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Risks and Influences of Climate Hazards for Agro-Pastoral Development and Strategies Adopted by Agro-Pastoralist Communities in the Bougouni District, Mali

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Abstract

In the southwest of Mali, pastoral resources play an important role in the production and reproduction of livestock. These pastoral resources are very sensitive to climatic hazards and negatively affected their availability in quantity and quality. The main objective of this study was to analyze the risks and influences of climate hazards on pastoral resources and the strategies taken by agropastoralists to cope with them. To achieve this objective, meteorological data trends from 1950 to 2022 were analyzed. The socio-economic data were collected through a semi-structured survey administered to 404 head households, from focus groups through discussion with local stakeholders by using climatic risks matrix. The results obtained indicate a concordance between agropastoralists perception on climate change and meteorological observations concerning the decrease of rainfall (−213 mm; 63.3%), the increase of maximum and minimum temperature (+1.33˚C, +1.24˚C; 93.1%), and the increase of wind speed (+0.59 m/s; 97%) over the past 70 years. Respondents noted a deterioration in the conditions of pastoral resources due to climatic hazards compared to the last 40 years (44.8% for watering points; 23.5% for pastures; 63.1% for salty lands). Agro pastoralists have adopted measures that allow them to be resilient. These include the collection and storage of crop residues (49.5%), regular watering of animals (39.6%), changing of animals rhythms driving (35.9%), protection of pruning species (31.7%), and concerted reforestation (37.9%). Climatic risk-related hazards constitute a real threat to pastorals resources in the district of Bougouni.

Keywords

Focus Groups Discussion, Perception on Climate Change, Meteorological Observations, Pastoral Resources, Pruning Species

1. Background

Climate change is one of the major challenges facing humanity in the 21st century (IPCC, 2022). It has been characterized by an increase in the frequency and intensity of extreme events, reduced food and water security, hindering efforts to achieve sustainable development goals (Ding et al., 2014; IPCC, 2022). In the Sahelian areas, observed temperatures have increased faster than global warming trends and expectations. This increase has fluctuated between 0.2˚C and 0.8˚C from 1961 to 2010 (Sarr et al., 2015). However, anthropogenic climate change has increased the intensity of extreme events such as flooding and associated impacts (WMO, 2021). Africa is currently a continent under multiple stresses and is highly vulnerable to the effects of climate change. The influence of these multiple stressors such as environmental disasters, economic turbulence due to globalization, privatization of resources, and civil strife, combined with the lack of resources, poses serious challenges for African communities struggling to adapt to climate change.

In addition, pastoral production systems account for more than 10% of the world's meat and support about 200 million households, which rely heavily on camel, cattle, and small ruminant livestock, about one-third of which are in Sub-Saharan Africa (Walter et al., 2020). Thus, in Africa, these systems face multiple stressors that can interact with climate change and variability to amplify the vulnerability of pastoralist communities. These stressors include rangeland degradation, increased variability in water access, fragmentation of grazing areas (IPCC, 2014). Increased temperatures led an increasing of the significance of plant tissue and thus reduced digestibility and degradation rates of plant species (Garnett, 2013; Amole et al., 2022). Climate change projections predict loss of livestock productivity, loss of range land, and loss of water sources (USAID, 2017). Rising temperatures in lowland areas of Africa could lead to a reduction in dairy cow loads in favor of cattle, a shift from cattle to sheep and goats, and a decrease in reliance on poultry (IPCC, 2014).

However, the current pastoral resources of the last five decades of the Saharo-Sahelian spaces have been strongly evaluated in terms of quantity and quality, spatial distribution and access to livestock (Hiernaux et al., 2014). This assessment shows that the social and environmental problems prevalent in the Sahel and in some West African countries were aggravated by the onset of droughts in 1974, 1984 and 1990. West Africa, in particular, has been described as an area at risk from climate change (Daniel et al., 2017; Filho et al., 2020). Thus, in the West African Sahel, an upward trend has been observed for maximum and minimum temperatures in the three ecological zones (Sudanian, Sahelian, and Sahelo-Saharan), with a more rapid increase in minimum temperatures (Diarra et al., 2022). Thus, the 1970-1990 period shown a rainfall deficit of 30% to 50% compared to the 1950-1969 period (Marega & Mering, 2018). Thus, the occurrence of these droughts negatively impacts forage and food production, water availability, and livestock productivity (USAID, 2017). Furthermore, droughts are likely to increase in the future due to climate change (Frischen et al., 2020). Climate change is expected to increase the vulnerability of livestock feed in terms of quality and quantity. Its effect is expected to induce vulnerability in animal production systems by altering feed consumption, metabolic activities, and defense mechanisms (Hidosa & Guyo, 2017). Hot and dry seasons cause the greatest reduction in biomass yield for different types of grasses grown in lowland environments (Hidosa & Guyo, 2017), and a loss of woody and herbaceous appetizing species (Sanogo et al., 2016). Pastoral resources in southwestern Mali play an important role in both livestock production and environmental restoration. This situation favors the livestock sub-sector, which is very important to the Malian economy. Its contribution to the gross domestic product (GDP) is 15.2% behind agriculture at 16.2% (UNOWAS, 2018; DNPIA, 2020). Livestock size in Mali is estimated at 12,474,462 cattle, 20,142,677 sheep, 27,810,553 goats, 595,869 horses, 1,167,223 donkeys, 1,265,915 camels, 87,216 pigs, and 52,098,451 poultry (DNPIA, 2020). The livestock population is very high and diverse in terms of breeds (PROGEBE, 2015). The second largest source of income after agriculture (IMPD, 2007), this sector employs 80% of the rural population and is an important source of their livelihood (PNDEM, 2004).

Despite the economic importance of this sector, Mali has already felt the negative influence of climatic hazards since the drought episodes of the 1970s, leading to a reduction in the quantity and quality of pastures (PANA-Mali, 2007). Uneven distribution of rainfall and strong winds lead to early drying of the water point, water shortage, and increased degradation of pastures (Sanogo et al., 2016). This research will contribute to analyzing the risks and influences of climate hazards on pastoral resources and the strategies taken by agropastoralists to cope with them.

