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Research Article

Livestock farmers' perception, perceived impacts, and adaptations to climate change in Koinadugu district, Sierra Leone

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ABSTRACT

Climate change is having a negative influence on agriculture and livestock production systems. This study aims to assess livestock farmers' perceptions and adaptive responses to climate change in the Koinadugu area of northern Sierra Leone. A sample of 126 livestock farmers was selected from four chiefdoms. The data were collected using a semi-structured questionnaire and meteorological time series data. The Statistical Package for Social Sciences (SPSS) version 23.0 and excel were used to analyze the data. According to the respondents' socioeconomic characteristics, most farmers (93.7%) were males between 46 and 55 years. The majority of the farmers (58.7%) were married, and family sizes ranged from 5-8 individuals per household. Most of the livestock farmers (59.5%) in the study area had no formal education. Farmers attested to their awareness of climate change by essential indications such as increasing heat waves (77.0%), decreased rainfall (54.0%), and an increase in humidity (82.5%). Feed shortages ($\bar{x}$ = 4.14), water scarcity ($\bar{x}$ = 4.10), and higher veterinary care expenditures ($\bar{x}$ = 4.25) are some of the impacts of climate change on livestock production. Numerous adaptation strategies include livestock reduction (87.3%), animal vaccination (95.2%), and Migration along with animals during the adverse climatic condition (75.4%), which the farmers employ. Lack of capital, inadequate information about climate change, and inadequate infrastructure impede adaptation. The study suggests that the government pursues strong policies to help livestock farmers adjust to climate unpredictability in the long run.

Key words: Adaptative response, Barrier, Climatic variables, Farmer's perception, livestock production

INTRODUCTION

Climate change is one of the world's most pressing environmental issues. Because of its potentially negative global consequences, it has become a significant concern for society. In its 5th assessment report, the Intergovernmental Panel on Climate Change (IPCC) predicted that the global average temperature would climb between 0.3 and 4.8 degrees Celsius by the end of this century (Stocker *et al.,* 2013). The rise in Sea level, the changing precipitation intensity and timing, and temperature changes, which leads to a duration of extreme climatic events such as droughts, floods, and tropical storms, are examples of climate change effects (Nkondze *et al.,* 2014). Climatic fluctuations have been a global problem that will require joint efforts from all countries to address their long-term impacts (Conway & Schipper, 2011).

By 2050, demand for all animal products is expected to triple in Sub-Saharan Africa and South Asia (Bekele, 2017; Khan *et al.,* 2022). On the other hand, climate change has lowered world agricultural productivity by 1-5 per cent every decade over the previous 30 years (Bekele, 2017). Sub-Saharan Africa (SSA) is one of the most climate-vulnerable regions. Due to severe poverty, recurrent droughts, an unequal allocation of land, over-dependence on rain-fed agriculture, and inadequate adaptation ability (Wesenbeeck *et al.,* 2016; Harrison *et al.,* 2019). Climate change's growing impact on agriculture and livestock production systems is harmful in nature (Porter *et al.,* 2014). Rising temperatures cause heat stress in livestock, negatively affecting milk production, reproduction, and health (Hammami *et al.,* 2013; Sanker *et al.,* 2013). In addition to contaminated water supplies, low feed quality, and livestock disease susceptibility, climate change has severely influenced livestock production (Thornton *et al.,* 2009; Rahut & Ali, 2018). According to the Intergovernmental Panel on Climate Change, livestock is one of the most climate-sensitive economic sectors in agriculture (IPCC, 2007). Furthermore, Climate change and its substantial implications on livestock productivity pose devastating threats to global food security. Developing-country smallholder and subsistence livestock owners are the most exposed to livelihood and food insecurity due to climate change (Heltberg, 2009). The IPCC's latest annual report (AR5) shows that the world's most tropical regions fail to adapt to climate change mitigation efforts, causing more significant negative consequences on food production systems (Porter *et al.,* 2014).

