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Research Article

METEOROLOGICAL DATA AND PERCEPTION OF CLIMATE CHANGE BY BREEDERS IN THE MAYO-KEBBI WEST PROVINCE, IN THE SOUDANIAN ZONE OF CHAD

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ABSTRACT

In sub-Saharan Africa, farmers are convinced of the existence of climate change. To deal with the harmful effects of climate change, producers have implemented various adaptation strategies, which the perception is the first factor that conditions their implementation. However, very few studies have focused on this question, especially among breeders. This study compares the perception of climate changes by breeders with meteorological data from 1991 to 2021 in the West Mayo-Kebbi Province in the soudanian zone of Chad. For this purpose, 845 breeders were interviewed. The data collected relates to socio-demographic characteristics and the perception of climate change. Data from the Pala weather station covering the period 1991 to 2021 were collected. The survey data were subjected to frequency analysis and the climate data to standardized anomalies. The results of this study reveal that the majority of breeders interviewed perceived a reduction in rainfall, a later onset of the season, a reduction in the length of the rainy season and a rise in temperatures. These results are consistent with climate data. On the other hand, there is a contradiction between meteorological observations and the breeders' conclusion on the early end of the rainy season. In addition, breeders highlight the resurgence of pockets of drought, poor distribution, and the intensification of rain and winds in recent years. This shows that the integration of indicators of change perceived by breeders would be relevant for developing strategies for adaptation to climate change in an appropriate, consensual and sustainable manner, by facilitating understanding and consultation between breeders and scientific communities.

Keywords: Breeders, Climate Change, Perception, Meteorological Data, SoudanianZone, Chad.

INTRODUCTION

In Chad, livestock constitutes an important resource for around 3.5 million of Chadians, or 40% of the rural population [1]and contributes up to 18% of Gross Domestic Product [2; 3]. It represents the country's second largest export after oil. This subsector creates a substantial source of income and food for poor rural communities [4]. It is also one of the main economic activities on which rural communities depend as a source of food and income [5]. Despite its importance, the livestock sector is today threatened by climate change [6; 7] because of its great dependence on resources with high climate sensitivity such as water and plant resources which the availability depends on the climate [8]. On a global scale, climate change induces a rise in temperature and a new distribution of precipitation [9]. The effects are evident on natural rangelands with a considerable drop in the biomass on which the fodder supply depends [10]. The deterioration of climatic conditions affects the productivity of natural pastures, the sustainability of streams and water points and the productivity of livestock [5]. It creates a real obstacle to the socio-economic development of rural populations [11]. Thus, livestock breeding which is based on the exploitation of fallows, savannahs and forests in Sudano-Sahelian environments [12] is increasingly threatened by these new climatic conditions which entail the risk of loss of terrestrial ecosystems, their biodiversity, the goods, functions and ecosystem services they provide for livelihoods. In this global context, sub-Saharan Africa, where agriculture is the main source of employment and income for most of the population [13] appears to be the region of the world most exposed to climate change [14].Chad is not immune to threats linked to climate change. A recent study carried out by Verisk Maplecroft [15] on the climate vulnerability of States, classifies Chad at the bottom of the scale as the most in danger because of conflicts, poverty and its geographical position. Furthermore, climate models show an increase in average temperature and an increase in precipitation across the country. With these scenarios, livestock farming highly dependent on pastoral resources will suffer the effects of climate variations with the corollary of declines in livestock productivity [16]**.** Other studies at the regional or national level [17; 18; 19] have shed light on peasant perceptions, vulnerabilities and adaptations to the variability and climate change. However, the literature providing in-depth information on the diversity of mechanisms at the local level is insufficient. The objective of this study is to compare meteorological data with the perceptions of breeders on climate change in the West Mayo-Kebbi Province, in the soudanian zone of Chad.