2. Materials and Methods

2.1. Study Area

The district of Bougouni is located in the Sudano-Guinean zone in the southwestern part of Mali, between latitudes 10˚00' and 12˚40' north and longitudes 06˚20' and 08˚20' west. It has been created in the years 1956 (Dembélé et al., 2013) and constitutes a real crossroads. Its climate is of the Sudano-Guinean type, characterized by two types of season. A dry season of 5 to 6 months (November to April) and a rainy season of 6 months (May to October). The average annual rainfall is approximately 1300 mm (Doumbia, 2009; Coulibaly, 2008). Respectively, August is the rainiest month and the hottest months are April and

May. The average wind speed in m/s is very high for the months of February, April, and May. The district of Bougouni is administratively composed of five hundred and forty (540) villages, twenty-six (26) communes, including one urban and twenty-five (25) rural, distributed in nine (9) sub-districts (Sanogo, 2006). Covering an area of approximately 20,028 km², or 1.6% of Mali's territory, the district of Bougouni is crossed by National Route 7, which allows it to be reached in part by Bamako (170 km) and in part by Sikasso (210 km). The district of Bougouni is part of the "Haut Bani Niger" zone located at an average altitude of 350 m above sea level (Traore et al., 2021). It is bounded to the north by the district of Kati and Dïola (Koulikoro Region); to the northwest by the district of Yanfolila; to the south by the Republic of Côte d'Ivoire and to the southwest by the district of Sikasso and Kolondieba (Sikasso Region) (Keïta, 2009; Doumbia, 2009). This study was conducted in the Bougouni district in four communes, namely Dogo, Koumantou, Garalo and Faragouaran (**Figure 1**).

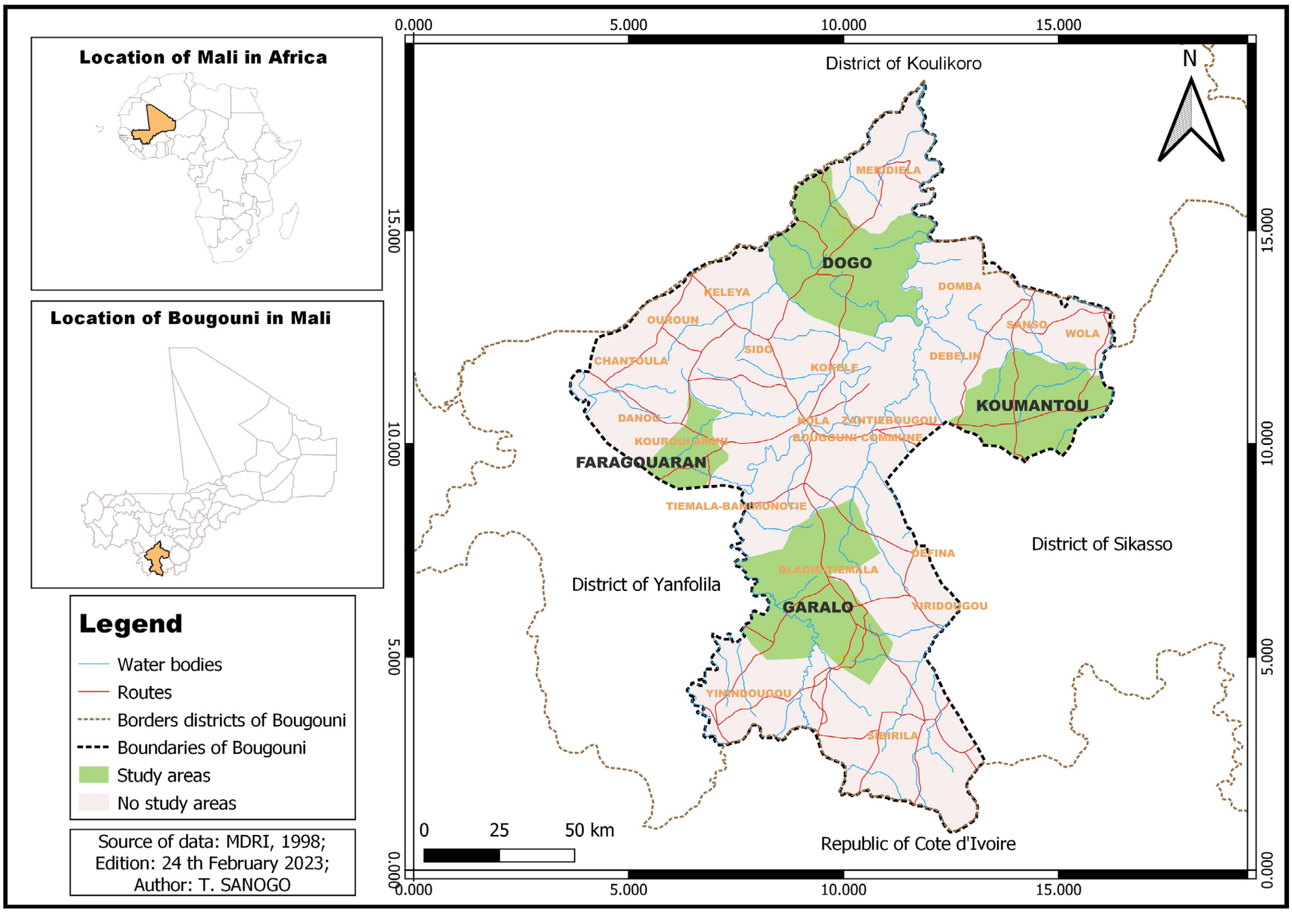

Figure 1. Map showing the study areas in Mali with the research locations highlighted.

2.2. Sample Size

The sample size was drawn on the basis of the 2022 population data for the Bougouni district provided by the National Population Directorate of Mali. The following formula from Nyangweso & Gede (2022) was used to determine the size of this sample

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

where n is the sample size, N is the finite population, e is the tolerable error limit and 1 is unit or constant. The simple random sampling method was used to randomly select respondents from a sampling frame (Bhattacherjee, 2012). The use of this formula allowed to determine 404 heads of household (men and women) as the survey population. The level of precision taken into consideration is 5% regarding limited financial means and difficulties related to time and access of some villages.