Livestock rearing is a significant activity in Sierra Leone, with over 70% of households engaging in livestock production, even though most of it is done using conventional livestock management approaches. While cattle are owned by fewer than 5% of the population, sheep and goats are raised by 75% of all livestock-producing families (Statistics Sierra Leone, 2017). As a result, cattle are a significant source of revenue and a contributor to family food security. Cattle and small ruminants are typically kept for sustenance, and animals are only sold as a negative coping strategy when the owners are in desperate need of cash. Nonetheless, productivity levels for all cattle species are deficient, and demand significantly outnumbers supply. As a result of high costs and rising poverty levels, cattle product consumption has been low (FAO & ECOWAS, 2016). Animals exposed to high temperatures and resulting heat stress have lower feed intake, lose body weight, and growth rate (Marai *et al.,* 2007). This decline in bodily condition is due to a lack of energy, lowering heat tolerance (Minka & Ayo, 2009). Increased occurrences of extreme climatic events, such as droughts and floods, are expected to squeeze lucrative livestock production (Ebele & Emodi, 2016). As a result of climate change, pasture supply and nutritional value will be severely limited, particularly during periods of frequent and protracted drought in the region, as witnessed in the Koinadugu district, the country's cattle production hub (Binns *et al.,* 2021).

Despite the importance of livestock agriculture to Sierra Leone's economy, current evidence on livestock producers' perceptions and adaptations to climate change effects is inadequate. As a result, this study looks at livestock farmers' perceptions and adaptive responses to climate change's livestock production.

STUDY AREA

The study was conducted in four Chiefdoms of Koinadugu district –sengbe, wara-wara yagala, Dembelia Sinkunia, and Folsaba Dembelia. Koinadugu district is in the Northern Province and borders Bombali district to the west, Tonkolili district to the southwest, Kono district to the south, and the Republic of Guinea to the North East. This is the largest district in terms of geographical area, with the least population density in the country. The population is ethnically diverse, and the major ethnic groups are the Fula, Kuranko, Mandingo, Limba, and Yalunka. The district is typical of the rest of the country, with two distinct seasons: the rainy and dry seasons. The dry season lasts from November to April, whereas May to October marks the rainy season with 147 rainy days where an average of 208 cm of rainfall is recorded. About 91% of the district population resides in rural areas, with the average family size for the district being 6. Agriculture is the main livelihood of more than 84% of the district population. The district has the highest livestock population in the country, providing animal protein sources.

SAMPLING PROCEDURE

The sample of livestock farmers was selected through non-probabilistic purposeful, convenience, and snowball sampling methods. The choice of sampling method was due to a lack of proper records of livestock farmers, and some farmers lived far from the villages with their animals. Some travel with their animals to a location that is difficult to reach. These methods are commonly used to access populations that are difficult to reach, where there is no sampling frame available, and where probabilistic sampling is thus impossible (Ritchie & Lewis, 2003). The household questionnaire was used to capture information from livestock farmers, with the main emphasis being on their perception of adaptation to climate change and constraints to adoption. Questionnaires were administered to livestock farmers operating in the district, resulting in 126 farmers being reached. Livestock farmers were identified with the help of local elders, local authorities, and livestock officers working in the district. The questionnaires were administered in face-to-face interviews. Questionnaires included both open and closed-ended questions.

DATA ANALYSIS

The socioeconomic characteristics of livestock farmers' adaptation and adaptation constraints were determined using frequency count and percentages. A four-point Likert-type scale: Increase = 4, decrease = 3, no change = 2, and don't know = 1, was used to determine the perceptions of the poultry farmers on the effect of climatic variables on livestock production and was analyzed and described. The extent of Perceptions of the impacts of climate change on livestock production was also studied and described using mean score values on a five-point Likert scale of to a very great extent= 5, to a great extent = 4, to some extent = 3, to little extent = 2, and to no extent = 1. Climate change's perceived impacts on livestock production were significant if a mean score is more than or equal to 3.0. Linear trend analyses of meteorological time series data were done on climate. Cluster analysis was used to build clusters based on respondents' responses to all items included in their perceptions of the consequences of climate change on their production activities. The Statistical Package for Social Scientists (SPSS) version 23.0 and excel were used to examine the data. The data was presented in tables and charts regarding frequencies and percentages.

RESULT

Socioeconomic characteristics of livestock farmers

Table 1 shows that males account for 93.7% of livestock producers in the research region, while females account for just 6.3%. The majority of farmers (56.3%) are between 46 and 55 years. According to the household size distribution, most farmers (59.5%) had a household size of 5-8 persons. The educational level indicator reveals that 59.5% of respondents have no formal schooling. The marital status variable indicates that (58.7%) of the respondents are married. Most livestock producers (62.7%) have between 21 and 30 years of experience with animals. This indicates that most farmers have many years of experience raising livestock and may have a solid understanding of climate change and its impact in the research region. Personal attributes such as gender, age, education, and agricultural experience affect how individuals perceive climate change (Akinyemi, 2017). Some studies use age to represent agricultural experience, whereas others argue that farmers would undoubtedly notice climatic changes as their farming expertise develops (Deressa *et al.,* 2009; Bryan *et al.,* 2013).