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MATERIAL AND METHODS

Study zone

Located in the southwest of Chad in the Sudanian zone between 9°21.48" north latitude and 14°54.30" east longitude, the Mayo-Kebbi West Province covers an area of 65,030 km^2 and represents 5.1% of the national territory. It is subdivided into three departments: Lake-Lere, Mayo Dallah and Mayo Binder. The Chadian Mayo-Kebbi basin is under the influence of the tropical climate of the Sudano-Guinean type [20] with two very dissimilar seasons: a dry season which lasts 6 to 7 months and a rainy season which goes from 5 at 6 months[21]. Precipitation is between 800 and 1200 mm. Temperatures vary greatly with maxima around 40°C and minima around 25°C. The hydrographic network is made up from East to West by the Mayo-Kebbi River and its tributaries.

The soils are ferruginous, sandy, lateritic, and alluvial. The vegetation consists mainly of light forests and wooded savannahs of the plateaus on granite bedrock, with a dominance of *combretaceae* in the north and legumes in the south [22; 23]. The species most encountered in these formations are*Acacia albida, Piliostigma rufescens, Anogeissus leiocarpus, Acacia scorpioidea* and *Boswellia dalzieli.* In the fluvio-lacustrine plains, the vegetation is reduced, dotted with trees, shrubs and a few perennial grasses; riparian galleries, where *Khaya senegalensis, Kigelia africana* and *Ficus* can sometimes reach impressive sizes. With more than 565,087 inhabitants, the majority (58%) young, the population practices agriculture, livestock breeding, fishing and crafts [24].

The choice of the province is based on the fact that it concentrates a large livestock population, more than 3% of the country's ruminants and its vulnerability to climate change [25; 26; 27].

Collection of data

Sixteen villages were selected on the basis of the size of the livestock population to carry out the study. The sociodemographic characteristics of breeders and their perception of climate variability and change were the subject of field data collection between 2020 and 2021 in the Mayo Kebbi West Province. Two main phases enabled the collections to be carried out.

Exploratory phase

Interviews with decentralized service development technicians made it possible to identify the villages to be investigated based on the accessibility of the village and the number of breeders living in the identified villages.The villages Biparé, Kahbi, Guegou, Mourbamé and Lagon in Department of Lake Lere;Binder, Ribao, Mbraou and Boursou in Mayo Binder;Wouro Dole, Mabachak-re, Guindi, Gamboke, Zetao, Bara and Gagal in Mayo Dallah were selected. 845 breeders spread across 16 villages were identified. Age (≥ 40 years) and the existence of cattle intended for animal production were the breeders' selection criteria. Sedentary households were chosen at random from the focus group attendance list organized in the villages. Mobile households were interviewed using the so-called interception method, either by chance encounters with transhumant camps, or during meetings organized in the selected villages.

In-depth phase

The previously tested and validated questionnaire made it possible to collect information through semi-structured interviews. The main data collected focused on the socio-demographic characteristics of breeders and their perception of climate variability and change (rainfall, temperature, wind).

Weather data

The climatic data from 1991 to 2021 of the Pala station were provided to us by the National Meteorological Agency. Rainfall amounts, duration, start and end dates of the season, maximum and minimum temperatures are the climate factors that were the subject of analysis in this study. The difference between the end and start dates of the season made it possible to determine the length of the season.

Statistical analyzes

The data from the respondents were entered into Excel then incorporated and analyzed by SPSS 23.0 software. The Excel spreadsheet version 2013 was used to construct the graphs. Descriptive statistics made it possible to translate the qualitative data into the form of centesimal proportions, then compared using the Chi-square test. When the test indicated a significant difference, a *post-hoc test* was carried out using the so-called standardized residual method. On the other hand, a one-way ANOVA followed by tests of homogeneity of variances and Welch was used to compare the means. A *post-hoc test* through the Tukey and Dunnett tests was carried out respectively in case of equal or unequal variances. The evolution of the different climatic variables was analyzed using the index method or reduced centered anomalies (Lamb 1982). The trends were highlighted by an affine-type regression line: $y = \alpha x + \beta$ where α is the coefficient, and β the average of the variable over 31 years. A trend is increasing if $\alpha > 0$, and the opposite if $\alpha < 0$. The meteorological observations were compared with the perceptions of the breeders in order to assess the consistency of the information. There is consistency when meteorological observations do not challenge the breeders' perceptions.