2.3. Data Collected

The data collected in the research framework is based on meteorological and socio-economic data. The meteorological data collected are rainfall (daily and annual), maximum and minimum temperatures (annual), and wind speed (annual) from 1950 to 2022. They were collected at the National Agency of Mali-Météo (annual data) and the Agrhymet Régional Centre of Niger (daily data). Based on semi-structured questionnaire tools, the Socioeconomic data were collected through a sample of four hundred-four heads of households through individual interviews in four (4) communes, including eight (8) focus groups discussion by using climatic risks matrix. The main parameters of this tool were focused on climatic risk-related hazards and its effects on existing pastoral resources, and adaptive response strategies. The collections, based on written survey, were carried out in 4 rural communes (Dogo, Garalo, Koumantou, Faragouraran). The survey population concerned agropastoralists aged at least 30 years in order to respect the dimension of climate change.

2.4. Method

2.4.1. Socioeconomic Data Analysis

These data were entered, coded, and analyzed in SPSS v23 and Jamovi v2.3 software and Excel 2013. These data were analyzed in two ways. The first consisted of descriptive statistical analysis, allowing us to identify trends expressed in numbers and percentages, and the second consisted of a cross-tabulation of the responses according to age and level of study. For aspects of endogenous climate knowledge, the term before (years < 1990) and actual (years ≥ 1990) are used to refer to the standard climate normal (1991-2020) of the World Meteorological Organization (OMM, 2017).

2.4.2. Meteorological Station Data Analysis

Climatic data were entered and analyzed using Excel 2013, Instat+.3.36, Xlsat2019 software. The types of analysis included the Standardized Precipitation Index (SPI), Lamb's Index, and statistical tests, rainy season analysis (Onset, length, end, dry sequence) for rainfall data. Statistical tests and anomalies on temperatures and wind speed.

- Lamb's standard index: It is used to highlight trends in time series and to estimate deficit and surplus periods on an annual scale (Dao et al., 2010; Alamou et al., 2016). It is calculated according to the following equation:

$$V_{cr} = \frac{x_i - \overline{x}}{\sigma} \tag{2}$$

x_i is data i for the annual data series; $\overline{x}$ is the average of the annual data series for the reference period; σ is the standard deviation of the annual data of the series of the reference period.

- Standardized Precipitation Index 9SPI): is calculated using the arithmetic mean and standard deviation of the precipitation series. It is used to illustrate and categorize drought periods. In the model, negative values obtained from this equation indicate precipitation deficits (drought events) while positive values illustrate precipitation excesses (wet events) (**Table 1**). Four different categories of drought are defined by McKee et al. (1993). It is calculated from the following equation:

$$SP_i = \frac{X_i - \overline{X}}{S_x} \tag{3}$$

X_i is the cumulative rainfall for year i; $\overline{X}$ is the cumulative average rainfall; S_x standard deviation of precipitation in the series.

Statistical tests used

- *Mann-Kendall trend test* (*1945*)

This non-parametric test allows to characterize a trend or a sudden jump. It is based on the correlation between the ranks of a time series and their order. Its null hypothesis is that there is no trend. For each pair of values y_i and y_j, where $i > j$, the test asks whether $y_i > y_j$ (P) or whether $y_i < y_j$ (M). Its statistic is equal to the sum of the differences between two observations, i.e., $S = P - M$. The significance of a trend can be tested by comparing the standardized value U to the test variable at the desired level of significance (Cédric, 2008; Hamed, 2008).

- *Pettitt test* (Pettitt, 1979): The Pettitt test is defined as the point at which a sudden change or jump occurs in a data series. It is used to determine the year of the break in precipitation or temperature for a station under consideration. The Pettitt approach is non-parametric and is derived from the Mann-Whitney test. The absence of a break in the series (X_i) of size N constitutes the null hypothesis. The implementation of the test assumes that for any time t between

Table 1. Classification and evaluation of different SPI.

N˚	SPI values	Drought category
1	0 to −0.99	Mild drought
2	−1.00 to −1.49	Moderate drought
3	−1.50 to −1.99	Severe drought
4	≤−2.00	Extreme drought

Source: (McKee et al., 1993).

1 and N, the time series (x^ i = 1 to t and t + 1 to N belong to the same population. The variable to be tested is the maximum of the absolute value of the variable $U_{t,N}$ defined by:

$$U_{t,N} = \sum_{i=1}^{t} \sum_{j=t+1}^{N} D_{ij} \quad (4)$$

where $D_{ij} = \text{sgn}(X_j - X_j)$ wth $\text{sgn}(x) = 1$ if $x > 0$, 0 si $x = 0$ et -1 if $x < 0$.

If the null hypothesis is rejected, an estimate of the break-up date is given by the time t defining the maximum in terms of the number of days in the week (Servat et al., 1998). Its null hypothesis being non-breakage (Paturel et al., 1998).

- Student's t test for comparison of means: it is used to compare two means. It tests the equality of two independent samples and thus makes it possible to prove that the difference between the two means is significant or not. T follows a Student's law with v degrees of freedom where $v = n_1 + n_2 - 2$, where n_1 and n_2 are the sizes of the first and second samples respectively (Cédric, 2008).

Analysis of rainy season parameters: The analysis of the characteristic parameters of the season (start date, end date and duration) was carried out using INSTAT + v3.36 software according to the criteria selected for the Sudano-Sahelian zone. These criteria are as follows:

- The start date, upon receipt of 20 mm of rain collected in one (1) or two (2) consecutive days after May 1, without a dry period of more than 20 days within the following 30 days (Stern, 1981).
- The end date, based on the water balance as a criterion, for example, the first day after September 1, when the water balance is less than or equal to 0.05 mm. Thus, when plant water consumption and climatic demand exhaust the soil water supply (Stern et al., 1982; Stern et al., 2006).
- Season length is obtained by calculating the difference between the end date and the start date of wintering (Sivakumar, 1988; Stern et al., 2006).
- Analysis of the frequency of dry spell: A dry spell for a given period is defined as the maximum number of consecutive days without rain after the start of the rainy season. The frequency and duration of dry spells are calculated for the months of May, June, July and August. The threshold chosen is 0.85 mm (Stern et al., 1982; 2006).