Livestock farmers' sources of climate change information

Among the many sources of information accessible to the livestock farmers, personal experience was the primary source reported by most (52.4%) of the respondents, followed by radio stations, extension services, family members, fellow farmers, and newspapers (Figure 1). The empirical findings are similar to those reported by Ateeq-Ur-Rehman *et al.* (2018). Farmers in the study areas spend much of their time with their livestock and have little interaction with extension workers or other sources of information. Farmers may readily link climate change knowledge based on historical catastrophe experiences of climate change scenarios (Weber & Stern, 2011).

Perception of respondents towards changing weather parameters

Changes in weather conditions are vital in determining farmers' attitudes about climate change. According to the study in Table 2, 77.0% of respondents perceived the temperature had risen. The majority of responders noticed a reduction in rainfall (54.0%). A higher percentage of respondents (65.9%) felt the increase in the sunshine across the research region. Similarly, 40.5 per cent of respondents said they didn't see a difference in evaporation. Most farmers reported an increase in humidity (82.5%) and drought (67.5%). The decrease in floods in the region was reported by most responders (65.9%). Different people have varying views on climate change based on their own experiences, as climate change is a natural phenomenon that affects humans, animals, and the world temperature (Ateeq-Ur-Rehman *et al.,* 2018). The findings corroborate those of Chatrchyan *et al.* (2017), who assert that farmers' exposure to extreme weather events shapes their perceptions of climate change.

Comparison between farmers' perception and meteorological data

Farmers' perception of climate change was compared to meteorological data from Sierra Leone's northern region, where the Koinadugu area is. Farmers' perceptions of temperature change were compared to yearly temperature data from 2000 to 2020. A rising trend of 0.0163 ^{0}C per year was noticed in the temperature time series (Figure 2). As a result, farmers' perceptions of increasing temperatures were likewise in line with the data. When it came to rainfall, most farmers thought it had somewhat decreased. According to the yearly rainfall data, rainfall exhibited a declining tendency of -2.5372 mm per year from 2000 to 2020 (Figure 3). As a result, farmer perceptions of decreasing rainfall frequency matched the recorded data.

Figure 4 confirms the farmers' perceptions, as the temperature has been increasing with minor variation from 2000 to 2020. In contrast, precipitation has decreased, a concern for livestock farmers because heavy rainfall causes floods, and deficient rain lengthens the drought period. Overall, we may infer those farmers correctly predicted climate change.

Table 1: Socioeconomic characteristics of backyard poultry farmers (N=126)

Variables	Frequency	Percentages
Gender		
Male	118	93.7
Female	8	6.3
Age		
Below 26	6	4.8
26-35	11	8.7
36-45	20	15.9
46-55	71	56.3
Above 56	18	14.3
Household size		
Less than 5	10	7.9
5-8	75	59.5
9-12	21	16.7
Above 13	20	15.9
Educational level		
No formal education	76	59.5
Primary school	28	22.3
Secondary school	16	12.7
Tertiary education	7	5.5
Marital Status		
Single	21	16.7
Married	74	58.7
Others	31	24.6
Years of keeping livestock		
1-10	10	7.9
11-20	8	6.4
21-30	79	62.7
31-40	20	15.9
41 and above	9	7.1

Source: Field survey, 2021

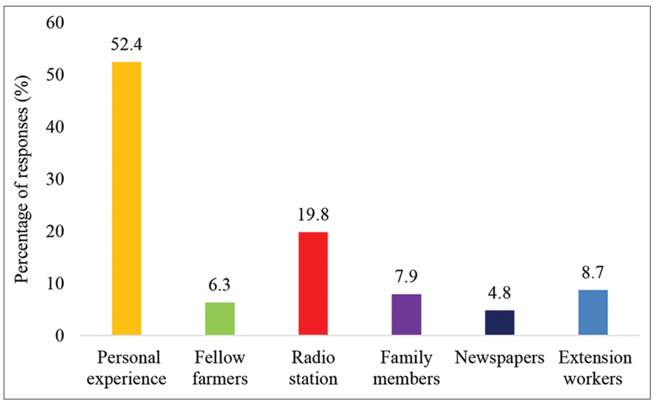

Figure 1: Livestock farmers' sources of information about climate change.

