Odessa centre | Pastoralism
Research, Policy and Practice

TYPE Original Research
PUBLISHED 29 August 2024
DOI 10.3389/past.2024.13548

OPEN ACCESS

EDITED BY
Carol Kerven,
University College London,
United Kingdom

*CORRESPONDENCE
Khululiwe Primrose Ntombela,
ntombelak@arc.agric.za

RECEIVED 16 July 2024
ACCEPTED 15 August 2024
PUBLISHED 29 August 2024

CITATION
Ntombela KP, Angula M, Samuels I, Cupido C, Swarts M, Menjono-Katjizeu E, Inman E and Nakanyala J (2024) Pastoral coping and adaptive management strategies to climate change in communal areas in Namibia and South Africa.
Pastor. Res. Policy Pract. 14:13548.
doi: 10.3389/past.2024.13548

Pastoral coping and adaptive management strategies to climate change in communal areas in Namibia and South Africa

Khululiwe Primrose Ntombela[1,2]*, Margaret Angula[3], Igshaan Samuels[1,2], Clement Cupido[1], Melvin Swarts[4,5], Ewaldine Menjono-Katjizeu[3], Emilia Inman[6] and Jesaya Nakanyala[7]

[1]Agricultural Research Council of South Africa (ARC-SA), Pretoria, South Africa, [2]Department of Biodiversity and Conservation Biology, Faculty of Natural Sciences, University of the Western Cape, Bellville, South Africa, [3]Department of Geography, History and Environmental Studies, Faculty of Humanities and Social Sciences, University of Namibia, Windhoek, Namibia, [4]Department of Agriculture, Land Reform and Rural Development, Pretoria, South Africa, [5]Department of Land Reform and Rural Development, Pretoria, South Africa, [6]Multidisciplinary Research Services, Centre for Research Services, University of Namibia, Windhoek, Namibia, [7]Department of Wildlife Management, University of Namibia, Katima Mulilo, Namibia

Climate change has brought about credible changes in arid landscapes which have resulted in further challenges for pastoralists who require good quality rangeland resources to sustain their livestock. This study assessed local level coping and adaptive management strategies by pastoralists in Namibia and South Africa using a capital assets approach, and also explored non-climate related barriers that increase their vulnerability to climate change. A case study approach was used, which included focus group discussions and semi-structured interviews. The main findings of the research indicate that pastoralists have been exposed to increased temperature extremes and droughts of varying duration over time which reduced the quality and quantity of forage and resulted in losses of income and animal health. The 46 different coping and adaptation strategies used by pastoralists included financial (n = 15), natural (n = 15), human (n = 12), physical (n = 2) and social (n = 2) capital. Of these, 61% of the strategies were common between the two countries. Strategies included income diversification, supplementary feeding and livestock mobility. Pastoralists had to overcome a hierarchy of barriers to implement their coping and adaptation strategies, which were largely related to human capital in Namibia and to natural capital in South Africa. These barriers included a lack of access to grazing lands, land degradation and the loss of traditional knowledge to manage livestock and rangeland resources. Policy development should take these barriers into account while building on the foundation of existing adaptation strategies to reduce the vulnerability to climate change of pastoralists in dryland regions.

KEYWORDS

adaptive capacity, capital assets, adaptation barriers, rangeland resources, pastoral mobility

Introduction

Climate change occurs over multiple temporal and spatial scales, causes many hazards and affects almost all aspects of our livelihoods. It has had negative impacts on pastoral systems around the world, but most severely during the last few decades (Mudombi, 2014). For example, in Kenya, climate change has resulted in large-scale mortality of cattle due to malnutrition during drought periods and disease outbreaks (Godde et al., 2021). In the Middle East, climate change in the form of rising temperatures and decreased precipitation has exacerbated water scarcity for pastoral households (Chatty and Sternberg, 2015). In Tanzania, pastoralists have reported increased cattle and sheep mortality of up to 90% of the total herd, and ensuing economic losses. Flooding due to climate change resulted in more than 4,000 deaths in people and higher rates of malaria and other disease infection in Africa (Horn of Africa Review, 1997, cited in Galvin et al., 2001). Droughts also result in livestock emaciation and thus reduce market prices for cattle, as well as lower milk yields as a result of heat stress (Kimaro et al., 2018). In most pastoral systems, climate change can be viewed as a "threat multiplier" as pastoralists are already exposed to poverty and environmental degradation (Chatty and Sternberg, 2015).

In Namibia, the drought period prevailing in 2017 brought almost 20,000 mainly small stock to the brink of starvation in the//Karas region where livestock was the only source of income for some pastoralists (Hamutenya, 2017). During the same drought, Otjimbingwe residents lost income of about N$10 million due to drought (Anon A, 2017). In Sesfontein, water scarcity due to the drying up of springs reduced crop production and increased livestock mortality (Anon B, 2017). In the Namaqualand region of South Africa, recurrent drought often results in the absence of valuable annual forage production, resulting in stock losses of up to 80% of the total herd size in some years (Richardson et al., 2007).

Southern Africa is projected to experience a rise in temperature at 2°C as compared to the 1.5°C of global warming (IPCC, 2018), therefore the region is regarded to be a climate change hotspot (Engelbrecht and Monteiro, 2021). The south-western region of Africa is projected to become hotter, drier, with increased drought frequency and heatwaves towards the end of the 21st century (Engelbrecht et al., 2015; IPCC, 2018; Lawal et al., 2019). In Namibia and South Africa, where this study took place, these future climate projections could further change vegetation structure and composition and expand arid vegetation types, as previously reported (Midgley et al., 2005; Driver et al., 2012). This could result in further deterioration of rangeland productivity and the availability of water points for livestock, adding to the constraint of having to compete for already limited natural resources (Mekonnen, 2006). Short term climate hazards such as droughts and flooding mean that pastoralists have to adapt at varying temporal scales to increase their resilience and survival (Mmbengwa et al., 2015). Hence, countries such as Namibia and South Africa are listed amongst the most vulnerable countries in the world (Huq and Ayers, 2007) due to a large component of their economies being dependant on climate-sensitive resources (Coetzee, 2010).

Poor grazing management can also have negative impacts on rangeland resources. This is often due to high stocking rates, grazing areas not being rested, and farming with livestock that are not appropriate to local conditions (Van der Merwe et al., 2018). Heavy grazing in the Karoo region in South Africa has been reported to have a potential to alter vegetation composition and soil properties (du Toit et al., 2009), which can cause degradation and biodiversity loss (Milton, 1994; Milton and Hoffman, 1994). Changes in plant species composition induced by heavy grazing often result in a decrease of palatable species, with an increase in unpalatable species (Sternberg et al., 2000; Wan et al., 2011), and an increase in annual species and decrease in palatable perennials (Wan et al., 2011; Severoğlu and Gullap, 2020). Heavy grazing has resulted in bush encroachment and invasive species dominance (Selemani, 2020). Overgrazing resulting in the removal of vegetation cover and the continuous trampling of livestock increases bare patches of exposed soil in rangelands, which leads to soil instability and increased soil erosion (Nellesen, 2007). Good rangeland management practices are thus needed to lessen some of the impacts of climate change and land degradation.

Adaptive capacity reflects the ability to adjust to exposures and sensitivities to climate hazards, and thus reduce vulnerability while taking advantage of opportunities (Smit et al., 2001; Smit and Wandel, 2006). As such, adaptive capacity should be dynamic and should evolve in response to actual or perceived climatic changes and its associated impacts (Smit and Wandel, 2006). Adaptive capacity is often measured in terms of resource availability which is encompassed within the sustainable livelihoods framework. This framework stipulates that access to resources is crucial in assessing which livelihood strategy to follow and to achieve sustainability (Scoones et al., 2015). These resources include human, technological, and financial capital (Nelson et al., 2007) as well as social capital and institutional capacity (Adger, 2003; Preston and Smith, 2009; Engle, 2011). These assets could also be described as the drivers of adaptive capacity (Adger, 2003; Pelling and High, 2005). The resources that pastoralists have to utilise to increase their adaptive capacity are complex and inter-connected and when these resources are not available, they may result in factors that can display themselves as barriers to adaptation (Fahim et al., 2013). Barriers are factors, conditions or obstacles that reduce the desired outcome of adaptation strategies (Moser and Ekstrom, 2010; Huang et al., 2011).

