

Research/Technical Note

Pastoralists and Agropastoralists Adaptation to Climate Change at Zallingei, Locality Central Darfur State, Sudan

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Abstract

Adaptive mechanisms of communities to cope with climate changes was studied in Zallingei, Central Darfur State. Samples of population in three selected areas (Teraj, Orukom and Abatta) were estimated according to villages family size. The study utilized primary data (questionnaire, field visits, open key informants discussion). SPSS was used for categorical analysis and multivariate correlation was carried out using R software. Chi-square was used for the correlations among natural resources and community perceptions. The results showed that respondents' perception (pastoralists and agropastoralists) of climate change impacts were conceived by most (77%) of the respondents for the last 40 years as increase in temperature and fluctuation in rainfall. Media was shown to be the source of information for 66%. For the historical situation of rangeland, most (69.3%) rated as dense, while some (24.3%) as medium. For the current changes were related to climate variability as confirmed by 73% but 40% related changes to degradation, whereas 16% related it to land degradation. The majority (85%) believed that palatable species had disappeared. Correlation analysis between the main sources of grazing and disappearance of pasture plants was significantly ($P \leq 0.001$). Availability of the pasture was not enough as expressed by most (88.3%) of the respondents. Impacts on animal production were related mostly to rainfall (92%) and temperature (60%), wind seemed to have no effect. Incidents of fire were highly (66%) recognized. Various mechanisms were adopted by pastoralists to adapt to climate variability. Migration to neighboring countries in search of pasture and forage (53%). 82.3% used trees as animal feed, 52% would sell their animals or change herd structure and composition (32%). Income generating activities was presented in charcoal making (42%), trading (31%), and as labor in cities (10%). Some of the herders would convert to agriculture activities (11%) or mining (3%), others who converted to agricultural activities included free lancers (26%), gold miners (4%) and animal breeders (2%). Women participation in dairy processing as income generating activities was cited by many participants (69%). It could be concluded that adaptive strategies adopted by farmers might not be enough to best cope with climate variability, some recommendations are provided to improve rangeland condition and animal performance.

Keywords

Pastoralists and Agro-pastoralists, Adaptation, Climate Chang, Sudan

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1. Introduction

Rangelands cover approximately 110 million hectares (ha), accounting for about 59% of the country's land area. These extensive rangelands span various ecological zones, ranging from desert and semi-desert regions in the north to low- and high-rainfall savannahs in the south [1]. The presence of such vast natural rangelands makes mobile and transhumant pastoral systems the dominant mode of production on communal grazing lands. Initially considered unsuitable for large-scale agriculture due to marginal soil and rainfall, these rangelands began to face encroachment from large-scale mechanised agriculture, particularly northward expansion, after the central clay plains were fully used by the mid-1980s. Historically, Sudan has hosted one of Africa's largest pastoralist populations. However, there is no current reliable information on their exact numbers. Previous estimates range from 2 million to 3.5 million people before South Sudan's secession in 2011 [2]. In 2019, the livestock population was estimated at approximately 108 million, with 31 million cattle, 40 million sheep, 32 million goats and 4.9 million camels. This ranks Sudan among Africa's top livestock-producing countries [3]. Sudan's pastoralist groups demonstrate flexibility and adaptability in response to changing environmental conditions [4]. They use environments that would otherwise remain untouched by human activities, such as the Gizu area - an ephemeral vegetation zone that sporadically appears in the northern, drier areas of North Kordofan and North Darfur in the Sahara Desert [5].

Mobility is a critical element of pastoral livelihood systems; migratory movements reflect the interplay of socio-economic considerations, bio-physical variability, vegetative constraints, and positive incentive which is probably home to one of the largest pastoralist's populations in Africa [6]. Pastoral groups have dealt with recurrent drought and other extreme climate events in a number of ways; including depending on social networks and trusts, switching between capital assets and migrating to other areas to look for work until droughts passed [7]. Their way of life is centered on their developed experience which helped them to adapt to the harsh condition of their environments; in order to survive, pastoralists have to struggle on different fronts simultaneously for grazing land to avoid overstocking to overcome feed shortage to solve water shortage to ensure their herds are productive to avoid diseases and ensure security [6]. Changes in herd structure and composition have also been adopted as each livestock species and breeds have a different capacity to deal with heat, water and nutritional stress [8].