Farmer's perceptions of climate change impacts on livestock production

Table 3 demonstrates that feed availability ($\bar{x}$ = 4.14) is the most pressing issue for livestock producers, followed by increased

Table 2: Impact of climatic variables on backyard poultry production (N=126)

Weather parameters	Increase	Decrease	No change	Don't know
Heat wave	77.0	4.8	7.1	11.1
Rainfall	36.5	54.0	5.6	4.0
Sunshine	65.9	12.7	16.7	4.8
Storm	38.1	16.7	24.6	20.6
Evaporation	15.9	19.8	40.5	23.8
Humidity	82.5	8.7	3.2	5.6
Drought	67.5	20.6	4.0	7.9
Flood	16.7	65.9	9.5	7.9

Source: Field survey, 2021

animal water intake ($\bar{x}$ = 4.13) due to rising temperatures. Water scarcity ($\bar{x}$ = 4.10) is a significant issue for the farmers in the region. The findings are similar to Mogotsi *et al.* (2013) report that a prolonged drought leads to livestock mortality, reduced water availability, and low pasture production. Climate change has a considerable impact on natural resources and livestock productivity (Thornton *et al.,* 2009).

Cluster analysis

The influence of climate change on livestock production was classified using a clustering analysis, which was carried out. Respondents were allocated to one of four clusters using the cluster analysis simulation approach. According to Köbrich *et al.* (2003) interpretation of the Dendrogram, an elbow test indicated that the correct number of clusters had been identified (Table 4).

Cluster 1- Perception of a decline in fodder supply was the most prevalent in this cluster, with the highest mean score ($\bar{x}$ = 4.41) in this study. Nonetheless, the mean score obtained in cluster one was more significant than the mean score obtained in any of the other clusters, indicating that respondents in cluster one regarded this impact to be severe.

Cluster 2 – Perceived rise in the cost of veterinary services had the highest mean score ($\bar{x}$ = 5.00), much greater than the other clusters' mean values. Additionally, this group of farmers saw the high expense of health maintenance as a severe consequence of the current climate change situation.

Cluster 3 – Perception of increasing feeding costs – received the highest mean score ($\bar{x}$ = 4.88). Moreover, this mean score for the cost of feeding was more significant than all other mean scores for the cost of feeding in different clusters, indicating that it had the most significant impact on chicken producers in this particular cluster.

Cluster 4 - Increased incidences of animal diseases, the mean score ($\bar{x}$ = 4.43) was much higher than the values obtained from the first, second, and fourth clusters, which was judged to be statistically significant. This shows that respondents in this cluster are more likely than respondents in other clusters to be confronted with challenges related to the incidence of animal diseases.

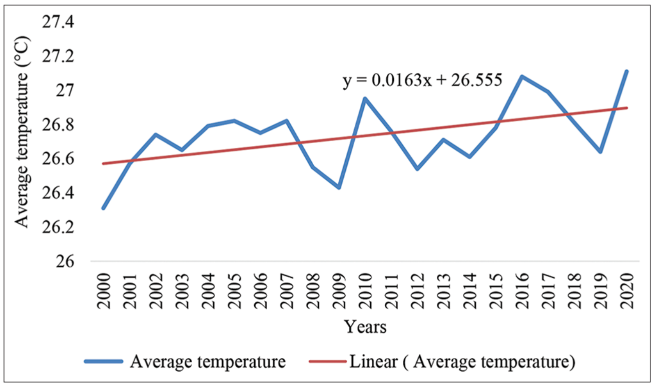

Figure 2: Temperature trend for Koinadugu district from 2000-2020. Source: Sierra Leone Meteorological Agency, 2021.

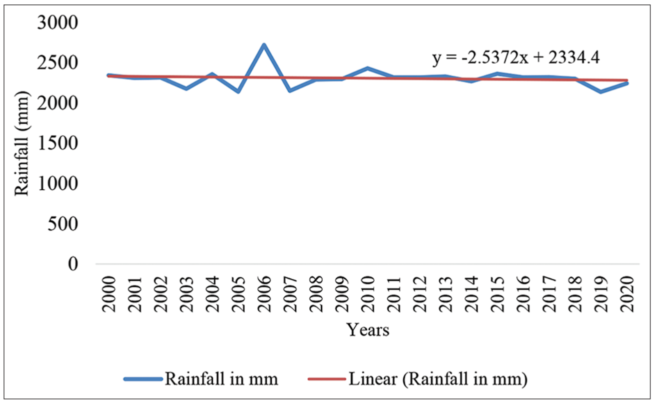

Figure 3: Rainfall trend for Koinadugu district from 2000-2020. Source: Sierra Leone Meteorological Agency, 2021.