RESULTS

Sociodemographic characteristics of breeders

The sociodemographic characteristics of breeders in the study area are very diverse. The proportions of Moundang, Peulh, Hausa, Mbororo and Ouda socio-cultural groups are 25.1%, 23.0%, 15.4%, 13.4% and 10.3% respectively decreasing in the study area. Those of the Kessou, Toupouri, Guidar, Mambay, Zimé, Guiziga and Kéra groups are 4.6%, 2.3%, 2.3%, 1.7%, 1.0%, 0.7% and 0.1% respectively minority. The Moundang and Peulh socio-cultural groups are in the majority in Lake Lere (71.5%) and Mayo Binder (52.4%). These rates are significantly different ($p < 0.05$) between the Departments. Of the entire sample surveyed, 99.8% are men compared to only 0.2% women. In the Departments of LakeLere and Mayo Dallah, the people surveyed are all male. On the other hand, in the Mayo Binder 1.3% are women. In general, the Muslim faith is the most practiced religion (71.2%) by breeders. The Christian faith is dominant in the locality of Lake Lere unlike the localities of Mayo Binder and Mayo Dallah. The proportions are significantly different ($p < 0.05$) between the Departments. Educationally, 73.1% of breeders have no education. The proportions of farmers with primary, secondary and no education are all significantly different ($p < 0.05$) between the Departments. On the other hand, those of higher level operators are not ($p > 0.05$). The origin of the breeders is varied. Table 1 shows that 43.4% of breeders are indigenous (local) that is to say from the Province followed by those from Nigeria (36.8%), Cameroon (13.9%, returning from the Central African Republic (CAR) (4.7%) and Niger (1.2%). Significant differences ($p < 0.05$) were observed between the proportions of locals, breeders from Cameroon and those from Nigeria in the Departments.

Table-1 presents the averages of the household characteristics of the breeders. The average age of breeders is 54.1±9.5 years across the entire study area. The average numbers of workers are practically the same in the Departments. The average size of the cattle population is 79.1±30.0 head, 68.0±55.3 head and 56.1±37.9 head respectively in the localities of Mayo Dallah, Mayo Binder and LakeLere. The average for the study area is 72.1±38.5 heads. The average sizes are 30.7±27.1 and 30.0±16.5 heads for the sheep and goat populations.

Table-1.Socio-demographic characteristics of breeders

	Department			Fisher	p-value
	Lake Lere	Mayo Dallah	Mayo Binder		
Age	51,91±1[a]	55,34±8,8[b]	52,77±10,4[ac]	11,089	0,000
Number of households	1,48±0,8[a]	1,87±0,9[b]	1,63±0,9[ac]	15,34	0,000
Active	8,26±5,1[a]	7,76±3,6[a]	8,33±4,4[a]	1,668	0,189
Cattle size	56,11±37,9[a]	79,08±30,0[b]	68,04±55,3[c]	26,783	0,000
Sheep size	27,96±28,0[a]	32,52±27,4[a]	28,06±23,6[a]	2,812	0,061
Goat size	27,26±16,5[a]	20,14±15,1[b]	27,20±19,2[ac]	19,433	0,000
Area (ha)	5,11±2,3[a]	1,37±1,7[b]	4,25±1,8[ac]	298,766	0,000

Values in the same line subscripted with different letters are significantly different at the 5% threshold.

Perception of climate variability and change by breeders

The variability and change in the rainfall regime, temperatures, winds and their characteristics are indicators perceived by the breeders during this study. Table 2 presents the rate of perception of these indicators by breeders. For the entire study area, more than 98.3% of breeders say they have noticed a drop in rainfall. The rates are not significantly different ($p > 0.05$) between the Departments.