2. Materials and Methods

2.1. Area of Study

The area of study lies within Zallingei locality (Capital of Central Darfur State, western Sudan). Zallingei is located in

the south western part of Sudan. It extends from 14.8 ° 11.8 'East and 24.5 ° 22.5 'North [9]. The state is bordered by three states, North, South, and West Darfur and both republics of Chad and Central Republic of Africa (Ahmed, 2016). Administratively Central Darfur State (CDS) comprises Nine's localities, namely: (Zallingei - Azom - Wadi salih - West of Jabel Marra - North of Jabel Marra - Um dokhon - Mokjar - Central of Jabel Marra - Bendesi). Three villages were selected namely: (Teraj, Orukom and Abatta) within latitude 12 ° 42 '576 north (South point) and 13 ° 39 '761 E (East point) and 23 ° 25 835 E (west point), altitude varying from 890 m to 1121 m above sea level. The area characterized as a semi-arid savanna zone affected by the elevation of Jabel Marra massif. The villages selected were the most affected by climate change and variability. The sites selected areas were: Teraj, Orukom, and Abatta.

2.2. Questionnaire

A questionnaire was designed for both key informants and households.

- a) Key informants interview (KIIs): The KIIs were used to collect relevant information needed in the study from experienced people chosen according to their knowledge and experience. The following institutions are involved in the sustainable management of natural resources such as Central Darfur State institutions related to environmental and natural resources (State Ministry of Agriculture, Forests and Animal resource, Forests National Corporation (FNC), General administrative of Animal Resources and Rangelands, Environmental Management NGOs, University of Zallingei, and traditional leadership institutions in Zallingei Locality. The KIIs involved 25 persons. The interview focused on the general description of the research site along with the extraction of ideas on the pastoralists' livelihood and climate change, perceptions of climate change and variability, and adaptation options on climate variability.

- b) Households survey questionnaire

A household survey questionnaire was used to gather information and data on the purposes of the study. A total number of 300 respondents were interviewed these were smallholder pastoralists and farmers. Sampling size was done according to household number in each village using the formula shown below. A total of 300 respondents were applied for the purpose of this study (Table 1). The sample size was obtained [10] by using the formula (1):

$$n = \frac{N}{1 + Ne^2} \quad (1)$$

Where, n = represents the sample size; N = represents the population size, and e = denotes the level of precision at 0.05. Then, the sample size of each village was determined by

dividing the total number of households by the total number of households working in the livestock in the three villages and multiplying it by the sample size of the study area. The formula (2) was used for:

Computation as follows Eq. (2):

$$\text{RPS} = (\text{N}_2/\text{N total}) \times \text{N} \quad (2)$$

Where:

- RPS = Respondents' Population per Stratum (the number of respondents selected from village v)
- N_v = population size of village v (livestock households)
- N_{total} = total population across all villages
- n = total sample size (from Eq. 1)

Table 1. Number of respondents from each village.

No	Villages	Household Size	Sample Size
1	Teraj	12,540	140
2	Orukom	5,632	65
3	Abatta	9,086	95
Total		27,086	300

2.3. Statistical Analysis

Statistical package for social study utilized (SPSS) version 26 used to describe respondents' socio-demographic conditions as well as their perception of climate change and its impact on the rangeland and livelihood of the pastoralists in the Zallingei locality. Chi-square tests were used to compare the difference among groups as well as regression analysis in determining factors that influence climate change perception.

3. Results

3.1. Community Information

65.6% of the surveyed households were headed by males, while 34.4% were headed by females. More than 94% of the

households were married, with only 4% widowed and 2% were single. 46.7% of the household heads were between 40-49 years old. 39.3% were between 50-59 years old. Around 12.7% of the respondents were aged 60-69, and only 1.3% was above 70 years old. Concerning education, 40% of respondents were illiterate, while about 37% of the household headed had khalwa, (pre-school teaching holy Quran). 15.7% and 6.3% received primary and secondary school respectively, while only 1% was university graduate. Regarding the family size of the household pastoralists the largest family size ranged between 6 to 10 members, represented about 56.3% while 25.7% of the family size range from 1 to 5 members, the smallest were 15 and above. Among the surveyed households, 43.3% were pastoralists, 26.3% were farmers, 17.3% were self-employed, 6.7% were traders, and 4.3% were gold miners (Table 2).

Table 2. Community information.

