precipitation field and water supply. *Drought Management: Scientific and Techinological Innovations.*, *A*(80), 83–86.

Benrhmach, G., Namir, K., Namir, A., & Bouyaghroumni, J. (2020). Nonlinear Autoregressive Neural Network and Extended Kalman Filters for Prediction of Financial Time Series. *Journal of Applied Mathematics*, *Volume 202*. https://doi.org/https://doi.org/10.1155/2020/5057801

Berhanu, W. (2011). Recurrent Shocks, Poverty Traps and the Degradation of Pastoralists' Social Capital in Southern Ethiopia. *African Journal of Agricultural and Resrouce Economics*, *6*(1), 1-15t.

Berhanu, W., & Beyene, F. (2015). *Climate Variability and Household Adaptation Strategies in Southern Ethiopia*. 6353–6375. https://doi.org/10.3390/su7066353

Berhanu, W., & Fayissa, B. (2009). Recurrent Shocks , Poverty Traps , and the Degradation of the Social Capital Base of Pastoralism : A Case Study from Southern Ethiopia. *African Journal of Agricultural and Resrouce Economics*, *6*(April), 1–36. https://doi.org/http://www.umb.no/statisk/noragric/publications/phdtheses/boku_fulltext_thesis.pdf

Berkes, F., Tsai, H., & Bayrak, M. M. (2021). *Indigenous Resilience to Disasters in Taiwan and Beyond*. 1–17.

Bevacqua, L. (2010). EXPLORING ADAPTATION AND RESILIENCE TO DROUGHT: A STUDY OF BRAZILIAN FAMILY FARMERS. *Journal of Chemical Information and Modeling*, *110*(9), 1689–1699.

Bhuiyan, C. (2000). Various Drought Indices For Monitoring Drought Condition In Aravalli Terrain Of India. *Department of Civil Engineering, Indian Institute of Technology Kanpur, Working Gr*. https://doi.org/Department of Civil Engineering, Indian Institute of Technology Kanpur Kanpur-208016, India, bhuiyan@iitk.ac.in

Binns, T., & Bateman, J. (2022). 'Resilience without development' in a remote rural West African community: the case of Kayima, Sierra Leone. *Journal of Modern African Studies*, *60*(3), 297–322. https://doi.org/10.1017/S0022278X22000179;https://www.cambridge.org/core/journals/journal-of-modern-african-studies/article/resilience-without-development-in-a-remote-rural-west-african-community-the-case-of-kayima-sierra-leone/CBAFF9D32EB43FE46C398478C4D13656

Blench, R., & Marriage, Z. (1999). *SEMI-ARID AFRICA AND SOUTHWEST ASIA Roger Blench Zoë Marriage*. *March*, 1–138.

Boka, G. T. (2017a). *Measuring Resilience to Climate Change Ethiopia*.

Boka, G. T. (2017b). *Measuring Resilience to Climate Change in Ethiopian*. https://doi.org/Working Paper Series N° 268, African Development Bank, Abidjan, Côte d'Ivoire. 1

Bolen, B., Sodwatana, M., & Hampson, H. (2021). Drought Prediction in the Western U.S. Using a Long Short-Term Memory (LSTM) Model. *CS230: Deep Learning, Winter 2021*, *Stanford University, CA. (LateX Template Borrowed from NIPS 2017.)*. https://doi.org/Department of Civil and Environmental Engineering hhampson@stanford.edu Abstract

Bots, P. W. G., Schlüter, M., & Sendzimir, J. (2015). A framework for analyzing, comparing, and diagnosing social-ecological systems. *Ecology and Society*, *20*(4). https://doi.org/10.5751/ES-08051-200418; https://ecologyandsociety.org/vol20/iss4/art18/

Boustani, A., & Ulke, A. (2020). Investigation of meteorological drought indices for environmental assessment of Yesilirmak Region. *Journal of Environmental Treatment Techniques*, *8*(1), 374–381.

Boyd, T., & Consultant, O. E. (2014). *If this scenario actually happened , what would your reaction be ? What questions would you would you be noticing about your fellow teammates and their reactions to the change ? Would My ' Yippee !' is your ' Oh no !' – Different reactions to change*. 1–7. https://doi.org/https://www.insights.com/resources/remaining-resilient-through-change/

Brleković, T. (2021). *APPLICATION OF PRINCIPAL COMPONENT ANALYSIS TO DROUGHT*. *1991*(22), 41–55.

Brown, K. (2021). Multisystemic Resilience. In M. Ungar (Ed.), *Multisystemic Resilience* (first edit). Oxford University Press. https://doi.org/10.1093/oso/9780190095888.003.0040

Bruchac, M. (2022). *ScholarlyCommons Indigenous Knowledge and Traditional Knowledge*. *2014*, 3814–3824. https://doi.org/. https://repository.upenn.edu/anthro_papers/171

Bruchac, M. M. (2020). Indigenous Knowledge and Traditional Knowledge. *Encyclopedia of Global Archaeology*, 5686–5696. https://doi.org/10.1007/978-3-030-30018-0_10

Brüntrup, Michael; Tsegai, D. (2017). Drought adaptation and resilience in developing countries. In *ECONSTOR* (Issue 23). https://doi.org/http://hdl.handle.net/10419/199811 Standard-Nutzungsbedingungen:

Brust, C., Kimball, J. S., Maneta, M. P., Jencso, K., & Reichle, R. H. (2021). DroughtCast: A Machine Learning Forecast of the United States Drought Monitor. *Frontiers in Big Data*, *4*(December), 1–16. https://doi.org/10.3389/fdata.2021.773478

Bule, D. M. G. (2021). *OPEN ACCESS FACTORS AFFECTING PASTORAL SUSTAINABLE LIVELIHOOD : THE CASE*. *11*, 46936–46944. https://doi.org/https://article.sciencepublishinggroup.com/pdf/10.11648.j.sr.20200805.13.pdf

Busch, M. H., Kopp, D. A., & Allen, D. C. (2021). *Energy pathways modulate the resilience of stream invertebrate communities to drought*. *November 2020*, 2053–2064. https://doi.org/10.1111/1365-2656.13490

Byakatonda, J., Parida, B. P., Kenabatho, P. K., & Moalafhi, D. B. (2016). MODELING DRYNESS SEVERITY USING ARTIFICIAL NEURAL NETWORK AT THE OKAVANGO DELTA , BOTSWANA. *Global NEST Journal, Vol 18, No X, Pp XX-XX,* *2016*, *18*(X).

Cai, H., Lam, N. S. N., Qiang, Y., Zou, L., & Correll, R. M. (2018). A Synthesis of Disaster Resilience Measurement Methods and Indices. *Sciencedirect*, *faf5fb28a1*, 1–35. https://doi.org/https://www.sciencedirect.com/science/article/pii/S2212420918304618

Cannon, C. M. (2022). *Alaska Athabascan stellar astronomy* [University of Alaska FairbanksTHESIS Presented to the Faculty of the University of Alaska Fairbanks in Partial Fulfillment of the Requirements for the Degree of MASTER OF ARTS]. https://doi.org/http://hdl.handle.net/11122/4817

CELSO AUGUSTO G. SANTOS, B. S. M. & G. B. L. S. (2009). Drought forecast using an artificial neural network for three hydrological zones in San Francisco River basin , Brazil. *New Approaches to Hydrological Prediction in Data-Sparse Regions (Proc. of Symposium HS.2 at the Joint IAHS & IAH Convention, Hyderabad, India, September 2009). IAHS Publ. 333, 2009.*, *IAHS Publ.*(September), 302–312.

Champagne, D. (2008). *The Indigenous Peoples ' Movement : Theory , Policy , and Practice*.

Chand, S. S., Chambers, L. E., Waiwai, M., Malsale, P., & Thompson, E. (2014). Indigenous knowledge for environmental prediction in the Pacific Island countries. *Weather, Climate, and Society*, *6*(4), 445–450. https://doi.org/10.1175/WCAS-D-13-00053.1

Chang, L. B., Yanda, P. Z., & Ngana, J. (2010a). Indigenous knowledge in seasonal rainfall prediction in Tanzania : A case of the South-western Highland of Tanzania, Full Length Research Paper. *Journal of Geography and Regional Planning*, *Vol. 3(4)*,(April ISSN 2070-1845© 2010 Academic Journals), 66–72. https://doi.org/https://www.cabidigitallibrary.org/doi/10.1079/PAVSNNR202116029

Chang, L. B., Yanda, P. Z., & Ngana, J. (2010b). *Indigenous knowledge in seasonal rainfall prediction in Tanzania : A case of the South-western Highland of Tanzania*. *3*(April), 66–72.

Chiroro, C. (2023). *An evaluation of the determinants of resilience to drought in Malawi Canford Chiroro*. University of Dundee.

Chour, K. E. A., Eddi, M. O. M., Eroual, A. Y. Z., & Ouabdelli, S. E. B. (2020). Spatio-temporal analysis and forecasting of drought in the plains of northwestern Algeria using the standardized precipitation index. *Indian Academy of Sciences, J. Earth S*. https://doi.org/10.1007/s12040-019-1306-3

Christopher B. Barrett , Kate Ghezzi-Kopel, John Hoddinott, Nima Homami, Elizabeth Tennant, Joanna Upton, and T. W. (2016). *A Scoping Review of the Development Resilience Literature: Theory, Methods and Evidence*. *January*, 1–23. https://doi.org/https://resilience.igad.int/regional_projects/drought-resilience-and-sustainable-livelihoods-programme-in-the-horn-of-africa-i-drslp-i/

Clarke, P. A. (2009a). Australian Aboriginal Ethnometeorology and Seasonal Calendars. *Aboriginal Policy Research Consortium International (APRCi), ISSN 0275–7206*.

https://ir.lib.uwo.ca/aprci

Clarke, P. A. (2009b). Australian Aboriginal Ethnometeorology and Seasonal Calendars. *History and Anthropology,Taylor & Francis*, *Vol. 20*, *N*(2), 79–106. https://doi.org/10.1080/02757200902867677

Clausen, C. (2016). *A status of archaeoastronomy in a cultural context*.

Coates, S. K., Trudgett, M., & Page, S. (2022). Indigenous institutional theory : a new theoretical framework and methodological tool. *The Australian Educational Researcher, 0123456789*. https://doi.org/10.1007/s13384-022-00533-4

Constas, M. A., Errico, M., & Pietrelli, R. (n.d.). *Core Indicators for Resilience Analysis : Toward an Integrated Framework to Support Harmonized Metrics*.

Coppock, D. L. (1993). Synthesis of pastoral research , development and change , 1980-91. *ILCA SYSTEMS STUDY*.

Cowley-Head, B. C. (2002). *PROTECTING INDIGENOUS KNOWLEDGE UNDER INTERNATIONAL LAW A Thesis Submitted to the College of Graduate Studies and Research in Partial Fulfillment of the Requirements for the Degree of Master of Laws in the College of Law University of Saskatchewan Saskato* (Issue November) [A Thesis Submitted to the College ofGraduate Studies and Research in Partial Fulfillment of the Requirements for the Degree of Master ofLaws in the College ofLaw University ofSaskatchewan Saskatoon By]. https://doi.org/Copyright Blanche Cowley-Head, 200

Crochemore, L., Cantone, C., Pechlivanidis, I. G., & Photiadou, C. S. (2021). How Does Seasonal Forecast Performance Influence Decision-Making? ; Insights from a Serious Game. *Bulletin of the American Meteorological Society*, *102*(9), E1682–E1699. https://doi.org/10.1175/BAMS-D-20-0169.1/https://www.diva-portal.org/smash/get/diva2:1641168/FULLTEXT01.pdf

Crossman, N. D. (2018). *Drought Resilience, Adaptation and Management Policy Framework: Supporting Technical Guidelines*. *July*, 17.

Crossman, N. D., & Crossman, N. D. (2018). *Drought Resilience , Adaptation and Management Policy (DRAMP) Framework*. *July*.

D. Western and D. L. Manzolillo Nightingale. (1993). *Environmental Change and the Vulnerability of Pastoralists to Drought: A Case Study of the Maasai in Amboseli, Kenya*. 1–35.

Dalle, G. (2014). *RELATIONSHIPS BETWEEN VEGETATION COMPOSITION AND ENVIRONMENTAL VARIABLES IN THE BORANA*. *37*(1), 1–12.