3. Results

3.1. Observations of Meteorological Stations Data

3.1.1. A Seasonal Rainfall with a Downward Trend and Variable Parameters and Increasingly Long Dry Spells

The analysis of the Mann Kendall test on rainfall from 1950 to 2022 shows a decreasing trend in rainfall. This decrease is significant with a p-value of 0.05. However, analysis of the Pettitt test showed a rupture in the series in 1966 with 0.023 as p-value. Comparison of the two means using Student's t Test reveals a reduction in rainfall of 213 mm from 1950 to 2022 (**Figure 2(a)**). The analysis of the SPI shows severe droughts in 1973 with an index of -1.5 and 2002 with an index of −1.9; moderate drought for the years 1968 and 2006 with an index of −1.2, 1972 and 1987 with an index of −1.1, 1984 with an index of −1.4. The Long-Term-Average (LTA) 5-year and 10-year illustrates a high alternation of wet and dry years after the 1970s (Figure 2(b)).

The Analysis of the season's parameters shows that the two recent 30-year periods (1950-1979; 1980-2009) were marked by a delay in the start of the rainy season (on average 6 days), an early cessation of rainy season (on average 4 days) and a reduction in the number of rainy days (on average 10 days) (Table 2). The

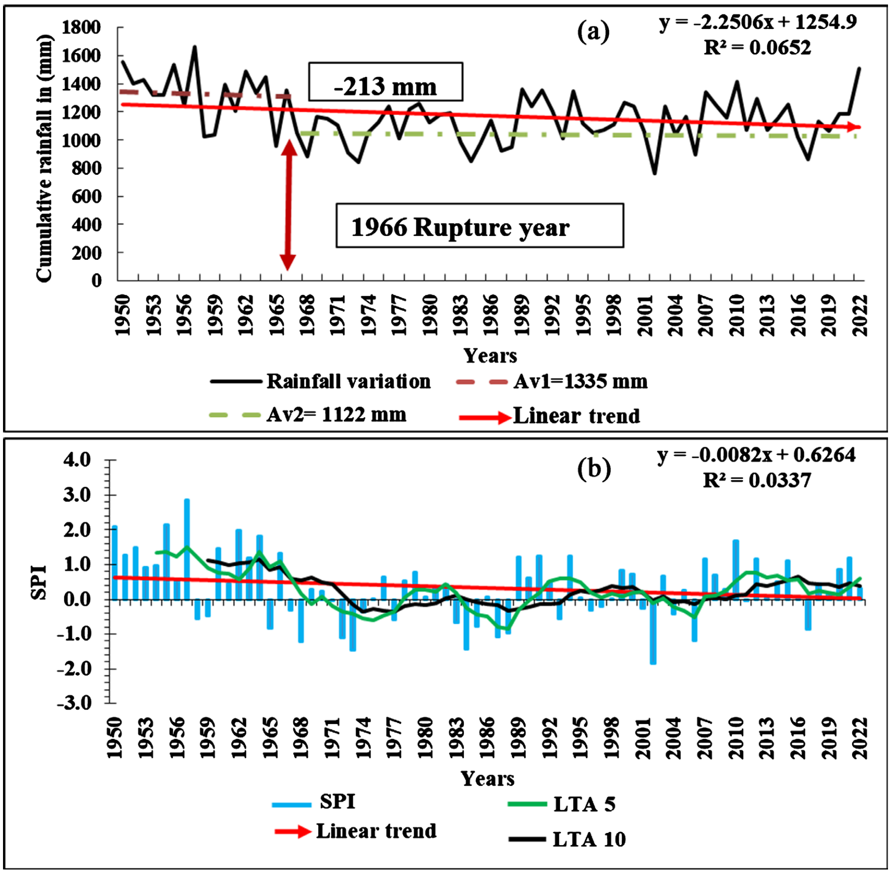

Figure 2. Rainfall interannual variation (a) and SPI evidence (b) in the station of Bougouni District from 1950 to 2022. **Source:** Personal work.

Table 2. Tendency of rainy season parameters of Bougouni station over the recent thirty-year-old (1950-2010).

Parameters	First Thirty-year-old 1950-1979	Second Thirty-year-old 1980-2009	Impacts
AORS[1]	15th May	21st Mai	6 days Late
AERS[2]	15th November	11th November	4 days early
ALRS[3]	184 days	174 days	10 days reduction

Source: Personal work. [1]Average Onset of Rainy Season; [2]Average End of Rainy Season; [3]Average Length of Rainy Season.

dry spell of May, June, July and August were analyzed. Figure 4 revealed that frequent of dry spells greater than or equal to five days was present in all months but very low in May. However, the frequency of those greater than or equal to 10, 15 and 20 days are very high for the month of May. This summarizes that July and August constitute the rainiest months (Figure 3).

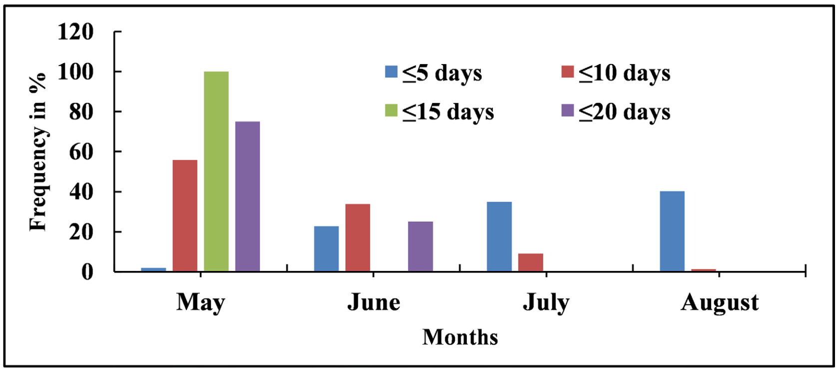

Figure 3. Dry spells frequency analysis in Boudouni station from 1950 to 2010. Source: Personal work.