Firstly, this study assessed local level coping and adaptation to climate change by pastoralists in Namibia and South Africa using a livelihood (capital) assets framework. These assets are important to sustain livelihoods in allowing them to resist or

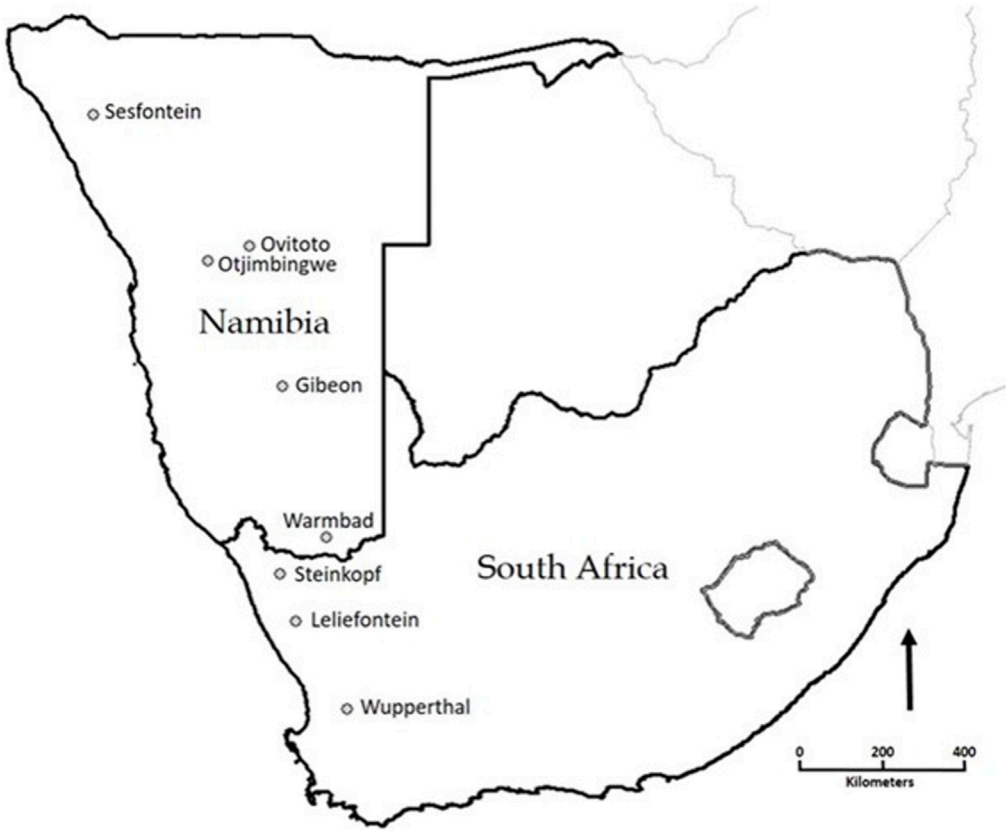

FIGURE 1
Distribution of study sites in Namibia and South Africa.

bounce back from stresses (Niehof and Price, 2001). Therefore, in the context of this paper, capital assets are not only the resources pastoralists have access to or identify with but also assets that allow them to react to changes (Scoones et al., 2015). Secondly, this study explored non-climate related barriers that could increase pastoralists' vulnerability to climate change. This study asked the following questions: 1) How have pastoralists in Namibia and South Africa coped and adapted to climate change? 2) On what capital assets did they rely on to support their adaptation to climate change? 3) What non-climate related barriers increased the vulnerability of pastoralists to climate change?

Materials and methods

Study sites

The study was conducted from March 2014 to March 2016 in eight sites (Figure 1) from South Africa to Namibia. Steinkopf was the most arid site from the South Africa sites, and Warmbad was the most arid from the Namibian sites. These sites also represented different pastoral groups that include Herero, Damara, Himba and Nama in Namibia, and Griqua, Nama, and mixed descent groups in South Africa. However, the focus was on how climate affected pastoralists' coping and adaptation strategies and not on how ethnicity affects adaptation.

The pastoral areas vary in size from 20,000 to 329,000 ha of unfenced rangeland and often span different topographic and vegetation zones (Table 1). This excludes land redistributed by the state to these communities in the last two decades as part of a country's land reform process. Right to access to pastoral areas in South Africa is through birth right or being married to someone who has the right. In Namibia, rights are granted by chiefs and headman or if one is allowed by the cultural leader to occasionally access their land. In South Africa, the spatial and temporal use of the grazing lands by herds is determined by interconnected climatic, environmental and socio-economic factors (Samuels et al., 2019). In Namibia, some households exercise group boundaries based on kinships or relationships with chiefs and headmen.

Dryland cropping occurs in some of the pastoral areas during the rainy season and access to stubble for livestock after harvesting is private. Some pastoralists also have garden plots at home or close to their stockpost where they mostly grow vegetables and fruit, and sometimes grow lucerne for their livestock.

TABLE 1 Description of the sizes of the eight study sites, current climate and future climate conditions (10th to 90th percentile) shown for 2021–2050 in relation to 1960–1990 for South Africa and mean values for 2040–2059 in relation to 1986–2005 for Namibia) using medium-low emissions scenarios (RCP 4.5).

Study area	Size (ha)	Rainy season	MAP (mm)	Mean min temp (°C)	Mean max temp (°C)	Human population	Municipal/Regional mean annual temp predictions (°C)	Municipal/Regional mean annual rainfall predictions (mm)
Wupperthal	20,003	Winter	303.5	10.5	25.1	3,484[a]	1.25–2.16	−101.8–14.9
Leliefontein	192,000	Winter	180.8	9.4	21.8	7,571[b]	1.2–2.46	−55.5–7.7
Steinkopf	329,000	Winter and Summer	99.0	7.2	24.4	7,255[c]	1.18–2.57	−35.0–7.5
Warmbad	14,523	Summer	100.6	13.0	29.0	4,045[d]	1.46	−29.18
Gibeon	28,300	Summer	185.6	13.5	30.2	1,234[d]	1.68	−18.84
Otjimbingue	92,000	Summer	209.0	15.8	26.1	3,704[d]	1.46	−9.61
Ovitoto	62,700	Summer	357.4	13.8	29.8	14,263[d]	1.90	−10.2
Sesfontein	95,104	Summer	195.0	14.8	22.9	23,639[d]	1.51	6.12

Temperature and MAP, data sourced from African Drought and Flood monitor.
Livestock data for South Africa were unpublished data sourced from municipal or dipping census and other studies. Climate predictions for South Africa was obtained from (Le Roux et al. 2019) and for Namibia, data was sourced from https://climateknowledgeportal.worldbank.org/country/namibia/climate-data-projections.
[a]Population size for entire pastoral area based on 1981 data (Unpublished ARC, report).
[b]Population size for entire pastoral area based on 2003 data (unpublished dipping data, State Vet).
[c]Population size for entire pastoral area based on 2011 data (StatsSA).
[d]Population size for entire regions in Namibia based 2012/13 estimates (NAC, report-2012/13).

Proportions of sheep, goats and cattle kept in each area are generally dictated by the dominant vegetation in the area. Donkeys and horses are also kept largely for transportation and drought power, but parts of the horses and donkey population have become feral in certain areas due to the shift towards the use of motorized transport and mechanized cultivation. In both Namibia and South Africa pastoral areas are overstocked beyond the recommended carrying capacities for decades which could be mainly due to the dispossession of their other traditional grazing lands by the colonists and the more recent increase in the human population, including those who return to the communal land after retirement or retrenchments in the other sectors (Todd and Hoffman, 2000; Kruger and Katjivikua, 2010). Furthermore, in some areas, traditional mobile pastoral strategies have been abandoned for a variety of reasons, including the need to remain stationary to protect cultivated fields from stray animals. This resulted in about one-third of pastoralists becoming sedentarised in one area (Samuels et al., 2008). Livestock are generally managed by temporary or permanent herders during the day or allowed to range freely, but corralled at night to prevent stock theft and predator loss. Herders guide their animals to selected grazing areas based on season and time of day, watering points and the risk of consuming poisonous plants (Allsopp et al., 2007).

Generally, pastoralists in the study areas are among the poorest households with some living below the poverty line (Rohde and Hoffman, 2008; Inman et al., 2020). While income from livestock is not the major source of income for many pastoralist households (Ogidan, 2014), local markets present opportunities for pastoralists to sell some livestock in times in need, e.g., to pay for school fees or for funeral arrangements. Livestock is also more than an income source, and may serve different purposes in different areas (Bundala et al., 2020). Pastoral households receive most of their income from state grants and remittances from those who work outside the pastoral areas (Ogidan, 2014). There are generally limited employment opportunities in the pastoral areas, hence people leave for the cities to find employment and earn an income.

Sampling approach

The case study approach used included different sampling and data collection methods to validate the data obtained. These included focus group discussions, semi-structured interviews and field observations. Respondents were selected based on who was available for interviews in the area during the study period. The interviews and focus group discussions were conducted by the researchers, and the interviewees included pastoralists and those who are considered headmen. A pastoralist was considered any livestock farmer who derives, at least, some form of income or personal or cultural association benefits from keeping livestock. Those interviewed included males and females and pastoralists who own small and/or large stock. They ranged between 21 and

TABLE 2 The number of participants in focus group discussions and interviews in the different study areas.

Study site	Focus group			Interviews		
	Male	Female	Total	Male	Female	Total
Sesfontein	4	2	6	6	4	10
Ovitoto	4	6	10	3	0	3
Otjimbingwe	4	0	4	3	0	3
Gideon	9	11	20	6	6	12
Warmbad	9	8	17	5	3	8
Steinkopf	11	3	14	18	2	20
Leliefontein	7	3	10	13	7	20
Wupperthal	14	8	22	—	—	—
Total	**62**	**41**	**103**	**54**	**22**	**76**

No interviews were held in Wupperthal due to time and budget constraints. Bold values represent the total overall number of female and male participants for focus groups and interviews, as a combined value for both South Africa and Namibia.

76 years old, and the interviewed pastoralists managed herd sizes ranging between less than 10 to more than 1,000 animals, which in those cases, had multiple owners. Background research was done on each study site using key informants and literature reviews. Draft questions were prepared for focus group discussions on the basis of the background information and prior experience of certain researchers in some of the study areas.