Table-2.Level of perception of climate change by breeders (%)

		Department			χ^2	*p*-value
		Lake Lere	M Binder	M Dallah		
Rainfall	Decrease	97,9[a]	97,3[a]	98,8[a]	11,99	0,062
	Rise	1,1[a]	0,0[a]	0,4[a]		
	Normal	1,1[a]	1,3[a]	0,8[a]		
	No response	0,0[a]	1,3[a]	0,0[a]		
Start of season	Normal	0,0[a]	0,0[a]	22,2[b]	85,56	0,000
	Early	0,0[a]	0,0[a]	0,2[a]		
	Late	100,0[a]	100,0[a]	77,7[b]		
End of season	Normal	2,7[a]	14,1[b]	45,5[c]	141,9	0,000
	Early	97,3[a]	85,9[b]	54,3[c]		
	Late	0,0[a]	0,0[a]	0,2[a]		
Season duration	Increased	0,0[a]	0,0[a]	4,5[a]	12,01	0,068
	Decreased	95,7[a]	97,3[a]	94,1[a]		
	No response	4,3[a]	2,7[a]	1,4[a]		
Daytime T.	T. Hot	100,0[a]	100,0[a]	100,0[a]	0,00	
Night time	T. Hot	100,0[a]	100,0[a]	80,2[b]	75,34	0,000
	Normal	0,0[a]	0,0[a]	19,8[b]		
Rain distribution	Irregular	96,8[a]	96,6[a]	66,9[b]	143,3	0,000
	No response	2,2[a]	2,0[a]	0,0[a]		
	Regular	1,1[a]	1,3[a]	33,1[b]		
Rainfall intensity	Average	22,6[a]	48,3[b]	73,5[c]	152,5	0,000
	No response	0,5[a]	0,0[a]	0,2[a]		
	Violent	76,9[a]	51,7[b]	26,3[c]		
Dryness pockets	Increased	98,9[a]	98,0[a]	87,7[b]	58,3	0,000
	Decreases	0,0[a]	0,0[a]	0,8[a]		
	No response	0,0[a]	2,0[a]	11,6[b]		
Wind intensity	Low	0,0[a]	0,7[b]	0,0[b]	173,8	0,000
	Average	54,8[a]	2,0[b]	14,9[c]		
	Violent	45,2[a]	97,3[b]	85,1[c]		

Values in the same line subscripted with different letters are significantly different at the 5% threshold. T = temperature

The drop in rainfall perceived by breeders is in agreement with the spatio-temporal rainfall behavior showing a downward trend in rainfall amounts compared to the average over the study period (figure-1). The shape of the trend curve is consistent with the breeders' conclusion on the drop in rainfall.

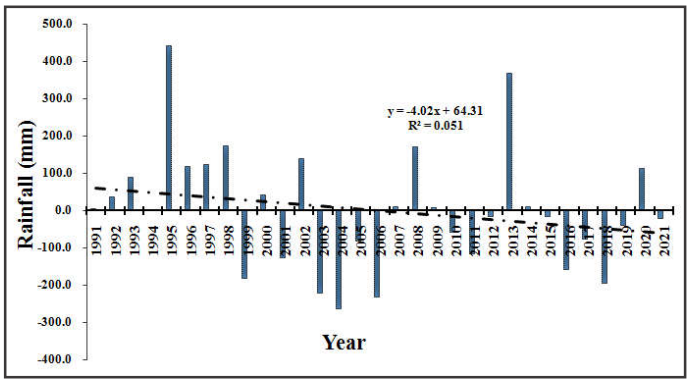

Figure-1. Deviation of rainfall from the average over the period 1991 to 2021

Breeders (85.6%) indicate the late onset of the rainy seasons and 69.3% agree on an early end to the rainy season in the study area. Significant differences ($p < 0.05$) are observed between the perception rates in the Departments. Late start perception rates are high in the localities of LakeLere and Mayo Binder.

The analysis of Figure 2 makes it possible to account for variability and decline in the start and end dates of the seasons over the study period. The delay in the onset of seasons is comparable with the conclusion of breeders on the late start of rainy seasons. On the other hand, the delay in the end of the season does not agree with the breeders' conclusion on the early end of the rainy seasons.