3.1.2. Maximum and Minimum Temperatures Trending Upwards

The standardized maximum temperature anomalies indicates that the years 2013, 2016 and 2021 were years of warmer days because the annual average maximum temperatures corresponding to these years are higher than the annual average maximum temperature (34.1˚C) over the reference period (1950-2022). However, the years 1950 to 1995 were years of less hot days due to the fact that the annual average of maximum temperatures for these years is lower than those over the reference period. At the same time, the moving average indicates an increase in maximum temperatures (Figure 4(a)). The Man-Kendall test shows a significant upward trend in maximum temperatures with a P-value of 0.0001. The Pettitt test indicates a rupture in the time series from 1950 to 2022 with a P-value of 0.0001. This rupture occurred in 1995. Comparison of the two means using Student's t-Test indicates an increase in maximum temperatures of 1.33˚C for the reference period (Figure 4(b)).

The standardized minimum temperature anomalies indicate that the years 1951, 2008 to 2010; 2021 were years of warmer nights as the annual average minimum temperatures corresponding to these years are higher than the annual average minimum temperatures (21.2˚C) over the reference period (1950-2022). In contrast, the years 1952 to 2007; 2011 to 2022 were years of less warm nights due to the fact that the annual average minimum temperatures corresponding to these years are lower than the annual average minimum temperatures over the reference period (Figure 4(c)). The Man Kendall test shows a significant upward trend in minimum temperatures with a p-value of 0.0001. The Pettitt test shows a rupture in the time series from 1950 to 2022 with a p-value of 0.0001. This rupture was observed in 1995. Thus, the application of the Student's test indicates an increase in minimum temperatures of 1.24˚C for the reference period (Figure 4(d)).

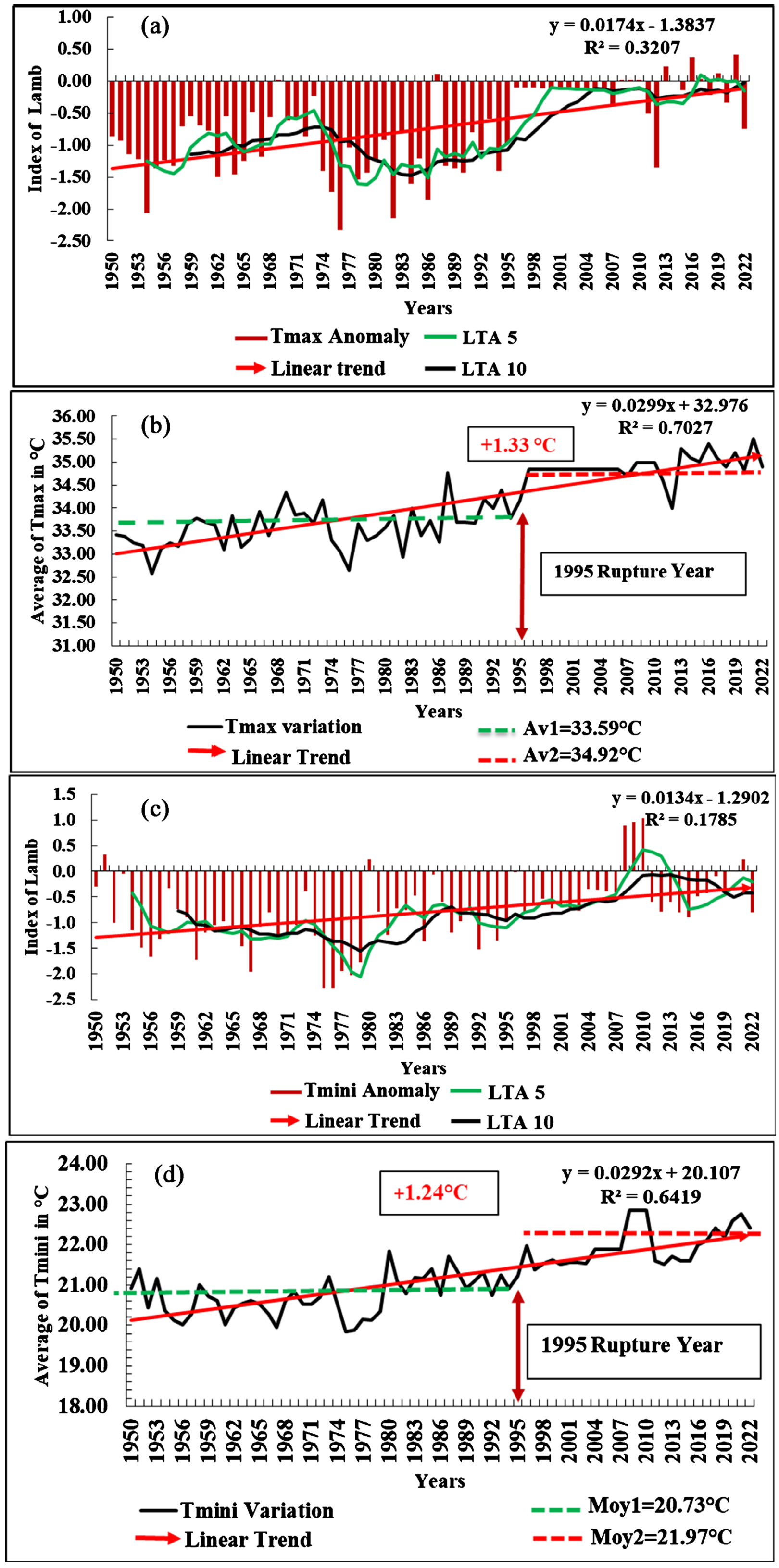

Figure 4. Anomalies Interannual variation of maximum (a) and minimum (c) temperatures anomalies; evidence of statistic tests of maximum (b) and minimum (d) temperatures in the station of Bougouni District from 1950 to 2022. Source: Personal work.