Danes, S. M. (2014). Understanding and Building Resilience. *University of Minnesota*. https://doi.org/https://apps.extension.umn.edu/family/courses/staying-resilient-in-times-of-change-online/story_content/external_files/Understanding%20and%20Building%20Resilience%20FINAL.pdf

Dare, O., Wolski, P., Ngwenya, B., & Mmopelwa, G. (2014). Ethno-meteorology and scientific weather forecasting : Small farmers and scientists ' perspectives on climate variability in the Okavango Delta , Climate Risk Management Ethno-meteorology and scientific weather forecasting : Small farmers and scientists '. *Climate Risk Managment, Climate Ri*(September), 17. https://doi.org/10.1016/j.crm.2014.08.002

Das, S., Choudhury, M. R., Gandhi, S., & Joshi, V. (2016). *Application of Earth Observation Data and Standardized Precipitation Index Based Approach for Meteorological Drought Monitoring , Assessment and Prediction Over Kutch , Gujarat , India*. *3*(2), 24–37.

Dastorani, M. T., & Afkhami, H. (2015). Application of artificial neural networks on drought prediction in Yazd Application of artificial neural networks on drought prediction in Yazd (Central Iran). *Desert*, *DESERT 16*(January 2011). https://doi.org/desert Online at http://jdesert.ut.ac.ir

David-Chavez, D. M. (2019). *A GUIDING MODEL FOR DECOLONIZING ENVIRONMENTAL SCIENCE RESEARCH AND RESTORING RELATIONAL ACCOUNTABILITY WITH INDIGENOUS COMMUNITIES*. Colorado State University,Fort Collins, ColoradoDepartment of Human Dimensions of Natural Resources In partial fulfillment of the requirements For the Degree of Doctor of Philosophy Colorado State University Fort Collins, Colorado.

De Sherbinin, A. M. (2016). Mapping the Unmeasurable? Spatial Analysis of Vulnerability to Climate Change and Climate Variability. In *Dissertation. Tyndall Centre for Climate Change Research* (Vol. 21, Issue November). https://doi.org/10.3990/1.9789036538091

Debela, N., Mcneil, D., Bridle, K., & Mohammed, C. (2019). Adaptation to Climate Change in the Pastoral and Agropastoral Systems of Borana , South Ethiopia : Options and Barriers. *American Journal of Climate Change, American J*, 40–60. https://doi.org/10.4236/ajcc.2019.81003

Debsu, D. N. (2013). *Local Institutions, external interventions, and adaptations to climate variablity*.

Degen, A. A. (2020). Transformation of Borana from nomadic pastoralists to agropastoralists and shift of livestock from cattle to include more goats , camels and sheep in Transformation of Borana from nomadic pastoralists to agropastoralists and shift of livestock from cattle. *Inderscience Enterprises Ltd*, *292 Int. J*(January 2011). https://doi.org/10.1504/IJBG.2011.039389

Dejene, A., & Yetebarek, H. (2022). The Relevance and Practices of Indigenous Weather Forecasting Knowledge among the Gabra Pastoralists of Southern Ethiopia. *Journal of Agriculture and Environment for International Development*, *116*(1), 59–76. https://doi.org/10.36253/jaeid-12295

Deo, Ravinesh C, Kisi, Ozgur, Singh, V. P. (2016). Drought forecasting in eastern Australia using multivariate adaptive regression spline, least square support vector machine and M5Tree model. *Atmospheric Research, S0169-8095*. https://doi.org/10.1016/j.atmosres.2016.10.004

Deo, R. C., Kisi, O., & Singh, V. P. (2017). Drought forecasting in eastern Australia using multivariate adaptive regression spline, least square support vector machine and M5Tree model. *Atmospheric Research*, *184*, 149–175. https://doi.org/10.1016/j.atmosres.2016.10.004

Desta, A. (2009). *Comprehending Indigenous Knowledge : An Ethnographic Study of Knowledge Processes within Natural Resource Management* (Issue May). Submitted for the degree of Doctor of Philosophy London School of Economics.

Desta, S. (2006). Pastoralism and development in Ethiopia. *Economic Focus, 9*(3), 12–20. https://doi.org/https://www.google.com/url?sa=t&rct=j&q

Dfid. (2011). Defining Disaster Resilience: A DFID Approach Paper. In *UKaid department for international development*. https://doi.org/https://www.fsnnetwork.org/sites/default/files/dfid_defining_disaster_resilience.pdf

Di, A. C. G., & Bonaccorso, M. B. (2007). Drought forecasting using the Standardized Precipitation Index. *Water Resour Manage, Water Reso*, 801–819. https://doi.org/10.1007/s11269-006-9062-y

Ding, Y., Hayes, M. J., & Widhalm, M. (2011). Measuring economic impacts of drought: A review and discussion. *Disaster Prevention and Management*, *20*(4), 434–446. https://doi.org/10.1108/09653561111161752

Dirriba, M., Simbone, T., & Bely, B. (2020). Pastoral farming system and its temporal shift: A case of Borana zone, Oromia National Regional State, Ethiopia. *African Journal of Agricultural Research*, *16*(9), 1233–1238. https://doi.org/10.5897/ajar2018.13847

Doshi, S. C., Shanmugam, M. S., & Akib, S. (2022). Assessment of Artificial Neural Network through Drought Indices. *Eng*, *4*(1), 31–46. https://doi.org/10.3390/eng4010003

Doyo, D. K., Okoyo, E. N., & Lemma, T. (2018). *Livelihood diversification strategies among the Borana pastoral households of Yabello District , Oromia Region , Ethiopia*. *10*(October), 211–221. https://doi.org/10.5897/JAERD2018.0960;https://academicjournals.org/journal/JAERD

Duba, G. W., Demissie, S. T., & Emiru, T. S. (2021). *Gelgelo Wako Duba, Solomon Tekalign Demissie, Tegegne Sishaw Emiru [1]*. *The Ethiop*(1). https://doi.org/http://idosi.org/gv/gv22(6)20/3.pdf

Dube, T., Moyo, P., Ndlovu, S., & Phiri, K. (2016). *Towards a Framework for the Integration of Traditional Ecological Knowledge and Meteorological Science in Seasonal Climate Forecasting : The Case of Smallholder Farmers in Zimbabwe*. *54*(1), 49–58.

Duguma. (2017). *Policy options for improving drought resilience and its implication for food security: the cases of Ethiopia and Kenya*.

Dyer, J. G., & Mcguinness, T. M. (2018). *Resilience : Analysis of the Concept*. *9417*(November 1996). https://doi.org/10.1016/S0883-9417(96)80036-7

Dyn, C., Sheffield, J., & Wood, Æ. E. F. (2007). *Projected changes in drought occurrence under future global warming from multi-model , multi-scenario , IPCC AR4 simulations*. https://doi.org/10.1007/s00382-007-0340-z

E Surmaini1, E Susanti1, M. R. S. and T. W. H. (2019). Exploring Standardized Precipitation Index for predicting drought on rice paddies in Indonesia Exploring Standardized Precipitation Index for predicting drought on rice paddies in Indonesia. *Earth and Enviromental Science, IOP Confer*, 0–9. https://doi.org/10.1088/1755-1315/303/1/012027

Echeverría, D., & Terton, A. (2016). *Review of Current and Planned Adaptation Action in Ethiopia*.

EDO. (2020). Standardized Precipitation Index (SPI). *European Drought Observatory*, 1–5. https://doi.org/Copernicus European Drought Observatory (EDO): https://edo.jrc.ec.europa.eu

Edwards, D. C., & McKee, T. B. (1997). Characteristics of 20 th centuary drought in the United States at multple time scale. *Colorado State University, Climatology Report No. 97-2, Climatolog*(634). http://weather.uwyo.edu/upperair/sounding.html

Elia, E. F. (2014a). *Indigenous Knowledge use in seasonal weather forecasting in Tanzania : the case of semi-arid central Tanzania*. *SA Jnl Lib*(1), 18–27. https://doi.org/10.7553/80-1-180

Elia, E. F. (2014b). *Indigenous Knowledge use in seasonal weather forecasting in Tanzania : the case of semi-arid central Tanzania*. *80*(1), 18–27. https://doi.org/10.7553/80-1-180

Enock, C. M. (2013). *Indigenous Knowledge Systems and Modern Weather Forecasting: Exploring the Linkages Enock, C.Makwara Curriculum Studies Department, Great Zimbabwe University*. *2*(1), 98–141.

Eun, J., Jisoo, K., Jae, Y., Ryu, H., Heon, J., Tae, L., & Kim, W. (2021). Assessment of regional drought vulnerability and risk using principal component analysis and a Gaussian mixture model. *Natural Hazards*, *109*(1), 707–724. https://doi.org/10.1007/s11069-021-04854-y

Archaeoastronomy of Easter Island, Australia, (2010).

Extreme drought in Ethiopia stretches drought management systems. (n.d.). *May 2016*, 1–5. https://doi.org/10.1002/joc.1078

Eyong, C. T. (2001). *Indigenous Knowledge and Sustainable Development in Africa : Case Study on Central Africa*.

Fajardo, J., Corcoran, D., Roehrdanz, P. R., Hannah, L., & Marquet, P. A. (2020). GCM compareR: A web application to assess differences and assist in the selection of general circulation models for climate change research. *Methods in Ecology and Evolution*, *11*(5), 656–663. https://doi.org/10.1111/2041-210X.13360

Farizawani, A. G., Puteh, M., Marina, Y., & Rivaie, A. (2020). A review of artificial neural network learning rule based on multiple variant of conjugate gradient approaches A review of artificial neural network learning rule based on multiple variant of conjugate gradient approaches. *Journal of Physics: Conference Series PAPER*, *1529 (2020*. https://doi.org/10.1088/1742-6596/1529/2/022040

Fedele, G., Donatti, C. I., Harvey, C. A., Hannah, L., & Hole, D. G. (2019). Transformative adaptation to climate change for sustainable social-ecological systems. *Environmental Science and Policy*, *101*(July), 116–125. https://doi.org/10.1016/j.envsci.2019.07.001;https://doi.org/10.1016/j.envsci.2019.07.001

Fenetahun, Y., & Fentahun, T. (2020). Socio-economic profile of arid and semi-arid agropastoral region of Borana rangeland Southern ,. *MedCeave, MOJ Ecology & Environmental Sciences*, *5 Issue 3*(3). https://doi.org/10.15406/mojes.2020.05.00183/https://medcraveonline.com/MOJES/socio-economic-profile-of-arid-and-semi-arid-agropastoral-region-of-borana-rangeland-southern-ethiopia.html

Fenta, M. M. (2017). *Understanding Resilience Pathways to Climate Change in a Changing Rangeland Environment amongst Pastoral Societies of Afar Region, Ethiopia* (Issue June).

Fernandez, A. (2015). *Indigenous knowledge of a changing environment : An ethnoecological perspective from Bolivian Amazonia PhD Dissertation Álvaro Fernández-Llamazares Onrubia*. PhD Thesis Universitat Autònoma de Barcelona, UAB September.

Folke, C. (2006). *Resilience : The emergence of a perspective for social – ecological systems analyses*. *16*, 253–267. https://doi.org/10.1016/j.gloenvcha.2006.04.002

Folke, C. (2016). Resilience (Republished). *Ecology and Society*, *21*(4). https://doi.org/10.5751/ES-09088-210444; https://doi.org/10.1093/acrefore/9780199389414.013.8

Folke, C., Carpenter, S. R., Walker, B., Scheffer, M., Chapin, T., & Rockström, J. (2010). Resilience thinking: Integrating resilience, adaptability and transformability. *Ecology and Society*, *15*(4). https://doi.org/10.5751/ES-03610-150420

Forum, A. D. (2015). *confronting drought in Africa's drylands* (R. C. and M. Morris (Ed.)).

Fraccascia, L., Giannoccaro, I., & Albino, V. (2019). Response to: Comment on (Resilience of Complex Systems: State of the Art and Directions for Future Research). *Complexity*, *2019*. https://doi.org/10.1155/2019/8420453

Fu, X. (2013). *PLANNING FOR DROUGHT-RESILIENT COMMUNITIES : EVALUATING THE FASTEST GROWING COUNTIES ' LOCAL Presented to the Faculty of The Graduate College at the University of Nebraska In Partial Fulfillment of Requirements For the Degree of Community and Regional Pla*. Lincoln, Nebraska.

Fuentes, I., Padarian, J., & Vervoort, R. W. (2022). Spatial and Temporal Global Patterns of Drought Propagation. *Frontiers in Environmental Science*, *10*(March), 1–21. https://doi.org/10.3389/fenvs.2022.788248

Fuller, R. S. (2020). *The astronomy and songline connections of the saltwater Aboriginal peoples of the New South Wales coast Thesis / Dissertation Sheet* (Issue August). UNSW.

Gallardo Gomez, V. K. (2021). Drought forecasting based on seasonal climate forecasting in combination with hydrological and crop growth models. *Published on The European Network for Rural Development*. https://doi.org/https://diana-h2020.eu/wp-content/uploads/D2.1.pd

Ganji, A. (2019). Challenges in Community Resilience Planning and Opportunities with Simulation Modeling. *Proceedings of the 16th ISCRAM Conference – València, Spain, May 2019, Proceeding*(May).

