

Research

Climate change adaptation strategies among smallholder livestock farmers in Namibia's Omaheke Region, Namibia

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Abstract

The challenges of climate change are continuously increasing, constituting a major threat to livestock production, which is more than a socio-economic cornerstone in Namibian rural communal farmers, contributing approximately two-thirds of the country's agricultural GDP. Climate variability, which may be in the form of drought, very high temperatures, floods and frosts has been reported to have detrimental effects on feed and water availability, leading to reduced livestock weight, growth, production and reproductive performance, and ultimately high mortality. Understanding smallholder farmers' socio-psychological antecedents such as knowledge, attitudes and perceptions and the way they influence their level of adaptation to CC mitigation strategies needs to be assessed, as it guides CC policy formulation and intervention programmes. The study investigated CC perception and adaptation strategies for livestock farmers in Omaheke Region. Data were gathered from ($n = 80$) purposively sampled farmers in Epukiro and Otjombinde constituencies based on livestock ownership. The study revealed that 93.8% of the respondents were aware that the climate is changing, with attributes such as very high and very low temperatures, high and low rainfall, and drought having been noticed. Climate change has been attributed to both human and natural activity. The study observed that the implementation of CC adaptation strategies in livestock agriculture is low, thus recommends that the improvement of adaptation techniques involving employing extension services, promotion of farmer-to-farmer extension, and utilization of various information sources of climate knowledge, such as farmers' associations and social organizations, should be the future policy priority.

Keywords Agriculture · Climate variability · Farmers' perception · Livestock production · Resilience · Rural development · Smallholder farmers

1 Introduction

Globally, the climate is changing and the public discourse on climate change (CC) has intensified [1] and is one of the greatest challenges the world is currently facing [2, 3]. Climate change refers to ongoing changes in the global climatic system, resulting primarily from anthropogenic global warming because of the increased and continuing emissions of greenhouse gases, and the loss of vegetation cover and other carbon sinks [4] resulting in gradual changes in climate norms, notably changes in the frequency, extent and severity of climate and weather extremes such as temperature, rainfall, humidity and soil moisture [5, 6]. These weather extremes are increasing [2] and global warming shows no signs of abating and is expected to bring long-term changes in weather conditions [2, 7].

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Drought and CC mostly affect agricultural and livestock production [8] which are the main sources of livelihood and food for rural communities [9], posing considerable challenges to pastoralists and other economic activities on ranchlands. Climate change affects livestock growth rates, milk and egg production, reproductive performance, morbidity, and mortality [10] leading to food insecurity, reduced market prices and household income [5] due to its impact on the quality and quantity of feed crops and forage, water availability, livestock parasites and diseases and biodiversity [11]. Climate change continues to affect agricultural production negatively [12, 13].

Namibia is one of the largest and driest countries in Sub-Saharan Africa, characterised by high climate variability through persistent droughts, unpredictable and variable rainfall patterns [14], high temperatures and water scarcity [3, 15], causing detrimental effects to the productivity of human, animal and plant life. In addition, climate models project that Namibia will experience increasing frequency and intensity of climate extremes and temperatures are set to grow much more than the global average [3, 16]. However, regardless of the susceptibility to climate variability, agriculture still plays a very crucial role in the Namibian economy, supporting about 70% of the Namibian population [9] and 23% rely on subsistence agriculture as their main source of income [14, 17]. Namibian agriculture rests on both livestock and crop production, of which the livestock industry pre-dominates as the mainstay of the agricultural output and land use in Namibia [18], with 78% of the arid to semi-arid environment used mainly to raise livestock to support the livelihood of the people [19]. Most livestock production is based on extensive rangeland. However, Namibian agriculture is vulnerable to climatic hazards such as recurrent drought and floods and other perils such as parasites and disease outbreaks coupled with unusually high temperatures and erratic and irregular rainfall patterns [10, 20].

The CC topic has been well deliberated on for years now. The Government of the Republic of Namibia has not been lying idle and has taken various measures by developing strategies and policies intended to capacitate the nation and its populace in mitigating and adapting to the consequences of CC and other hazards. The National Drought Task Force [21] drafted the National Drought and Policy Strategy (NDPS) in 1997 while the National Climate Change Committee (NCCC) developed the National Climate Change Policy [22], the National Climate Change Strategy and Action Plan (NCCSAP) 2013–2020 [23], the Disaster Risk Management Act 10 of 2012 all aimed at guiding the national activities and measures to mitigate CC hazards. These policies encouraged individual farmers to adopt self-reliant approaches to drought risk mitigation. In addition, Namibia is an active part of the United Nations Convention on Climate Change and is eligible to receive aid from interventions such as the Green Climate Fund, the Adaptation Fund and the Global Environmental Facility. Furthermore, Namibia's 5th National Development Plan (NDP5) (Working Together Prosperity 2017/18–2021/22)'s aims for an increase in agricultural and livestock production and increased smallholder communal farmers productivity and preparedness for effective response, recovery and reconstruction and increase the share of livestock productivity [24]. Namibia is one of the 196 countries that partook in the Paris Agreement to limit global warming to 2 °C (or ideally 1.5 °C). However, for Namibia, local warming and drying will be greater than the global average [16], implying that there is an urgent need for Namibia to adopt extensive adaptive and transformative measures to deal with risks associated with global temperature rises, extremely low temperatures in winter, floods due to unpredictably heavy rains and ever-occurring droughts.

Omaheke Region lies in Eastern Namibia bordering Botswana and it is the western extension of the Kalahari Basin Desert, at the edge of a vast basin of sand that determines vegetation and land use. Savanna characteristics of the Kalahari Sands dominate the eastern two-thirds of the region with broad-leafed deciduous trees in the north and thorn species in the south while the western parts are covered in Camelthorn -*Terminalia* species suited to browsing and grazing of animals [19]. Due to poor soils and rainfall variability, the region is considered less suitable for crop production and rain-fed agriculture register [25] thus, extensive cattle ranching dominates land-use patterns. Consequently, the region is called 'cattle country' because of its habitats [26], as livestock production (cattle farming in particular) is not just a mainstay in the region's economy, but also a cultural identity. About 6.7% of the regional population relies on subsistence agriculture as their main source of income [27, 28] with livestock production being the main agricultural activity for 60% of the region's population. Omaheke is ranked as the fifth region with severely poor households [29] and is considered one of the regions severely food-insecure [30]. Poverty among subsistence farmers is prevalent because of the low productive potential of vegetation and soils of the Kalahari Sands, a high population of invader bush species than other parts of the country [19], subsequently limiting the carrying capacity of the farmland's prevalent climatic hazards. For instance, prolonged drought conditions in 2018 led to the death of 300 cattle and the relocation of 17,000 cattle in the region [16, 31]. The vulnerability assessment of 2012/13 on the impacts of drought ranked the Omaheke Region (38.2% of the

population vulnerable) third behind the Kunene and Kavango regions [30]. However, groundwater is generally available throughout the region [19].

Farmers' ability to adopt CC mitigation strategies is driven by intrinsic factors such as perceptions, attitudes and knowledge [32] and social capital [33] which are shaped by (i) experience, (ii) memory, (iii) definition and (iv) expectation [34]. In this case, perception refers to people's understanding of the reality and causes of CC, its consequences, and the factors that determine the decision to apply appropriate measures [35]. Knowledge refers to understanding information, which is the conscious and non-symbolic perception of meaning [36], while attitudes refer to an object's positive and negative evaluation [37]. Practice refers to regular activities that are influenced by shared social norms and beliefs [38]. Hungerford and Volk [39] argued that knowledge of issues and possession of skills are required for behavioural change (practices). Subjective norm refers to an individual receipt of social influence from peers and other important people who wish that the individual would engage in a particular behaviour [40] while perceived behaviours such as the ability to implement new farming practices to combat CC hazards.

A variety of factors play a role in influencing perceptions [41], making it important to identify general socio-psychological antecedents that motivate people to engage in responses to CC hazards. People who perceived CC to be real were more likely to support CC adaptation actions policy [42] but were not likely to engage in concrete adaptive behaviours such as purchasing flood insurance and saving water during drought [43]. The more negative people perceived the consequences, the more likely they were to invest in emergency measure strategies but not preparedness measures [44]. Studies concluded that CC perceptions are more related to policy support but less associated with actual behaviour. Because the country is highly susceptible to climatic disasters, and various policies have been developed, the researchers found it necessary to assess the knowledge, attitudes perceptions and practices of livestock farmers towards CC to determine the cognition factors that affect individual and collective practices that address consequences of CC as knowledge, attitudes and practices (KAP) are critical for behavioural change. So, the KAP model was structured to quantify and analyse what is known (knowledge), believed (attitudes) and done (practices) concerning CC and how these social discourses are interrelated so that intervention can be targeted as well as information pathways that can be utilized when disseminating CC information to the general public. Currently little is known about how livestock farmers in Omaheke Region perceive climate change, their adaptation and mitigation strategies they adopt in order to sustain their livestock agriculture. Consequently, an in-depth understanding of how livestock farmers in Omaheke Region perceives climatic trends and their implications to livestock farming is very useful in contributing to minimizing the impact of climate change to livestock agriculture. Therefore, the objective of this study was to assess the knowledge, attitudes, and perceptions of livestock farmers to CC and the way they influence their level of mitigation and adaptation strategies.