Characteristics Variables		Frequency	Per cent
Gender composition	Male	197	65.6
	Female	103	34.4
	Total	300	100
Age Group of Respondents	40 - 49	140	46.7
	50 - 59	118	39.3
	60 - 69	38	12.7
	70 & above	4	1.3
	Total	300	100

Characteristics Variables		Frequency	Per cent
Social Status of Respondent	Married	282	94.0
	Single	6	2.0
	Widow	12	4.0
	Total	300	100
Family size of the Respondents	1 - 5 person	77	25.7
	6 - 10 person	169	56.3
	11 - 15 person	42	14.0
	15 - above	12	4.0
	Total	300	100
Education level of respondents	Illiterate	120	40.0
	Khalwa	111	37.0
	Primary school	47	15.7
	Secondary school	19	6.3
	University	3	1.0
	Total	300	100
Occupation of the respondents	Farmer	79	26.3
	Trader	20	6.7
	Freelancer	52	17.3
	Herders	130	43.3
	Gold miner	13	4.3
	Total	300	100

3.2. Pastoralists' Perception of Rangeland Situation and Degree of Change

The historical rangelands situation was rated by the respondents as dense, medium or low, most (69.3%) rated it as dense, while some (24.3%) as medium whereas very little (2.0%) as low. The rate of degradation was shown to 4.3% (Table 3). For the current situation of rangeland and change related to climate variability, 73% strongly agreed that the change was due to climate variability of which 40% was related to degradation, while 25.3% believed in the change

where 16% related it to land degradation (Table 4).

Pastoralist's perception of the current status of rangelands and source of grazing had rated these sources as dense, medium, little and degraded. For the rangeland source, 100% rated rangeland as dense, 8.0% rated rangeland source as medium, while 22.3% rated forest as medium. These sources were rated as little for rangeland (12.7%), forest (40%) and for fodder (2.3%), degradation of rangeland was expressed by 57% of the respondents, but only by 16% for forest and fodder (Table 5).

Table 3. The previous status of the Natural Rangeland.

Status	Frequency	Percent
Dense	208	69.3
Medium	73	24.3
Little	6	2.0

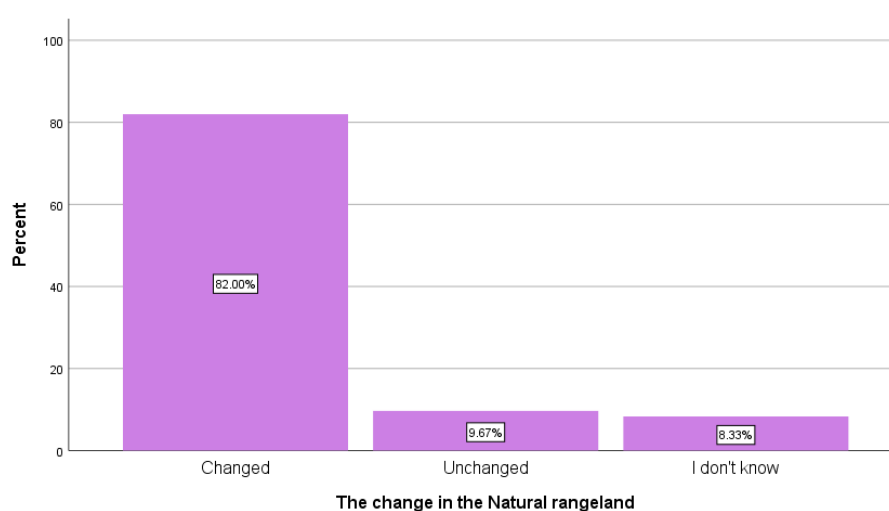
Status	Frequency	Percent
Degraded	13	4.3
Total	300	100

Table 4. Current rangeland situation and climate variability and change over time.

Current status of the rangeland	Climate Variability and change over time			Total
	I strongly agree	Agree	I don't know	
Dense	5.7%	0.7%	1.7%	8.0%
Medium	17.0%	5.3%		22.3%
Little	10.0%	2.7%		12.7%
Degraded	40.3%	16.7%		57.0%
	73.0%	25.3%	1.7%	100.0%

Table 5. Current status of rangeland as sources of animal grazing.

Main source of animal grazing areas	Current status of the rangeland in the study area				Total
	Dense	Medium	Little	Degraded	
Natural rangeland	8.0%	18.7%	6.3%	41.0%	74.0%
Forest		3.7%	5.7%	6.7%	16.0%
Fodder			0.7%	7.0%	7.7%
Others				2.3%	2.3%
	8.0%	22.3%	12.7%	57.0%	100.0%

**Figure 1.** Perception of pastoralists about the degree of change in the natural rangeland in the study area over the last four decades (1980-2020).

3.3. Rate of Change

3.3.1. Disappearance of Species and Fodder Availability

For the degree in change of rangelands, and as shown by Figure 1, changes over the past 40-years; as pointed by most of the respondents (82%) very clear, whereas very few (9.7%) shared same opinion while the rest (8.3%) could not detect the changes. Some of the palatable disappearance species had been observed by the pastoralists, the majority (85%) believed that palatable species had disappeared while 15% did not agree (Table 6). Correlation analysis between the main sources of grazing and disappearance of pasture plants was strongly and significantly ($P \leq 0.001$) (Table 7).