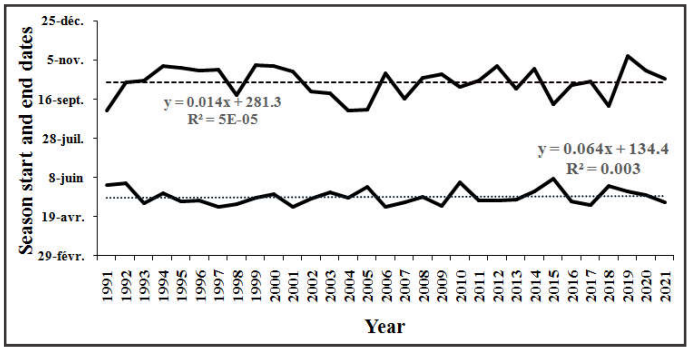

Figure-2. Evolution of the end and start dates of the seasons over the period 1991 to 2021

The duration or length of the rainy season is defined as the difference between the end dates and those of the onset of the rainy season. In fact, 95.0% of breeders indicate that they have noticed a shortening of the duration of the rainy season. The perception rates are not significantly different ($p > 0.05$) in the Departments. Figure 3 highlights the narrowing of the rainy season and the widening of the dry season due either to a delay in the start and/or to the precocity of the rainy season. Analysis of meteorological data shows that the shortest seasons during the study period are 118, 89 and 103 days for the first, second and third decades respectively. It highlights that approximately one month (29 days) separates the shortest seasons during the first and second decades. Two weeks (14 days) separate the third and second decades. These differences reflect a decreasing trend in the duration of the rainy season over the study period. These results corroborate the breeders' conclusion on the shortening of the duration of the rainy season.

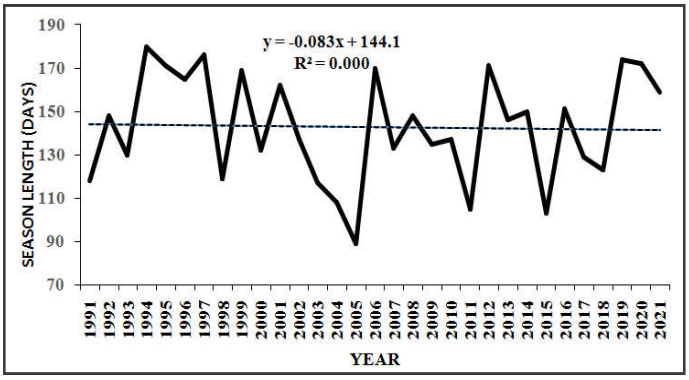

Figure-3. Evolution of the duration of the rainy season over the period 1991 to 2021

All the breeders surveyed say that the days are getting hotter and hotter. Furthermore, 88.1% of breeders report that the nights are hot. The perception rates are significantly different ($p < 0.05$) in the localities. Figure 4and 5 persistently show that the maximum and minimum temperatures over the study period experienced an increasing trend. Indeed, the minimum average temperature is 19.3° C. The minimum ten-year averages are 19.1° C, 19.3° C and 19.4° C respectively during the decades 1991-2000, 2001-2010 and 2011-2021; i.e. an increase of 0.1°C compared to the average over the study period. The maximum average temperature is 37.8°C over the study period. The ten-year averages were 37.3°C, 38.4°C and 37.7°C during the decades 1991-2000, 2001-2010 and 2011-2021 respectively. The decade 2001-2010 is the hottest (+0.6°C). These results are in line with the breeders' conclusion on rising temperatures.