1.1 Conceptual framework

The conceptual framework for the study is shown Direct Acrylic Graph (DAG) in Fig. 1. The study conceptualises that farmers' exposure to information on climate change and their past experiences on climate change will shape their awareness of climate change, which will in turn build their beliefs on whether the climate is changing, knowledge and understanding about the climate change phenomenon, its causes and risks. The knowledge, beliefs and understanding of climate change contribute to their attitudes and perceptions towards the climate change phenomenon and the information they receive about climate change and the risks associated with CC. From attitudes and experiences, different coping strategies emerge, based on the farmers' understanding, willingness to adopt the climate change adaptation and mitigation strategies, and perceptions towards climate change risks. For instance, farmers who perceive that climate is a significant threat and will continue to change in future may be motivated to learn more about its causes and impacts and adaptation strategies they can implement to vie the consequences of CC.

2 Materials and methods

2.1 Description of study area

The study was conducted in Otjombinde and Epukiro constituencies of the Omaheke Region of Namibia (Fig. 2), located at latitude 21.83° 50' south; longitude. 20.75°45' east and an altitude of 1,236 m above sea level. The region lies in eastern

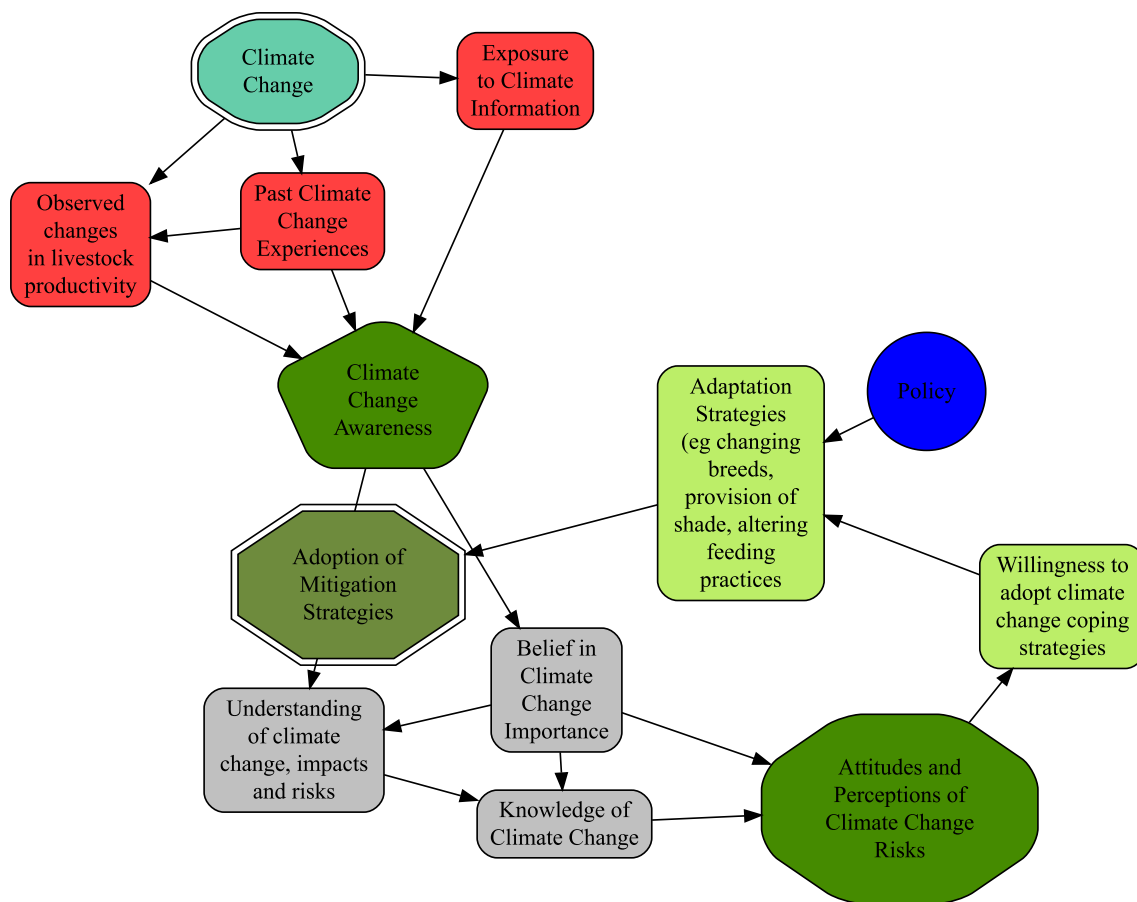


Fig. 1 The conceptual framework of the study

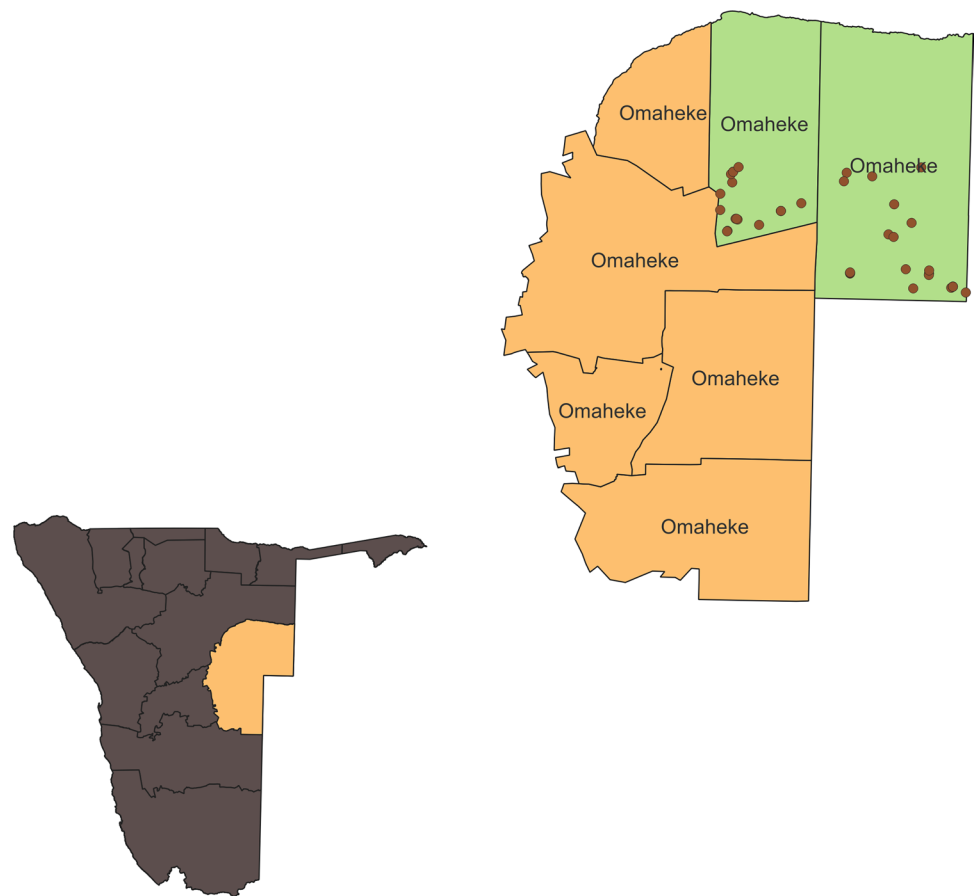
Namibia on the border with Botswana and is the western extension of the Kalahari Desert. The annual mean temperature ranges from 15 °C to 38 °C, and the mean annual rainfall ranges from 300 and 400 mm [45]. As of 2011, livestock farming was the most dominant agricultural activity, sustaining the livelihoods of 26.5% of the regional population, followed by crop farming (7.4%) and poultry production (6.6%) [27]. Livestock farming in the Omaheke Region includes cattle, goats, sheep, and poultry and these dominate in all constituencies of the regions, being highest in Epukiro Constituency where 64.8% of 1231 households were into livestock farming followed by Otjombinde Constituency where 44.7% of 1505 households farmed with livestock [27]. As a result, the Epukiro and Otjombinde constituencies were selected ahead of the other five constituencies in the region because of a greater proportion of households that are reliant on livestock production.