As for the requirement of fodder, the majority (88.3%) ex-

pressed that it was not enough while little (11.7%) percentages would see that it was enough (Table 8).

3.3.2. Sources of Water Availability

It could be shown that 75% of the respondents suffered from water scarcity while 24% did not suffer. The main sources of water are seasonal streams (Kairan), as pointed out by 69% of the respondent, then 20.3% who relied on Wells and about 4.7% relied on Tankers. Others depended on water Pumps (2.7%) and other sources (3.3%) respectively (Figure 2). To meet water shortages, the majority (88.3%) would move to water places with their animals to meet water scarcity, while small percentages (11.7%) use to buy water for their animal (Table 9).

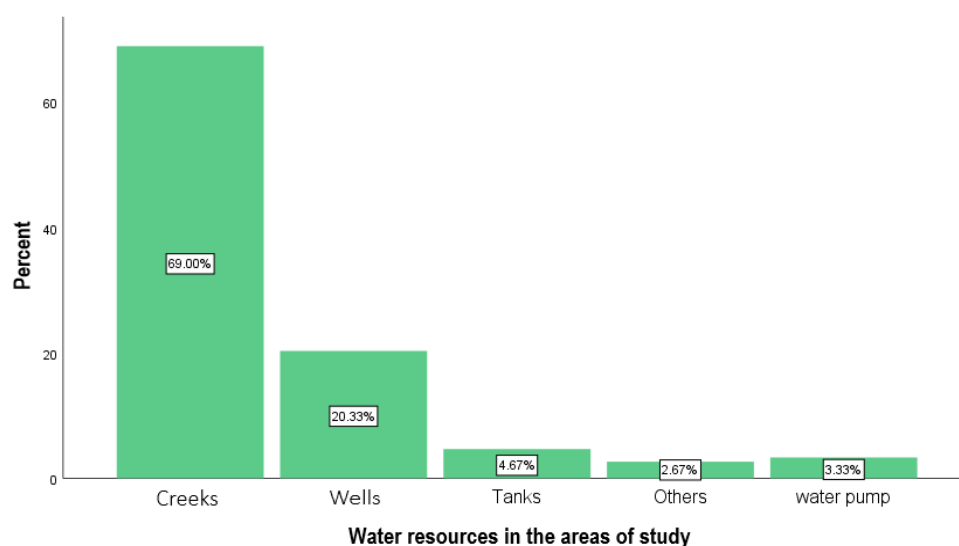


Figure 2. Water resources in the areas of study.

Table 6. Disappearance of palatable species in the study area.

Variable	Frequency	Per cent
Yes	255	85.0
No	45	15.0
Total	300	100

Table 7. Chi-Square Tests for the correlation analysis between the main sources of grazing and disappears of pasture plants in the study area.

	Value	Df	Asymptotic Sig. (2-sided)
Pearson Chi-Square	6.677 ^a	3	.083
Likelihood Ratio	11.096	3	.011

	Value	Df	Asymptotic Sig. (2-sided)
Linear-by-Linear Association	6.226	1	.013
N of Valid Cases	300		

Table 8. Perception of pastoralists about the requirement of forage in natural rangeland.

	Frequency	Percent
Yes	35	11.7
No	265	88.3
Total	300	100.0

Table 9. Pastoralists perceived of the difficulties of having water.

	Frequency	Percent
Yes	227	75.7
No	73	24.3
Total	300	100.0

3.4. Source of Information About Climate Change and Perception of Climate Change and Variability

Source of information about climate change had shown that, most of the respondents (61.3%) have heard about climate change before, while about 57% of the respondents got the information by their own observations, whereas only 14.4% were informed about climate change by related institutions mainly (organizations) and about 12.3% got their information by media mainly Radio, while, only 16% did not hear about climate change (Table 10). For the different institutions that could be held responsible for public awareness raising about climate change, 33.4% of the respondents pointed to the effect of the media, radio and television, then civil society (28.4%), universities or no institutions came next (13.3%), while governmental institutions (7.3%) and international (4.3%) showed non-significant effects (Table 11).

Perception of the respondents about climate variability over the past 40 years (1980 -2020), showed that most (77%) believed there was an increase in temperature, whereas 11.3%

believed that it decreases and 11.7% it did not change. As for the rainfall the 61.7% believed that rainfall had decreased. For the wind velocity, 83.3% believed it had increased high velocity, whereas about 12% and 4.7% noticed wind with medium and low velocity respectively (Table 12).