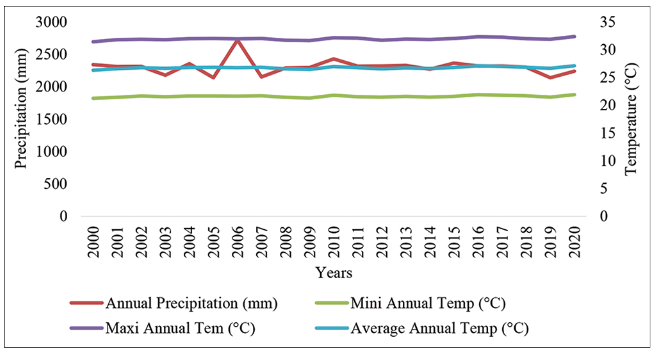

Figure 4: Historical trend of climate change for Koinadugu district, from 2000-2020.

Livestock farming adaptive response to climate change.

The research region clearly shows that (Table 5) vaccination of animals against disease transmission was the most widely employed strategy (95.2%). The second-best method for overcoming severe climatic circumstances was to reduce herd size (87.3%). The farmers reduced herd size by selling animals during extreme times, such as a severe hot drought in the region, which causes heat stress. Farmers sell their livestock when they grow weak or sick, especially during periods of drought when feed and water are scarce, and they must

Table 3: Perceptions of the impacts of climate change on livestock production

Perception of climate change impacts on livestock production	To a very great extent	To a great extent	To some extent (%)	To a little extent (%)	To no extent (%)	Total	Mean
Increased spread of diseases	16.7	11.9	49.2	13.5	8.7	126	3.14
Reduce Grazing time	44.4	20.6	16.7	12.7	5.6	126	3.86
Fodder availability	59.5	14.3	11.9	9.5	4.8	126	4.14
Loss of weight of animal	14.3	61.1	12.7	7.9	4.0	126	3.74
Increase in cost of feeding	20.6	46.8	16.7	8.7	7.1	126	3.65
Increase in cost of veterinary services	65.1	13.5	9.5	5.6	6.3	126	4.25
Increase in water intake	50.8	28.6	8.7	6.3	5.6	126	4.13
Increased mortality rate of animals	13.5	619	15.1	5.6	4.0	126	3.75
Water shortage	49.2	28.6	10.3	7.1	4.8	126	4.10
Reduced reproduction performance	25.4	57.1	7.9	5.6	4.0	126	3.94

* = Significant impact if mean score is ≥ 3.0
Sources: Field survey, 2021

Table 4: Mean scores calculated for all items in the four clusters

Perception of climate change impacts on livestock production	Cluster 1 fodder availability	Cluster 2 Increase in the cost of veterinary services	Cluster 3 Increase in the cost of feeding	Cluster 4 Increased spread of diseases
Increased spread of diseases	3.09	2.43	3.18	4.43
Reduce Grazing time	2.91	3.64	4.48	2.14
Fodder availability	4.41	3.93	4.21	2.71
Loss of weight of the animal	3.56	4.00	3.74	4.00
Increase in cost of feeding	3.44	1.36	4.88	2.29
Increase the cost of veterinary services	3.84	5.00	4.30	4.14
Increase in water intake	2.56	3.86	4.32	4.00
The increased mortality rate of animals	4.03	2.29	3.86	4.29
Water shortage	4.22	2.14	4.66	1.71
Reduced reproduction performance	3.91	2.64	4.38	2.14

Source: Authors computation, 2021

Table 5: Adaptive approaches of livestock farmers' to climatic change

Adaptation Strategies	Frequency	Percentage	Ranking
Reduction livestock number	110	87.3	2
Shade/house to reduce the effect of the heatwave	82	65.1	6
Planting fast-growing trees to provide shade for animals	77	61.1	7
Installing drinking water tanks under the shade	65	51.6	9
Vaccination of animals	120	95.2	1
Livestock diversification	68	54.0	8
Provision of salt and urea molasses block	89	70.6	4
Preservation of fodder	86	68.3	5
Migration along with animals during the adverse climatic condition	95	75.4	3
Rain water harvest	25	19.8	12
Mixed farming	57	45.2	10
Non-farming activities	36	28.6	11