2.2 Sampling methods and data collection techniques

A total of 80 households was sampled, calculated based on the population of livestock farmers in Epukiro and Otjombinde constituencies (approximately 1500), 95% confidence interval, 8% error margin and an estimated proportion of farmers implementing agricultural coping strategies of 30%, following findings by Charamba et al. (2021) who reported 34% of the households in Etayi Constituency preserved pearl millet stocks for livestock feeding. Households were purposively sampled for the study where farmers with more than 10 animals were eligible for the survey. In each constituency, 10 villages were randomly selected and, in each of the villages, 5 farmers with more than 10 cattle were selected. The household heads of the selected households or their proxies above 18 years in their absence, were interviewed.

A structured questionnaire was used to collect data from the livestock farmers. The questionnaire was pre-tested with households in another village not sampled for the study. Both quantitative and qualitative data were collected through a household knowledge, attitudes and practices (KAP) survey to measure respondents' general knowledge of CC, including

Fig. 2 Omaheke Region Map showing the constituencies and some sampled farms



their understanding of what CC is, causes and perceived impacts of CC. Data on socio-economic characteristics, farmers' perceptions of CC and adaptation strategies developed by farmers to address CC and factors affecting farmers' ability to implement adaptation/ coping strategies to mitigate or cope with CC were collected using a semi-structured questionnaire. The questions related to the general CC perception were open-ended, while the specific questions related to CC effect and temperature and rainfall were organized with sequential options.

2.3 Data analysis

The questionnaire's internal consistency was assessed using Cronbach's alpha reliability coefficient. Descriptive graphical, tabular, and summary statistics were presented. The chi-square test of association was employed to assess the relationship between farmers' knowledge, attitude and experiences with the adaptation practices they implement to mitigate drought consequences. If the relationship was statistically significant, the odds ratios obtained by exponentiating the log odds from the Binary Logistic Regression Model (BLRM) were utilised to assess the strength of the association between the variable and the copying strategy (response variables).

The overall quality of information received from the supporting organisations (church, NGOs, extension officers, farmer-to-farmer, Indigenous Knowledge Systems and farming organisations) was determined by computing the mean for responses on timeliness, access, accuracy, reliability, ease of use and depth of content, all measured on a three-point Likert Scale (poor (1), moderate (2) and good (3)). The resulting interval scaled mean was interpreted where 1–1.66 (poor), 1.67–2.33 (moderate) and an average of 2.34–3 was considered to be good following Pimentel [46]. The five-point Likert scale (strongly disagree, agree, neutral, agree, strongly agree) was dichotomized to a disagree (neutral, strongly disagree, disagree) and agree

(agree, strongly agree) following suggestions by Jeong and Lee [47] before the Chi-square and odds ratios were employed for further analysis.

3 Results

The Cronbach's alpha (α) coefficients for related questionnaire items measuring the same construct were high for reliability. Coping strategy items ($\alpha=0.801$), losses observed due to CC ($\alpha=0.913$), the effectiveness of coping strategies ($\alpha=0.825$), attitudes towards institutions providing CC information ($\alpha=0.913$) and severity of the impacts of CC ($\alpha=0.724$), an indication that the questionnaire items were consistent in the construct they were measuring. Coping strategies such as growing fodder under irrigation were removed from further analysis as any of the interviewed small-holder farmers did not implement them.

3.1 The demographic characteristics of the Otjombinde and Epukiro constituencies

Table 1 presents the socio-economic-demographic characteristics of the respondents in the Otjombinde and Epukiro constituencies. The study sample was largely composed of men (76.3%). The ages of the sampled farmers ranged from 20 to over 61 years with an average age of 46 years. About 95% of the sampled farmers rely on livestock production as a source of livelihood and 30% are into crop production (both categories include farmers who practice both livestock and crop production). About 88.8% of the respondents farm on state-owned communal farms of more than 2.5 hectares while 11.2% of farmers own private land that they had purchased or inherited. Approximately 57% of respondents earn above N\$ 10 000 on-farm while 23.4% and 19.5% earn from N\$ 5001–10 000 and > N\$ 5000, respectively. Regarding off-farm income, about 41% of the farmers earn off-farm revenue of over N\$ 10,000. The respondents had an average of 13 years of farming experience, ranging from 5 to 21 years (not shown in the table). Concerning the education level of the households, about half of the farmers attained tertiary level education (48.8%), while 25% had a secondary education with only 3.8% having no formal education.

Table 1 The socio-demographics of the respondents (n=80)

Attribute	Frequency	Percentage	Attribute	Frequency	Percentage
Gender			Marital status		
Male	61	76.3	Single	51	66.3
Female	19	23.8	Married	35	43.8
Age			Educational level		
Less than 20 years	3	3.8	No formal education	3	3.8
20–40 years	33	41.3	Primary	18	22.5
41–60 years	36	45.0	Secondary	20	25.0
61 years and over	8	10	Tertiary	39	48.8
Farming activities			Farming experience		
Livestock	76	95.0	0–5 years	6	7.5
Crop	24	30.0	6–10 years	18	22.5
Poultry	6	7.5	11–15 years	18	22.5
			16–20 years	13	16.3
			Above 20 years	25	31.3
On -Farm Income			Off - farm income		
Less than N\$ 5000	15	19.5	Less than N\$ 5000	8	10.4
N\$ 5001–10 000	18	23.4	N\$ 5001–10 000	14	17.5
Above N\$ 10 000	44	57.1	Above N\$ 10 000	33	41.3

Table 2 Major CCs observed by farmers in the past 10 years

Change	Frequency	Percentage
Prolonged droughts	72	91.3
Very hot seasons	46	57.5
Very cold winter seasons	22	27.5
Very wet seasons	7	8.8
Floods	2	2.5
Violent winds	15	15

Table 3 The views of respondents on why climate is changing (n = 80)

Reason for CC	Strongly Disagree (%)	Disagree (%)	Neutral (%)	Agree (%)	Strongly Agree (%)
Human activities	13.8	7.5	6.3	21.3	43.8
Natural change	7.5	13.8	27.5	33.8	10
Both natural changes and human causes	8.8	12.5	23.8	35	13.8
Not sure if the climate is changing	13.8	22.5	15	15	6.3
The climate is not changing	23.8	33.8	8.8	0	3.8

3.2 Smallholder livestock farmers' knowledge of CC

The survey results showed that about 93.8% of the farmers were aware of the CC phenomenon, while 97.5% have noticed the change in climate over the past 10 years. The major changes observed were prolonged droughts and very hot seasons, observed by 91.3% and 57.5% of the respondents, respectively among other changes (Table 2).

Respondents had different opinions as to why the climate is changing (Table 3). About 65% of the respondents believe that CC is caused by human activities such as deforestation, overgrazing, mining, de-bushing and explosions (Box 1), while 44% agreed that the climate is changing naturally. However, about 4% of the respondents strongly agreed that the climate is not changing. Moreover, some respondents believe that the world is experiencing very high temperatures because the sun is getting closer to the Earth (Box 1).

3.2.1 Box 1: Causes of CC according to the interviewed farmers

1. "Yes the climate has severely changed, raining patterns have adjusted to different months, and increased temperatures"
2. "Yes the climate is changing due to carbon emissions and deforestation and overgrazing and an increase in the population of carbon monoxide"
3. "The ecosystem is changing because of human behaviour e.g. mining, de-bushing, and explosions"
4. "The climate is changing, and we are now experiencing drought regularly and it has become very hot because of global warming, increase in population, pollution, and industrialization"
5. "This heat we are experiencing nowadays is all because the sun is getting closer to the earth"
6. "This is all caused by human beings because industries emission, oil and gas emission, production of electricity from fossil fuels"

Sixty-five percent of the respondents indicated that early warning signals that help smallholder farmers to predict upcoming weather include atmospheric indicators such as moon position, wind swirls and cloud cover. About 47.5% and 38.8% of farmers stated that animal behaviour, and plant phenology, respectively, provided them with early warning signs.