Focus group discussions

During the focus group discussions, which did not last for more than 2 h, shared adaptation strategies and constraints were identified and discussed. Although there is always the probability of a few respondents dominating the discussion, focus group discussions may overcome the problem of some people being reluctant to answer questions during one-on-one interviews (Ho, 2006; Kamberelis and Dimitriadis, 2013); for example, certain topics are too sensitive or the participant believes that his or her information is not valuable or relevant to the question. During a one on one interview, a person might be reluctant to answer a certain question, however, focus group discussions provide an advantage of shared experiences amongst participants which might result in the person who was reluctant to answer a sensitive question, sharing their inputs to answer a question they might have initially seen as sensitive with the "support" from fellow participants with similar experience. Focus group discussions also provide detailed information on topics of interest. One focus group was employed per locality. A total of 62 males and 41 females participated in the focus group discussions (Table 2). During some of our focus groups, we encountered the dominance of certain participants in discussions and the moderators would then continually encourage the quieter participants to provide their opinions and inputs in the language they were most comfortable with. At least one researcher was present who could understand the local language and he/she would translate the message to other researchers in the group.

Semi-structured interviews

A semi-structured questionnaire was used for the interviews, which did not last for more than an hour. The questions focused on the choice of adaptation strategy, the knowledge flow of these strategies among the farmers, pastoralists' preparation for drought periods, their historic and current spatio-temporal livestock mobility patterns, and barriers they encountered when implementing their adaptation strategies.

Sit-down interviews were held either at home or at the stockposts of pastoralists. Interviewees were informed about the ethics protocol that the researcher observed and were reminded that the interviews were confidential and that they were free to exit the interview without any repercussions. All interviews were completed at all the study sites, except for Wupperthal due to time and financial constraints. During our interviews, our approach allowed for further probing on why certain adaptation strategies are adopted to gain a detailed understanding of livestock management practices and if or how they have been modified to cope to extreme events. A snowballing method was used where respondents referred to other pastoralists that can be interviewed. Interviews were conducted until saturation was reached for each area. In total, 54 males and 22 females were interviewed during this study (Table 2). All interviews were conducted in local languages, recorded and later translated into English.

Data analysis

A thematic analysis was used to analyse the qualitative data arising from interviews and focus group discussions. The analysis involved coding participant's responses to pre-thought themes related to the five livelihood capitals, namely,; financial, natural, human, social and physical. Grouping the responses into the pre-thought themes, also involved identifying and examining underlying ideas, assumptions and conceptualisations that form the content participants' response. *Financial capital* in the context of this study encompassed the income that pastoralists had from the different sources including livestock sales, remittances, state grants, loans, and investments. It also included how they managed their budgets and activities to save costs. *Natural capital* involved the natural resources that pastoralists depended on to raise and sustain their animals, which were mainly forage and water resources. *Human capital* pertained to the knowledge and skills of pastoralists to manage the rangeland and their herds as well as their ability to source relevant information. *Social capital* involved the social relationships between different land users and their associations with stakeholder organizations in their regions such as farmer unions. *Physical capital* was related to the infrastructure that pastoralists depended on to shelter, water and transport their animals.

Steps followed during data analysis involved 1) generating initial codes, 2) organising data into pre-thought themes, 3) searching for underlying concepts, 4) reviewing, refining and pre-thought themes by considering the validity participant responses, and 5) producing final thematic maps with sufficient evidence of the themes in text extracts or quotations. Percentages were calculated firstly by drafting a list of all adaptation strategies used, then grouping it into categories of capital assets. Descriptive statistical analyses were performed on the themes using MS Excel.

Study limitations

One of the limitations of this study was farmers' perception and observations of climatic changes being stimulated by specific historical events such as the 2015 drought occurrence. However, measures were taken to ensure that the study was not affected by this limitation. The researchers used triangulation methods and ensured that more than one farmer per pastoral area was interviewed in order not to generalize an individual's perspective for the entire pastoral area. In cases of new information given by the respondent, other respondents were asked for the validation of that new information during interviews. Critiques commonly levied against case study research, particularly its reliance on a single case, were acknowledged. Despite similarities in livestock management practices and socio-economic conditions climate change adaptation coping strategies and adaptation barriers among villages, caution is warranted when extending the findings of this study to other semi-arid regions within South Africa and Namibia.

Results

Exposure to climate hazards

Participants in the focus group discussions and interviews reported that they have been exposed to increased temperature extremes in the long term and that they have had to adapt to hotter summers.

Respondents also reported that rainfall had decreased in their lifetime that the seasons have changed, and that the rains no longer come at the same time as in the past. As a result, pastoralists have been exposed to discrete recurrent (drought) and continuous climate hazards (drying, warming and cooling), which have brought about several shocks and constraints. These conclusions were based on observations of forage production and composition, soil moisture, livestock and wildlife behaviour, and rainfall gauges.

Climate related shocks and constraints

Shocks and constraints identified by pastoralists (Table 3) mostly occurred during drought periods or during extreme cold or hot conditions in winter and summer respectively. However, they also experienced uncertainty regarding intra and inter-annual seasonality.

During the recurrent droughts pastoralists in all the sites experienced limited quality and quantity of forage. Other shocks and constraints during droughts in six of the sites included losses in income and poor animal health, especially in Sesfontein and Steinkopf. Pastoralists also reported unfamiliar and uncertain environmental conditions, including the drying up of water points, livestock disease outbreaks, increased drought and flooding intensities.

Adaptation responses to climate change

In total, 46 different strategies were used by pastoralists in the two countries to adapt to the changing climate. In South Africa, 31 strategies were recorded, and 26 in Namibia. About 61% of the strategies were used in both countries. The strategies could be divided into financial (n = 15), natural (n = 15), human (n = 12), physical (n = 2) and social (n = 2) capitals.

Figure 2 shows the capital assets for each of the study sites. Each line indicates the number of pastoralists (%) that used the that specific livelihood capital. Each percentage represents the

TABLE 3 Main shocks and constraints pastoralists encountered over different time scales in Namibia and South Africa.

Temporal scale		Wup	Lel	Ste	War	Gib	Otj	Ovi	Ses
Seasonal	Limited forage	X	X	X			X		X
	Limited knowledge			X		X			X
	Limited water			X					
	Poor animal health		X		X				
Drought	High livestock mortality					X			
	Increased predation								X
	Limited finance			X					
	Limited forage	X	X	X	X	X	X	X	X
	Loss of income		X		X	X	X	X	X
	Poor animal health		X	X				X	X
Long term	Financial security				X				
	Limited forage	X	X	X		X	X	X	X
	Limited knowledge			X	X		X	X	X
	Loss of livestock products	X				X			

Wup, Wupperthal; Lel, Leliefontein; Ste, Steinkopf; War, Warmbad; Gib, Gibeon; Otj, Otjimbingue; Ovi, Ovitoto; Ses, Sesfontein.

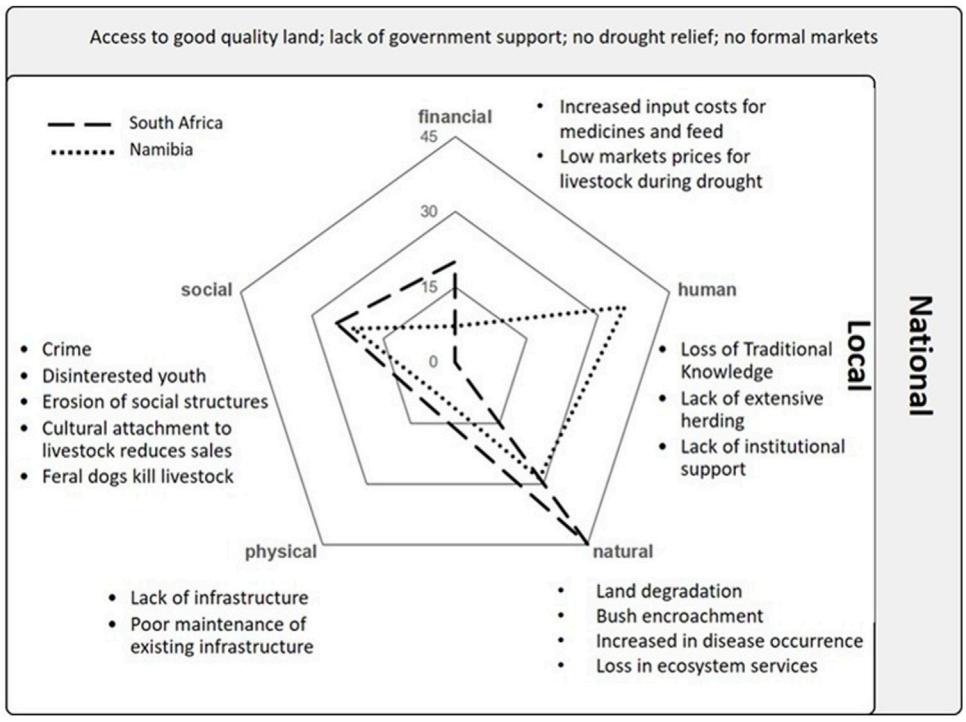

FIGURE 2
A multi-scale representation of non-climate related barriers pastoralists face in overcoming climate change.

10.3389/past.2024.13548

proportion of each capital asset category to the total adaptation strategies used. At the South African sites, natural (37%), human (26%) and financial (26%) capital were mostly accessed. In Wuppertal, pastoralists accessed mostly natural (43%) and financial capital (29%), but no social capital. In Leliefontein, natural (37%) and human (32%) capitals were mostly accessed, but no physical capital. Of the South African sites, Leliefontein made most use of human capital assets. In Steinkopf, natural capital (35%) was most accessed and social capital least (6%) (Figure 2).