3.1.3. Wind Speed

The normalized average wind speed anomalies indicates that the years 1950 to 1954; 2016 to 2020 were higher average wind speed years because the corresponding annual averages for these years are higher than the annual average wind speed (1.28 m/s) over the baseline period (1950-2022). In contrast, the years 1957 to 1994; 2004 to 2015; 2021 and 2022 were years of lower average wind speed because the corresponding annual averages for these years are lower than the average annual wind speed over the baseline period (Figure 5(a)). The Man Kendall test revealed a non-significant upward trend in mean wind speed with a p-value of 0.228. The Pettitt test indicated a rupture in the time series from 1950 to 2022 with a p-value of 0.002. This rupture was observed in 1994. Thus, application of Student's t-test indicates an increase in mean wind speed of 0.59 m/s for the baseline period (Figure 5(b)).

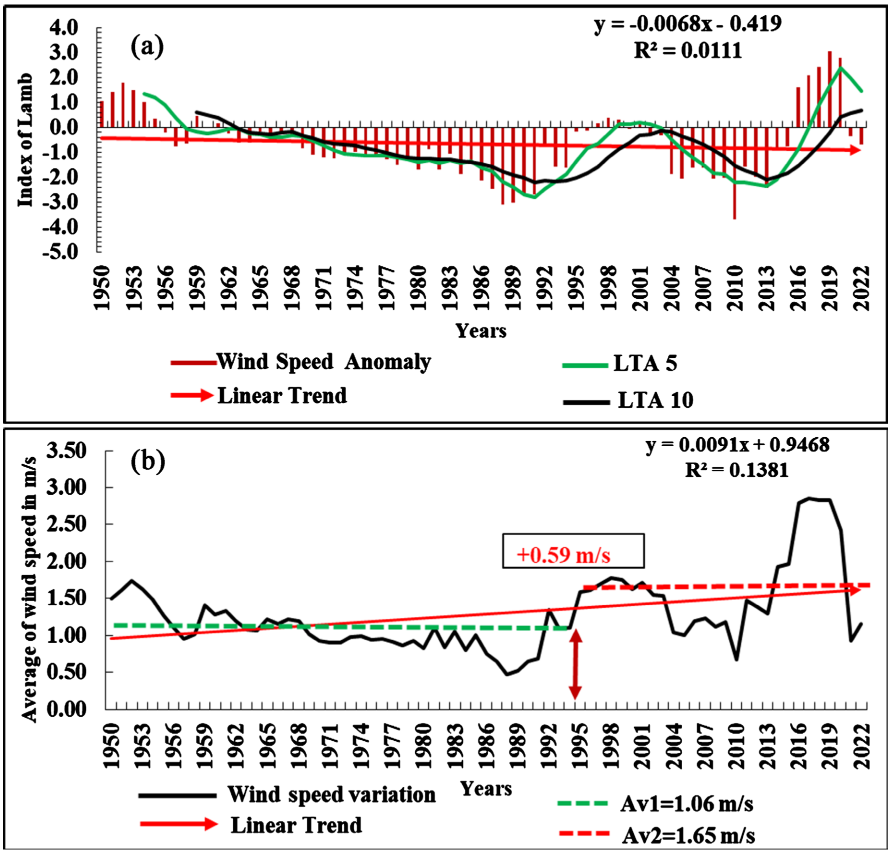

Figure 5. Anomalies Interannual variation (a) and evidence of statistic tests (b) of wind speed in the station of Bougouni District from 1950 to 2022. Source: Personal work.

3.2. Observations of Socio-Economic Data

3.2.1. Highly Variable Demographic Characteristics

The observation of the demographic characteristics of the agropastoralists shows that 52% of the respondents are between 30 and 49 years of age; 49.5% are not educated; 68.6% have fewer than 5 working persons; 76.7% have not received any training on pasture management (Table 3).

Table 3. Socio-demographic characteristics of agropastoralists/respondents in the study area.

Parameters	Frequency	%	Rank
Tranches of ages			
30 - 39	104	25.7	2
40 - 49	106	26.2	1
50 - 59	102	25.2	3
60 - 69	73	18.1	4
≥70	19	4.7	5
Level of study			
Primary	84	20.8	2
Fundamental	36	8.9	4
Secondary	20	5	5
University	8	2	6
Koranic	56	13.9	3
Uneducated	200	49.5	1
Member of a socio-professional organization			
Yes	201	49.8	2
No	203	50.2	1
Possession of working persons			
<5	277	68.6	1
[5 - 10]	93	23.0	2
>10	34	8.4	3
Training in pastures management			
Yes (have got training)	94	23.3	2
No (have not got training)	310	76.7	1

Source: Individual Survey (December, 2022)

3.2.2. Agropastoralists with Good Endogenous Perceptions of Climate Parameters

Table 4 shows the endogenous perceptions of agropastoralists regarding rainfall. It indicates that the season is increasingly dry (63.4%). The onset of the rainy season before (years < 1990) is at onset of May (62.4%) and actual (years ≥ 1990) is at onset of June (51%) with an increasingly later start of the rainy season. In contrast, the rainy season ended in October before (30.9%) and actual (20.2%) with an increasingly erratic rainy season duration. A large majority of the surveys noted a frequency of dry spell (93.6%) particularly those greater than or equal to 20 days (55.7%). They have noted that it is getting hotter (93.1%) and the winds are increasingly violent (97%) (**Table 4**).

Table 4. Observation of agropastoralists' endogenous perceptions of rainfall.