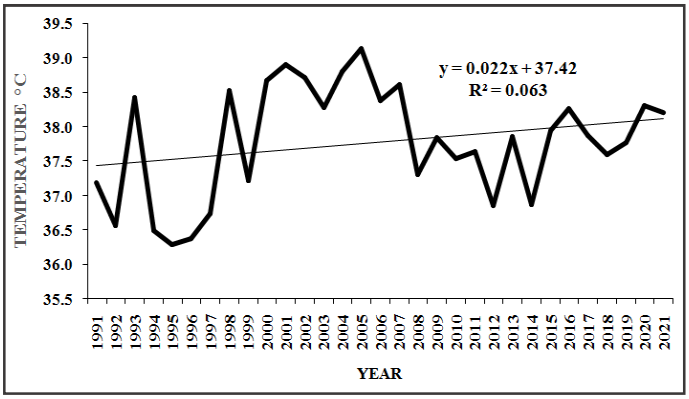

Figure-4. Evolution of annual maximal temperature over the period 1991 to 2021

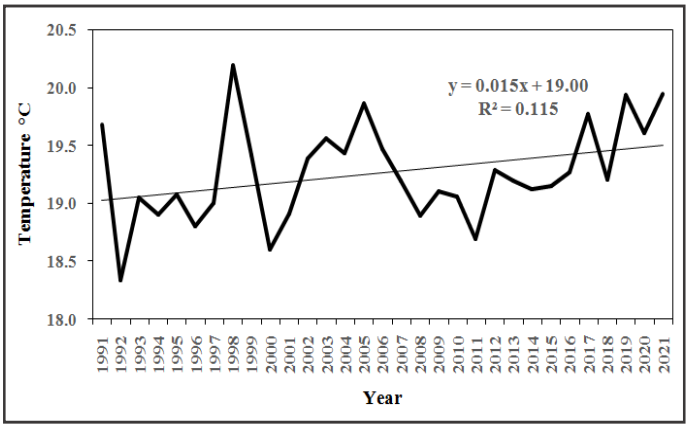

Figure-5. Evolution of annual minimal temperatures over the period 1991 to 2021

Other settings

Across the entire area, 79.0% of respondents criticize the irregularity of rains during the seasons in recent years. Furthermore, 41.9% of respondents report that the rains are violent and 57.9% indicate that they are not. Significant differences ($p < 0.05$) are observed between these rates in the Departments. Indeed, for the people surveyed, the rainy seasons experience a succession of days without rain at the beginning and end of the seasons while they are concentrated in July, August and September causing enormous damage. These observations reflect the irregular and violent nature of the rains. More than 92.0% consider that rainfall breaks have increased in recent years. Significant differences ($p < 0.05$) are observed between these proportions in the Departments. Breeders also say they have observed recurring successions of dry sequences after the start of the season and a drastic reduction in the number of rainy days. Likewise, more than 78.0% of respondents also criticize an intensification of winds through damage caused to plants and the silting of land. Significant differences ($p < 0.05$) are observed between the proportions in the Departments.

DISCUSSION

The analysis of daily rainfall data collected at the Pala station during the period 1991 to 2021 highlights the importance of rainfall irregularity in Mayo-Kebbi West. The treatment of cumulative rainfall for this period indicates a decrease in rainfall in the Region. This fact is consistent with the conclusion of the breeders surveyed in the study area on the decrease in rainfall in recent years. This drop in rainfall was highlighted by the work of Snaibi *et al.,*[28] in Morocco; from Zakari *et al.,*[29] in Benin; from Sanfo *et al.,*[30] in Burkina Faso; by Komba and Muchapondwa [31] in Tanzania; by Kemausuor *et al*., [32] in Ghana. However, our results are in contradiction with those reported by Idrissou *et al.,*[33] in Beninand Vall and Loankoande [34] in Burkina Faso who reported an increase in rainfall in their work. These authors came to the conclusion that breeders perceive climate change through irregularity and not through rainfall amounts. For these authors [34], breeders often use indicators such as water levels in ponds, the state of the vegetation on a given date and the state of the animals to assess climatic parameters. Farmers' climate expectations influence their perceptions of climate change. Meze-hausken [35] suggests that the growing needs of Ethiopian farmers for rainwater push them to interpret recent developments as a rainfall deficit, where observations indicate stable rainfall. The difference between our results and those of these authors could be explained by the fact that scientists often analyze meteorological data on a regional scale and populations always perceive climate on a local scale [36; 37].

The analysis of meteorological data shows, for the start of the rainy season, a tendency towards lateness. This trend is in harmony with the conclusions of breeders on the increasingly later onset of the rainy season. Abdou *et al*.,[38] made the same observations among farmers in east-central Niger. In Ivory Coast, Brou *et al.,*[39] reported a later start to the rainy season as we progress towards northern localities. The work of Kouassi *et al.,*[40] and Goula *et al.,*[41] in Ivory Coast also highlighted the delay in the start of the rainy season. Projections in West Africa indicate that rainy seasons would start even later in the coming decades, when precipitation would be more intense [42]. However, a significant difference ($p < 0.05$) is observed between the rates of respondents from the department of Mayo Dallah compared to the rates of the others. This dissimilarity would be due to its geographical position further south of the study area, in the soudanian zone. The late arrival of the season would be due to the

existence of a relationship between the climate and the progression of the monsoon [43]. The consistency between the analysis of meteorological data and the breeders' conclusion on the late start of the season could be explained by the long waits of the breeders for the return of the first rains necessary for the regrowth of the grasses and the recharge of the water tables to support the first months of lactation and which put an end to the harsh ordeal of the lean period.