In Namibia, financial (41%) and natural (31%) capital were accessed most whereas no physical capital was accessed. Access to human capital assets at Sesfontein (38%) was almost twice as much the total at other Namibian sites. Pastoralists in Sesfontein were also less dependent on financial capital than those as other Namibian sites. Pastoralists in Ovitoto mostly used natural capital (44%), and more so than elsewhere in Namibia. In Otjimbingwe (50%) and Gibeon (60%), financial capital was mostly accessed, more than all other sites. The use of natural capital at Warmbad was less than elsewhere.

When accessing human capital, the most common adaptation response was a change in grazing management. In South Africa, herds were moved between different biomes, vegetation types or along an elevational gradient. For example, in the Steinkopf pastoral system, transhumance to access natural capital occurred mainly between the summer rainfall Nama Karoo biome, which is dominated by perennial grasses, and the winter rainfall Succulent Karoo biome where succulent and non-succulent perennial shrubs dominate. A common practice used by the Leliefontein pastoralists to escape freezing conditions in the uplands mountains is an altitudinal transhumance between the ephemeral wetlands in the upland mountains that provide summer grazing areas, and the low-lying that provide winter grazing areas. This practice allows for plants to germinate and flower while the rangeland is resting during the winter season. The following responses from respondents captures the transhumance patterns of pastoralists in the pastoral areas.

> "*We move between the winter and summer rainfall areas. Our grandparents did it as well. The N7* (national road) *splits the rainfall, actually the mountains next to the N7. Most of the farmers are currently in Bushmanland (summer), we use Steinkopf area during winter times. But some of us do not have the finances to transport our livestock to the different regions. So not all of us are moving anymore. As stated earlier, I try to split my ewes and try to move but not always, depends on how the veld is looking and rainfall of course*" . . . . . (Steinkopf farmer)

> "*All the farmers here know, and as a farmer here you know that you must move, you cannot stay here the whole year. The environment is changing so we must move, but also we want to take care of our piece of land. We must move here, because of the snow and the cold cattle will die. We came back September-October, because there is 'opslag'* (ephemeral plants) *and livestock likes it very much. April / May is when we move down to warmer places, and come back September / October. The time we move to lowlands and come back has not changed*" . . . . . (Leliefontein farmer)

> "*When the first rains start, this is an indication that we must move. I move after the first rains. April or May or June or July it varies each year. I move down to Kliphoek. Sometimes I move back to Leliefontein at the end of August or beginning of September. I move back so early not because the area that I moved to has deteriorated, but it is because I have ploughed in Leliefontein, so I must come back earlier to make sure donkey do not eat my crops, wheat and lucerne*" . . . . . (Leliefontein female farmer)

During drought periods and other periods of low forage availability, some pastoralists opportunistically sought better water and forage within the boundaries of their rangelands. This planned coping strategy of nomadic movements incorporates the use of pastoralists' local knowledge to strategically use nomadic movements to areas that provide better forage quality than the surrounding rangeland matrix. When financially possible, some pastoralists migrated beyond the boundaries of the rangeland to access forage on other communal lands or private farms.

In addition, pastoralists coped with forage limitations by accessing other natural capital, for example, by planting cereal crops such as oats, barley, rye or lucerne for supplementary feed. They also adopted cut-and-carry strategies to provide livestock with nutritive forage, which included grasses, branches and leaves from trees and non-succulent shrubs and pods from leguminous tree species not usually found in areas accessible to livestock.

To escape the effects of extreme heat during the day, pastoralists in northern Namibia allowed their animals to graze at night. At night, cattle were allowed to range freely whereas dogs guarded small stock herds from predators. Physical capital was reported as an important strategy to cope to extreme weather temperatures. For example, shade in the kraals were built for livestock to escape hot temperatures during the day in Namibia; stone corrals where built in Leliefontein to protect livestock from wind chills at night; and livestock sheds were built in Wupperthal to protect livestock from frost.

Financial capital reported by pastoralists in South Africa and Namibia to cope with prolonged droughts, decreased rangeland forage quantity and quality included the utilization of other income sources such as social grants, local saving schemes, retain trades, remittances, income from non-agricultural

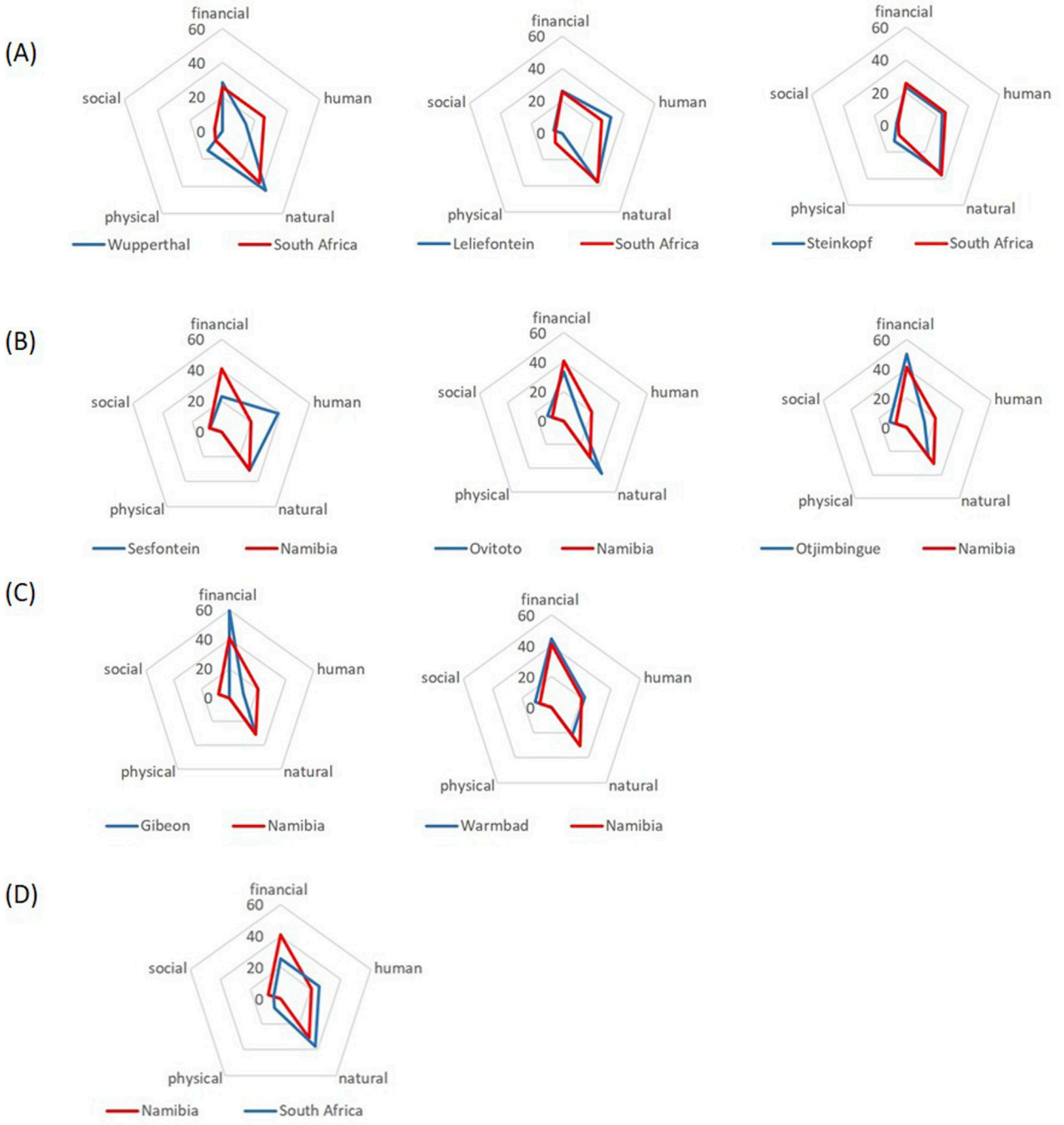

FIGURE 3
Categorised capital assets of Namibian and South African pastoralists to adapt to climate change and variability. **(A)** Capital asset comparison between each of the South African sites and the overall country. **(B, C)** Asset comparison between each of the Namibian sites and the overall country. **(D)** Asset comparison between Namibia and South Africa.

activities or wages. These income sources allowed pastoralists to provide commercially available feed to their stock. In Namibia, pastoralists sometimes sold livestock at local auctions to buy feed and medicines for their animals. In Otjimbingwe, for example, pastoralists borrowed money to get their animals through periods of drought.

Pastoralists also implemented long-term adaptation strategies such as changing the mix of livestock types in their

herds, adapting their breeding seasons to changes in the rainfall season, and by introducing new genetic stock perceived to be more drought tolerant than their existing livestock. In response to climatic and environmental conditions brought about by such unfamiliar phenomena such as El Nino, pastoralists sought new knowledge to mitigate the impacts of drought, for example, from information workshops, knowledgeable neighbouring farmers, the media or local agricultural extension services.

Barriers to climate change adaptation

Pastoralists had to overcome a hierarchy of barriers to implement their adaptation strategies. These barriers affected them at different temporal and spatial scales and influenced aspects of their management system (Figure 3).

In Namibia, 35% of the reported barriers by respondents were largely related to human capital, whereas 45% of the reported barriers in South Africa were related to natural capital. Natural barriers that were common in both countries included the deterioration of rangeland condition as a result poor management by some pastoralists and climate change. Pastoralists in all eight study areas reported that their rangeland was generally overgrazed and that palatable plants were less abundant than in the past. A general lack of access to sufficient land resulted in their grazing areas being degraded. Respondents reported decreases in water and palatable forage availability as a direct impact of experienced drought.