Table 4 Farmer's perception of the main impact of CC on the local community

The perceived main impact of CC	Perceived extent of impact		
	Very severe (%)	Moderately severe (%)	Not severe (%)
Crop production losses	36.3	33.8	6.3
Livestock production losses	36.3	47.5	8.8
Infrastructure	3.8	22.5	55.0
Disease outbreak	35.0	37.5	15.0
Food insecurity	47.5	33.8	5.0
Water shortages	60.0	28.8	2.5
Lower no growth of vegetation	26.3	42.5	15.0

Table 5 Farmer's perception of the losses experienced by livestock production (n = 80)

Perceived loss	Perceived extent of loss		
	Very severe (%)	Moderately severe (%)	Not severe (%)
The growth rate of livestock has decreased	37.5	42.5	8.8
There have been decreases in livestock weight	21.3	43.8	13.8
Decrease in milk production	25	33.8	18.8
Negative impact on lactation length	13.8	38.8	20
Decrease growth of young stock (calves, kids, lambs)	17.5	28.8	28.8
Increase in livestock diseases	21.3	30	26.3
Increase in pests and parasitic infections	32.5	28.8	15.0
There have been increases in livestock deaths	30	33.8	12.5
Decreased conception rate	13.8	37.5	21.3
Feed and fodder resources are decreasing	17.5	32.5	25.0
Shortage of high-quality fodder	17.5	27.5	28.8
There is a scarcity of water resources	26.3	31.3	18.8
Decrease in intensity of estrous period	12.5	36.3	21.3
Reduction in reproduction rates of livestock	17.5	36.3	23.8
Limited grazing lands for livestock	46.3	20.0	10.0
Decreased number of natural water resources	45	21.3	11.3
Loss of farm income or earnings	36.3	28.0	7.5
Land degradation	35.5	40.3	24.2

3.3 Farmers perceived impacts and losses experienced due to the changing climate

Table 4 shows the impacts that farmers perceived to have incurred due to CC. More than 60% of the respondents experienced severe water shortages. In addition, severe livestock (36.3%) and crop production losses (36.3%) were experienced in the past 10 years, resulting in severe food insecurity (47.5%). Very severe (26.3%) to moderately severe (42.5%) low vegetation growth was reported to have occurred in the past 10 years. However, CC never impacted much on infrastructure, with 55% of the farmers considering the damage incurred not to be severe.

Table 5 gives the severity of the losses incurred by the farmers in livestock production over the past 10 years. A very severe and moderately severe decrease in growth rates of livestock was noticed by 80% of the farmers while about 65% experienced moderate to severe reduction in livestock weight over the past 10 years. Severe decrease in milk production (58.8%), severe to moderate increase in disease incidents (51.3%), decrease in fodder and feed resources (50%) and limited grazing lands (66.3%), water scarcity (57.3%) and reduced reproduction rates (53.8%) were observed over the past 10 years, leading to loss of income (71.3%).

Table 6 Climate change information dissemination pathways

Attribute	Frequency	Percentage %
Sources of information		
Radio	64	80
Newspaper	33	41.3
Television	48	60.0
Farmer to farmer	43	53.8
Extension officer	14	17.5
WhatsApp messages	34	42.5
The institution that provides support		
Extension services	35	43.8
Farmers organization	51	63.7
Social groups	25	31.3
NGOs	9	11.3
Family member	6	7.5
Media	43	53.8

3.4 Climate change information dissemination

About 92.5% of farmers receive climate information on CC while only 5% of the respondents have received training on CC. Most farmers received CC information over the radio (80%), followed by television (60%) (Table 6). Moreover, farmers receive CC information from other farmers (53.8%) and via WhatsApp (42.5%). Extension officers were ranked least source of information with only 17.5% of the farmers receiving CC information from them. Only 5% of the interviewed farmers received training on CC adaptation. However, farmers get support on animal care and wellbeing from farmer's organizations such as the Epukiro Farmers Association (63.7%), extension services (43.8%), social groups (31.3%), NGOs (11.3%) and the media such as televisions, radios and social media (53.8%).

Farmers' perceptions of the knowledge and resourcefulness of extension officers in building their CC adaptive capacity were examined. About 51% of the farmers either agreed or strongly agreed that extension offers are knowledgeable about CC issues, 35% were neutral, while 13.8% of the farmers disagreed that extension officers are knowledgeable about CC. In addition, 38.7% of the farmers agreed that extension officers are resourceful on CC issues, 40% were neutral and 21.3% disagreed that extension officers serving their area are resourceful on CC issues.

The perception of the quality of information provided by the supporting institutions in terms of timeliness, accuracy, reliability, accessibility, usability, and breadth of content about CC is presented in Fig. 3. The results show that farmers had not considered information received from most institutions and organizations to be of high quality as most institutions were ranked poorly (average of 1–1.66) across all facets. However, NGOs had a moderate reliability score. Extension services fared poorly on timeliness but scored moderately (1.67 – 2.33) on reliability, accessibility, ease of use, accuracy

Fig. 3 Institutions ranks on information dissemination. *NGO* Non-governmental organisation, *IKS* Indigenous knowledge systems

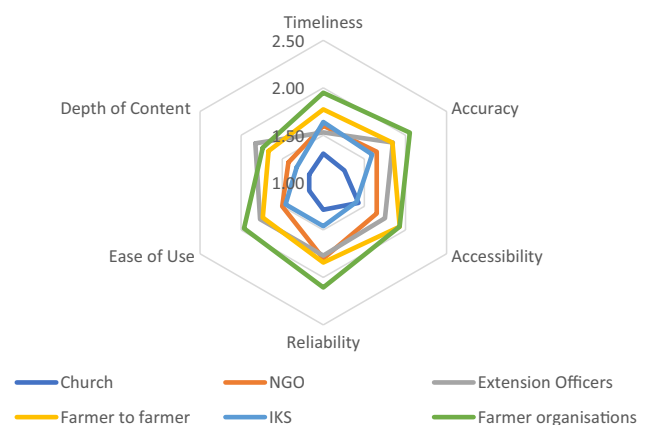


Table 7 CC coping strategies and their perceived effectiveness in mitigating CC consequences

Coping strategy	Yes	No	If yes, to what extent?		
			Not effective	Effective	Very effective
Using improved animal breeds	27.5	72.5	0.0	42.9	57.1
Changes in the breeding season	11.3	88.7	0.0	60.0	40.0
Dietary change for livestock	35	65	7.1	71.4	21.4
Dipping of livestock	67.5	32.5	5.6	42.5	51.9
Using dose treatments	76.3	23.7	1.7	42.6	55.7
Uses of encroacher bush as feed	11.3	88.7	6.7	75.6	17.8
Vaccination of livestock	76.3	23.7	1.7	36.0	62.3
Fodder production	16.3	83.7	0.0	63.6	36.4
Fodder conservation (grass hay/silage)	15	85	5.7	49.0	45.2
Preserving pearl millet stalks	10	90	16.7	50.0	33.3
Supplementary feeding	27.5	72.5	6.8	75.4	17.8
Fencing of grazing lands	25	75	7.7	38.5	53.8
Mixed livestock farming	63.7	36.3	3.9	68.7	27.4
Cross-breeding of local breeds	62.5	37.5	4.1	57.1	38.8
Provision of shade for livestock	22.5	77.5	4.0	52.0	44.0
Plant shade trees in rest camps	12.5	87.5	4.0	52.0	44.0
Land management to degradation	7.5	92.5	20.0	40.0	40.0
Water harvesting and storage	70	30	1.9	37.5	60.6
Water conservation	40	60	0.0	44.0	56.0
Rainwater harvesting	50	50	0.0	44.4	55.6
Dams	42.5	57.5	0.0	42.3	57.7
Tanks purchased	52.5	47.5	0.0	35.3	64.7
Drilling wells and boreholes	62.5	37.5	0.0	39.0	61.0
Fencing water sources	16.3	83.7	0.0	50.0	50.0
Pastoral nomadism	38.8	61.2	9.8	45.1	45.1
Diversifying income source	36.3	63.7	10.5	62.0	27.5
Destocking	35	65	5.4	40.6	54.0
Switching to another agro-enterprise	13.8	86.2	27.5	54.3	18.1
Dependent on social welfare	10	90	15.3	23.3	61.3
Use of insurance	10	90	12.3	64.2	23.6
Selling assets	10	90	24.8	62.4	12.9
Other*	11.3	88.7			

*Other coping strategies include livestock insurance, provision of bedding for livestock in extreme weather, planting of fodder trees around camps, changing livestock composition, keeping more livestock to reduce reliance on crops and irrigation system

and depth of information. Information farming organisations, flowed by farmer-to-farmer communications were moderately rated ahead of all the other institutions.