* Responses are not 100% due to multiple responses of the respondents.
Sources: Field survey, 2021

purchase it from the market (Batima *et al.,* 2005). Farmers migrating with the animal (75.4%) to locations with plenty of feed and water is also common. During the drought, several livestock farmers were compelled to relocate for their animals' survival (Ma *et al.,* 2019). Furthermore, agricultural and animal species diversification efficiently resists disease and pest outbreaks linked to climate change (Twongyirwe *et al.,* 2019).

Obstacles to adaptation to climate change

Table 6 examined obstacles to climate change adaptation based on respondents' perceptions in the research region and found nine key restrictions to adaptation. The farmers reveal that key obstacle to adaptation is inadequate access to veterinary services (96.0%), followed by insufficient forage and pasture (88.9%), insufficient access to water resources (81.7%), low capital (76.2%), and inadequate information about climate change (71.4%). The findings are consistent with those of Mertz *et al.* (2009), who showed that a lack of finances, high prices for essential supplies and commodities, and livestock theft were the biggest hurdles to proper climate change variability adaptation in Senegal. Institutional problems such as lack of access to financing, lack of knowledge, and inconsistency of extension services were also mentioned

Table 6: Barrier to the adaptation of livestock farmers to climate change

Barrier to adaptation	Frequency	Percentage	Ranking
Lack of information	90	71.4	5
No improved breeds	74	58.7	8
Disease and parasite	88	69.8	6
Inadequate capital	96	76.2	4
Inadequate access to water resources	103	81.7	3
Inadequate forage and pasture	112	88.9	2
Inadequate access to veterinary services	121	96.0	1
Poor infrastructure	85	67.5	7
Limited knowledge of management practices	70	55.6	9

* Responses are not 100% due to multiple responses of the respondents.
Source: Field survey, 2021

by Fadina and Barjolle (2018). According to Assoumana *et al.* (2016), the main climate change adaptation constraints in West Africa are a lack of access to inputs, a lack of knowledge about other adaptation options, a lack of water, a lack of credit, a lack of information about climate change, a high cost of adaptation, and insecure property rights.

DISCUSSION

Perceived about Climatic Variability

Livestock farmers in Sierra Leone are highly concerned about climate risks and unpredictability. Their previous exposure to climate change in their production system has made them acutely aware of the occurrence and severity of climate change. Due to climate change, changes in the livestock production system are critical factors to consider (Henry *et al.*, 2018). Researchers feel that understanding livestock farmers' perceptions of climate-related hazards is crucial because it can realize their vulnerable nature and adaption behavior (Kuchimanchi *et al.*, 2021). Based on historical catastrophe experiences and knowledge of future climate change scenarios, farmers may readily link climate change to productivity adjustments (Weber & Stern, 2011). Almost every livestock farmer in Sierra Leone pays close attention to climate change and fluctuation. Farmers' understanding of climate change and their experiences with extreme weather occurrences, according to this fact, might enhance their perception.

The findings of this study show that farmers have a strong understanding of climate change and its variability at the livestock production level and that their judgments of the severity and frequency of temperature and precipitation changes are similar. Some farmers' perceptions of climate change can be shaped more by information than experience (Le Dang *et al.*, 2014). Frequent interaction with extension services can improve farmers' perceptions of climate influences on their farms and livelihoods (Abid *et al.*, 2019). Several researchers worldwide have come to the same conclusion: providing extension services improves farmers' risk resilience. Farmers who believed climate change would have a more significant impact desired to adapt (Lin, 2011; Tripathi & Mishra, 2017).