Human captial related barriers included the loss of traditional knowledge, and pastoralists fear that future farmers will not have sufficient knowledge to adapt to a changing climate. This was partly due to the perception that young people are not interested in farming and the transfer of agricultural knowledge between generations was lacking. Furthermore, many youths aspire to live urban lifestyles resulting in a disconnection with their rural heritage. A huge barrier mentioned in all the study areas was the increase in crime which was fuelled by increase substance abuse mainly amongst the youth. The high unemployment rates of youth in South Africa has increased crime rates in the country. Unemployed youth was said to sometimes vandalize or steal infrastructure that are needed by livestock farmers, in order for the unemployed youth to have cash to sustain their substance abuse habits. This crime results in additional expenses for pastoralists or divergence of money that could have been used for an adaptation strategy.

Most pastoralists did not always have the necessary finances to assist them in bringing their animals through drought periods. Markets were also a barrier since several pastoralists interviewed indicated that the markets dictated to them to keep single species and breeds, such as Meatmaster or Swakara sheep. This increases vulnerability since all the animals in a herd then have similar sensitivities to climatic changes.

Although the infrastructure for the provision of water to livestock is present, its maintenance is poor or non-existent. Pastoralists viewed this as a barrier to climate change adaptation. In some areas, boreholes have not worked for more than 20 years, resulting in herds congregating around the few functional watering points.

Discussion

Vulnerability to shocks and constraints

Different factors influenced the vulnerability of pastoralists to shocks and constraints related to climate change. They included the species of livestock kept (Godde et al., 2021), herd size, management of livestock (Thornton et al., 2007) and variability in forage availability (Rust and Rust, 2013). The degree of sensitivity to hazards by livestock species and breeds is a consequence of the animals having different tolerance limits (Rojas-Downing et al., 2017). Temperatures outside livestock thermal comfort zone result heat stress, where animals cannot dissipate enough heat to maintain internal body temperatures. Ultimately, this results to decreases in feed intake, reproduction and milk production (Cheng et al., 2022). Animals with dark coats are to be more affected by increases in temperature, as their dark coats have greater absorption of thermal radiation (Silanikove, 2000). Therefore, one can deduce that livestock kept by pastoralists from this current study are less susceptibility to heat stress due to their light coats. It is therefore unlikely that all livestock will succumb to one extreme weather event (Orindi et al., 2007). Even though goats are regarded to be less susceptible to heat stress, their feed intake declines when the ambient temperature is more than 10°C above their thermal comfort zone (Lu, 1989). Therefore, climate change adaptation strategies practices by pastoralist need to involve robust animals that are heat tolerant and are able to adapt to changing environmental conditions (Rust and Rust, 2013). Hybrid breeds such as in the study areas may thus be more tolerant. Boer goats are hardy and kept in all eight of the study sites. They were developed in South Africa through crossing indigenous African goats with European and Indian breeds, and have been suggested as the goat breed best adapted to breed in hot arid climates (Tilahun, 2012). However, they are not conditioned to cold weather, which may have devastating consequences for pastoralists if cold spells become more frequent.

We expect that large herds kept by some pastoralists might also be more vulnerable to hazards because the effects of forage shortages will be more severe. Also, large herds and high stocking densities have transformed rangelands from a palatable to a less palatable state (Todd and Hoffman, 2000; Anderson and Hoffman, 2007), and annuals have replaced perennials (Todd and Hoffman, 1999). Increasing the dependence on rain to produce forage from annual grasses increases the vulnerability

of pastoralism since any extended drought period over multiple years could have devastating effects.

The management of livestock also affects sensitivity to hazards. Herding and livestock mobility, which are common in most pastoral areas in the form of transhumance, semi-nomadism, short range movements and migrations, have been recognized as important management tools to access resource heterogeneity and escape unfavourable conditions in pastoral systems such as drought (Niamir-Fuller and Turner, 1999; Samuels et al., 2008). Transhumance is a common strategy in global traditional communities and pastoralists continue to practice it as a climate change adaptation. Through movement of livestock between grazing lands, pastoralists are able to maximise resource availability across a variety of climate regimes in the rangelands (Katanha and Chigunwe, 2014; Teshager, 2014). While there are also benefits to fencing and measures to control grazing as a climate change adaptation, fencing in pastoral areas in this study would constrain the practice of livestock mobility, (Igshaan Samuels et al., 2021). While pastoral mobility has been used for millennia as a strategy to manage climate variability, they also use variability as a resource to ensure constant supply of water and forage in different areas at different times, Thus, the impact of climate change on pastoralists may not necessary be due to changing environmental conditions, but rather socio-economic and policy conditions that limit mobility and thus expose pastoralist to more drought events which they could have escaped through mobility.

Indigenous knowledge informs micro-level adaptation strategies (Ajani et al., 2013) and increases resilience to climate variability (Newsham and Thomas, 2011). Some focus group discussions and interviews during this study pointed that their knowledge on how to adapt to a changing climate may not be adequate because agro-ecological conditions have changed more intensely and quickly than had been experienced over the years of natural climate variability. A cornerstone of indigenous knowledge is trial and error, and pastoralists have not had sufficient time to test new strategies under different conditions. While coping with climate variability may have to some extent prepared pastoralists on how to adapt to climate change, a lack of tested new strategies makes pastoralists and their grazing landscape more vulnerable to changes in climate.

Climate change adaptation strategies

Herd mobility allows livestock to access natural capital. Herd mobility allows livestock to access natural capital. This is particularly evident in South Africa where three of the pastoral areas involved in this study are located within pastoralists two of the world's 34 biodiversity hotspots. Pastoralists in these areas have access to a diversity of forage species at different spatiotemporal scales. Pastoralists reported that a diverse diet is the best since livestock can obtain all the energy, nutrients and minerals they require to grow and reproduce.

Mobility to manage livestock and adapt to climate variability and change has the added value of increasing the chances of vegetation regeneration, seed dispersal and nutrient cycling through manure and the sustainable use of rangelands. Mobile practices will also gain increased importance to combat the impacts of climate change since forage availability is likely to become more variable in the future, and the reliance on supplementary fodder will also be reduced (Sunil et al., 2020). During drought periods, pastoralists involved in the current study make use of grazing reserve areas that are unused in 'normal' dry seasons. Other kinds of livestock mobility include the use of rangelands belonging to others, for example, private landowners or other communal traditional authorities. In other parts of Africa, the livestock of pastoralists may gain access to crop residues in return for the fertilizing of agro-pastoral crops through manure and urine (Bayer and Waters-Bayer, 1989).

Supplementary feeding becomes necessary when herd mobility is not possible during drought conditions (Ntombela, 2017). However, supplementary food is often expensive and beyond the means of many pastoralists. An alternative is 'cut and carry' practices using natural capital to provide nutrition for livestock. This practice is common in Africa (Coppock, 1994; GebreMichael and Kifle, 2009) and in pastoral areas beyond the continent (Roder, 2002; Suttie and Reynolds, 2003). In the eight South African and Namibian study areas, water is also carried in the dry and hot seasons when the forage lacks sufficient moisture. Physical capital was used to pump and transport water. It can be expected that the use of physical capital by pastoralists in the study sites would increase as the pastoralists have observed increases in temperatures that decrease water and forage availability in the rangelands. These observations agree with the measurement of higher temperatures in the region. For example, (Davis, 2013), reported a rise since 1984 in minimum temperatures of 0.75°C above the 1961–1990 average. More generally, in the Namaqualand region, minimum and maximum temperatures have increased significantly by 0.33°C and 0.1°C per decade respectively since 1960 (Davis, 2013). Most parts of Namibia have seen a warming trend of about 0.05°C–0.25°C per decade from 1951 to 2006 (Haensler et al., 2011).

The planting of crops as supplementary feed and as a climate change adaptation strategy is common among pastoralists all over the world (Bayer and Waters-Bayer, 1989). However, cultivation has been abandoned in many pastoral areas because of greater rainfall variability and frequent drought (Samuels, 2013). In some study areas such as in Steinkopf, dryland cropping has largely disappeared whereas in wetter areas such as Wupperthal, cultivation is continuing but reported by pastoralists as becoming riskier due to unpredictable rainfall. Furthermore, the lack of farming implements, loss of skills, a lack of knowledge transfers and

damage caused by stray animals have also contributed to cropping being abandoned and pastoralists becoming less able to provide their animals with food during periods of resource scarcity (Samuels, 2013).

Financial capital was most prevalent in Namibia where pastoralists used income from livestock sales for medicines or supplementary feed. Farming with a smaller herd in general, is also more manageable for herders during the grazing period since fewer animals will wander away from the herd in search of green forage (Samuels, 2006). Since animals in poor condition sell at lower prices, wealthier pastoralists also used other sources of income or savings to buy feed and medicines without having to sell off their animals. It has been shown that having other income streams increases resilience to drought (Letsoalo et al., 2023; Muller and Shackleton, 2014), and livestock insurance schemes reduce risks associated with climate-related livestock mortalities (Mude et al., 2010). However, these schemes are still in their pilot phase and lack strategic partners for these schemes to become more widely accepted (Kunow, 2016).