Gantevoort, M., & Hamacher, D. W. (2015). Reconstructing the Star Knowledge of Aboriginal Tasmanians. *Ournal of Astronomical History and Heritage, Vol. 19(3), Preprint*, *Vol. 19(3)*(3), 1–32.

Gantevoort, M., Hamacher, D. W., & Lischick, S. (2016). Reconstructing the Star Knowledge of Aboriginal Tasmanians. *Journal of Astronomical History and Heritage*, *19(3), 327*(3), 327–347.

Garofalo, D. M. (2021). Worlds More or Less : Nineteenth-Century Ethno- Astronomy and Cosmologies of Reference Worlds More or Less : Nineteenth-Century Ethno-Astronomy and Cosmologies of Reference. *Routledge.European Romantic ReviewW*, *2021*, *VOL.* https://doi.org/10.1080/10509585.2021.1989874

Gayle, R. S. (2018). *DigitalCommons @ USU Sociodemographic and Climatic Factors Shaping the Development of Drought Policies in Major U . S . Cities*. UtahStateUniversity.

Gb, O., & Paper, W. (2013). A Multidimensional Approach for Measuring Resilience. In *A Multidimensional Approach for Measuring Resilience*.

Gelder, V., & Decisions, L. (2018). *Linking ground , space and knowledge : the role of weather forecasting in pastoralists ' decision-making*. https://doi.org/https://www.sciencedirect.com/science/article/pii/S2212094716300159

Gidey, E., Dikinya, O., Sebego, R., Segosebe, E., & Zenebe, A. (2018). Analysis of the long-term agricultural drought onset, cessation, duration, frequency, severity and spatial extent using Vegetation Health Index (VHI) in Raya and its environs, Northern Ethiopia. *Environmental Systems Research*, *7*(1). https://doi.org/10.1186/s40068-018-0115-z

Ginibre, A. (2009). *From Traditional Meterology to Astrophysics: Observation and Interpretation of Local Time-Resolved Structures of Weather, and Brainstorming. 21 9 01*(Version:21 9 01), 1–28.

Godana G, D. (2016). The Role of Indigenous Knowledge in Rangeland Management in Yabello Woreda, Southern Oromia, Ethiopia. *Arts and Social Sciences Journal*, *07*(02). https://doi.org/10.4172/2151-6200.1000172

Gonzaga, L., Ruiz, B., Cuéllar, M. P., Calvo-flores, M. D., Del, M., & Pegalajar, C. (2016). An Application of Non-Linear Autoregressive Neural Public Buildings. *MDPI, Energies*. https://doi.org/10.3390/en9090684

Goto, A. (2018). Cultural Astronomy of the Japanese Archipelago. In *Routledge* (p. 34). Taylor

& Francis Group.

Greenacre, M., Groenen, P. J. F., Hastie, T., D’Enza, A. I., Markos, A., & Tuzhilina, E. (2022). Principal component analysis. *Nature Reviews Methods Primers*, *2*(1). https://doi.org/10.1038/s43586-022-00184-w

Greenacre, M., Groenen, P. J. F., Hastie, T., Enza, A. I. D., Markos, A., & Tuzhilina, E. (2022). Principal component analysis. *Nature Reviews Methods Primers*, *Nature Rev*. https://doi.org/10.1038/s43586-022-00184-w

Grigg, N., Connell, D. O., & Dunlop, M. (2019). *Literature review 3 : community adaptation and resilience*. *September,* 1–40.

Gullberg, S. R. (2021). *Cultural Astronomy*. *48*, 183–201.

Guttman, N. B. (1999a). Accepting the standardized precipitation index: A calculation algorithm. *Journal of the American Water Resources Association, 35*(2), 311–322. https://doi.org/10.1111/j.1752-1688.1999.tb03592.x

Guttman, N. B. (1999b). Journal of the American Water Resources Association. *Journal of the American Water Resources Association, 35*(2).

Haile, B. T., Bekitie, K. T., Zeleke, T. T., Ayal, D. Y., Feyisa, G. L., & Anose, F. A. (2022). Drought Analysis Using Standardized Evapotranspiration and Aridity Index at Bilate Watershed : Sub-Basins of Ethiopian Rift Valley. ?*?E Scientific World Journal*, *Volume 202*. https://doi.org/s https://doi.org/10.1155/2022/1181198

Hamacher, D. W. (2014). Observations of red – giant variable stars by Aboriginal Australians. *Australian Journal of Anthropology*, 1–20.

Hamacher, D. W. (2015). IDENTIFYING SEASONAL STARS IN KAURNA ASTRONOMICAL TRADITIONS. *Journal of Astronomical History and Heritage*, *18(1)*, *39*–(1), 39–52.

Hamacher, D. W. (2019). *INDIGENOUS USE OF STELLAR SCINTILLATION TO PREDICT WEATHER AND SEASONAL CHANGE*. *131*(10.1071/RS19003), 24–33. www.publish.csiro.au/journals/rs

Hamacher, D. W., Barsa, J., Passi, S., & Tapim, A. (2015). Indigenous use of stellar scintillation to predict weather and seasonal change. *Preprint – Proceedings of the Royal Society of Victoria*, 1–16.

Hamarash, H. R., Rasul, A., & Hamad, R. O. (2022). *A Review of Methods used to Monitor and Predict Droughts*. *August*. https://doi.org/10.20944/preprints202208.0539.v1

Hao, Z., Singh, V. P., & Xia, Y. (2018). Seasonal Drought Prediction: Advances, Challenges, and Future Prospects. *Reviews of Geophysics*, *56*(1), 108–141. https://doi.org/10.1002/2016RG000549

Hassanzadeh, Y., Ghazvinian, M., & Abdi, A. (2014). Prediction of short and long-term droughts using artificial neural networks and hydro-meteorological variables. *Journal of Computer Science & Computational Mathematics, Volume 6, Issue 4, December 2016, Journal of*. https://doi.org/10.20967/jcscm.2016.04.005

Haugum, S. V. (2021). *Land-use and climate impacts on drought resistance and resilience in coastal heathland ecosystems*. University of Bergen, Norway.

Hayes, M. J., Svoboda, M. D., Wardlow, B. D., Anderson, M. C., & Kogan, F. (2012). Drought monitoring: Historical and current perspectives. *Remote Sensing of Drought: Innovative Monitoring Approaches*, 1–19. https://doi.org/10.1201/b11863

Hayes, M., Svoboda, M., Wall, N., & Widhalm, M. (2011). The lincoln declaration on drought indices: Universal meteorological drought index recommended. *Bulletin of the American Meteorological Society*, *92*(4), 485–488. https://doi.org/10.1175/2010BAMS3103.1

Hodge, A. O. and I. (2011). Building livelihood resilience : a case study of factors affecting farm households ' adoption of coping and adaptive strategies in rural Nigeria. *International Food Policy Research Institute, University of Cambridge*, *MPRA*, *MPRA Paper*(39162). https://doi.org/https://mpra.ub.uni-muenchen.de/39162/

Hodgson, A. (2010). Transformative Resilience: A Respon to the Adaptive Imperative. *International Futures Forum*, 1–29.

Holbrook, J. (2016). Astronomy , Indigenous Knowledge , and Interpretation : Advancing studies of Cultural Astronomy in South Africa Jarita Holbrook University of the Western Cape. *Journal of Astronomy in Culture 1(1), 2016, Pp. 1-7 Copyright*, *1*(1997), 1–7.

Holling, C. S. (2013). RESILIENCE AND STABILITY OF ECOLOGICAL SYSTEMS. *Annual Review of Ecology and Systematics*, *4*(1973), 1–23. https://doi.org/http://www.jstor.org/stable/2096802;https://www.jstor.org/stable/2096802

Homann, S., Rischkowsky, B., Steinbach, J., Kirk, M., & Mathias, E. (2008). Towards Endogenous Livestock Development : Borana Pastoralists ' Responses to Environmental and Institutional Changes. *Springer Science, Published Online, Hum Ecol (*, 503–520. https://doi.org/10.1007/s10745-008-9180-7

Hurst, M., & Pedersen, S. H. (2014a). *Changing Climate Adaptation Strategies of Boran Pastoralists in Southern Ethiopia*. *55865*.

Hurst, M., & Pedersen, S. H. (2014b). Changing Climate Adaptation Strategies of Boran Pastoralists in Southern Ethiopia. In *MRPA, Munich Personal RePEc Archive: Vol. MPRA Paper* (Issue 55865). https://doi.org/https://mpra.ub.uni-muenchen.de/55865/

IASG. (2014). *THE KNOWLEDGE OF INDIGENOUS PEOPLES AND POLICIES FOR SUSTAINABLE DEVELOPMENT: UPDATES AND TRENDS IN THE SECOND DECADE OF THE WORLD'S INDIGENOUS PEOPLE* (Issue June).

Ibañez, J. C. (2014). *Knowledge integration and Indigenous planning in the Philippines*. Research Institute for Environment and Livelihoods Faculty of Engineering, Health, Science, and the Environment Charles Darwin University.

Ibinarriaga, D. H. (2020). *Critical Co-design Methodology : Privileging Indigenous Knowledges and Biocultural Diversity (Australia / Mexico) by*. Submitted in fulfilment of the requirements for the degree of Doctor of Philosophy Deakin University.

Ibrahimm, Y. (2020). *The role of indigenous knowledge in disaster risk reduction in Shinile woreda of Somali regional State, Ethiopia*.

IES - CRM Unit. (2013). SPI: Standardized Precipitation Index. PRODUCT FACT SHEET: SPI – Africa. *PRODUCT FACT SHEET: SPI – Africa*, *Version 1*, 1–6.

Ifejika, C., Boniface, S., Ambenje, P., Wiesmann, U., & Makali, S. (2009). *Indigenous knowledge related to climate variability and change : insights from droughts in semi-arid areas of former Makueni District , Kenya*. https://doi.org/10.1007/s10584-009-9713-0

Ihunov, V. V, Lam, N. S. N., Zou, L., Rohli, R. V, Reams, M. A., Argote, J. E., Mihunov, V. V, Lam, N. S. N., Zou, L., Rohli, R. V, Reams, M. A., Argote, J. E., Resilience, C., Lam, N. S. N., Zou, L., Rohli, R. V, Reams, M. A., & Argote, J. E. (2018). Community Resilience to Drought Hazard in the Community Resilience to Drought Hazard in the South-Central United States. *Annals of the American Association of Geographers ISSN:*, *4452*. https://doi.org/10.1080/24694452.2017.1372177

Illeperuma, G. D., & Sonnadara, U. (2014). Forecasting Droughts using Artificial Neural Networks. *National Symposium on Disaster Risk Reduction & Climate Change Adaptation (2009) Forecasting*, *June*.

IPCC Working Group 1, I., Stocker, T. F., Qin, D., Plattner, G.-K., Tignor, M., Allen, S. K., Boschung, J., Nauels, A., Xia, Y., Bex, V., & Midgley, P. M. (2013). IPCC, 2013: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. *Ipcc,Summary for Policymakers Drafting*, *AR5*(September), 1535.

Issn, S. (2013). *Indigenous Knowledge Systems and Modern Weather Forecasting: Exploring the Linkages Enock, C.Makwara Curriculum Studies Department, Great Zimbabwe University*. *2*(1), 98–141.

Iván Ayala Bizarro, Miguel Zubiaur Alejos, & Jessica Zúñiga Mendoza. (2018). Prediction of Drought with Artificial Neural Networks and Genetic Algorithms Using Precipitation by Remote Perception. *Journal of Environmental Science and Engineering B*, *7*(7), 253–265. https://doi.org/10.17265/2162-5263/2018.07.002

Jenkins, K. L. (2011). *Modelling the Economic and Social Consequences of Drought under Future Projections of Climate Change*. *March*, 222. http://www.dspace.cam.ac.uk/bitstream/1810/242439/1/KJenkins_PhD_Thesis.pdf

Jing, L., Weng, B., Yan, D., Zhang, S., Bi, W., & Yan, S. (2023). The persistent impact of drought stress on the resilience of summer maize. *Frontiers in Plant Science*, *14*(January), 1–14. https://doi.org/10.3389/fpls.2023.1016993

Jiri, O., Mafongoya, P., & Chivenge, P. (2015). *climate change adaptation in Zimbabwe*

Seasonal Climate Prediction and Adaptation Using Indigenous Knowledge Systems in Agriculture Systems in Southern Africa : A Review. *May 2016*. https://doi.org/10.3354/cr01334

JOHANNES, A. (2012). *DROUGHT RISK REDUCTION IN THE NORTHERN CAPE, SOUTH AFRICA*. University of the Free State.