Climate variability and impact on livestock production

Livestock farmers in Sierra Leone observed increasing temperature, humidity, and decreased rainfall. Climate change, particularly global warming, is predicted to have a growing detrimental impact on livestock production systems (Nardone *et al.*, 2010). While domestic animals' adaptations to environmental changes are required for life, they frequently jeopardize the productivity and profitability of livestock systems (Thornton *et al.*, 2009). Through observation, livestock farmers are well-versed in identifying the impact of climate-related hazards on their animals. They may quickly spot several distinct indicators in animals that indicate whether they are sick or confined due to heat stress (Mihiretu *et al.*, 2021). Farmers are more likely to describe whatever component of the livestock production system is impacted by climate-related hazards, resulting in significant farm productivity and income losses (Ndlovu *et al.*, 2020). Changes in the quantity and quality of feed supplies, access to water, the types and breeds of livestock that may be kept, livestock movement, and animal diseases are all possible effects of climate change on livestock (Wreford & Topp, 2020). Changes in herbage growth, changes in the floristic composition of vegetation, changes in herbage quality, and changes in the relevance of crop leftovers as animal feed are all possible effects of climate change on forage availability and quality (Thornton *et al.*, 2009). Climate change was also seen as hampered animal production due to a loss in grazing pastures and a deterioration in animal health, negatively impacting meat and milk supply (Sejian *et al.*, 2015).

Farmers observed an increase in the spread of animal diseases in the area. Changes in precipitation and humidity and global warming have a favorable impact on the reproduction and spread of vector-borne pests such as midges, flies, ticks, and mosquitoes (Thornton *et al.*, 2009). In subhumid and humid zones, a hotter and drier environment would affect the habitat of endemic livestock breeds resistant to trypanosomiasis, the predominant animal disease in the zones, and hence the breeds that may be kept. This approach can transmit vector-borne diseases, including bluetongue, lumpy skin diseases (LSDs), anaplasmosis, babesiosis, and theileriosis, throughout a larger geographic area (Zougmoré *et al.*, 2016). According to the IPCC report from 2007, global climate change trends might positively impact the spatial distribution of vectors like mosquitos and ticks (IPCC, 2007). Climate conditions influence helminths' quantity, prevalence, severity, and geographic distribution. The rate of development of the free-living larval stage of Haemonchus contortus has been reported to increase in tropical locations as the temperature rises (Fox *et al.,* 2015). In a laboratory setting, Kim *et al.* (2012) found that increasing the ambient temperature from 25°C to 35°C accelerates the development of Ascaris suum eggs through improved embryonated. According to Aluwong and Bello (2010), changes in temperature and rainfall might increase the frequency of zoonotic diseases and increase animal species' mobility, posing a threat to cattle health. The consequences were thought to be an increase in cattle mortality rates.

As temperatures rise over the typical range, animal death rates rise and higher mortality rates under extreme weather situations (Vitali *et al.,* 2015). Temperature rises of 1 to 5 degrees Celsius above the average have been associated with more significant mortality in grazing animals (Howden *et al.,* 2007). These effects must be viewed as potential challenges to Sierra Leone's livestock industry growth. Although climate-related hazards such as heatwaves, humidity, pests and diseases, and drought significantly impact livestock productivity, indigenous breeds are more climate-adaptive. In brief, farmers believe climate-related concerns negatively influence the animal production system (Ndlovu *et al.,* 2020).

Several studies have found that the poorest nations bear the brunt of climate change's negative consequences (O'Brien *et al.,* 2006). More impoverished communities, according to studies, contribute less to climate change but are more susceptible due to their reliance on livestock production for survival (Warner *et al.,* 2012). As a result, the climate change problem must be considered while addressing poverty and hunger and promoting environmental sustainability. Livestock farmers in Sierra Leone reside in poor rural areas, making them more vulnerable. They depend on livestock to provide disadvantaged households with avenues out of poverty. Even though the environment is becoming increasingly changeable and unstable, livestock production continues to serve as a springboard for rural communities in times of duress (Ndlovu *et al.,* 2020). Climate-induced shocks frequently result in harmful coping methods that decrease livestock assets (Mekuyie & Mulu, 2021). The loss of animal assets implies falling into chronic poverty for many impoverished people, with long-term consequences for their livelihoods (Hänke & Barkmann, 2017).

Response to climate variability by livestock farmers

Improved understanding of the effects of climate change on various livestock systems and adaptive techniques to combat climate change is critical for livestock farmers in Sierra Leone. The farmers employed several adaptation strategies such as vaccination of animals against pests and diseases, reducing livestock number by selling animals, and some farmers migrated with their animals in search of forage and water. Climate change adaptation is well-defined by the Food and Agriculture Organization of the United Nations (FAO) as "spontaneous or organized processes by which human beings and society adjust to changes in climate by making changes in the operation of land and natural resource-based systems, as well as other forms of social and economic organization, to reduce vulnerability to changing climatic conditions" (FAO, 2009).