3.5. Impacts of Climatic Variables on Livelihood of Pastoralists

For the different climatic variables as shown in table 13, the impact of temperature was shown by many (60.3%) participants as to affect animal production and land degradation 22.7%. very little percentages could see the positive impact of temperature on animal production or improved income. For rainfall impact the majority (92.3%) related the fluctuations in rainfall to reduced animal production, very little could see the positive effect. The highest effect of wind velocity was related to reduced forage production (67%) drought and desertification (14%), and degradation of rangelands (4.3%), very few could see the positive effect of wind.

Table 10. Source of information about climate change.

		Source of information about climate change				Total
		Own Observation	Related institution	Media	I don't know	
Pastoralist opinion about climate change	Yes	43.7%	6.7%	9%	2%	61.3%
	No	13.3%	6%	5.3%	14%	38.7
Total		57%	12.7%	14.3%	16%	100

Table 11. Institutions responsible for raising awareness about climate change.

Items	Frequency	Percent (%)
Governmental Institutions	22	7.3
Civil Society Organization	85	28.4
Universities	40	13.3
International Organization	13	4.3
Media (Radio and television)	100	33.4
No institutions	40	13.3
Total	300	100.0

Table 12. Climate variability (change in temperature, rainfall and wind velocity).

Characteristic variable		Frequency	Per cent
Change in the temperature	Increase	208	77
	Decrease	34	11.3
	Unchanged	35	11.7
	Total	300	100
Change in Rainfall	Increase	121	33.3
	Decrease	164	61.7
	unchanged	15	5.0
	Total	300	100
Change in wind velocity	High	250	83.3
	Medium	36	12.0
	Low	14	4.7
	Total	300	100.0

Table 13. Impacts of climatic variables on the rangeland condition.

Impact of temperature	Frequency	Percent
Reduced of animal production	181	60.3

Impact of temperature	Frequency	Percent
Increased the growth of animal production	30	10.0
Land degradation/ decreased soil fertility	68	22.7
Reduced household income	19	6.3
Increased the household income	2	0.7
Impact of rainfall	Frequency	Percent
Reduced livestock production	277	92.3
Increase in the forage productivity	7	2.4
There is no impact on animal production and pastoralist livelihoods.	16	5.3
Impact of wind velocity	Frequency	Percent
Decrease in the forage production	201	67.0
Increase in the forage productivity	25	8.3
No impact on animal production.	19	6.3
Drought and desertification.	42	14
Degradation of rangeland.	13	4.3

3.6. Causes of Climate Variability and Impacts

Causes of climate variability was greatly (48.7%) to human activities, while 33% related the causes both to human activities and natural factors, and only 18.3% related them to natural factors only. Causes of rangeland degradation could be related to incidence of fire as expressed by the majority of the respondents (67%), while the rest did not agree (33%) (Table 14).

Perception of Respondents of Change Climate Variability over the Four Decades (1980 -2020)

Perception of respondents of change climate variability over the four decades (1980 -2020) have shown about 33% of the respondents expressed that for the last 40 years there were early less rainfall, while 21% witnessed less late rainfall, and 17.3% experienced heavy late rains, 13% experienced both heavy and early rains. On the other hand, about 7.3%, 5.7% and 2.3% expressed that high temperature, droughts and floods occurred in study area respectively (Table 15).

Table 14. Perception of respondents about fire incidence in the study area.

Fire incidence	Frequency	Percent
Yes	201	67.0
No	99	33.0
Total	300	100.0

Table 15. Perception of respondents of change climate variability over the four decades (1980 -2020).

Items	Frequency	Percent
Heavy and early rainfall	40	13.3
Early less rainfall	99	33
Heavy late rains	52	17.3
Less late rainfall	63	21

Items	Frequency	Percent
Drought	17	5.7
High temperature	22	7.3
Floods	7	2.3
Total	300	100.0

3.7. Adaptation Strategies to Climate Change and Variability

Pastoral communities in the study area have developed various climate change adaptation strategies over the years

which help them to minimize their vulnerabilities to the impacts of climate change. 82% agreed that they have alternative strategies for adaptation to cope with climate change and variability, whereas 9.7% did not have alternative strategies during (Figure 3).