3.5 Climate change adaptation practices employed by the smallholder livestock farmers.

The results showed that 90.8% of farmers had observed CC, while 61% of them reacted to this change. Table 7 shows adaptation practices made by livestock production farmers to curb the effects of CC and their perceived effectiveness in mitigating CC hazards. The common strategies employed include drilling wells and boreholes (62%), construction of small dams to capture rainwater (42.5%), purchasing water tanks (52.5%) using improved livestock breeds (27.5%), provision of shade (22.5%), provision of supplements (27.5%), fodder production (16.25%), changing the breeding season

(11.5%), fencing of grazing lands (25%), and practised pastoral nomadism (16.25%). Other coping strategies such as livestock insurance, provision of bedding for livestock in extreme weather, planting fodder trees around camps, changing livestock composition, and keeping more livestock to reduce reliance on crops and irrigation systems were lowly implemented. Farmers perceived the effectiveness of various coping mechanisms in addressing the consequences of CC on livestock production. Use of encroacher bush-based feed, vaccination and storage were reported to be the most effective strategies undertaken by the farmers with 47.5%, 42.5%, and 42.5%, respectively. Using improved breeds was ineffective as 38.8% of farmers agreed.

According to the information in Box 2, farmers who do not implement any CC adaptation strategies are constrained by government regulations that include financial resources, lack of knowledge, and the difficulty of implementing adaptation strategies in communal area setup.

3.5.1 Box 2: Reasons for not employing CC adaptation strategies

- "We are communal farmers and it is always tough to introduce adaptation measures"
- "We cannot implement any adaptation measures because of governmental regulations and limitations in the communal area"
- "It is very costly to make dams or to purchase water tanks. we don't have money"
- "Yes, it is very hot and our livestock are dying but we do not know what measures to take"
- "We don't know what to do with these impacts of drought and no information is available for us"
- "We don't have money"

Farmers were asked about their attitude when dealing with CC. About 66% of the farmers felt concerned about dealing with CC, 18% felt helpless, 14% felt motivated and to a lesser extent, 2% felt confident in dealing with CC. From the responses in Box 3, most farmers perceived that CC would continue in future, if not worsen depending on human activities, hence it is necessary to try and adapt as well as predict the future.

3.5.2 Box 3: Perceptions on whether CC will continue or not

- "Yes, because I believe that CC will forever change, because of the people that degrade the land"

Table 8 Chi-square test p-values on the effects of knowledge and experience on climate change adaptation practices

	Improved Breeds	Planting of shade trees	Changes in breeding season	Fodder production	Supplementary feeding	Provision of shade	Fencing grazing lands	Livestock insurance	Fodder conservation	Pastoral nomadism	More livestock	Bush feed	Bedding for livestock	Planting fodder trees	Land management	Change livestock composition	Hay/silage	Preserving pearl millet	Replacement of exotic breeds	Destocking	Water conservation	Rainwater harvesting	Dams	Tanks purchased	Drilling well and boreholes	Fencing water sources
Heard of CC	0.470	0.383	0.441	0.309	0.168	0.944	0.182	0.137	0.33	0.137		0.411	0.712	0.649	0.511	0.712	0.475	0.441	0.475	0.226	0.346	0.021	0.293	0.729	0.905	0.309
Noticed CC	0.558	0.702	0.736	0.655	0.545	0.612	0.558	0.871	0.670	0.670	0.909	0.718	0.871	0.842	0.773	0.871	0.754	0.736	0.754	0.468	0.419	0.308	0.394	0.296	0.198	0.655
Prolonged drought	0.635	0.930	0.317	0.861	0.442	0.594	0.529	0.161	0.654	0.714	0.938	0.933	0.878	0.385	0.663	0.878	0.885	0.317	0.885	0.615	0.702	0.469	0.630	0.518	0.536	0.374
Very hot seasons	0.133	0.124	0.651	0.122	0.901	0.433	0.322	0.218	0.050	0.748	0.387	0.555	0.218	0.129	0.183	0.218	0.114	0.070	0.114	0.368	0.002	0.007	0.507	0.197	0.726	0.350
Very cold seasons	0.205	0.850	0.504	0.696	0.205	0.042	0.386	0.378	<0.001	0.020	0.102	0.707	0.378	0.818	0.199	0.378	0.818	0.199	0.066	0.495	0.102	0.012	0.064	0.821	0.897	0.333
Floods	0.393	0.588	0.633	0.527	0.457	0.439	0.408	0.817	0.547	0.528	0.870	0.619	0.817	0.773	0.683	0.817	0.037	0.633	0.652	0.652	0.242	0.152	0.213	0.173	0.267	0.528
Very wet seasons	0.884	0.178	0.086	0.355	0.052	0.143	0.253	0.657	0.292	0.355	0.001	0.324	0.657	0.585	0.430	0.657	<0.001	0.002	0.358	0.648	0.076	0.048	0.015	0.294	0.032	0.355
Violent winds	0.545	0.636	0.404	0.082	0.545	0.235	0.654	0.160	0.293	0.424	0.017	0.520	0.547	0.011	0.285	0.547	0.003	0.003	0.956	0.431	0.160	0.531	0.569	0.286	0.024	0.966

Table 9 Chi-square test p-values on the effects of climate change impacts (experiences) on adaptation practices

	Improved Breeds	Planting of shade trees	Changes in breeding season	Fodder production	Supplementary feeding	Provision of shade	Fencing grazing lands	Livestock insurance	Fodder conservation	Pastoral nomadism	More livestock	Bush feed	Bedding for livestock	Planting fodder trees	Land management	Change livestock composition	Hay/silage	Preserving pearl millet	Replacement of exotic breeds	Destocking	Water conservation	Rainwater harvesting	Dams	Tanks purchased	Drilling well and boreholes	Fencing water sources
Low growth rate	0.55	0.383	0.657	0.584	0.555	0.138	0.424	0.267	0.322	0.481	0.436	0.555	0.267	0.879	0.826	0.267	0.609	0.124	0.759	0.809	0.637	0.644	0.199	0.729	0.905	0.938
Decreased weight	0.364	0.470	0.785	0.572	0.774	0.281	0.430	0.457	0.235	0.860	0.601	0.347	0.457	0.602	0.775	0.457	0.50	0.121	0.143	0.264	0.315	0.412	0.498	0.613	0.832	0.359
Low milk production	0.463	0.689	0.386	0.600	0.107	0.430	0.233	0.408	0.450	0.561	0.101	0.408	0.634	0.734	0.624	0.408	0.493	0.389	0.040	0.588	0.092	0.220	0.303	0.404	0.499	0.861
Lactation length	0.934	0.177	0.330	0.488	0.934	0.288	0.092	0.567	0.750	0.286	0.688	0.433	0.567	0.315	0.309	0.567	0.69	0.914	0.001	0.563	0.791	0.330	0.831	0.884	0.933	0.826
Diseases	0.282	0.642	0.341	0.771	0.108	0.486	0.574	0.606	0.505	0.557	0.707	0.087	0.398	0.483	0.738	0.043	0.538	0.542	0.161	0.593	0.438	0.137	0.064	0.095	0.134	0.503
Pests and parasites	0.181	0.416	0.036	0.131	0.239	0.281	0.295	0.453	0.038	0.580	0.675	0.146	0.547	0.302	0.298	0.103	0.409	0.232	0.409	0.241	0.295	0.406	0.587	0.471	0.546	0.203
High mortality	0.551	0.655	0.241	0.408	0.250	0.171	0.617	0.487	0.486	0.179	0.100	0.261	0.487	0.337	0.808	0.750	0.50	0.50	0.73	0.285	0.494	0.404	0.002	0.177	0.404	0.49
Low conception rates	0.314	0.415	0.698	0.123	0.596	0.175	0.555	0.42	0.21	0.30	0.62	0.44	0.258	0.638	0.003	0.017	0.40	0.234	0.245	0.223	0.31	0.45	0.59	0.115	0.094	0.251
Feed insecurity	0.898	0.443	0.617	0.072	0.554	0.232	0.577	0.223	0.498	0.494	0.725	0.028	0.477	0.624	0.025	0.020	0.088	0.294	0.292	0.537	0.192	0.599	0.175	0.152	0.257	0.259
Water scarcity	0.506	0.038	0.076	0.74	0.06	0.82	0.33	0.59	0.35	0.22	0.37	0.55	0.259	0.96	0.009	0.393	0.505	0.24	0.95	0.68	0.24	0.00	0.16	0.27	0.37	0.87
Decreased estrous cycle intensity	0.481	0.241	0.739	0.136	0.198	0.242	0.55	0.64	0.36	0.12	0.88	0.64	0.34	0.36	0.64	0.23	0.23	0.26	0.23	0.11	0.60	0.369	0.28	0.35	0.412	0.512
Decreased reproductive rates	0.287	0.422	0.603	0.457	0.570	0.275	0.598	0.188	0.603	0.75	0.350	0.598	0.125	0.205	0.598	0.503	0.422	0.503	0.332	0.431	0.605	0.321	0.288	0.166	0.603	0.353