Livestock farmers have a wealth of indigenous knowledge on managing climatic uncertainty and risk. Numerous adaptations or coping strategies are available, ranging from technological advancements to learning, legislation, investment in specific sectors, and risk reduction strategies, all of which can assist disadvantaged livestock keepers in increasing their adaptive ability (Howden *et al.,* 2007). Kurukulasuriya and Rosenthal (2003) advocated altering farm productivity by diversifying and intensifying crop and livestock production, adjusting land use and irrigation, and shifting activity times. Institutional and regulatory reforms include eliminating or replacing subsidies, creating income stabilization alternatives, agricultural market improvements, and promoting the inter-regional agrarian market.

Like the study's findings, farmers and local communities in other African countries have attempted to use different methods to respond to climate change. Zimbabwe's traditional coping mechanisms for mitigating the effects of climate change included the sale of small animals such as goats and the sale of forest products and firewood to compensate for revenue losses (Zvigadza *et al.,* 2010). According to Mertz *et al.* (2009), Adaptation options in the Sahel included keeping animals in stables and substituting draught horses with cattle that were less expensive to feed. Morocco's government devised some policies and initiatives aimed at protecting livestock. Herders were convinced to progressively destock their herds, purchase feed to offset the feed shortfall, and vaccinate their animals. Hudson and Jones (2002) researched South Africa's North-West province, a semi-arid region, where the primary adaptation tactics were selling livestock and purchasing feed. Migration with animals is also a usual norm for some farmers in South Africa. Tree planting, soil conservation, different crop kinds, shifting planting dates, and irrigation were all used as adaptation methods in Ethiopia (Deressa *et al.,* 2011).

Challenges to climate variability response

In Sierra Leone, livestock farmers devise several methods to adapt to climate change but face some obstacles in adaptation. Some barriers to climate change adaptation are inadequate access to veterinary services, inadequate forage and pasture, inadequate water resources, inadequate capital, and lack of information about climate change. Economic resources, geographic position, accessible technology and knowledge, infrastructures, institutions, and networks all have a role in a community's ability to adapt to climate change and its associated risks (FAO, 2007). Those communities or localities with the capacity and resources to adapt to climate change are typically adapted. Those that cannot adapt to climate change are referred to as vulnerable communities (Adger, 2010). Poor infrastructure and institutions hinder a community's adaptive capabilities and planning. Poverty in rural areas was one of the critical issues that limited adaptation (Dungumaro & Hyden, 2010). Farmers in Sierra Leone are not exceptional poverty is quietly visible due to relying significantly on natural resources to maintain their livelihoods; as temperatures rise and precipitation decreases, agricultural productivity and harvests fall. The rural population group relied significantly on agriculture, animal husbandry, forestry, and fishing for a living is particularly significant. These activities were climate-dependent, putting the rural community in danger of the consequences of climate change (Wesenbeeck *et al.,* 2016).

CONCLUSIONS

This study looked at climate variability, farmers' perceptions, and perceived consequences on livestock production and livestock farmers' adaptations and barriers to adaptation in koinadugu district. Livestock farmers are well informed about climate change and its impact on extreme weather occurrences. Droughts, heatwaves, sunlight, and humidity, among other climate-related effects, have risen in frequency and intensity in the research region, wreaking havoc on the livestock production system. Farmers in the research region believe that some climatic phenomena have decreased, such as rainfall and flooding. On the other hand, drought was deemed the most hazardous climatic risk since it significantly impacted feed supply, raising production costs. Increased animal disease transmission, limited grazing time, fodder availability, increased feed costs, and increased veterinary care costs are some of the significant effects of climate change on livestock productivity. Farmers used risk coping adaption tactics such as reducing livestock numbers, migrating with animals during poor weather conditions, and vaccinating animals to maintain their livelihoods and production. They also engaged in non-farm activities. Lack of cash, inadequate information about climate change, poor infrastructure, and little knowledge of management methods were barriers to this adaptation's practices.

According to the findings, livestock farmers in the Koinadugu area rely on livestock for their livelihood. As a result, policies should be created to assist livestock farmers, and these policies should be long-term, climatically robust, and locally adaptive. However, the government should focus on farmer education, collaborating with the agriculture ministry and research groups to provide farmers with learning opportunities related to livestock development. Finally, our study proposes that the government strengthen the role of extension and veterinary services in encouraging livestock farmers to adapt to climate change.

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