Jolliffe, I. T., Cadima, J., & Cadima, J. (2016). Principal component analysis : a review and recent developments Subject Areas : Author for correspondence : *Rsta.Royalsocietypublishing.Org Downloaded*, *http://dx*. https://doi.org/http://dx.doi.org/10.1098/rsta.2015.0202

Jones, L. (2019). Resilience isn ’ t the same for all : Comparing subjective and objective approaches to resilience measurement. *Wiley, London Sch*(August 2018), 1–19. https://doi.org/10.1002/wcc.552

JU, C. (2018). Relevance of Indigenous Knowledge in Weather and Climate Forecast for Planning Farm Activities by Farmers in Imo State, Nigeria. *Agricultural Research & Technology: Open Access Journal*, *19*(1). https://doi.org/10.19080/artoaj.2018.19.556082

Ju, C., Jo, A., Mn, I., Jo, O., & Onogu, B. (2018). *Relevance of Indigenous Knowledge in Weather and Climate Forecast for Planning Farm Activities by Farmers in Imo State , Nigeria*. *19*(1). https://doi.org/10.19080/ARTOAJ.2018.19.556082

Kafle, S. K. (2017). Measuring Resilience Capability of Drought-prone Desert Communities : A Case Study of Tharparkar , Pakistan Geography & Natural Disasters. *Geography & Natural Disasters*, *7*(2). https://doi.org/10.4172/2167-0587.1000193

Kaimkhani, U., Naz, B., & Narejo, S. (2021). Rainfall Prediction Using Time Series Nonlinear Autoregressive Neural Network. *SSRG International Journal of Computer Science and Engineering*, *8*(1), 30–38. https://doi.org/10.14445/23488387/IJCSE-V8I1P106

Kamara, J. K., Agho, K., & Renzaho, A. M. N. (2019). Understanding disaster resilience in communities affected by recurrent drought in Lesotho and Swaziland—A qualitative study. *PLoS ONE*, *14*(3), 1–27. https://doi.org/10.1371/journal.pone.0212994

Kamara, J. K., Sahle, B. W., Agho, K. E., & Renzaho, A. M. N. (2020). Governments’ Policy Response to Drought in Eswatini and Lesotho: A Systematic Review of the Characteristics, Comprehensiveness, and Quality of Existing Policies to Improve Community Resilience to Drought Hazards. *Discrete Dynamics in Nature and Society*, *2020*. https://doi.org/10.1155/2020/3294614

Kane, S. N., Mishra, A., & Dutta, A. K. (2016). Preface: International Conference on Recent Trends in Physics (ICRTP 2016). *Journal of Physics: Conference Series*, *755*(1). https://doi.org/10.1088/1742-6596/755/1/011001

Kapalla, D. D. (2021). *Socio-Ecological Resilience in a Southern California Dryland Agroecosystem : Contributions from General and Specified Resilience*. Norwagian Ubiversity of Life Sciences.

Karavitis, C. A., Alexandris, S., Tsesmelis, D. E., & Athanasopoulos, G. (2011). Application of the Standardized Precipitation Index (SPI). *Water 2011, 3, 787-805; Doi:10.3390/W3030787*, *ISSN 2073-*, 787–805. https://doi.org/10.3390/w3030787

Karavitis, C. A., Tsesmelis, D. E., Skondras, N. A., Stamatakos, D., Alexandris, S., Fassouli, V., Vasilakou, C. G., Oikonomou, P. D., Gregorič, G., Grigg, N. S., & Vlachos, E. C. (2014). Linking drought characteristics to impacts on a spatial and temporal scale. *Water Policy*, *16*(6), 1172–1197. https://doi.org/10.2166/wp.2014.205

KASAHARA, A., & WASHINGTON, W. M. (1967). Ncar Global General Circulation Model of the Atmosphere. *Monthly Weather Review*, *95*(7), 389–402. https://doi.org/10.1175/1520-0493(1967)095<0389:nggcmo>2.3.co;2

Katip, A. (2018). *Meteorological drought analysis using artificial neural networks for bursa city, turkey*. *16*(3), 3315–3332.

Keil, A. (2011). *Drought impacts and related risk management by smallholder farmers in developing countries : Evidence from Awash River Basin , Ethiopia Discussion Paper No . 3 / 2010 Drought impacts and related risk management by smallholder farmers in developing countri*. *March 2014*. https://doi.org/10.2307/41407076

Kemboi, E., Agwata, J. F., & Anyango, S. O. (2018). Institutional Impact on Pastoral Community Resilience to Drought in Kajiado County , Kenya. *International Journal of Science and Research (IJSR) ISSN:*, *7*(9), 348–354. https://doi.org/10.21275/ART20191020

Kena, D. (2021). Pastoral household's perceptions of non pastoral activities in Yabello district, Oromia region, Ethiopia. *Cogent Economics and Finance*, *9*(1). https://doi.org/10.1080/23322039.2021.1966917

Kesik, T. (2017). *Resilience Planning Guide*. *November*, 29.

Kettle, N. P., Dow, K., Tuler, S., Webler, T., Whitehead, J., & Miller, K. M. (2014). *Climate Risk Management Integrating scientific and local knowledge to inform risk-based management approaches for climate adaptation*. *5*, 17–31.

Khanna, V. K. P. M., Kaur, M. S. R., & Singh, R. N. S. D. K. (2022). PCA – based composite drought index for drought assessment in Marathwada region of Maharashtra state , India. *Theoretical and Applied Climatology*, 207–220. https://doi.org/10.1007/s00704-022-04044-1

Kim, E. A. (2018). *The Relationships at Play in Integrating Indigenous Knowledges-Sciences (IK-S) in Science Curriculum: A Case Study of Saskatchewan K-12 Science Curriculum Eun-Ji* (Issue June). A thesis submitted to McGill University in partial fulfillment of the requirements of the degree of Doctor of Philosophy (Education)McGill University, Montreal.

Kirmayer, L. J., Dandeneau, S., Marshall, E., Phillips, M. K., & Williamson, K. J. (2011). Rethinking resilience from indigenous perspectives. *Canadian Journal of Psychiatry*, *56*(2), 84–91. https://doi.org/10.1177/070674371105600203

Koem, S., Hidayat, R., & Prasasti, I. (2019). Assessment of the Standardized Precipitation Index (SPI) in Tegal City , Central Java , Indonesia Assessment of the Standardized Precipitation Index (SPI) in Tegal City , Central Java , Indonesia. *IOP Conference Series: Earth and Environmental Science PAPER, IOP Conf.* https://doi.org/doi :10.1088/1755-1315/129/1/012019

Krakauer, N. Y., Lakhankar, T., & Hudson, D. (2019). Trends in drought over the Northeast United States. *Water (Switzerland)*, *11*(9), 1–17. https://doi.org/10.3390/w11091834

Kumar, M. N., Murthy, C. S., Sesha, M. V. R., & Roy, P. S. (2009). On the use of Standardized Precipitation Index (SPI) for drought intensity assessment. *M Eteorological Application*, *389*(April), 381–389. https://doi.org/10.1002/met

Kumar, U., Werners, S., Roy, S., Ashraf, S., & Hoang, L. P. (2020). Role of Information in Farmers ' Response to Weather and Water Related Stresses in the Lower Bengal Delta , Bangladesh. *MDPI, Sustainabi*. https://doi.org/https://uknowledge.uky.edu/igc/24/5-2/9/

Kuo, P. H., & Huang, C. J. (2018). A high precision artificial neural networks model for short-Term energy load forecasting. *Energies*, *11*(1), 1–13. https://doi.org/10.3390/en11010213

Kuwayama, Y., Thompson, A., Bernknopf, R., Zaitchik, B., & Vail, P. (2019). Estimating the impact of drought on agriculture using the U.S. Drought Monitor. *American Journal of Agricultural Economics*, *101*(1), 193–210. https://doi.org/10.1093/ajae/aay037

Lain, J. (2017). *Resilience in Ethiopia and Somaliland*. *June*.

Lambert, S. J., & Scott, J. C. (2019). International disaster risk reduction strategies and indigenous peoples. *International Indigenous Policy Journal*, *10*(2), 23. https://doi.org/10.18584/iipj.2019.10.2.2

Langill, S., & Initiative, W. P. (1999). *Indigenous Knowledge A Resource Kit for Sustainable Development Researchers in Dryland Africa. People, Land and Water Program Initiative, IDRC*.

Lawrence-mathers, A. (2021). Medieval weather prediction. *Physics Today, American Institute of Physics*, *38*, 8. https://doi.org/10.1063/PT.3.4724

Lawrence-Mathers, A. (2021). Medieval weather prediction. In *Physics Today* (Vol. 74, Issue 4, pp. 38–44). American Institute of Physics. https://doi.org/10.1063/PT.3.4724

Lee, A. S., Maryboy, N., Begay, D., Buck, W., Catricheo, Y., Lee, A. S., Maryboy, N. C., Begay, D., Buck, W., Ycatricheoauiedu, Y. C., & Hamacher, D. (2020). *Indigenous Astronomy – Best Practices and Protocols for Including Indigenous Astronomy in the Planetarium Setting "*. 1–16.

Lehoux, D. (2021a). The Predictive Sciences : Measuring and Forecasting Weather Conditions. *Classical Studies, Ancient Science and Medicine*, *November*, 1–16. https://doi.org/10.1093/oxfordhb/9780199935390.013.86

Lehoux, D. (2021b). *The Predictive Sciences : Measuring and Forecasting Weather Conditions I*

. *Observing and recording*. *August*, 1–16. https://doi.org/10.1093/oxfordhb/9780199935390.013.86

Lemenih, M., Fetene, M., & Teketay, D. (2011). SOCIO-ECONOMIC IMPORTANCE OF GUM AND RESIN RESOURCES IN THE DRY WOODLANDS OF BORANA ,. *A B Academic Publishers—Printed in Great Britain SOCIO-ECONOMIC*, *Forests*, *T*, 137–156.

Liao, C. (2014). *Case Study : Borana , Ethiopia Rural Resilience Assessment in Borana , Ethiopia*. *March*, 1–31.

Lin, Y., Deng, X., & Jin, Q. (2013). Economic effects of drought on agriculture in North China. *International Journal of Disaster Risk Science*, *Int. J. Di*(2), 59–67. https://doi.org/10.1007/s13753-013-0007-9

Little, P. D. (2017). Applying the concept of resilience to pastoralist household data. *Pastoralism: Research, Policy and Practice*, *McPeak and*. https://doi.org/10.1186/s13570-017-0082-4

Little, P. D., & Mcpeak, J. G. (2014). Resilience and pastoralism in Africa south of the Sahara. *IFPRI 2020 Policy Consultation & Conference: Building Resilience for Food & Nutrition Security*, *May*, 75–82.

Little, P. D., & Mcpeak, J. G. (2020a). *PASTORALISM AND RESILIENCE SOUTH OF THE SAHARA*. *May 2014*.

Little, P. D., & Mcpeak, J. G. (2020b). *RESILIENCE AND PASTORALISM IN AFRICA SOUTH OF THE SAHARA , WITH A PARTICULAR FOCUS ON THE HORN OF AFRICA AND THE SAHEL , WEST AFRICA*. *May 2014*.

Liu, Z., Lu, G., He, H., Wu, Z., & He, J. (2018). A conceptual prediction model for seasonal drought processes using atmospheric and oceanic standardized anomalies: Application to regional drought processes in China. *Hydrology and Earth System Sciences*, *22*(1), 529–546. https://doi.org/10.5194/hess-22-529-2018

López, A. M. (2011). Ethnoastronomy as an academic field: A framework for a South American program. In E. ve L. N. Ruggles (Ed.), *Proceedings of the International Astronomical Union* (Vol. 7, Issue S278, pp. 38–49). https://doi.org/10.1017/S1743921311012452

LORETTA, M. (2014). *THE ROLE OF AFRICAN CULTURAL ASTRONOMY IN DISASTER MANAGEMENT AMONG BAROLONG BOORA - TSHIDI , MAHIKENG IN THE NORTH WEST PROVINCE Mini-dissertation submitted in partial fulfillment of the requirements for the degree Masters in IKS Cultural Astronomy and D*. NorthWest University.

Lunga, W. (2014). *The Inclusion of Indigenous Knowledge Systems into Disaster Risk Reduction Policy : The Case of Zimbabwe W Lunga* (Issue November). North-West University.

Luo, X., Zhang, C., Song, J., Qiu, Z., Li, W., & Wang, W. (2022). Do Livelihood Strategies Affect the Livelihood Resilience of Farm Households in Flooded Areas? Evidence From Hubei Province, China. *Frontiers in Ecology and Evolution*, *10*(June), 1–11. https://doi.org/10.3389/fevo.2022.909172;https://www.frontiersin.org/articles/10.3389/fevo.