Parameters	Frequency	%	Rank
Rainy season is more and more			
Rainy	90	22.3	2
Dry	256	63.4	1
Normal	25	6.2	4
Erratic	33	8.2	3
Onset of Rainy Season before			
Onset of April	10	2.5	5
Middle of April	5	1.2	7
End of April	7	1.7	6
Onset of May	252	62.4	1
Middle of Mai	93	23	2
End of May	24	5.9	3
Onset of June	11	2.7	4
Middle of June	1	0.2	8
End of June	1	0.2	9
Onset of Rainy Season actual			
Onset of April	2	0.5	7
Middle of April	1	0.2	9
End of April	3	0.7	8
Onset of May	41	10.1	3
Middle of May	37	9.2	4
End of May	69	17.1	2
Onset of June	206	51	1
Middle of June	31	7.7	5
End of June	14	3.5	6
End of Rainy Season Before			
Onset of September	7	1.7	9
Middle of September	13	3.2	8
End of September	73	18.1	3
Onset of October	43	10.6	4
Middle of October	28	6.9	5
End of October	125	30.9	1
Onset of November	16	4	7
Middle of November	22	5.4	6

Continued

End of November	77	19	2
End of Rainy Season actual			
Onset of September	13	3.2	9
Middle of September	24	5.9	8
End of September	44	10.9	4
Onset of October	72	17.8	3
Middle of October	28	6.9	7
End of October	82	20.2	1
Onset of November	75	18.6	2
Middle of November	32	7.9	6
End of November	34	8.4	5
Length of rainy season			
Long	34	8.4	4
Short	110	27.2	2
Normal	36	8.9	3
Erratic	224	55.4	1
Frequency of dry spell			
Yes	378	93.6	1
No	26	6.4	2
Average of dry spell length in days			
≥5	13	3.2	4
≥10	82	20.3	3
≥15	84	20.8	2
≥20	225	55.7	1
Increasingly hot			
Yes	376	93.1	1
No	28	69	2
Increasingly violent wind			
Yes	392	97	1
No	12	3	2

Source: Individual Survey (December, 2022).

3.2.3. Degradation of Pastoral Resources due to the Negative Effects of Climatic Hazards

Table 5 is based on the effects of climate hazards on pastoral resources before (years < 1990) and actual (years ≥ 1990). It shows that the condition of watering points for animals was good before (56.2%) compared to poor at present (44.8%). The condition of pastures was similar to watering points (44.6%), but very poor

Table 5. Agropastoralists' perception of the effects of climatic hazards on pastoral resource conditions.

Variables	Before		Rank	Actual		Rank
	Frequency	%		Frequency	%	
Status of watering points						
Little good	15	3.7	4	56	13.9	3
Good	227	56.2	1	62	15.3	2
Very good	139	34.4	2	33	8.2	5
Little bad	3	0.7	5	40	9.9	4
Bad	18	4.5	3	181	44.8	1
Very bad	2	0.5	6	32	7.9	6
Status of pastures						
Little good	58	14.4	3	5	1.2	5
Good	144	35.6	2	10	2.5	4
Very good	180	44.6	1	4	1.0	6
Little bad	9	2.2	5	70	17.3	3
Bad	11	2.7	4	95	23.5	2
Very bad	2	0.5	6	220	54.5	1
Status of salty land						
Little good	52	12.9	3	15	3.7	4
Good	86	21.3	2	12	3.0	5
Very good	232	57.4	1	7	1.7	6
Little bad	12	3.0	5	32	7.9	3
Bad	15	3.7	4	255	63.1	1
Very bad	7	1.7	6	83	20.5	2

Source: Individual Survey (December, 2022).

at the moment (54.5%). The 57.4% of agropastoralists perceived that the saline lands were in very good condition before, but are in poor condition currently (63.1%). In the Bougouni district, agropastoralists' observations show that there is an increasing number of highly palatable species (herbaceous and woody) for all the different categories of animal species. However, most of them are disappearing due to climatic risk-related hazards (Table 6). In particular for the herbaceous species, it is about *Andropogon guyanus* (*Kunth*), *Cymbopogon giganteus* (*Chiovenda, Kerhar*), *Diheteropogon amplectens* (*Nees*), *Rottboellia exaltata* (*Robuta hook*), *Digitaria horizontalis* (*Willd*), *Sporobolus pyramida-lis* (*P. Beauv*). For woody plants, these are *Afzelia africana* (*Smith ex Pers*), *Pterocarpus erinaceus* (*Poir*), *Khaya senegalensis* (*Desr A. juss*), *Ficus gnaphalocarpa* (*miq, steud.ex A. Rick*), *Securinega virosa* (*Roxb. Ex Willd. Baill*), *Baissea multiflora*

(*Stapf*) (Figure 6).

Table 6. Main causes of these changes cited by agropastoralists on pastoral resources.

Main causes	Fréquency	%	Rank
Increasing of dry spell length	224	55.4	1
Erratic rainfall	43	10.6	3
Agricultural pressure	102	25.2	2
Abandonment of tradition	6	1.5	5
Livestock pressure	17	4.2	4
Land degradation	6	1.5	5
Late bush fires	5	1.2	6
Herbicide	1	0.2	7

Source: Individual Survey (December, 2022).