The duration of the rainy season is obtained by the difference between the end and start dates of the season. This study shows a concordance between the analysis of meteorological data and the perception of breeders on the duration of the rainy season. Abdou *et al*.,[38] reported similar results in East-Central Niger. Nassourou *et al*.,[44] and Panthou *et al*.,[45] suggest that the trends detected for season length mainly indicate a reduction despite very variable behavior of climatic indices. Descroit *et al.,*[46]believe that the Central Sahel is experiencing a decrease in the duration of the agronomic monsoon. The birth, adoption and generalization of agropastoralism within the same farm in the region could explain this concordance.

Breeders characterize the end of the season through several indicators (clean and thundering cloud, foliage of *Faidherbia albida* etc.). In the study, breeders establish an early end to the rainy season. Even if their perceptions about the start and duration of the season corroborate the weather data, the opposite is observed at the end, because the climate data reveals a delay. Souley *et al*.,[47], Abdou *et al*.,[38] in Niger and Idrissou *et al.,* [33] in Benin obtained similar results. There is a discrepancy between the weather data and the breeders' conclusion on the early end of the rainy season. However, fewer issues were observed by breeders at the end of the season compared to farmers. For Cameron [48] and Loboguerrero *et al*.,[49], farmers adopt short-cycle varieties, as an adaptation option to accommodate various climatic stresses, in order to harvest on time while it rains. , thus offering vain pasture to the animals. This situation could reflect the dissimilarity of the breeders' conclusions on the early end of the season and the weather data.

The study shows that the breeders surveyed are sensitive to warming day and night temperatures and agree on their elevations. Analysis of meteorological data indicates an increase in minimum and maximum temperatures. Similar results are reported by Hasan and Kumar [50] in Bangladesh and by Idrissou *et al.,*[33] in Benin. On the other hand, Cuni Sanchez *et al*.,[51] reported that pastoralists on Mount Nyiro in Kenya observed no change in temperature. The difference between our results and theirs would be due to the type of climate that reigns in each study area and could be explained by the fact that the temperature increases slowly and continuously, which makes the warming difficult to perceive.

However, other important factors such as pockets of drought, the distribution of rainfall during the season and the frequency of violent winds are likely to influence agropastoral activities. This study establishes that breeders agree on an irregular distribution of rain (78.7%), an increase in the frequency of pockets of drought (92.2%), an intensification of wind (78.5%) and stability relative rainfall (57.9%). Abdou *et al.,*[7] reported similar results for drought pockets and poor rainfall distribution. Our results corroborate those of Mertz *et al.*[52] and Paraïso *et al.,*[53] who show that populations are aware of climate variability and identify wind, lack and excess precipitation as the most important factors perceptible. The intensification of wind and rain is reported by several authors such as Ozer *et al.,*[54; 55] in West Africa. The differences in proportions observed in the departments could be explained by a profound and disproportionate degradation of the plant cover due to land pressure and the overexploitation of natural resources leading to changes in local rain and wind patterns in these departments [56].

CONCLUSION

The study on the perception of breeders of climate change in the Mayo-Kebbi West Province in the soudanian zone of Chad made it possible to understand that climate change is a reality for breeders who perceive it and modify their behavior in response in order to adapt. The results of this study show that breeders are aware of the changing climate of their environment. Their perceptions of climate change are consistent with data on cumulative rainfall, onset, duration of the rainy season and temperatures. However, they differ from the data at the end of the rainy season. Furthermore, they also perceived change through pockets of drought, the distribution of rain during the season and wind. In light of the results obtained, the variables cumulative rainfall, start of season, length of season and temperatures would be those to be used when discussing climate change with breeders in the study area. Aware of the variability and climate change in their environment, these breeders will be able to implement climate change mitigation measures decreed by the government and partners through programs and projects.

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