- "Yes, the climate will continue to change from now onwards and maybe we should try and predict the future"
- "Yes, the climate will continue to change in the future and farmers need to learn and adapt fast for profit-based farming"
- "The world is becoming more and more industrialized and hence the climate will continue to change"
- "Yes, CC is never-ending. It will continue in the future or even get worse depending on what we are going to do as human beings"
- "Yes, but we don't know what the future holds"
- "Yes, and it depends on us human beings whether it will be better or worse"
- "Yes the climate will continue to change if we continue to pollute the environment"
- "Yes, the climate will continue to change in the future but we have some knowledge on how to go about it"

3.6 The effect of knowledge and experiences on CC adaptation practices

From the results shown in Table 8 CC awareness did not significantly affect the coping strategies implemented by the small-holder farmers except for rainwater harvesting. Experiencing prolonged drought did not affect the employed adaptation practices. However, experiencing scorching seasons significantly ($p < 0.05$) affected fodder conservation, with households that reported the experience having 4.444 odds of conserving fodder, preserving pearl millet stalks ($OR = 5.923$), conserving water ($OR = 4.592$) and harvesting rainwater ($OR = 3.657$) than those that did not report the experience. Farmers who experienced frigid seasons were more likely to provide shade/shelter ($OR = 3.111$), conserve fodder ($OR = 2.280$), harvest rainwater ($OR = 3.778$) and construct dams ($OR = 2.545$). Farmers who observed very wet seasons were less likely to conserve hay and silage ($OR = 0.077$), harvest rainwater ($OR = 0.145$), and drill wells and boreholes (0.667). However, wet seasons make farmers keep more livestock ($OR = 1.667$).

Experiencing decreased livestock growth and weight negatively impacted lactation length, decreased oestrous cycle and decreased reproductive performance did not ($p > 0.05$) affect the CC adaptation practices employed by the small-holder farmers in the Epukiro and Otjombinde constituencies (Table 9). Increased disease incidence led farmers to change their livestock composition ($OR = 1.952$) and divert to small stock (sheep and goats) and poultry production in backyards. The incidence of pests and parasites led farmers to change their livestock composition ($OR = 1.857$). High mortality rate experience led farmers to replace exotic breeds with indigenous breeds ($OR = 2.3$) as well as fencing water sources ($OR = 1.857$) ($p < 0.05$). In addition, farmers who observed a severe decrease in conception rates resorted to practices, such as land management ($OR = 1.45$), and changing livestock composition ($OR = 2.294$). A decrease in feed security significantly ($p < 0.05$) affected the use of bush feed ($OR = 2.176$) and fencing of water sources ($OR = 2.618$) as CC adaptation strategies.

Table 10 Chi-square test p-values on the effects of information dissemination on climate change adaptation practices

	Improved Breeds	Planting of shade trees	Changes in breeding season	Fodder production	Supplementary feeding	Provision of shade	Fencing grazing lands	Livestock insurance	Fodder conservation	Pastoral nomadism	More livestock	Bush feed	Bedding for livestock	Planting fodder trees	Land management	Change livestock competition	Hay/silage	Preserving pearl millet	Replacement of exotic breeds	Destocking	Water conservation	Rainwater harvesting	Dams	Tanks purchased	Drilling well and boreholes	Fencing water sources	
Receive CC information	0.150	0.436	0.480	0.332	0.500	0.226	0.162	0.855	0.636	0.332	0.925	0.523	0.855	0.789	0.616	0.855	0.566	0.480	0.434	0.310	0.456	0.662	0.186	0.291	0.402	0.332	
Trained on CC	0.288	0.420	0.350	0.122	0.053	0.377	0.692	0.902	0.485	0.485	0.950	0.002	0.906	0.858	0.728	0.902	0.312	0.650	0.312	0.171	0.473	0.692	0.570	0.653	0.483	0.515	
Source of information																											
Radio	0.055	0.318	0.496	0.010	0.202	0.270	0.166	0.362	0.055	0.208	0.800	0.254	0.362	0.493	0.655	0.638	0.196	0.496	0.197	0.103	0.473	0.393	0.436	0.052	0.192	0.042	
Newspaper	0.530	0.607	0.185	0.035	0.045	0.574	0.694	0.658	0.391	0.467	0.588	0.198	0.658	0.066	0.218	0.167	0.137	0.567	0.098	0.310	0.370	0.509	0.249	0.531	0.342	0.004	
TV	0.323	0.372	0.597	0.079	0.138	0.652	0.493	0.640	0.572	0.410	0.606	0.083	0.350	0.653	0.223	0.357	0.283	0.403	0.147	0.032	0.140	0.590	0.307	0.551	0.243	0.043	
Farmer to farmer	0.458	0.531	0.444	0.180	0.456	0.229	0.447	0.286	0.510	0.180	0.537	0.597	0.714	0.443	0.588	0.211	0.585	0.156	0.583	0.153	0.276	0.500	0.362	0.013	0.112	0.002	
Extension Officer	0.221	0.128	0.574	0.284	0.065	0.617	0.259	0.679	0.336	0.406	0.820	0.169	0.677	0.552	0.309	0.679	0.245	0.198	0.358	0.065	0.102	0.556	0.065	0.534	0.143	0.594	
WhatsApp	0.233	0.309	0.464	0.498	0.093	0.563	0.019	0.672	0.356	0.273	0.426	0.586	0.177	0.387	0.208	0.178	0.359	0.536	0.337	0.383	0.483	0.411	0.315	0.144	0.362	0.113	
Institution that provided support																											
Extension services	0.543	0.279	0.062	0.089	0.194	0.279	0.120	0.313	0.432	0.542	0.437	0.036	0.313	0.173	0.464	0.313	0.360	0.229	0.649	0.363	0.246	0.326	0.229	0.522	0.570	0.458	
Social groups	0.284	0.117	0.203	0.153	0.144	0.448	0.241	0.470	0.055	0.059	0.689	0.570	0.530	0.681	0.640	0.532	0.292	0.042	0.133	0.349	0.400	0.503	0.293	0.429	0.176	0.173	
NGOs	0.564	0.280	0.367	0.550	0.546	0.388	0.284	0.786	0.595	0.551	0.114	0.734	0.786	0.697	0.476	0.786	0.583	0.631	0.412	0.614	0.470	0.504	0.414	0.296	0.546	0.550	
Family members	0.500	0.436	0.480	0.332	0.150	0.624	0.167	0.855	0.364	0.332	0.925	0.477	0.855	0.789	0.616	0.855	0.566	0.520	0.566	0.310	0.170	0.662	0.031	0.387	0.402	0.668	
Media	0.167	0.072	0.046	0.038	0.129	0.229	0.006	0.286	0.257	0.180	0.462	0.322	0.286	0.150	0.020	0.286	0.585	0.186	0.585	0.052	0.146	0.327	0.071	0.487	0.046	0.180	

Table 11 Chi-square test p-values on the effects of attitudes and perceptions on climate change adaptation practices