Pastoralists at the Namibian study sites keep indigenous Sanga cattle breeds which are well adapted to local climates. It has been argued that compared to exotic cattle breeds in Namibia, Sanga cattle have higher tolerance to parasites, diseases and heat (Mendelsohn, 2006). They also cost less to maintain due to their smaller size and thus lower requirements for forage and water. Similarly, indigenous sheep such as Damara, which are kept in some of the study areas are well adapted to the harsh arid environments of Namibia and are resistant to resistance ticks (Mendelsohn, 2006). Goat breeds and ecotypes kept in Namibian pastoral areas include Owambo, Kavango, Caprivi and Kunene and Boer goats, which are all well suited to the local conditions (Els et al., 2004).

Adaptation barriers

Due to their similar colonial histories, pastoralists in Namibia and South Africa are confined to rangeland which is generally of poor forage quality compared to adjacent private farms. The poor condition could be attributed to the fact that the best agricultural lands were appropriated by the settlers, but also non-regenerative management practices by some pastoralists as well as general overcrowding in pastoral areas. There are also no grazing reserves for livestock in most pastoral areas. Apartheid legislation enforced by the South African government in both countries perpetuated these inequalities as in most instances entrenched further hardship for non-European citizens (Igshaan Samuels et al., 2021; Kiljunen, 1981).

Thus, the general lack of access to sufficient and good quality forage and further degradation of grazing lands are barriers that pastoralists in South Africa are most concerned about since they largely depend on these natural resources. Furthermore, a lack of water points has severe consequences when livestock have to congregate around the few functional ones, thereby causing overgrazing. For example, in Leliefontein, a study by Samuels (2013) reveals that 18 out of 54 boreholes were functional, and in some villages 46% of herds used one water point. These circumstances do not enable all pastoralists to implement mobile practices under normal average rainfall years, therefore further inhibiting the pastoralists strategic planning of herd mobility. Davies et al. (2020) also concur that frequently severe droughts and water shortages are climate change barriers faced by rural communities in Namibia.

Social injustices of colonialism and apartheid brought about the erosion of informal traditional institutions and loss of indigenous technical knowledge due to establishment of coerced institutions and forced employment outside reserves. Informal institutions are important to ensure implementation of rules and regulations to protect critical infrastructure such as boreholes which pastoralists depend on during dry periods. Also, the loss of indigenous knowledge led to a reduction in extensive herding because for herding to be successfully implemented, a knowledge of the plants, their palatability over various temporal scales and the agro-ecosystem in general is required to bring animals through drought periods (Samuels, 2006). As a result, Namibian pastoralists view a lack of herding as a barrier because the risk of high mortality rates during drought periods.

As a result of increased levels of crime, pastoralists note that they lose income which could be used to acquire resources to adapt to climatic changes. Politically, pastoralists are still marginalized during policy development and the lack of institutional support from local government for infrastructure management, and the implementation of grazing regulations.

Pastoralists in the eight study areas farm different animals for different international and local markets, as well as for local consumption. Some pastoralists in Gibeon, Warmbad and Steinkopf keep only Swakara sheep largely for European fashion markets. The Namibian government has increased support to grow the Swakara market. However, as mentioned, keeping a single breed in large numbers is risky as they may succumb to one hazard. Diversifying herd composition also ensures that resources could be partitioned (Ifejika Speranza, 2010; Opiyo et al., 2015). Furthermore, the majority of respondents in the South African study areas were not keen on partaking in the Swakara industry since prices are linked to prevailing fashion trends, which means high incomes are not always assured. During the times when markets prices are down, pastoralists cannot buy the necessary medicines and supplementary fodder for their livestock or they have less income for their household requirements.

Conclusion

Pastoralists have adaptive capacity towards climate change since they access various capital assets. The majority of pastoralists have

not changed their tried and tested traditional adaptation strategies that were developed over many years in response to climate variability. This shows that strategies developed under climate variability over time is still the best means to adapt to climate change and foster resilience. For example, current strategies, of which mobility is a core factor, are still flexible enough to be used under changing climatic conditions. Even though herb mobility has been practiced largely in South Africa to access the diverse rangeland resources, the flexibility of this strategy still allows for it to be relevant in the current changing climatic conditions. Pastoralists largely made use of herd mobility to access the diverse rangeland resources particularly in South Africa where it has been practiced for centuries. In the absence of mobility or reduced mobility particularly in Namibia, pastoralists accessed financial capital to provide the necessary feed for their livestock to overcome forage constraints induced by climate change. However, this is expensive and not sustainable as their management practices are not regenerative and the resource base is declining.

These pastoral systems are not in isolation from broader non-climate related societal challenges that reduce the adaptive capacity of pastoralists. The ongoing degradation of rangeland vegetation due to overgrazing in some areas which led to lower quality forage will result in livestock further experiencing nutrient and mineral deficiencies. Consequently, livestock production levels will decrease leading to lower levels of income and financial security. The loss of indigenous knowledge, which is a crucial cornerstone for successful adaptation to a changing climate, is a particular concern in Namibia. The general increase in social problems including crime and substance abuse in rural communities affect pastoralists who anticipate that their farming activities might also become increasing targeted for theft.

Reducing barriers to adapt to climate anomalies requires a holistic approach whereby climate change vulnerability is addressed in all levels of government and management institutions. Policy development should take these barriers into account while building on the foundation of current adaptation strategies to reduce the vulnerability of pastoralists in dryland regions to climate change and variability. If not, pastoralists will continue to be marginalized and disadvantaged and will have to continue deal with climate change on their own.

Data availability statement

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

Ethics statement

The studies involving humans were approved by University of the Western Cape Human and Social Sciences Research Ethics Committee. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

KN, IS, MA, JN, CC, and MS developed the proposal for this research. IS was a direct supervisor for the South Africa, and MA was a direct supervisor for Namibia. All authors contributed to the article and approved the submitted version.

Funding

The authors declare that financial support was received for the research, authorship, and/or publication of this article. This bilateral study was funded by the National Research Foundation (NRF) in South Africa (UID: 89135) and the National Commission on Research, Science and Technology in Namibia.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Acknowledgments

We are very thankful to the community members of Wupperthal, Leliefontein, Steinkopf, Warmbad, Gibeon, Otjimbingwe, Ovitoto and Sesfontein for their time and willingness to participate in this study.

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontierspartnerships.org/articles/10.3389/past.2024.13548/full#supplementary-material

References

Adger, W. N. (2003). Social capital, collective action, and adaptation to climate change. *Econ. Geogr.* 79 (4), 387–404. doi:10.1111/j.1944-8287.2003.tb00220.x

Ajani, E. N., Mgbenka, R. N., and Okeke, M. N. (2013). Use of indigenous knowledge as a strategy for climate change adaptation among farmers in sub-

Saharan Africa: implications for Policy. *Asian J. Agric. Ext. Econ. and Sociol.* 2 (1), 23–40. doi:10.9734/AJAEES/2013/1856

Allsopp, N., Laurent, C., Debeaudoin, L. M. C., and Igshaan Samuels, M. (2007). Environmental perceptions and practices of livestock keepers on the Namaqualand Commons challenge conventional rangeland management. *J. Arid Environ.* 70 (4), 740–754. doi:10.1016/j.jaridenv.2006.11.005

Anderson, P. M. L., and Hoffman, M. T. (2007). The impacts of sustained heavy grazing on plant diversity and composition in lowland and upland habitats across the Kamiesberg mountain range in the Succulent Karoo, South Africa. *J. Arid Environ.* 70 (4), 686–700. doi:10.1016/j.jaridenv.2006.05.017

Anon, A. (2017). Otjimbingwe farmers lose 1 318 cattle to drought. Available at: https://neweralive.na/posts/otjimbingwe-farmers-lose-1-318-cattle-drought (Accessed 29 April 2021).

Anon, B. (2017). Drought hits Sesfontein hard - truth, for its own sake. Available at: https://neweralive.na/posts/drought-hits-sesfontein-hard (Accessed April 29, 2021).

Bayer, W., and Waters Bayer, A. (1989). *Crop-livestock interactions for sustainable agriculture*. Sustainable Agriculture Programme, IIED. Available at: http://www.jstor.org/stable/resrep01655.

Bundala, N., Kinabo, J., Jumbe, T., Rybak, C., and Sieber, S. (2020). Does homestead livestock production and ownership contribute to consumption of animal source foods? A pre-intervention assessment of rural farming communities in Tanzania. *Sci. Afr.* 7, e00252. doi:10.1016/j.sciaf.2019.e00252

Chatty, D., and Sternberg, T. (2015). Climate effects on nomadic pastoralist societies. *Forced Migr. Rev.* 49, 27.

Cheng, M., McCarl, B., and Fei, C. (2022). Climate change and livestock production: a literature review. *Atmosphere* 13, 140. doi:10.3390/atmos13010140

Climate change and livestock: impacts, adaptation, and mitigation. *Clim. Risk Manag.* 16: 145–163. doi:10.1016/j.crm.2017.02.001

Coetzee, M. (2010). Climate change and agriculture in Namibia - adaptation and opportunities. Available at: http://www.agrinamibia.com.na/?module=Downloadsandfunc=prep_hand_outandlid=28 (Accessed April 29, 2021).

Coppock, D. (1994). *The Borana plateau of Southern Ethiopia: synthesis of pastoral research, development and change, 1980-91*. Addis Ababa, Ethiopia: ILCA Systems Study.

Davies, J. E., Spear, D., Ziervogel, G., Hegga, S., Ndapewa Angula, M., Kunamwene, I., et al. (2020). Avenues of understanding: Mapping the intersecting barriers to adaptation in Namibia. *Clim. Dev.* 12 (3), 268–280. doi:10.1080/17565529.2019.1613952

Davis, C. L. (2013). Trends in vegetation productivity and seasonality for Namaqualand, South Africa between 1986 and 2011: an approach combining remote sensing and repeat photography. Master's Thesis. University of Cape Town. Available at: https://open.uct.ac.za/handle/11427/6625.