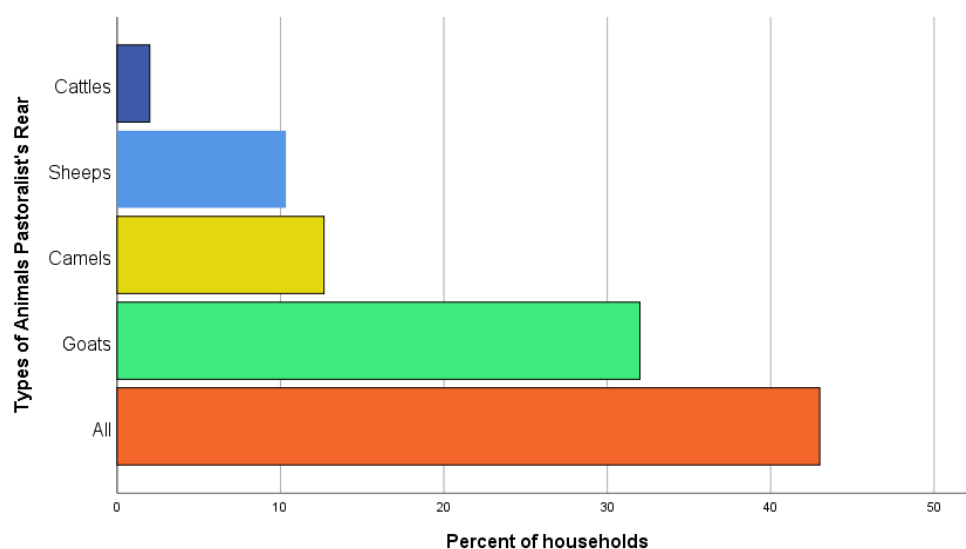


Figure 3. Animal composition.

Various mechanisms were adopted by pastoralists to adapt to climate variability. 82.3% mentioned that they relying on tree feed as animal feeds during rangeland degradation, 52% would sell their animals during forage scarcity. Others (37.3%) would move with their animals to areas where forage was available. 17.7% did not depend on tree as animal feed. Only 5.7% used supplementary feeding, and 5% used other sources as animal feed. Pastoralists would also diversify their animal composition (camel and goats) to adapt to harsh rangeland conditions (Table 16). Migration to neighboring countries was carried out by 53.3% of the respondents, while about 46.7% did not migrate (Figure 4, table 17). Countries migrated to carried out by (34.7%), these were: Central Republic of Africa and Chad for fodder and water resource, whereas 16.3% move to Chad and only 5.7% move to South Sudan.

The correlation between family size and the sale of live-stock as an adaptation mechanism was found to be significant

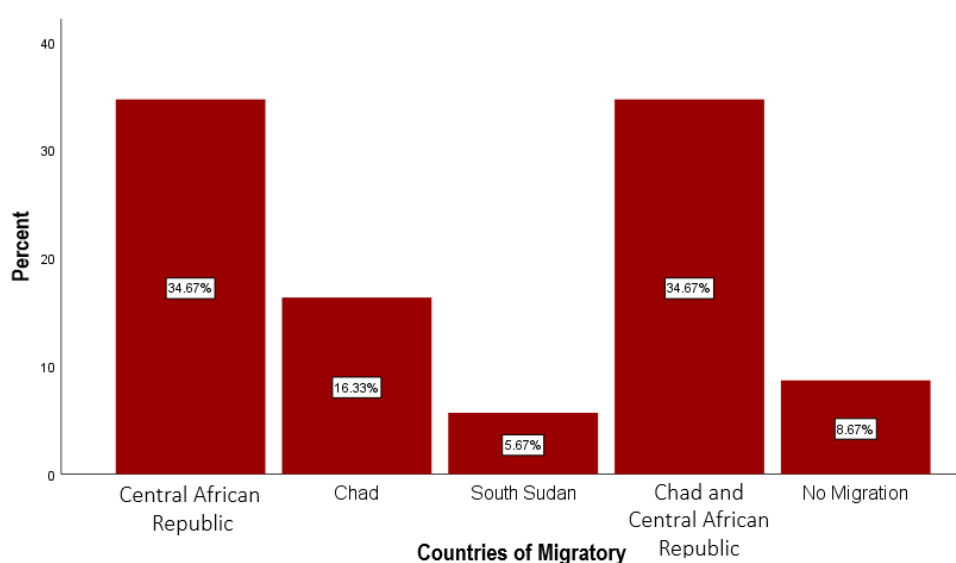
($P < 0.083$) (Table 18). Similarly, the correlation between family size and herd diversification was highly significant ($P < 0.045$) (Table 19), as was the correlation between family size and moving with herds to areas with available forage ($P < 0.025$) (table 20).

Herd Composition and Species Diversification

Animals reared by pastoral communities in the study area, showed 43% kept all types of animals (Goats, Camels, Sheep and cattle) 32% of keep goats and 12.7% kept camels only. 10.3% and 2% were keeping sheep and cattle respectively (Figure 5). Market existence in the area would help pastoral-ists to sale their animals as to adapt to rangeland deterioration. The majority of (75.7%) mentioned the availability of local market for animal selling and so it was possible to them to sell their animals as adaptation to deterioration rangeland conditions. However, 24.3% expressed the unavailability of market as in Orukom area (Table 21).