2022.909172/full

Lv, C., Xing, Y., Zhang, J., Na, X., Li, Y., Liu, T., Cao, D., & Wang, F. Y. (2018). Levenberg-marquardt backpropagation training of multilayer neural networks for state estimation of a safety-critical cyber-physical system. *IEEE Transactions on Industrial Informatics*, *14*(8), 3436–3446. https://doi.org/10.1109/TII.2017.2777460

M. Naresh Kumar, a C. S. Murthy, b M. V. R. S. S. and P. S. R. (2009). Tracking the uncertainty in flood alerts driven by grand. *Meteorological Applications*, *101*(February), 91–101. https://doi.org/10.1002/met

M. Naresh Kumara, C.S. Murthyb, M. V. R. S. S. and P. S. R. (2015). On the use of Standardized Precipitation Index (SPI) for drought intensity assessment. *National Remote Sensing Centre, Hyderabad 500 625, India*.

Mafongoya, P.L. and Ajayi, O. C. (2017). *INDIGENOUS KNOWLEDGE SYSTEMS AND CLIMATE CHANGE MANAGEMENT IN AFRICA* (2017 Mafongoya, P.L. and Ajayi, O.C. (editors) (Ed.)). CTA, ISBN 978-92-9081-619-5 CITATION. www.cta.int

Mafongoya, O., Mafongoya, P. L., & Mudhara, M. (2021). Using Indigenous Knowledge Systems in Seasonal Prediction and Adapting to Climate Change Impacts in Bikita District in Zimbabwe. *Oriental Anthropologist*, *21*(1), 195–209. https://doi.org/10.1177/0972558X21997662

Magarsa Abara, Komariah, S. B. (2020). Drought Frequency , Severity , and Duration Monitoring Based on Climate Change in Southern and Southeastern Ethiopia Drought Frequency , Severity , and Duration Monitoring Based on Climate Change in Southern and Southeastern Ethiopia. *IOP Conference Series: Earth and Environmental Science PAPER*, *Earth and*. https://doi.org/10.1088/1755-1315/477/1/012011

Mahoo, H., Mbungu, W., Yonah, I., Recha, J., Radeny, M., Kimeli, P., & Kinyangi, J. (2015). *Working Paper* (Issue 103). https://doi.org/Mahoo H, Mbungu W, Yonah I, Recha J, Radeny M, Kimeli P, Kinyangi J. 2015. Integrating Indigenous Knowledge with Scientific Seasonal Forecasts for Climate Risk Management in Lushoto District in Tanzania. CCAFS Working Paper no. 103. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Copenhagen, Denmark. Available online at: www.ccafs.cgiar.org

Mandaluyong, & Donato-kinomis, X. G. (2016).Indigenous Knowledge . *13th National Convention on Statistics (NCS) EDSA Shangri-La Hotel, Mandaluyong City October 3-4, 2016 INDIGENOUS*, 1–8.

Mariotti, A., Schubert, S., Mo, K., Peters-Lidard, C., Wood, A., Pulwarty, R., Huang, J., & Barrie, D. (2013). Advancing drought understanding, monitoring, and prediction. *Bulletin of the American Meteorological Society*, *94*(12), 1–4. https://doi.org/10.1175/BAMS-D-12-00248.1

Markos, A., & Tuzhilina, E. (2022). *Principal Component Analysis*. *December*. https://doi.org/10.1038/s43586-022-00184-w

Mart, A. (2016). *Ethnoastronomy as an academic field : a framework for a South American program †. No. 278*, *2*(January 2011), 13. https://doi.org/10.1017/S1743921311012452

Masinde, E. M., & Thesis. (2012). *Bridge between African Indigenous Knowledge and Modern Science on Drought Prediction By* (Issue November).

Masinde, M., & Bagula, A. (2011). ITIKI: bridge between African indigenous knowledge and modern science of drought prediction. *Knowledge Management for Development Journal*, *7*(3), 274–290. https://doi.org/10.1080/19474199.2012.683444

Mauro, F., Hardison, P. D., Mauro, F., & Hardison, P. D. (2010). Traditional Knowledge of Indigenous and Local Communities : International Debate and Policy Initiatives Published by : Ecological Society of America Traditional knowledge of inddigenous and local communities: International Debate and and Policy initiatives . *Promoting the Science of Ecology*, *Vol. 10*, *N*(5), 1263–1269. https://doi.org/http://www.jstor.org/page/info/about/policies/terms.jsp.

Mbewe, M., Phiri, A., & Siyambango, N. (2019). *Indigenous Knowledge Systems for Local Weather Predictions : A Case of Mukonchi Chiefdom in Zambia*. *9*(2), 16–26. https://doi.org/10.5539/enrr.v9n2p16

Mbilinyi, D. (2020). the Role of Indigenous Weather Forecasting Knowledge Systems for Adaptation To the Effects of Climate Variability on Agriculture in Kondoa District-Tanzania. *Gsj*, *8GSJ: Volu*(1), 855–876. https://doi.org/https://www.globalscientificjournal.com/researchpaper/THE_ROLE_OF_INDIGENOUS_WEATHER_FORECASTING_KNOWLEDGE_SYSTEMS_FOR_ADAPTATION_TO_THE_EFFECTS_OF_CLIMATE_VARIABILITY_ON_AGRICULTURE_IN_KONDOA_DISTRICT_TANZANIA.pdf

Mckee, T. B., Doesken, N. J., & Kleist, J. (1993). *The relationship of drought frequency and duration to time scales*. *Department*(January), 17–22. https://doi.org/Eighth Conference on Applied Climatology, 17-22 January 1993, Anaheim, California THE

McPeak, J. G., & Little, P. D. (2017). Applying the concept of resilience to pastoralist household data. *Pastoralism*, *7*(1). https://doi.org/10.1186/s13570-017-0082-4

Mehdi Bahrami, S. B. and A. R. Z. (2019a). Modeling , prediction and trend assessment of drought in Iran using standardized precipitation index Mehdi Bahrami , Samira Bazrkar and Abdol Rassoul Zarei. *IWA Publishing 2019*, 181–196. https://doi.org/10.2166/wcc.2018.174

Mehdi Bahrami, S. B. and A. R. Z. (2019b). Modeling , prediction and trend assessment of drought in Iran using standardized precipitation index Mehdi Bahrami , Samira Bazrkar and Abdol Rassoul Zarei. *Journal of Water and Climate Change*, *m http://iwaponline.com/jwcc/article-pdf/10/1/181/533404/jwc0100181.pd*, 181–196. https://doi.org/10.2166/wcc.2018.174

Mehran, A., Mazdiyasni, O., & Aghakouchak, A. (2015). A hybrid framework for assessing socioeconomic drought: Linking. *Joiurnal of Geophysical Research: Atmospheres*, *10.1002/20*, 1–14. https://doi.org/10.1002/2015JD023147.Received

MENG, B., LI, N., & FANG, D. (2018). Attributes, challenges and future directions of community resilience. *Frontiers of Engineering Management*, *0*(0), 0. https://doi.org/10.15302/j-fem-2018030

Mengistu, D. (2016). Impacts of Drought and Conventional Coping Strategies of Borana Community, Southern Ethiopia. *Research on Humanities and Social Sciences*, *6*(23), 29–37. https://www.iiste.org/Journals/index.php/RHSS/article/view/34788

Mera, G. A. (2018). Drought and its impacts in Ethiopia. *Weather and Climate Extremes*, *22*(September), 24–35. https://doi.org/10.1016/j.wace.2018.10.002

Messages, K. E. Y. (2019). *ETHIOPIA Food Security Outlook February to September 2019 The level of conflict-induced displacement needs begin to surpass drought-induced needs*. *September*.

Mihertu, Y. F. (2018). The Role of Indigenous People Knowledge in the Biodiversity Conservation in Gursumwoerda , Easternhararghe Ethiopia. *Annals of Ecology and Environmental Science*, *Volume 2*,(January). https://www.researchgate.net/publication/324476468

Mihunov, V. V, Lam, N. S. N., Rohli, R. V, Zou, L., Rouge, B., Sciences, C., Rouge, B., & Rouge, B. (2019). *Emerging Disparities in Community Resilience to Drought Hazard in South-Central United States*. 1–37.

Mohamed, A. A. (2019). Pastoralism and Development Policy in Ethiopia: A Review Study. *Budapest International Research and Critics Institute (BIRCI-Journal) : Humanities and Social Sciences*, *2*(4), 01–11. https://doi.org/10.33258/birci.v2i4.562

Moller, M. F. (1990). Scaled Conjugate Gradient. *Computer Science Department AARHUS University, Denmark, DAIMIPB-*.

Mosime, B. (2018). *The use of traditional weather forecasting by agro- pastoralists of different social groups in Bobirwa sub- district , Botswana*. UNIVERSITY OF CAPE TOWN.

MoSTE. (2015). *INDIGENOUS AND FOR CLIMATE AND PRACTICES LOCAL KNOWLEDGE RESILIENCE IN NEPAL*. Singha Durbar, Kathmandu.

Muche, T. (2022). Meteorological Drought in Three Woredas of Eastern Harerghe and Shinile Zones ,. *Journal of Climatology & Weather Forecastings*, *10*(3), 1–9. https://doi.org/10.35248/2332-2594.22.10(3).34

Mugabe, F., Mubaya, C. P., Nanja, D., & Gondwe, P. (2011). *Engaging smallholder farmers with seasonal climate forecasts for sustainable crop production in semi-arid areas of Zimbabwe*. *November 2015*. https://doi.org/10.5897/AJAR2014.

Muguti;, T. S. (2012). Indigenous Weather Forecasting : A Phenomenological Study Engaging the Shona of Zimbabwe by. *The Journal of Pan African Studies, vol.4*, no.(9), 102–113.

Mukaka, M. M. (2012). Statistics corner: A guide to appropriate use of correlation coefficient in medical research. *Malawi Medical Journal*, *24*(3), 69–71.

Mulualem, G. M., & Liou, Y. A. (2020). Application of artificial neural networks in forecasting a standardized precipitation evapotranspiration index for the upper Blue Nile basin. *Water (Switzerland)*, *12*(3). https://doi.org/10.3390/w12030643

Mung, H. G., Mbonile, M. J., & Maganga, F. P. (2019). Innovative pathways for enhancing climate change and variability resilience among agro-pastoral communities in semi-arid areas of Kiteto and Kilindi Districts , Tanzania. *African Journal of Environmental Science and Technology*, *13*(May), 201–219. https://doi.org/10.5897/AJEST2019.2650

Muñoz-Erickson, T. A., Selkirk, K., Hobbins, R., Miller, C., Feagan, M., Iwaniec, D. M., Miller, T. R., & Cook, E. M. (2021). Anticipatory Resilience Bringing Back the Future into Urban Planning and Knowledge Systems. In *Urban Book Series* (pp. 159–172). https://doi.org/10.1007/978-3-030-63131-4_11

Muricho, D. N., Otieno, D. J., & Oluoch-kosura, W. (2017). *Building Pastoralists ' Resilience : Strengthening Participation in Markets and Local Governance Institutions in West Pokot , Kenya Department of Agricultural Economics , University of Nairobi * presenting author : deborahmuricho@gmail.com ** correspondin*. 1–21.

Mwinzi, J. M. (2015). *Theoretical Frameworks and Indigenous Knowledge Systems Subject Area : Philosophy of Education*. *3*(2), 677–684. https://doi.org/www.ijern.com

N, D. L., & Star, O. I. (2013). The Red Day Star, the Women's Star and Venus: D(L/N)akota, Ojibwe and Other Indigenous Star Knowledge. *The International Journal of Science in Society*, *The Common Ground*, *4Volume 4*,(L), 14.

Nabipour, N., Dehghani, M., & Mosavi, A. (2020). Short-Term Hydrological Drought Forecasting Based on Different Nature-Inspired Optimization Algorithms Hybridized With Artificial Neural Networks. *IEEEAccess*, *8*, 2. https://doi.org/10.1109/ACCESS.2020.2964584

Nakashima, D., Krupnik, I. and Rubis, J. T. (2018). *Indigenous Knowledge for Climate Change Assessment and Adaptation* (First).

NASE. (2018). NASE kaleidoscope of experiences in cultural astronomy. Archeoastronomy and Astronomy in the City. In R. M. R. & J. A. Belmonte (Ed.), *Proceedings of the Second Seminar on NASE Experiences in Cultural Astronomy* (p. 205). Albedo Full Dome, S.L.