Driver, A., Sink, K. J., Nel, J. N., Holness, S., Van Niekerk, L., Daniels, F., et al. (2012). National biodiversity assessment 2011: an assessment of South Africa's biodiversity and ecosystems. *Synth. Rep.* South African National Biodiversity Institute and Department of Environmental Affairs, Pretoria. doi:10.13140/RG.2.2.29769.70240

du Toit, G. van N., Snyman, H. A., and Malan, P. J. (2009). Physical impact of grazing by sheep on soil parameters in the Nama Karoo subshrub/grass rangeland of South Africa. *J. Arid Environ.* 73 (9), 804–810. doi:10.1016/j.jaridenv.2009.03.013

Els, J., Kotze, A., and Swartz, H. (2004). Genetic diversity of indigenous goats in Namibia using microsatellite markers: Preliminary results. *South Afr. J. Animal Sci.* 65–67. Available at: http://www.sasas.co.za/sajas.html.

Engelbrecht, F., Adegoke, J., Bopape, M., Naidoo, M., Garland, R., Thatcher, M., et al. (2015). Projections of rapidly rising surface temperatures over Africa under low mitigation. *Environ. Res. Lett.* 10, 085004. doi:10.1088/1748-9326/10/8/085004

Engelbrecht, F. A., and Monteiro, P. M. S. (2021). The IPCC assessment report six working group 1 report and southern Africa: reasons to take action. *South Afr. J. Sci.* 117 (11/12), 12679. doi:10.17159/sajs.2021/12679sajs.2021/1267

Engle, N. L. (2011). Adaptive capacity and its assessment. *Glob. Environ. Change* 21 (2), 647–656. doi:10.1016/j.gloenvcha.2011.01.019

Fahim, M., Hassanein, M. K., Khalil, A., and Abou Hadid, A. (2013). Climate change adaptation needs for food security in Egypt. *Nat. and Sci.* 11 (12), 68–74.

Galvin, K. A., Boone, R. B., Smith, N. M., and Lynn, S. J. (2001). Impacts of climate variability on East African pastoralists: Linking social science and remote sensing. *Clim. Res.* 19 (2), 161–172. doi:10.3354/cr019161

GebreMichael, Y., and Kifle, M. (2009). "Local innovation in climate-change adaptation by Ethiopian pastoralists," in *Final report PROLINNOVA–Ethiopia and pastoralist forum Ethiopia (PFE)* (Addis Ababa,Ethiopia). Available at: http://www.prolinnova.net/sites/default/files/documents/thematic_pages/climate_change_pid/2009/Ethiopia%20pastoral%20climate-change%20adaptation%20FINAL%20_2_.pdf (Accessed May 16, 2024).

Godde, C. M., Mason-D'CrozMayberryThornton, D. D. P., Herrero, M., Thornton, P. K., and Herrero, M. (2021). Impacts of climate change on the livestock food supply chain; a review of the evidence. *Glob. Food Secur.* 28, 100488. doi:10.1016/j.gfs.2020.100488

Haensler, A., Hagemann, S., and Jacob, D. (2011). The role of the simulation setup in a long-term high-resolution climate change projection for the southern African region. *Theor. Appl. Climatol.* 106 (1), 153–169. doi:10.1007/s00704-011-0420-1

Hamutenya, M. (2017). Warmbad farmers risk losing 19,000 livestock to drought. *New Era Newsp. Namib.* Available at: https://www.newera.com.na/2017/05/10/warmbad-farmers-risk-losing-19000-livestock-to-drought/(Accessed May 16, 2024).

Ho, D. (2006). The focus group interview: rising to the challenge in qualitative research methodology, *Aust. Rev. Appl. Linguistics.* 29, 5.1, 5.19. doi:10.2104/aral0605

Horn of Africa Review (1997). *Horn of Africa Review compiledby the UNDP-EUE, 6/1-7/31 1997*. Philadelphia: University of Penn-sylvania. Available at www.sas.upenn.edu/Africa_Studies/Newsletters/har_797.html (Accessed May 16, 2024).

Huang, C., Vaneckova, P., Wang, X., FitzGerald, G., Guo, Y., and Tong, S. (2011). Constraints and barriers to public health adaptation to climate change: A review of the literature. *Am. J. Prev. Med.* 40 (2), 183–190. doi:10.1016/j.amepre.2010.10.025

Huq, S., and Ayers, J. (2007). Critical list: The 100 nations most vulnerable to climate change. Available at: https://pubs.iied.org/17022iied (Accessed May 2, 2021).

Ifejika Speranza, C. (2010). Drought coping and adaptation strategies: understanding adaptations to climate change in agro-pastoral livestock production in Makueni District, Kenya. *Eur. J. Dev. Res.* 22, 623–642. doi:10.1057/ejdr.2010.39

Igshaan Samuels, M., Allsopp, N., and Timm Hoffman, M. (2021). Changes in pastoral mobility in a semi-arid montane region of South Africa: the role of policy and legislation. *Afr. J. Range and Forage Sci.* 38 (1), 1–13. doi:10.2989/10220119.2020.1861096

Inman, E., Hobbs, R., and Tsvuura, Z. (2020). No safety net in the face of climate change: the case of pastoralists in Kunene Region, Namibia. *PloS One* 15, e0238982. doi:10.1371/journal.pone.0238982

International Panel on Climate Change (IPCC) (2018). "Global Warming of 1.5°C. An IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways," in *The context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*. Editors V. Masson-Delmotte, P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P. R. Shukla, et al. In Press.

Kamberelis, G., and Dimitriadis, G. (2013). *Focus groups: from structured interviews to collective conversations*. London: Routledge.

Katanha, A., and Chigunwe, G. (2014). Climate change adaptation challenges in semiarid region of Dande Valley in Zimbabwe. *Int. J. Sci. Res.*, 633–640.

Kiljunen, M. L. (1981). "The land and its people," in *Namibia: the last colony, essex*. Editors R. Green, M. L. Kiljunen, and K. Kiljunen (Longman).

Kimaro, E., Mor, S., and Toribio, J.-A. (2018). Climate change perception and impacts on cattle production in pastoral communities of northern Tanzania. *Pastoralism* 8, 19. doi:10.1186/s13570-018-0125-5

Kruger, B., and Katjivikua, R. (2010). Towards sustainable rangeland management in Ovitoto. A booklet published with help of the ministry of environment and tourism, the global environment facility and the undp. Available at: http://theeis.com/elibrary/sites/default/files/downloads/literature/Towards%20sustainable%20rangeland%20management%20and%20livestock%20production%20in%20Namibia_1996.pdf (Accessed June 29, 2023).

Kunow, A. (2016). Livestock insurance for risk management. *CapEx Pastor.* Available at: https://www.shareweb.ch/site/Agriculture-andFoodSecurity/aboutus/Documents/pastoralism/pastoralism_brief_insurance.pdf (Accessed August 12, 2024).

Lawal, S., Lennard, C., and Hewitson, B. (2019). Response of southern African vegetation to climate change at 1.5 and 2.0° global warming above the pre-industrial level. *Clim. Serv.* 16, 100134. doi:10.1016/j.cliser.2019.100134

Letsoalo, N., Samuels, I., Cupido, C., Ntombela, K., Finca, A., Foster, J., et al. (2023). Coping and adapting to drought in semi-arid Karoo rangelands: key lessons from livestock farmers. *J. Arid Environ.* 219, 105070. doi:10.1016/j.jaridenv.2023.105070

Lu, C. D. (1989). Effects of heat stress on goat production. *Small Ruminant Res.* 2, 151–162. doi:10.1016/0921-4488(89)90040-0

Mekonnen, M. (2006). Drought, famine, and conflict: a case from the horn of Africa. Beyond Intractability. Available at: https://www.beyondintractability.org/casestudy/mekonnen-drought (Accessed May 2, 2021).

Mendelsohn, J. (2006). *Farming systems in Namibia*. Windhoek, Namibia: Namibian National Farmers Union.

Midgley, G., Hughes, G., Thuiller, W., Drew, G., and Foden, W. (2005). *Assessment of potential climate change impacts on Namibia's floristic diversity, ecosystem structure and function*. Cape Town: South African National Biodiversity Institute.

Milton, S. (1994). Growth, flowering and recruitment of shrubs in grazed and in protected rangeland in the arid Karoo, South Africa. *Vegetatio* 111, 17–27. doi:10.1007/BF00045574

Milton, S. J., and Hoffman, M. T. (1994). The application of state-and-transition models to rangeland research and management in arid succulent and semi-arid grassy Karoo, South Africa. *Afr. J. Range and Forage Sci.* 11 (1), 18–26. doi:10.1080/10220119.1994.9638349

Mmbengwa, V., Nyhodo, B., Lindikaya, M., and Schalkwyk, P. H. (2015). Communal livestock farming in South Africa: does this farming system create jobs for poverty stricken rural areas? *Sylwan* 159 (10), 176–192.