Table 16. Adaptation Strategies.

Variable		The rely on tree-fodder during the scarcity		Total
		Yes	No	
Pastoralists local mechanisms pasture scarcity	Sale of animals	41.4%	10.7%	52%
	Move to available forage area	30.3%	7%	37.3%
	Supplementary feeding	6.7	0	6.7%
	Others	5%	0	5%
Total		82.3%	17.7%	100

**Figure 4.** shows the countries where pastoralists were migrated in search for grazing land and water resource.**Table 17.** Migration to neighboring countries in search for fodder.

Answer	Frequency	Percent
Yes	160	53.3
No	140	46.7
Total	300	100

Table 18. Chi-Square Tests for the correlation between the family size and animal sale.

	Value	df	Asymptotic Sig. (2-sided)
Pearson Chi-Square	6.677 ^a	3	.083
Likelihood Ratio	11.096	3	.011
Linear-by-Linear Association	6.226	1	.013
N of Valid Cases	300		

Table 19. Chi-Square Tests for the correlation between the family size and herd diversification.

	Value	df	Asymptotic Sig. (2-sided)
Pearson Chi-Square	6.677 ^a	18	.045
Likelihood Ratio	11.096	18	.017
Linear-by-Linear Association	6.226	1	.018
N of Valid Cases	300		

Table 20. Chi-Square Tests for the correlation between the family size move to forage area.

	Value	df	Asymptotic Sig. (2-sided)
Pearson Chi-Square	6.677 ^a	27	.025
Likelihood Ratio	11.096	27	.09
Linear-by-Linear Association	6.226	1	.015
N of Valid Cases	300		

Table 21. Household respondents about availability of livestock local markets in the study area.

	Frequency	Percent
Yes	227	75.7
No	73	24.3
Total	300	100

Table 22. Alternative income generating activities.

Variable	Frequency	Percent
Charcoal production	127	42.3
Trading	93	31
Works in cities	31	10.3
Others	49	16.3
Total	300	100

3.8. Alternative Income Generating Activities (Men and Women)

As coping mechanism with the deteriorating rangeland conditions, pastoralists resolved to other income generating activities. Making charcoal came as the main activity as alternative adaptation mechanism as expressed by most of the respondents (93%), then trade (31%), then other activities

and working in cities (Table 22).

Community with different occupations showed alternative income activities, of the 21% farmers, 5% were involved in trading. 2.3% of 11% of herders were involved in trading. Traders (5%), freelancer (15.3%), 4.3% of gold miner were involved in agriculture and 2% of animal breeders were involved in agriculture (Table 23).

For women alternative income generating activities many respondents 69.2% cited women engaged while 30.8% did

agree. Engagement in trading activities was undertaken by 56.2%, then working in agriculture (24.3%) and as labors in cities (19.5%) (Table 24). Women were involved in dairy

activities (51%), and 35.7% expressed that they produce cheese, while very few percentages were involved ghee production (8%) and leather handicraft (figure 5).

Table 23. Community alternative income sources.

Occupation	Community alternative income			Total
	Agriculture	Trading	Mining	
Farmer	21.3%	5.0%		26.3%
Trader	5.0%		1.7%	6.7%
Herders	11.3%	2.3%	3.7%	17.3%
Freelancer	26.7%	15.3%	1.3%	43.3%
Gold miner	4.3%			4.3%
Animal raising	2.0%			2.0%
	70.7%	22.7%	6.7%	100.0%

Table 24. Alternative income generating activities for women and in response to climate change and variability.

Type of activities	Alternative sources of income		Total
	Women activities	Role of women in the community	
Trading	56.2%	69.2%	69.2%
Agriculture	24.3%	30.8%	30.8%
Works in cities	19.5%		
Total	100%		100%