Nasir, J., Assefa, E., Zeleke, T., & Gidey, E. (2021). Meteorological Drought in Northwestern Escarpment of Ethiopian Rift Valley: detection seasonal and spatial trends. *Environmental Systems Research*, *10*(1). https://doi.org/10.1186/s40068-021-00219-3

Nawi, N. M., Khan, A., & Rehman, M. Z. (2013). A New Levenberg Marquardt based Back Propagation Algorithm Trained with Cuckoo Search. *Procedia Technology*, *11*(Iceei), 18–23. https://doi.org/10.1016/j.protcy.2013.12.157

Nelson, D. R., Adger, W. N., & Brown, K. (2007). Adaptation to environmental change: contributions of a resilience framework. *Annual Review of Environment and Resources*, *32*, 395–419.

https://doi.org/10.1146/annurev.energy.32.051807.090348;https://www.annualreviews.org/doi/10.1146/annurev.energy.32.051807.090348

Neofotis, P., Oettlé, N., Rosenzweig, C., Sakakibara, C., Shadrin, V., Waterhouse, J., & Weeks, B. (2011). *Linking Indigenous and Scientific Knowledge of Climate Change*. *June*. https://doi.org/10.1525/bio.2011.61.6.10

Nhamo, L., & Mabhaudhi, T. (2019). Preparedness or repeated short-term relief aid ? Building drought resilience through early warning in southern Africa. *International Water Management Institute (IWMI)*, *45*(1), 75–85. https://doi.org/doi.org/10.4314/wsa.v45i1.09

Nitoiu, C., & Pasatoiu, F. (2021). Resilience and the world order : the EU and the RIC states. *International Politics*, *58*(3), 444–461. https://doi.org/10.1057/s41311-020-00259-z

No Title. (1999). 1–11.

Normandin, H. (2023). *Inclusive Multilateralism : Cities Take a Seat at the Table*. https://doi.org/10.1163/9789004516489

Norris, R. P., & Harney, B. Y. (2012). Songlines and Navigation in Wardaman and other Australian Aboriginal Cultures. *Journal of Astronomical History and Heritage, Volume 17*,(2), 1–15.

Norton-smith, K., Lynn, K., Chief, K., Cozzetto, K., Donatuto, J., Redsteer, M. H., Kruger, L. E., Maldonado, J., Viles, C., & Whyte, K. P. (2016). *Climate Change and Indigenous Peoples : A Synthesis of Current Impacts and Experiences*. *October*.

Nowell, L. S., Norris, J. M., White, D. E., & Moules, N. J. (2017). Thematic Analysis: Striving to Meet the Trustworthiness Criteria. *International Journal of Qualitative Methods*, *16*(1), 1–13. https://doi.org/10.1177/1609406917733847

Nuvey, F. S., Addo-lartey, A., Nortey, P. A., Addo, K. K., & Bonfoh, B. (2021). Coping with Adversity : Resilience Dynamics of Livestock Farmers in Two Agroecological Zones of Ghana. *Environmental Research and Public Health*, *Int. J. En*. https://doi.org/10.3390/ijerph18179008

Nyadzi, E., Werners, S. E., Biesbroek, R., & Ludwig, F. (2021). Techniques and skills of indigenous weather and seasonal climate forecast in Northern Ghana. *Climate and Development*, *13*(6), 551–562. https://doi.org/10.1080/17565529.2020.1831429

Nyamwanza, A., Jacobs, P., & Nyezi, K. (2023). Advancing a transformative human development approach to climate resilience through local innovation in South Africa. *Development Southern Africa*, *February*, 1–14. https://doi.org/10.1080/0376835X.2023.2171365

Ohlsson, M. (2017). *Exploring Social-Ecological Response Capacity to Drought of Swedish Farms*. Swdeen University.

Okonya, J. S., & Kroschel, J. (2013a). Indigenous knowledge of seasonal weather forecasting : A case study in six regions of Uganda. *Journal of Agricultural Sciences*, *Vol.4*, *No.*(12), 641–

648. https://doi.org/Vol.4, No.12, 641-648 (2013) http://dx.doi.org/10.4236/as.2013.412086

Okonya, J. S., & Kroschel, J. (2013b). Indigenous knowledge of seasonal weather forecasting: A case study in six regions of Uganda. *Agricultural Sciences*, *04*(12), 641–648. https://doi.org/10.4236/as.2013.412086

Oktaviani.J. (2000). Early Warning System for drought prepaaredness amd drought managment. *Sereal Untuk*, *51*(1), 51.

Oruru, B., Najjemba, H., Zawedde, A. E., Nteziyaremye, R., & D, F. M. (2020). The first track of cultural astronomy in Uganda : Perspectives of the Baganda , Bagisu , Banyoro and Langi. *African Journal of History and Culture African Journal of History and Culture*, *Vol. 12(2)*(December), 35–48. https://doi.org/10.5897/AJHC2020.0484

Oshagbemi, T. (2017). RESEARCH DESIGN AND METHODOLOGY. In *Leadership and Management in Universities* (Issue 2003, pp. 67–95). https://doi.org/10.1515/9783110853681-006/https://www.intechopen.com/chapters/68505

Oyekale, A. S. (2015). Access to risk mitigating weather forecasts and changes in farming operations in east and west Africa: Evidence from a baseline survey. *Sustainability (Switzerland)*, *7https://w*(11), 14599–14617. https://doi.org/10.3390/su71114599/Sustainability 2015, 7, 14599-14617

Palmer, W. C. (1965). Meteorological Drought. In *U.S. Weather Bureau, Res. Pap. No. 45* (p. 58). https://www.ncdc.noaa.gov/temp-and-precip/drought/docs/palmer.pdf

Panampitiya, G. (2019). *A REVIEW OF INDIGENOUS KNOWLEDGE RELATED TO THE TRADITIONAL AGRICULTURE IN SRI LANKA*. *October 2018*.

Parvaze, S., Majid, M., & Kanth, R. H. (2016). Analysis of Historical Rainfall Data for Drought Investigation Using Standard Precipitation Index (SPI) Under Temperate Conditions of Srinagar Kashmir. *Pakistan Journal of Meteorology*, *13Vol. 13,*(25), 29–38. https://doi.org/Sher-e-Kashmir University of Agricultural Sciences andAnalysis of Historical Rainfall Data for Drought Investigation Using Standard Precipitation Index … Technology of Kashmir Shalimar (J&K) 190025.

Pauley, C. M., Mckim, A. J., & Hodbod, J. (2019). A Social-Ecological Resilience Perspective for the Social Sciences of Agriculture , Food , and Natural Resources. *Journal of Agricultural Education*, *60*(4), 132–148. https://doi.org/https://doi.org/10.5032/jae.2019.04132 A

Pazoki, M. (2022). *Journal of Research and Rural Planning*. *11*(4), 21–40. https://doi.org/http://dx.doi.org/10.22067/jrrp.v11i4.2202.1040

Petzold, J., Andrews, N., Ford, J. D., Hedemann, C., & Postigo, J. C. (2020). Indigenous knowledge on climate change adaptation: A global evidence map of academic literature. *Environmental Research Letters*, *15*(11). https://doi.org/10.1088/1748-9326/abb330

Pezzoli, A., & Ponte, E. (2014). *Vulnerability and Resilience to Drought in the*. *April*. https://doi.org/http://www.ncdc.noaa.gov/.

Pidgeon, M., & Riley, T. (2021). Understanding the Application and Use of Indigenous Research Methodologies in the Social Sciences by Indigenous and Non-Indigenous Scholars. *International Journal of Education Policy and Leadership*, *17*(8). https://doi.org/10.22230/ijepl.2021v17n8a1065

Pieper, P., Düsterhus, A., & Baehr, J. (2020). A universal Standardized Precipitation Index candidate distribution function for observations and simulations. *Hydrology and Earth System Sciences*, *24*(9), 4541–4565. https://doi.org/10.5194/hess-24-4541-2020

Prasad, A., & Ganesan, D. (2020). Research Trends in Agriculture Sciences. In *Research Trends in Agriculture Sciences* (Issue November 2022). https://doi.org/10.22271/ed.book.787/https://www.researchgate.net/profile/J-Tarafdar/post/Research_papers_related_to_weather_forecasting_in_managing_chemical_spray_or_nutrient_management_in_crops/attachment/64843f0528b5df6cef1813d8/AS%3A11431281166757775%401686388485158/download/3.2_WeatherForecastinginAgriculture.pdf

Pregowska, A., & Osial, M. (2021). What Is An Artificial Neural Network And Why Do We Need It? *Frontiers for Young Minds*, *9*. https://doi.org/10.3389/frym.2021.560631

Puffer, B. P., & Associate, C. (1995). *The Value of Indigenous Knowledge in Development Programs Concerning Somali Pastoralists and Their Camels*.

Purvis, B., Mao, Y., & Robinson, D. (2019). Three pillars of sustainability: in search of conceptual origins. *Sustainability Science*, *14*(3), 681–695. https://doi.org/10.1007/s11625-018-0627-5

Radeny, M., Desalegn, A., Mubiru, D., Kyazze, F., Mahoo, H., Recha, J., Kimeli, P., & Solomon, D. (2019a). *Indigenous knowledge for seasonal weather and climate forecasting across East Africa*. 509–526.

Radeny, M., Desalegn, A., Mubiru, D., Kyazze, F., Mahoo, H., Recha, J., Kimeli, P., & Solomon, D. (2019b). Indigenous knowledge for seasonal weather and climate forecasting across East Africa Content courtesy of Springer Nature , terms of use apply . Rights reserved . Content courtesy of Springer Nature , terms of use apply . Rights reserved . *Climatic Change (2019) 156:509–526*, *Climatic C*, 509–526. https://doi.org/10.1007/s10584-019-02476-9%0AIndigenous

Rahman, A., & Rusli, B. I. N. (2017). *Development Processes of Indigenous Knowledge on Tsunami Risk Reduction to Increase Community Resilience: The Case of the Smong in Simeulue Island, Aceh, Indonesia* [Tohoku UniversityDoctorial Desertation,]. https://doi.org/http://hdl.handle.net/10097/00122571

RAJ, R. (n.d.). *Harmonizing Traditional and Scientific Knowledge Systems in Rainfall Prediction and Utilization*.

RAJ, R. (2011). Harmonizing Traditional and Scientific Knowledge Systems in Rainfall Prediction and Utilization. In *Bridging Scales and Knowledge Systems* (p. 227). https://doi.org/https://www.millenniumassessment.org/documents/bridging/bridging.12.pdf

Rajasekaran, B. (1993). *A framework for incorporating indigenous knowledge systems into agricultural research and extension organizations for sustainable agricultural development in India*. Iowa State University Capstones, Theses and Dissertations.

Ranjan, R. (2011). *Drought Resilient Strategies*.

Rawn, V., Echeverria, W. De, & Thornton, T. F. (2019). Using traditional ecological knowledge to understand and adapt to climate and biodiversity change on the Paci fi c coast of North America. *Ambio*, *2019*, *48:1*(12), 1447–1469. https://doi.org/10.1007/s13280-019-01218-6

Reflection, A. C., Communal, O. N., Holding, L., Borana, I. N., & Pastoralists, O. (2000). *Perspectives on common property regimes in ethiopia: a critical reflection on communal land holding rights in borana oromo pastoralists context*.

Reris, R., & Brooks, J. P. (2015). Principal Component Analysis and Optimization : A Tutorial. *Statistical Sciences and Operations Research Publications Virginia*, *14th INFOR*. https://doi.org/doi.org/10.1287/ics.2015.0016

Resilience, R., & Practices, G. (n.d.). *Promoting effective resilience investments*.

Rhodes, D. H. (2009). *Anticipatory Capacity : March*.

Richman, M. B., Leslie, L. M., & Segele, Z. T. (2016). Classifying Drought in Ethiopia Using Machine Learning. *Procedia Computer Science*, *95*, 229–236. https://doi.org/10.1016/j.procs.2016.09.319

Rishona Basdew, M. (2016). *an Investigation of Scientific and Indigenous Weather Forecasting for Improved Decision-Making By Farmers*. http://ukzn-dspace.ukzn.ac.za/bitstream/handle/10413/15924/Basdew_Myuri_Rishona_2016.pdf?sequence=1&isAllowed=y

Romani, J. F. (1981). *Astronomy and Social Information; An examination of Astronomy In a Hunter and Gatherer Society.A thesis submitted in partial satisfaction of the requirements for the degree of Master of Arts in Anthropology*. California State University, Northridge.

Rudnev, V. (2002). Etheno Meteorology and Folk Knowledge. *Lnstitute of Ethnology and Anthropology. Russian Academy of Sciences.*, *32-A*, *Leni*, 183–188.

Ruggles, C. L. N. (2015). *Handbook of Archaeoastronomy and Ethnoastronomy*.