	Improved Breeds	Planting of shade trees	Changes in breeding season	Fodder production	Supplementary feeding	Provision of shade	Fencing grazing lands	Livestock insurance	Fodder conservation	Pastoral nomadism	More livestock	Bush feed	Bedding for livestock	Planting fodder trees	Land management	Change livestock competition	Hay/silage	Preserving pearl millet	Replacement of exotic breeds	Destocking	Water conservation	Rainwater harvesting	Dams	Tanks purchased	Drilling well and boreholes		
No CC	0.636	0.698	0.664	0.723	0.837	0.691	0.263	-	0.808	0.396	-	0.798	0.779	-	0.142	0.527	0.753	0.265	0.753	0.106	0.862	0.844	0.978	0.110	0.957	0.430	
Dealing with CC	0.788	0.481	0.656	0.030	0.108	0.174	0.961	0.491	0.629	0.376	0.100	0.032	0.785	0.0320	0.648	0.491	0.474	0.535	0.784	0.499	0.808	0.503	0.614	0.434	0.538	0.321	
Whether CC will continue	0.772	0.716	0.154	0.109	0.406	0.752	0.459	<0.001	0.370	0.575	0.590	0.094	0.789	0.002	0.473	0.891	0.112	0.080	0.413	0.328	0.502	0.351	0.313	0.333	0.404	0.676	
Resourcefulness of EOs	0.231	0.792	0.428	0.884	0.956	0.104	0.941	0.115	0.397	0.049	0.648	0.068	0.618	0.131	0.545	0.020	0.534	0.061	0.711	0.412	0.641	0.153	0.440	0.426	0.023	0.006	
Knowledge of EOs	0.159	0.890	0.740	0.207	0.893	0.080	0.832	0.107	0.562	0.239	0.776	0.038	0.432	0.020	0.623	0.432	0.830	0.079	0.689	0.330	0.440	0.529	0.358	0.551	0.002	0.071	
Perception on the quality of information received from supporting organisations																											
Church	0.484	0.018	0.635	0.125	0.120	0.568	0.594	0.800	0.303	0.501	-	0.079	0.635	0.800	0.171	0.365	0.499	0.635	0.609	0.272	0.130	0.340	0.340	0.534	0.214	0.242	
NGO	0.122	0.403	0.500	0.089	0.008	0.150	0.106	0.500	0.837	0.837	-	0.024	0.934	0.506	0.867	0.386	0.386	0.343	0.771	0.719	0.939	0.287	0.433	0.402	0.337	0.335	
Extension Officers	0.642	0.496	0.829	0.888	0.851	0.405	0.351	0.546	0.871	0.834	-	0.929	0.900	0.566	0.860	0.706	0.690	0.829	0.838	0.238	0.404	0.543	0.333	0.449	0.403	0.373	
Farmer to farmer	0.030	<0.001	0.094	0.360	0.009	0.019	0.007	0.019	0.889	0.630	-	0.180	0.919	0.466	0.187	0.003	0.184	0.094	0.206	0.050	0.002	0.330	0.030	0.092	0.336	0.051	
IKS	0.866	0.281	0.026	0.219	0.091	0.484	0.167	0.154	0.840	0.083	-	0.502	0.880	0.402	0.762	0.469	0.502	0.026	0.209	0.900	0.800	0.286	0.708	0.813	0.314	0.514	
FOs	0.402	0.136	0.987	0.125	0.122	0.535	0.203	0.100	0.766	<0.001	-	0.188	0.780	0.780	0.900	0.922	0.676	0.688	0.299	0.818	0.635	0.105	0.295	0.209	0.244	0.465	

3.7 Effect of CC information dissemination on CC adaptation practices

From the results in Table 10, farmers' reception of information on CC did not ($p > 0.05$) affect any of the adaptation practices. However, training on CC significantly affected the use of bush-based feed with farmers who have been trained having odds of 35.000 of using bush feed as a coping strategy. In addition, the reception of CC information through all media channels (newspaper, radio, TV, WhatsApp) significantly ($p < 0.05$) affected the fencing of water sources adaptation practice (OR=3.109). Receiving CC information from other farmers affected the purchasing of water tanks (OR=3.760) and fencing of water sources (OR=8.695) strategies. Information received from the extension officers affected ($p < 0.05$) supplementary feeding (OR=5.882), purchasing of water tanks (OR=1.330) and destocking (OR=3.938) adaptation practices.

3.8 Effects of attitudes and perceptions of farmers' CC adaptation practices

From the results in Table 11, the perception that the climate is not changing did not significantly ($p > 0.05$) affect any of the adaptation practices. However, attitude when dealing with CC (whether concerned, helpless, confident or motivated) significantly ($p < 0.05$) affected fodder production and the use of bush-based feed with those who are motivated and confident more likely to implement long-term coping strategies than those who are helpless. The perception as to whether CC would continue or not significantly ($p < 0.05$) affected the employment of livestock insurance (OR=2.646), use of bush-based feed (OR=1.965), planting of fodder trees (OR=3.170), preservation of pearl millet stalks (1.689) and purchasing water tanks (OR=2.646) adaptation practices. The attitude on the knowledge and resourcefulness of extension officers on CC issues significantly ($p < 0.05$) affected the implementation of pastoral nomadism (OR=2.093), use of bush-based feed (OR=2.014), preservation of pearl millet stalks (OR=3.427), purchasing of water tanks (OR=1.862) and drilling of wells and boreholes (OR=1.511).

Perception on the quality of information from non-governmental organisations (NGO) (timeliness, accuracy, accessibility, reliability, ease of use and depth of content) significantly ($p < 0.05$) affected fodder production (OR=2.667), supplementary feeding (OR=7.518), bush-based feed (OR=52.612) and rainwater harvesting (OR=5.340), while perception on the quality of information from farmer to farmer affected ($p < 0.05$) the use of improved breeds (OR=1.395), planting of shade trees (OR=5.747), fencing of grazing land (OR=3.125), livestock insurance (1.912), destocking (OR=1.089), water conservation (OR=2.057), water harvesting (OR=1.448) and fencing of water sources (OR=2.641). Perception of the quality of information from Indigenous knowledge systems (IKS) significantly ($p < 0.05$) affected the changing of the breeding season (OR=2.50), pastoral nomadism (OR=2.944) and preservation of pearl millet stalks (OR=2.50). Perception of the quality of information disseminated by farmers' organisations significantly ($p < 0.05$) affected pastoral nomadism (OR=1.880) conservation of pearl millet stalks (OR=1.223) and destocking as adaptation practices.

4 Discussion

4.1 Farmers' perception of the existing CC

The study used the KAP model to examine the farmers' general knowledge of CC, including their understanding of CC, what causes CC and how CC impacts their communities. The survey also measured respondents' attitudes to CC their experiences and perceptions of the information received from various institutions and how they shape the actions and strategies that the small-scale livestock farmers implement to address the negative impacts of CC on their livestock production systems.

In Otjombinde and Epukiro constituencies, farmers are aware of CC, and this conforms with observations made in other studies [48, 49] that have observed changes in climate over the past 10 years. The changes observed in the past 10 years were mainly prolonged droughts, followed by very hot seasons and very cold seasons, and floods. The findings of this study correspond with the findings of other studies [49–52] that reported similar meteorological observations. The proportion of respondents who believe that the climate is not changing (3.8%) is comparable to observations made by UNDP [49], which reported 3.6% of respondents in Belize (in the Caribbean) being unaware that the climate is changing. The farmers attributed CC prominently to human activities, and global warming due to greenhouse gas emissions from human activities such as deforestation, burning of fossil fuel and inappropriate industrial practices. However, the understanding of some of the respondents about the causes of CC is limited, with some respondents emphasizing the

increase in population, electricity generation and the sun moment being closer to the earth, as possible causes of CC. Similar limited comprehension was observed by UNDP [49]. The focal warning signal used by the farmers to forecast upcoming weather conditions is the changing atmospheric indicators, such as moon position, wind swirls and cloud cover followed by animal behaviours and plant phenology.

Most respondents confirmed that CC is particularly detrimental to their community and livestock production. Water shortage is one of the major challenges faced by farmers in Omaheke, as a result of CC, which agrees with many studies conducted in sub-Saharan Africa [15, 50, 53], followed by feed insecurity [13]. The perceived impacts of CC on livestock production include decreased growth rate, decreased weight, decreased milk production, decreased reproduction rates, increased pest and disease incidents, poor vegetation and limited grazing land, water scarcity, increased livestock mortality and loss of farm income. This study's findings were consistent with the results of other researchers [8, 54], who reiterated that CC poses considerable challenges to pastoralists and other economic activities on rangelands. The observed impacts are in line with the most experienced CC effects, namely droughts and very hot temperatures as direct effects of heat and water stress that mostly reduce animal feed appetite, resulting in decreased feed intake, milk production, growth performance, reproductive efficiency, increased embryo mortality, and consequently lactation energy, which reduces with temperature and deemed the most important climatic factors affecting the performance of animals [54].

Extremely hot temperatures result in reduced grazing time, as animals turn to look for shade, resulting in reduced animal productivity. As a result, it is important that farmers can provide supplementary feeding and shade for their animals when temperatures are high. The reason why diseases and parasite influx were reported as one of the impacts of CC is probably because many animal diseases in Namibia are directly or indirectly affected by weather and climate [54, 55]. The climate seems to be closely associated with many non-vector-borne diseases as high temperatures may increase the rate of development of certain pathogens, leading to higher parasitic populations [55].