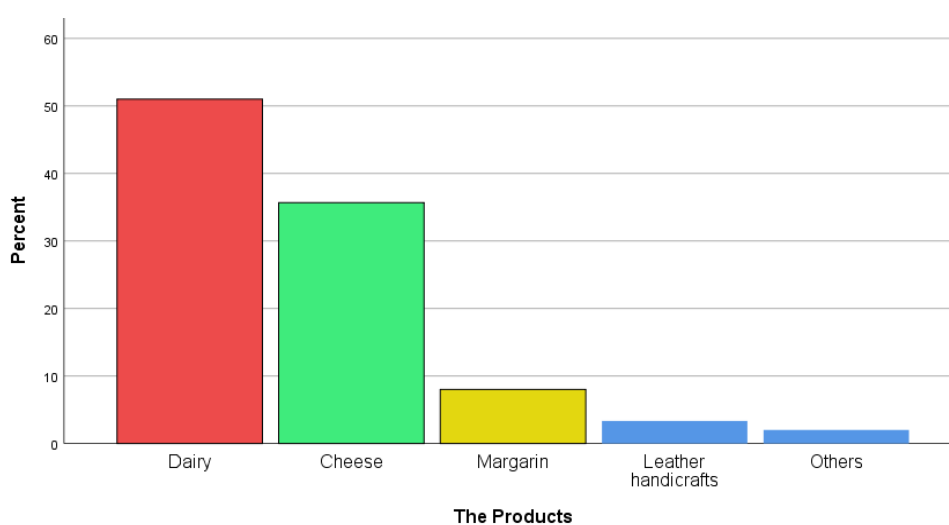


Figure 5. Women other income generating activities.

4. Discussion

4.1. Alternative Source of Animal Feed

Pastoral communities in the study area have developed various climate change adaptation strategies over the years which helped them to minimize their vulnerabilities to the impacts of climate change. 82.3% mentioned that they rely on tree as animal feed during rangeland degradation. Similarly, pastoralists in Africa during time of drought completely depend on trees as animal feed [8], this strategy was shown to have both positive and negative impacts as depending only on fodder trees will lead to forests degradation in the future [9].

4.2. Diversification of Animal Species

Diversification of animal species was reported in this study by respondents, who kept different types of animal species, 43% kept all types of animals (Goats, Camels, Sheep and cattle), 32% of kept goats and 12.7% kept camels only. 10.3% and 2% were keeping sheep and cattle respectively. Similar observations were obtained in vulnerable areas of the Horn of Africa where herd diversification is considered as important strategy [11]. It was also shown that multiple animal species help pastoral groups in Sudan to adapt to climate change, especially during forage shortages in natural rangelands [12]. Also confirmed by other authors [13]. Pastoralists used camel and goats as they are better adapted to harsh rangeland conditions.

4.3. Migration

In this study, migration to neighboring countries was carried out by 53% while 46% did not experience any migration. Others (37.3%) would move with their animals to nearby areas where forage was available. Mobility in Africa is considered as most valuable and effective strategies to cope with climate change and variability [8]. Migration of animals has been observed towards areas of comparatively better pasture and water availability [11, 14]. The majority of the pastoralists in Eastern Darfur State migrate south even before the independent of South-Sudan from Sudan looking for fodder [15]. However, in Darfur, it was noticed that some pastoralists who used to move with their cattle looking for forage and water, have shifted to agro-pastoralis to adapt to changing environment [6].

4.4. Water Availability

In this study sources of water were Hafeer (man-made reservoir) and Khairans (seasonal streams) as also confirmed by [15] that rural people in Darfur mainly depend on the seasonal water source (rainy water) and used local harvesting system to collect the water. On the other hand, 24.3% of the respondents did not suffer from water shortage due to presence of low lands with water catchment. Similarly, it was observed that wadi system in Darfur is very rich with different vegetation species and water [16].

4.5. Alternative Income Generating Activities

In this study, the respondents resolved to different income generating activities, 24.3% of respondents identified agriculture as an alternative income source alongside animal husbandry. Studies carried by [17] within the area of study further noticed that most of the pastoralists and agro-pastoralists shifted to crop production as adaption strategy. Similar observations were obtained in Mali [18], where pastoralists were practicing agriculture to secure their basic needs of food. Selling of animals was a source of income during range deterioration, 52% would sell.

In this study, nearly 42% of the respondents were involved in charcoal making, similar findings were obtained by [19], who indicated that pastoral communities were responsible for producing charcoal from cutting of trees. Other alternative activities found in this study, were their animals during forage scarcity, and was encouraged by existence of local market, trade (31%), work in cities, others (16%), freelancer (43%) and gold mining (4%). Similar jobs were among pastoral communities in South Kordofan [20]. Others will look for jobs outside their countries as findings, as Libya and Chad for work [21]. Women played pivotal roles in securing livelihoods through activities such as home gardening, selling products in local markets, and assisting with household responsibilities, this was supported by observations of [21].

It could be concluded various coping strategies support were adopted to withstand impact of climate change on rangeland conditions. It is recommended that alternative feeds could be offered as crop residues and other non-traditional feeds. Government institutions and NGOs should be involved in pastoralist awareness raising, community sources of information about negative impacts of climate especially overcutting trees.

Conflicts of Interest

The authors declare no conflicts of interest.

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