Rustomjee, C. (2015). Indigenous knowledge as a driver of resilience. In Reineira Arguello Sanjuan (Ed.), *Commonwealth Foundation,, Common Wealthe Insights. People Forum: Indigenous knowledge and resilience* (p. 4). https://doi.org/www.commonwealthfoundation.com

Rutter, M. (2006). Implications of resilience concepts for scientific understanding. *Annals of the New York Academy of Sciences*, *1094*, 1–12. https://doi.org/10.1196/annals.1376.002;http://www.antoniocasella.eu/dnlaw/RUTTER_Resilience_2006.pdf

Ryan, J. C. (2013). Toward a phen (omen) ology of the seasons : The emergence of the Indigenous Weather Knowledge Project (IWKP) Environment , Space , Place. *Edith Cowan University Research Online.Environment, Space, Place, 55(1), 103*, 103–131. https://ro.ecu.edu.au/ecuworks2013

S.Sapna1, D. A. T. and M. P. K., & 1. (2012). Backpropagation Learning Algorithm Based on Levenberg Marquardt Algorithm. *Computer Science & Information Technology*, 393–398. https://doi.org/10.5121/csit.2012.2438

Saccenti, E., Hendriks, M. H. W. B., & Smilde, A. K. (2020). Corruption of the Pearson correlation coefficient by measurement error and its estimation, bias, and correction under different error models. *Scientific Reports, Nature Research*, *10*(1), 1–19. https://doi.org/10.1038/s41598-019-57247-4

Šakić, R. (2020). *The role of local knowledge in community-based flood risk management in Malawi Robert Šakić Trogrlić Submitted for the degree of Doctor of Philosophy School of Energy , Geoscience , Infrastructure and Society Institute for Infrastructure and Environment M* (Issue March). Heriot-Watt University School Heriot-Watt University School of Energy, Geoscience, Infrastructure and Society Institute for Infrastructure and Environment.

Salehnia, N., Alizadeh, A., Sanaeinejad, H., Bannayan, M., Zarrin, A., & Hoogenboom, G. (2017). Estimation of meteorological drought indices based on AgMERRA precipitation data and station-observed precipitation data. *Journal of Arid Land*, *9*(6), 797–809. https://doi.org/10.1007/s40333-017-0070-y

Salifu, B. (2020). *Climate Change Impact and Traditional Coping Mechanisms of Borana Pastoralists in Southern Ethiopia Building Adaptive Capacity and Resili ence from an Indigenous People ' s Perspective*. *June*.

Salite, D. (2019). uncertainty : analyzing the challenges and opportunities for small-scale farmers in Gaza Article : for small - scale farmers in Gaza province , southern region of Mozambique. *White Rose University Consortium, Natural Hazard*, *Natural Ha*, 22.

Sancho-Zamora, R., Gutiérrez-Broncano, S., Hernández-Perlines, F., & Peña-García, I. (2021). A Multidimensional Study of Absorptive Capacity and Innovation Capacity and Their Impact on Business Performance. *Frontiers in Psychology*, *12*(October). https://doi.org/10.3389/fpsyg.2021.751997

Sandi, S. G., Rodriguez, J. F., Saintilan, N., Wen, L., Kuczera, G., Riccardi, G., & Saco, P. M. (2020). Resilience to drought of dryland wetlands threatened by climate change. *Scientific Reports*, 1–14. https://doi.org/10.1038/s41598-020-70087-x

Sankar, T., Ga, D., Panneerselvam, S., & Kokilavani, S. (2019). *ASTROMETEOROLOGICAL RELATIONSHIP BETWEEN PLANET AZIMUTH AND CYCLONE EVENTS IN BAY OF BENGAL*. *11*(11), 8595–8598.

Santos, C. A. G., Morais, B. S., & Silva, G. B. L. (2009). Drought forecast using an artificial neural network for three hydrological zones in San Francisco River basin , Brazil.

Department of Civil and Environmental Engineering, Brazil, *September*, 302–312.

Sapna, S. (2012). Backpropagation Learning Algorithm Based on Levenberg Marquardt Algorithm. *Computer Science & Information Technology*, 393–398. https://doi.org/10.5121/csit.2012.2438

Schaefer, M., Thinh, N. X., & Greiving, S. (2020). *How Can Climate Resilience Be Measured and Visualized ? Assessing a Vague Concept Using GIS-Based Fuzzy Logic*.

Schmidt, D. H., & Garland, K. A. (2012). Bone Dry in Texas : Resilience to Drought on the Upper Texas Gulf Coast. *Journal of Planning Literature*, *Journal of*(0), 1–12. https://doi.org/10.1177/0885412212454013

Schrijver, A. P. (2019). *Pastoralists , Mobility and Conservation*.

Scofield, B. (2010a). *A History and Test of Planetary Weather Forecasting*. Massachusetts Amherst.

Scofield, B. (2010b). *A History and Test of Planetary Weather Forecasting*. University of Massachusetts Amherst.

Scofield, B. (2010c). *ScholarWorks @ UMass Amherst A History and Test of Planetary Weather Forecasting*. University of Massachusetts Amherst Follow.

Semplici, G., Campbell, T., & Semplici, G. (2023a). The revival of the drylands : re-learning resilience to climate change from pastoral livelihoods in East Africa The revival of the drylands : re-learning resilience to climate change from pastoral livelihoods in East Africa. *Climate and Development*, 1–14. https://doi.org/10.1080/17565529.2022.2160197/https://www.tandfonline.com/doi/full/10.1080/17565529.2022.2160197

Semplici, G., Campbell, T., & Semplici, G. (2023b). The revival of the drylands : re-learning resilience to climate change from pastoral livelihoods in East Africa The revival of the drylands : re-learning resilience to climate change from pastoral livelihoods in East Africa. *Climate and Development*, 1–14. https://doi.org/10.1080/17565529.2022.2160197

Sgier, L. (2017). *Content / Thematic Analysis*. *2*(2009), 2006–2009.

Shad, M. Y., Shoukry, A. M., & Gani, S. H. (2017). Forecasting Drought Using Multilayer Perceptron Artificial Neural Network Mode. *Advances in Meteorology, Volume 201*, 10. https://doi.org/https://doi.org/10.1155/2017/5681308

Shammin, R., Haque, A. K. E., & Faisal, I. M. (2022). Climate Change and Community Resilience. In *Climate Change and Community Resilience*. Springer Singapore. https://doi.org/10.1007/978-981-16-0680-9; http://crossmark.crossref.org/dialog/?doi=10.1007/978-981-16-0680-9_2&domain=pdf

Shoko, K., & Shoko, N. (2017). Indigenous Weather Forecasting Systems : A Case Study of the Abiotic Weather Forecasting Indicators for Wards 12 and 13 in Mberengwa District Zimbabwe. *Asian Social Science;*, *Vol. 9, No*(5), 285–297.

https://doi.org/10.5539/ass.v9n5p285

Sillitoe, P., & Sillitoe, A. P. (2006). Introduction : Indigenous Knowledge in Development. *Anthropology in Action, 13, 3 (200*(Anthropology in Action, 13, 3 (2006): 1–12), 1–12. https://doi.org/10.3167/aia.2006.130302

Simelton, E., Fraser, E. D. G., Termansen, M., Forster, P. M., & Dougill, A. J. (2009). Typologies of crop-drought vulnerability : an empirical analysis of the socio-economic factors that influence the sensitivity and resilience to drought of three major food crops in China (1961 – 2001). *Environmental Science and Policy*. https://doi.org/10.1016/j.envsci.2008.11.005

Simone. (2017). *Ethiopia ' s Arid and Semi-Arid Lowlands : Towards Inclusive and Sustainable Rural Transformation* (Issue March).

Simonia, I., Ruggles, C., & Le, L. (2008). Ethnographic and Literary Reflection on Ancient Georgian Astronomical Heritage. *Journal of Astronomical History and Heritage, 11(3), 213-218 (2008).*, *11*(3), 213–218.

Singh, A. K., Singh, N., Singh, H., & Kushwaha, H. S. (2021). *Role and Importance of Weather Forecasts in Modern Agriculture*. *10Int.J.Cu*(01), 2646–2662. https://doi.org/https://www.ijcmas.com/10-1-2021/Aditya%20Kumar%20Singh,%20et%20al.pdf

Singh, M. &. (2011). Drought modeling. *Journal of Hydrology*, *403*(1–2), 157–175. https://www.sciencedirect.com/science/article/abs/pii/S0022169411002393?via%3Dihub

Sirima, A. (2015). *The Contribution of Indigenous Ecological Knowledge in Conservation of Enguserosambu Community Forest*. A Dissertation Presented to the Graduate School of Clemson University.

Siseho, S. C. (3013). *The Effect of an Argumentation Instructional Model on Pre-Service Teachers" Ability to Implement a Science-IK Curriculum*. University of the Western Cape.

Sivaprakasam, S., & Kanakasabai, V. (2009). Traditional almanac predicted rainfall – A case study. *Indian Journal of Traditional Knowledge, Vol. 8 (4)*(October), 621–625.

Smilde, R. B. and A. K. (2014). Analytical Methods. *Royal Society of Chemistry*, 2812–2831. https://doi.org/10.1039/c3ay41907j

Snell, M. L., Eisenberg, D. A., Seager, T. P., Clark, S. S., Oh, Y. J., Thomas, J. E., & McBurnett, L. R. (2016). A Multidimensional Review of Resilience: Resources, Processes, and Outcomes. *IRGC Resource Guide on Resilience, January 2017*, 1–7.

SsetteeE, P. (2007). *PIMATISIWIN: INDIGENOUS KNOWLEDGE SYSTEMS, OUR TIME HAS COME* (Issue April). University of Saskatchewan.

Steen, J. (2021). *Indigenous North American Cosmological and Astronomical Knowledge Perspectives and Teachings* (P. A. J. A. Chen (Ed.); First Prin, Issue October). Golden Meteorite Press. https://www.researchgate.net/publication/355199902%0AIndigenous

Subiyanto, A., & Boer, R. (2020). *E nvironment A sia Climate Resilience : January*. https://doi.org/10.14456/ea.2020.1

Sundararajan, K., Garg, L., Srinivasan, K., Bashir, A. K., Ganapathy, G. P., Selvaraj, S. K., & Meena, T. (2021). *A Contemporary Review on Drought Modeling Using Machine Learning Approaches ARID. Computer M*. https://doi.org/10.32604/cmes.2021.015528

Tadesse, T. (2016). *Strategic Framework for Drought Risk Management and Enhancing Resilience in Africa*.

Tadicha, H. (2015). *An integrated assessment of resource use strategies in the Borana pastoral system of southern Ethiopia*. University of Kassel, Germany.

Takele Gebissa, D. (2015). Husbandry Practices and Utilization of Camel Products in Borana Zone of Southern Oromia, Ethiopia. *Science Research*, *3*(4), 191. https://doi.org/10.11648/j.sr.20150304.16

Tang, R. (2012). An Analysis of Traditional ecological knowledge's status and its conservation options. In *Thesis*.

Tanner, T., Lewis, D., Wrathall, D., Bronen, R., Cradock-Henry, N., Huq, S., Lawless, C., Nawrotzki, R., Prasad, V., Rahman, M. A., Alaniz, R., King, K., McNamara, K., Nadiruzzaman, M., Henly-Shepard, S., & Thomalla, F. (2015). Livelihood resilience in the face of climate change. *Nature Climate Change*, *5*(1), 23–26. https://doi.org/10.1038/nclimate2431

Tesfaye, A., Hansen, J. W., Kassie, G. T., Radeny, M., & Solomon, D. (2018). *Working Paper Estimating the economic* (CCAFS Working Paper no. 252).

The Best of Both Worlds : A Decision-Making Framework for Combining Traditional and Contemporary Forecast Systems. (2017). https://doi.org/10.1175/JAMC-D-17-0012.1

Theodory, T. F. (2016). Dealing with Change : Indigenous Knowledge & Adaptation to CC in the Ngono River Basin , Tanzania. In *PhD.Tanzania*. Faculty of Mathematics and Natural Sciences of the Rheinische Friedrich-Wilhelms-University of Bonn.

Theses, M., Bartels, R., & Bartels, R. (2014). *A Climatological Study of Drought in Southern Michigan by*.

Thulstrup, A. W. (2015). Livelihood Resilience and Adaptive Capacity: Tracing Changes in Household Access to Capital in Central Vietnam. *World Development*, *World Deve*, 352–362. https://doi.org/10.1016/j.worlddev.2015.05.019;https://daneshyari.com/article/preview/7393642.pdf

Trifonov, R., Yoshinov, R., Pavlova, G., & Tsochev, G. (2017). Artificial neural network intelligent method for prediction. *AIP Conference Proceedings*, *1872*(September 2017). https://doi.org/10.1063/1.4996678

Tura, G. B., & Reddy, P. R. (2015). Study of Vegetation Composition of Magada Forest, Borana

Zone, Oromia, Ethiopia. *Universal Journal of Plant Science*, *3*(5), 87–96. https://doi.org/10.13189/ujps.2015.030501

UNDP. (2011). *Mainstreaming Drought Risk Management a primer*.