4.2 Climate change adaptation practised by smallholder livestock farmers

Water scarcity was identified as one of the major challenges caused by CC, and farmers have mainly employed adaptation strategies to address water shortage through water harvesting, water conservation, drilling of boreholes, purchasing water tanks and igging earth dams. Mendelsohn [19] study concurred with the present study by pointing out that water scarcity reduces livestock productivity through reduced metabolic rates and feed intake. In addition, livestock tend to graze closer to water points, which might result in overgrazing in areas closer to water points, ultimately resulting in land degradation and soil erosion. Hence, small-scale farmers should be encouraged to drill boreholes and purchase water tanks to provide livestock with water during dry seasons. Since most farmers claim to have financial constraints, initiative measures should also target water availability as groundwater may be available in the region [19].

The well-being and productivity of livestock in natural conditions depend on the ability of animals' ability to adapt to environmental challenges, such as nutritional and thermal changes and exposure to disease and parasites [54]. However, the study has shown that few of the farmers either reported resorting to a change in breeds or replacing exotic breeds with indigenous breeds as coping strategies. However, it was noticed that adaptation on livestock husbandry is low as few farmers adjusted on livestock breeds, provision of supplements, destocking, fencing of grazing land, provision of shade, pastoral nomadism, and fodder production, which concurs with observations by other researchers [56, 57]. According to those researchers, existing livestock adaptation measures are limited and carried out by only a small number of farmers. This could probably be because farmers are already farming with Indigenous breeds such as Sanga (eg Nguni) that are tolerant to heat and drought conditions [58, 59] and have exceptional walking ability enabling them to walk long distances in search of pastures, water and shade, and hence the strategy of changing breeds might not be necessary. Although animals have considerable resilience, there are limits to the heat, water and feed stress they can endure. Consequently, farmers need to provide shade, water and feed supplements. However, the study has shown that these coping strategies are not well implemented probably due to financial constraints. Farmers are thus encouraged to utilize readily available bush-based feed or destock in the case of impending drought, also making information dissemination valuable. However, destocking was not implemented by many respondents in the study. This is probably because some of the farmers had lower herd sizes as the target population considered a minimum of 10 cattle for sample selection, although many agro-pastoralists view destocking as a crucial form of insurance and defense mechanism utilized by certain smallholder farmers during uncertain times [60]. It is possible that farmers were forced to sell their animals even if they may not have wanted to

deal with food insecurity in climatic shocks as market prices are typically lower during these periods, thus reducing rather than enhancing households' purchasing power [13].

Some of the farmers referred to land degradation and lack of feed resources as impacts of CC. As such, there is a need to resuscitate degraded lands by adopting good ranch management principles, that include flexible herding, economies of scale and viable utilization of encroacher bushes to increase the profitability of livestock production [8]. Conversely, the pastoral nomadism strategy was employed by a few respondents, probably because of land tenure systems in the communal areas, as some of the respondents pointed out that the community policies refrain them from implementing CC coping strategies. These observations agree with Dirx [54] who noted that the farmers are less likely to have flexibility in adapting strategies such as changing livestock type or mixing of grazing livestock, and cross-breeding because of customary laws and tenure systems. Moreover, opportunistic cultivation on the less arid margins of the rangeland territory is a good CC adaptation strategy, although it reduces grazing land and limits nomadism. The problem is also exacerbated by grazing conflicts, overgrazing and desertification. Furthermore, Dirx [54] claimed that short-distance mobility, which is critical to agro-pastoral coping and adaptation mechanisms, is becoming a difficult adaptation measure due to prevailing socio-political conditions in various communities.

Farmers mentioned various constraints such as limited government legislations at communal areas, financial resources that make it difficult for them to adopt coping strategies that require money to implement. Some of the respondents indicated that they do not have adequate information and do not have knowledge of which strategies to implement to address CC hazards. Non-governmental organisations also reported of respondents not having enough information on what coping mechanisms to implement to address CC effects.

4.3 The link between CC adaptation practices and knowledge, attitude and perceptions.

Most of the respondents affirmed that they receive CC information from various modalities, mainly through media platforms such as radios and televisions. However, very few of the respondents receive information from extension officers and farmer organisations, an indication of a lack of capacitation and a lack of visible activities that are being carried out to address CC at the community level.

The study shows that experience does not seem to directly affect farmers' adaptation strategies, which agrees with observations by Deng et al. [43]. However, Van Valkengoed et al. [35] observed that farmer disaster experiences shape economic and technical strategies indirectly through perceptions, though the study observed that to some extent, there is a relationship between farmers' cognition (knowledge, attitude and perceptions) and adaptation practices which agrees with the findings of Jiri et al. [51] who argued that perceptions shape small-holder farmers' adaptation strategies.

The belief that the climate is changing, and the change will continue in future seems to affect long-term adaptation strategies employed by the farmers, as farmers who believe CC to continue in the future implement strategies such as planting of fodder and shade trees. These findings concur with Alotaibi et al. [50] who confirmed that CC is interdependent with the belief that the climate is changing. Farmers who are less concerned about CC are less worried about potential problems on their farms, due to CC and they are less likely to implement both adaptive and mitigative practices [50].

The study found that using extension services does not seem to aid farmers' beliefs in CC, as farmers seem to rank the CC information received through extension services lowly. Similar observations were made by other researchers where there was no evidence that extension programs about CC have been delivered in Saudi Arabia, citing a lack of knowledge among farmers and extension agencies [50]. The weakness of extension services on CC capacity building was also reported by [50]. However, it is undeniable that extension officers are the people on the ground and a conduit to transmit CC policy information to the farmers in the community. This suggests a need to improve the extension services at the communal level so that smallholder farmers are more capacitated with valuable information on CC and mitigation of the associated hazards. On a similar note, Kalimba and Culas [61] suggested that the government should invest in extension services to facilitate information dissemination and change farmers' attitudes by implementing training programmes and networking with other stakeholders interested in CC issues to strengthen extension to meet the needs of farmers. Implementing innovative approaches for climate-smart agriculture is crucial to encourage farmers to change their attitudes and perceptions of adaptation and mitigation.

Alotaibi et al. [50] the Farmer Field School (FFS) approach was proposed to promote social learning among farmers by developing their problem-solving skills, increasing technical knowledge and enhancing their decision-making ability. Awareness campaigns using information technology such as social media should be designed to improve

farmers' access to CC information, adaptation and mitigation and therefore enhance farmers' ability to adapt. This may have positive impacts on farmers' understanding of different components of climate-smart agroecosystems.

5 Conclusion

The study concluded that farmers perceive CC as droughts, very hot temperatures, very cold temperatures and experience severe losses in livestock husbandry. It is basically these experiences, perceptions, losses and attitudes that shape the adaptation strategies that the farmers would choose to adopt.

The study's findings revealed that CC has negative impacts on the livelihoods of smallholder farmers. Farmers have experienced extreme weather events such as droughts and reduced rainfall that negatively impacted on crop production. Smallholder livestock farmers in the study area perceived decreased livestock growth rates, decreased livestock weight, low milk production, poor reproduction rates, increased pest and disease occurrences, poor vegetation, livestock deaths, and loss of farm income earnings as major impacts of CC on their livestock production activities. Identified adaptation responses are primarily limited to changing grazing routes, increasing grazing distances, destocking, water harvesting and storage, and reliance on social welfare; all of which are viewed as insufficiently effective by livestock farmers in dealing with current climatic stresses. The agricultural extension could play an important role in climate change capacity building among livestock farmers.

6 Recommendations

This study recommends the need for programmes and seminars to familiarize farmers with modern adaptation strategies, particularly the use of water harvesting techniques to supplement rainfall in Namibia, where agriculture is primarily rain-fed. Some of the interviewed farmers have boreholes and thus interventions might consider irrigating fodder crops if the water quantity allows. There is a need to improve the quality and quantity of innovative extension services provided to livestock farmers to capacitate them more with CC information. Communal farmers should be encouraged to form or join the production, marketing and other service-oriented associations where they can share CC information and mitigation strategies. Namibia needs to accelerate the implementation of its CC policies and ensure that they are being implemented through monitoring and evaluation processes. Climate-smart livestock production systems require the government to dedicate efforts to develop and disseminate information about projected CCs as agriculture is important not only for economic development but also for the identity of local communities in Namibia.

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Data availability The data is available from the corresponding author on request.

Declarations

Ethics approval and consent to participate The manuscript is based on an undergraduate research project for N.A.S. The University of Namibia does not require formal ethical clearance for undergraduate research projects. However, by the university guidelines, the proposal was reviewed for scientific merit and ethical compliance by the supervisors/lecturers of students at the departmental level. The proposal was approved by the department committee, following research ethics guidelines as it is a minimum-risk study that does not include human tissue, children and other vulnerable groups. The research participants volunteered and consented to participate by signing informed consent forms and were treated respectfully. Moreover, they were free to withdraw at any time during the interview and their data was handled confidentially.

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