Moser, S., and Ekstrom, J. (2010). A Framework to diagnose barriers to climate change adaptation. *Proc. Natl. Acad. Sci.* 107, 22026–22031. doi:10.1073/pnas.1007887107

Mude, A., Chantarat, S., Barrett, C., Carter, M., Ikegami, M., and Mcpeak, J. (2010). Insuring against drought-related livestock mortality: piloting index based livestock insurance in Northern Kenya. *SSRN*. Available at: https://ssrn.com/abstract=1844745. doi:10.2139/ssrn.1844745

Mudombi, S. (2014). Analysing the contribution of ICTS in addressing climate change amongst communal farmers from two districts of Zimbabwe. Doctoral Thesis. University of South Africa. Available at: https://uir.unisa.ac.za/handle/10500/14668.

Muller, C., and Shackleton, S. E. (2014). Perceptions of climate change and barriers to adaptation amongst commonage and commercial livestock farmers in the semi-arid Eastern Cape Karoo. *Afr. J. Range and Forage Sci.* 31, 1–12. doi:10.2989/10220119.2013.845606

Nellesen, S. L. (2007). Grazing management effects on sediment and phosphorus losses from streambanks. Master's Thesis. Iowa State University. Available at: https://dr.lib.iastate.edu/handle/20.500.12876/68369.

Nelson, D. R., Adger, W. N., and Brown, K. (2007). Adaptation to environmental change: contributions of a resilience framework. *Annu. Rev. Environ. Resour.* 32 (1), 395–419. doi:10.1146/annurev.energy.32.051807.090348

Newsham, A. J., and Thomas, D. S. G. (2011). Knowing, farming and climate change adaptation in North-Central Namibia. *Glob. Environ. Change* 21 (2), 761–770. doi:10.1016/j.gloenvcha.2010.12.003

Niamir-Fuller, M., and Turner, M. D. (1999). "A review of recent literature on pastoralism and transhumance in Africa," in *Managing mobility in african rangelands: the legitimization of transhumance*. Editor M. Niamir-Fuller (London: Intermediate Technology Publications), 18–46.

Niehof, A., and Price, L. (2001). Rural livelihood systems: a conceptual framework. *UPWARD Work. Pap. Ser. 5. Wageningen -UPWARD Ser. Rural Livelihoods*. Available at: https://edepot.wur.nl/379081.

Ntombela, K. P. (2017) Assessing livestock farmers' ecological knowledge and adaptation to climate and environmental change in arid regions of South Africa. Master's thesis. University of the Western Cape. Available at: http://hdl.handle.net/11394/5864.

Ogidan, O. O. (2014). Valuing the natural resources and ecosystem services of Leliefontein communal rangeland in Namaqualand, South Africa. Master's Thesis. Cape Town: University of the Western Cape. Available at: http://etd.uwc.ac.za/xmlui/handle/11394/4461.

Opiyo, F., Wasonga, O., Nyangito, M., Schilling, J., and Munang, R. (2015). Drought adaptation and coping strategies among the Turkana pastoralists of Northern Kenya. *Int. J. Disaster Risk Sci.* 6 (3), 295–309. doi:10.1007/s13753-015-0063-4

Orindi, V., Nyong, A., and Herrero, M. T. (2007). Pastoral livelihood adaptation to drought and institutional interventions in Kenya. *UNDP Hum. Dev. Rep. 2007/2008*.

Pelling, M., and High, C. (2005). Understanding adaptation: what can social capital offer assessments of adaptive capacity? *Glob. Environ. Change* 15 (4), 308–319. doi:10.1016/j.gloenvcha.2005.02.001

Preston, B., and Smith, S. M. (2009). Framing vulnerability and adaptive capacity assessment: discussion paper. *Clim. Adapt. Natl. Res. Flagship Work. Pap. No 2. CSIRO*. Available at: http://www.csiro.au/org/ClimateAdaptationFlagship.html.

Richardson, F., Hahn, B., and Hoffman, M. T. (2007). Modelling the sustainability and productivity of pastoral systems in the communal areas of Namaqualand. *J. Arid Environ.* 70, 701–717. doi:10.1016/j.jaridenv.2006.07.013

Roder, W. (2002). Grazing management of temperate grasslands and fallows. *J. Bhutan Stud.* 7, 44–60. Available at: http://himalaya.socanth.cam.ac.uk/collections/journals/jbs/pdf/JBS_07_02.pdf.

Rohde, R. F., and Hoffman, M. T. (2008). One hundred years of separation: the historical ecology of a South African 'Coloured Reserve. *Africa* 78 (2), 189–222. doi:10.3366/E0001972008000132

Rust, J. M., and Rust, T. (2013). Climate change and livestock production: a review with emphasis on Africa. *South Afr. J. Animal Sci.* 43 (3), 255–267. doi:10.4314/sajas.v43i3.3

Samuels, M. I. (2006). Patterns of resources use by livestock during and after drought in a communal rangeland in Namaqualand in South Africa. Master's Thesis. South Africa: University of the Western Cape.

Samuels, M. I. (2013). Pastoral mobility in a variable and spatially constrained South African environment. Doctoral Thesis. Cape Town, South Africa: University of Cape Town. Available at: https://open.uct.ac.za/handle/11427/6180.

Samuels, M. I., Allsopp, N., and Hoffman, M. T. (2019). Traditional mobile pastoralism in a contemporary semiarid rangeland in Namaqualand, South Africa. *Rangel. Ecol. and Manag.* 72 (1), 195–203. doi:10.1016/j.rama.2018.08.005

Samuels, M. I., Allsopp, N., and Hoffman, T. (2008). Mobility patterns of livestock keepers in semi-arid communal rangelands of Namaqualand, South Africa. *Nomadic Peoples* 12 (1), 123–148. doi:10.3167/np.2008.120108

Scoones, I., Leach, M., and Newell, P. (2015). *The politics of green transformations*. London: Routledge.

Selemani, I. S. (2020). Indigenous knowledge and rangelands' biodiversity conservation in Tanzania: Success and failure. *Biodivers. Conservation* 29 (14), 3863–3876. doi:10.1007/s10531-020-02060-z

Severoğlu, S., and Gullap, M. (2020). Effects of animal grazing on favorable forage yield and quality of rangelands with different slope. *Turkish J. Field Crops* 25, 168–173. doi:10.17557/tjfc.735570

Silanikove, N. (2000). Effects of heat stress on the welfare of extensively managed domestic ruminants. *Livest. Prod. Sci.* 67, 1–18. doi:10.1016/S0301-6226(00)00162-7

Smit, B., Pilifosova, O., Burton, I., Challenger, B., Huq, S., Klein, R. T. J., et al. (2001). "Adaptation to climate change in the context of sustainable development and equity," in *Impacts, adaptation, and vulnerability. Contribution of working group II to the third assessment report of the intergovernmental panel on climate change*. Editors J. J. McCarthy, O. F. Canziani, N. A. Leary, D. J. Dokken, and K. S. White (Cambridge: Cambridge University Press), 879–906.

Smit, B., and Wandel, J. (2006). Adaptation, adaptive capacity and vulnerability. *Glob. Environ. Change* 16 (3), 282–292. doi:10.1016/j.gloenvcha.2006.03.008

Sternberg, M., Gutman, M., Perevolotsky, A., Ungar, E. D., and Kigel, J. (2000). Vegetation response to grazing management in a mediterranean herbaceous community: A functional group approach. *J. Appl. Ecol.* 37 (2), 224–237. doi:10.1046/j.1365-2664.2000.00491.x

Sunil, S., Akshit, R., Sheoran, R. S., Singh, S., Dagar, H., Loura, D., et al. (2020). Impact of climate change on forage and pasture production and strategies for its mitigation - a review. *Forage Res.* 46 (2), 105–113. Available at: http://forageresearch.in.

Suttie, J., and Reynolds, S. (2003). Transhumant grazing systems in temperate Asia. Available at: http://www.fao.org/3/Y4856E/y4856e00.htm (Accessed May 3, 2021).

Teshager, M. (2014). Analysis of climate change perceptions, effects and adaptation strategies in Raytu District of Oromiya Region, Ethiopia. *Int. J. Sci. and Technoledge*, 188–198.

Thornton, P., Herrero, M., Freeman, A., Mwai, O., Rege, E., Jones, P., et al. (2007). Vulnerability, climate change and livestock - research opportunities and challenges for poverty alleviation. *J. SAT Agric. Res.* 4 (1), 1–23.

Tilahun, M. (2012). Growth performance and carcass characteristics of Dorper sheep and Boer goat crosses compared with local sheep and goat breeds. Master's Thesis. University of Haramaya.

Todd, S., and Hoffman, M. T. (2000). Correlates of stocking rate and overgrazing in the Leliefontein communal reserve, central Namaqualand. *Afr. J. Range and Forage Sci.* 17, 36–45. doi:10.2989/10220110009485737

Todd, S. W., and Hoffman, M. T. (1999). A fence-line contrast reveals effects of heavy grazing on plant diversity and community composition in Namaqualand, South Africa. *Plant Ecol.* 142 (1), 169–178. doi:10.1023/A:1009810008982

Van der Merwe, H., Du Toit, J. C. O., Van den Berg, L., and O'Connor, T. G. (2018). Impact of sheep grazing intensity on vegetation at the arid Karoo stocking rate trial after 27 years, carnarvon, South Africa. *J. Arid Environ.* 155, 36–45. doi:10.1016/j.jaridenv.2018.02.005

Wan, H., Bai, Y., Schönbach, P., Gierus, M., and Taube, F. (2011). Effects of grazing management system on plant community structure and functioning in a semiarid steppe: Scaling from species to community. *Plant Soil* 340 (1–2), 215–226. doi:10.1007/s11104-010-0661-2