UNDP. (2019). *Building Resilience to Climate Shocks in Ethiopia* (J. KOO (Ed.)). International Food Policy Research Institute.

UNE. (2017). Drought forecasting systems. *Climate Change Adaptation Technologies for Water, WATER ADAP*. http://www.unepdhi.org/publications

UNESCO. (2009). Investing in cultural diversity and intercultural dialogue. In *UNESCO World Report*.

UNFCCC. (2013). *Best practices and available tools for the use of indigenous and traditional knowledge and practices for adaptation , and the application of gender-sensitive approaches and tools for understanding and assessing impacts , vulnerability and adaptation to cl*. *October*.

Ungar, M. (2018). Systemic resilience: principles and processes for a science of change in contexts of adversity. *Ecology and Society*, *23*(4). https://doi.org/10.5751/ES-10385-230434;https://www.jstor.org/stable/26796886

UNSDR. (2007). *International Strategy for Disaster Reduction Drought Risk Reduction Framework and Practices : May*.

USAID, 2022. (2022). *2022 Resilience Policy Revision*. *December*. https://doi.org/https://www.usaid.gov/sites/default/files/2022-12/Resilience-Policy-Revision-Jan-2023.pdf

Van Breda, A. D. (2018). A critical review of resilience theory and its relevance for social work. *Social Work (South Africa)*, *54*(1), 1–18. https://doi.org/10.15270/54-1-611;https://ujcontent.uj.ac.za/view/pdfCoverPage?instCode=27UOJ_INST&filePid=136309240007691&download=true

van der Merwe, S. E., Biggs, R., & Preiser, R. (2018). A framework for conceptualizing and assessing the resilience of essential services produced by socio-technical systems. *Ecology and Society*, *23*(2). https://doi.org/10.5751/ES-09623-230212; https://consecol.org/vol23/iss2/art12/ES-2017-9623.pdf

Veloz, T., Maldonado, P., Bussseniers, E., Bassi, A., Beigi, S., Lenartowicz, M., & Heylighen, F. (2022). Towards an Analytic Framework for System Resilience Based on Reaction Networks. *Complexity*, *2022*. https://doi.org/10.1155/2022/9944562; https://www.hindawi.com/journals/complexity/2022/9944562/

Venton, C. C. (2018). *ECONOMICS OF RESILIENCE TO DROUGHT*. *January*.

Vicente-serrano, S. M. (2006). *Differences in Spatial Patterns of Drought on Different Time Scales : An Analysis of the Iberian Peninsula*. 37–60. https://doi.org/10.1007/s11269-006-2974-8

VICENTE-SERRANO, S. M. (2010). *A New Global 0.58 Gridded Dataset (1901–2006) of a Multiscalar Drought Index: Comparison with Current Drought Index Datasets Based on the Palmer Drought Severity Index*. 1033–1043. https://doi.org/10.1175/2010JHM1224.1

Vicente-Serrano, S. M., Peña-Angulo, D., Beguería, S., Domínguez-Castro, F., Tomás-Burguera, M., Noguera, I., Gimeno-Sotelo, L., & El Kenawy, A. (2022). Global drought trends and future projections. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *380*(2238). https://doi.org/10.1098/rsta.2021.0285

VSF International. (2018). From emergency to development building resilience through livestock-based interventions. *VSF International Policy Paper n. 4 – February 2018 FROM*, *February*, 8. https://doi.org/https://www.avsf.org/en/posts/2218/full/from-emergency-to-development-building-resilience-through-livestock-based-interverventions

Waldmann, P. (2019). On the use of the pearson correlation coefficient for model evaluation in genome-wide prediction. *Frontiers in Genetics*, *10*(SEP), 1–4. https://doi.org/10.3389/fgene.2019.00899

Walker, B. (2003). *Resilience Defined* (pp. 1–2).

Wambua, R. M., Mutua, B. M., & Raude, J. M. (2014). Drought Forecasting Using Indices and Artificial Neural Networks for Upper Tana River Basin , Kenya-A Review Concept. *Journal of Civil & Environmental Engineering*, *4*(4). https://doi.org/10.4172/2165-784X.1000152

Wienroth, M., Granja, R., McCartney, C., Lipphardt, V., & Amoako, E. N. (2021). Ethics as lived practice. Anticipatory capacity and ethical decision-making in forensic genetics. *Genes*, *12*(12). https://doi.org/10.3390/genes12121868

Wilhite, D. A. (2000). Drought As a Natural Hazard. *Droughts*, 33–33. https://doi.org/10.4324/9781315830896-24

Wilhite, D. A., Svoboda, M. D., & Hayes, M. J. (2007). Understanding the complex impacts of drought: A key to enhancing drought mitigation and preparedness. *Water Resources Management*, *Water Reso*(5), 763–774. https://doi.org/10.1007/s11269-006-9076-5

Williams, P. A., & Sikutshwa, L. (2020). *Acknowledging Indigenous and Local Knowledge to Facilitate Collaboration in Landscape Approaches — Lessons from a Systematic Review*. 1–17.

Willis, D., & Ii, H. (2011). *On the Astronomical Knowledge and Traditions of Aboriginal Australians By* (Issue December). a thesis submitted in fulfilment of the requirements for the degree of Doctor of PhilosophyMACQUARIE UNIVERSITY.

Winnie K. Lusenoa, John G. McPeaka, b, Christopher B. Barrett*a, P. D. L. and G. G. (n.d.). *Assessing the value of climate forecast information for pastoralists : Evidence from southern Ethiopia and northern Kenya*. *02*.

WMO. (2006). WORLD METEOROLOGICAL ORGANIZATION CAgM Report No . 101 IMPACTS OF DESERTIFICATION AND DROUGHT. *Report of the Working Group on* *the Impacts of Desertification and Drought and of Other Extreme Meteorological Events, CAgM Repor*(101). https://doi.org/WMO/TD No. 1343

WMO. (2008). WMO statement on the status of the global climate in 2012. *World Meteorological Organization*, *1108*, WMO-No. 1108. http://www.wmo.int/pages/mediacentre/press_releases/documents/WMO_1108_EN_web_000.pdf

WMO. (2012). Standardized Precipitation Index User Guide. In *Standardized Precipitation Index User Guide* (WMO-No. 1090; ISBN 978-92-63-11090-9, Issue 1090). https://doi.org/METEOTERM, the WMO terminology database, may be consulted at: http://www.wmo.int/pages/prog/ lsp/meteoterm_wmo_en.html. Acronyms may also be found at: http://www.wmo.int/pages/themes/ acronyms/index_en.html

Wong, G. H. (2010). Drought predictions: applications in Australia. *Statistics*, *PhD*, 102.

Woods, D. D. (2011). Resilience and the ability to anticipate. *Resilience Engineering in Practice: A Guidebooks*, *May*, 121–125. https://doi.org/10.1201/9781317065265-9

Workineh, M. Y., Garfield, M. J., & Boudreau, M. C. (2010). Indigenous knowledge creation practices: The case of Ethiopia. *18th European Conference on Information Systems, ECIS 2010*. https://doi.org/http://aisel.aisnet.org/ecis2010

Worku, M. A. (2022). Rainfall variability and trends in the Borana zone of southern Ethiopia. *Journal of Water and Climate Change*, *© 2022 The*(8), 3132–3151. https://doi.org/10.2166/wcc.2022.173;https://books.google.com/books?id=4aV-DwAAQBAJ&printsec=frontcover&dq=The+Authors+Journal+of+Water+and+Climate+Change&hl=am&newbks=1&newbks_redir=1&sa=X&ved=2ahUKEwia0tTfl7mAAxXASPEDHUHyD6IQ6AF6BAgFEAI

World, T., & Group, B. (2019). *POVERTY AND VULNERABILITY IN THE ETHIOPIAN*.

Xu, L., & Mo, K. C. (2019). A Preliminary Study of Deep Learning Based Drought Forecast. *NOAA's National Weather Service*, *Climate Pr*(October), 22–24. https://doi.org/44th NOAA Annual Climate Diagnostics and Prediction Workshop Durham, NC, 22-24 October 2019 A

YADU, A. K., & SHRIVASTAVA, G. (2019). Application of Neural Network in Drought Forecasting; an Intense Literature Review. *International Journal of Computer Engineering & Technology*, *10*(2), 180–195. https://doi.org/10.34218/ijcet.10.2.2019.019

Yao, Y., Fu, B., Liu, Y., Li, Y., Wang, S., Zhan, T., & Wang, Y. (2022). Agricultural and Forest Meteorology Evaluation of ecosystem resilience to drought based on drought intensity and recovery time. *Agricultural and Forest Meteorology*, *314*(November 2021), 108809. https://doi.org/10.1016/j.agrformet.2022.108809

Yaseen, Z. M., Ali, M., Sharafati, A., Al-Ansari, N., & Shahid, S. (2021). Forecasting standardized precipitation index using data intelligence models: regional investigation of Bangladesh. *Scientific Reports*, *11*(1), 1–25. https://doi.org/10.1038/s41598-021-82977-9

Yotov, K., Hadzhikolev, E., & Hadzhikoleva, S. (2020). *Determining the Number of Neurons in Artificial Neural Networks for Approximation , Trained with Algorithms Using the Jacobi Matrix*. *9*(4), 1320–1329. https://doi.org/10.18421/TEM94

Youssefnia, D. (2014). The Importance of Cultural Alignment. *LinkedIn*, *3*. https://www.linkedin.com/pulse/20141119165946-324527-the-importance-of-cultural-alignment

Yu, C., Huang, X., Chen, H., Huang, G., Ni, S., Wright, J. S., Hall, J., Ciais, P., Zhang, J., Xiao, Y., Sun, Z., Wang, X., & Yu, L. (2018). Assessing the Impacts of Extreme Agricultural Droughts in China Under Climate and Socioeconomic Changes. *Earth's Future*, *6*(5), 689–703. https://doi.org/10.1002/2017EF000768

Yu, J., Kim, J. E., Lee, J., & Kim, T. (2021). Development of a PCA-Based Vulnerability and Copula-Based Hazard Analysis for Assessing Regional Drought Risk. *KSCE Journal of Civil Engineering (2021) 25(5):1901-1908 DOI*, *25*, 1901–1908. https://doi.org/10.1007/s12205-021-0922-z

Zewdie Birhanu1*, Argaw Ambelu2, Abraraw Tesfaye3, Negalign Berhanu4, Wondwossen Kassahun5, Teferi Daba3, K. W. (2015). *Prevalence of household food insecurity and associated factors in drought-prone pastoralist communities in Borana ,*.

Zhong, F., Cheng, Q., Cheng, Q., & Wang, P. (2020). Meteorological Drought, Hydrological Drought, and NDVI in the Heihe River Basin, Northwest China: Evolution and Propagation. *Advances in Meteorology*, *2020*. https://doi.org/10.1155/2020/2409068

Zhou, W., Guo, S., Deng, X., & Xu, D. (2021). Livelihood resilience and strategies of rural residents of earthquake - threatened areas in Sichuan Province , China. *Natural Hazards*, *106*(1), 255–275. https://doi.org/10.1007/s11069-020-04460-4;https://link.springer.com/article/10.1007/s11069-020-04460-4https://link.springer.com/article/10.1007/s11069-020-04460-4,

Zimu-Biyela, A. N. (2016). *The Managment and Preservation of Indigenous Knowledge In Kwazulu-Natal, Southe Africa* (Issue 45910227). PhD Thesis, University of South Africa.

Zotti, G., Hoffmann, S. M., Wolf, A., Chéreau, F., & Chéreau, G. (2020). The Simulated Sky : Stellarium for Cultural Astronomy Research. *EQUINOX*, *2*(2020), 221–258. https://doi.org/10.1558/jsa.17822

Zounon, H. N., Baco, N. M., & Akowedaho, B. (2020). Traditional Ecological knowledge of predicting rain for climate adapting in North Benin. *International Journal for Innovation Education and Research*, *Vol 8 No 0*(01), 141155. https://doi.org/: https://doi.org/10.31686/ijier.Vol8.Iss1.2132

ZOUNON, H. N., BACO, N. M., DAGOUDO, B. A., & SAHAGUI, S. K. (2020). Traditional Ecological knowledge of predicting rain for climate adapting in North Benin. *International Journal for Innovation Education and Research*, *8*(1), 141–155. https://doi.org/10.31686/ijier.vol8.iss1.2132/https://scholarsjournal.net/index.php/ijier/article/view/2132