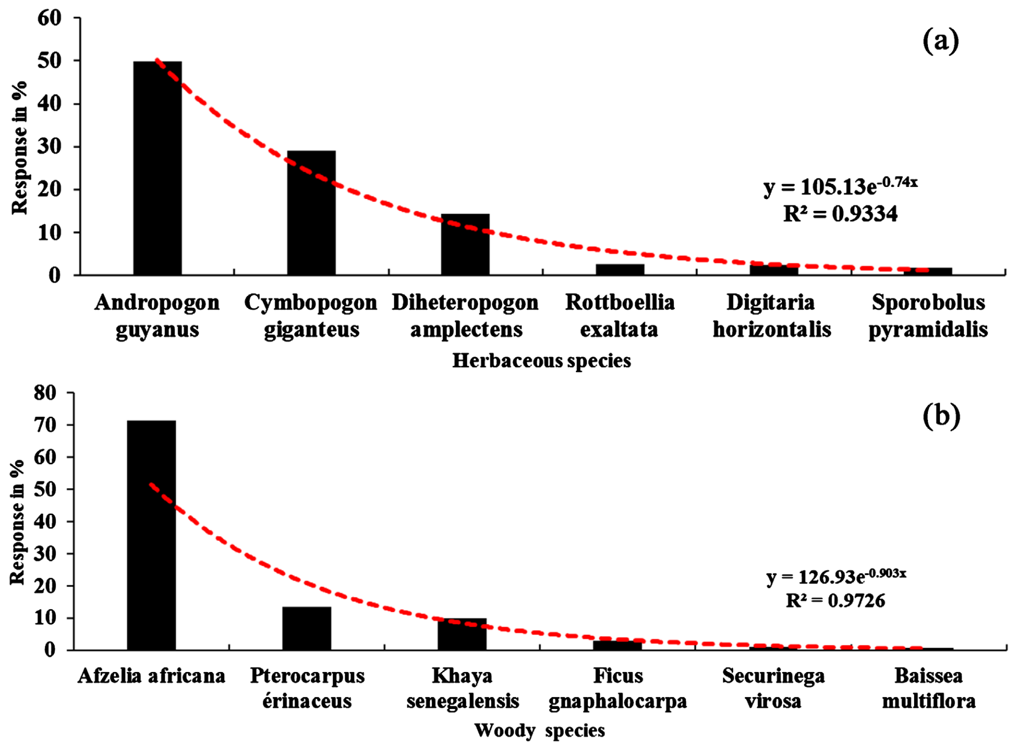

Figure 6. The six (6) main herbaceous (a) and woody (b) species highly palatable to endangered animals in the research sites. Source: Individual Survey (December, 2022).

3.2.4. Climate Change as the Main Cause of Degradation of Pastoral Resources

The main causes of degradation of pastoral resources cited by agropastoralists are the increase in long dry spells (55.4%), agricultural pressure (25.2%), erratic rainfall (10.6%), and livestock pressure (overgrazing…) (4.2%) (Table 6).

3.2.5. Multiple and Diversified Strategies to Multiple Climate Risks

Agropastoralists in the research sites have adopted response strategies to reduce their vulnerability to climate risks related to hazards. Thus, to adapt to the frequency of droughts and erratic rainfall, 49.5% practice collection and storage of crop residues; 25.7% practice adapted forage cultivation. In face to temperatures increasing, regular watering of animals (39.6%) and changing of animal rhythm driving (35.9%) are the most common strategies used. Concerted reforestation (37.9%) and the practice of protection and pruning species (31.7%) are the most important strategies to adapt to frequency of violent winds (Table 7).

Table 7. Agropastoralists' response strategies in the face of climatic risks related to hazards.

Strategies for dealing with the various climatic risks related with hazards			
	Frequency	**%**	**Rank**
Adopted strategies in face to frequent droughts			
Practice of adapted forage cultivation	104	25.7	2
Collection and storage of crop residues	200	49.5	1
Practice of woody biomass Mowing	56	13.9	3
Practice of transhumance	14	3.5	4
Action in face to rising temperatures			
Driving the herds in the early evening	74	18.3	3
Changing of animals rhythms driving	145	35.9	1
Regular watering of the animals	160	39.6	2
Reforestation of shaded species	15	3.7	4
Action in face to Strong Winds			
Concerted Rebuilding	153	37.9	1
Assisted Natural Regeneration practice	113	28.0	3
Protection of pruning species	128	31.7	2
Planting of palatable woody species	10	2.5	4
Action in face to erratic rainfall			
Practice of adapted forage cultivation	90	22.3	2
Creation of water reservoirs and development of watering points	53	13.1	4
Collection and storage of crop residues	100	24.8	1
Purchase of supplementary feed	55	13.6	3

Source: Individual Survey (December, 2022).

4. Discussion

4.1. Concordance between Agro-Pastoralists Perceptions and Evidence from Meteorological Station Data

In the Bougouni district, agropastoralists perceived the manifestations of climate change. This perception is in concordance or in contradiction with observations from meteorological stations. In comparison, the decrease in rainfall perceived by agropastoralists is consistent with meteorological data from 1950 to 2022 indicating a reduction in rainfall of 213 mm. These results are contradictory to that obtained by Traore et al. (2022) in the Sudanian zone of Mali, who reported an increasing in rainfall trend since 1997 for meteorological data observations from 1983 to 2018. Agropastoralists perceived an increasingly late start to the rainy season corroborating meteorological observations that illustrate a delay in the start of the rainy season at 6 days between 1950-1979 and 1980-2009. The end of the rainy season remains stable according to the respondents, but the meteorological observations reveal an early end of 4 days. The frequency of dry sequences greater than or equal to 20 days is perceived by agropastoralists at the beginning of the rainy season, which is consistent with meteorological observations indicating a frequency of dry spells greater than or equal to 20 days in May. Idrissou et al. (2020) in the dry and sub-humid tropical zone of Benin and those obtained by Alle (2014), in southern Benin illustrated that there is a concordance between meteorological observations data and the perceptions of herders regarding later dates of installation of the rainy season. There is a slight contradiction between the meteorological observations and the perceptions of herders regarding the dates of the end of the rainy season.

Respondents indicated that an increase in temperature and frequency of high winds. This is consistent with meteorological observations data (+1.33˚C for maximum and +1.24˚C for minimum temperatures and +0.59 m/s for winds). Similar studies were conducted by Coulilbal et al. (2022) in Diéma in Mali and Borana in southern Ethiopia (Debela et al., 2015), reporting that respondents observed an increase in temperature during both the dry and rainy seasons and the strength of the wind is increasingly violent compared to the past. Increasingly hot temperatures and increasingly violent winds have been observed by surveys in the Sahelo-Sudanian zone of Burkina Faso (Bambara et al., 2013). According to Gnanglè et al. (2005), farmers' perceptions of climate change are consistent with trends of meteorological observations data.

4.2. Adverse Effects of Climatic Hazards on Pastoral Resources Degradation

The majority of respondents noted that a degradation of pastoral resources, particularly watering points, pastures, and salty lands. These influences on pastoral resources are mainly due to the increase in long-term dry spells, erratic rainfall, and agricultural and livestock pressures. Similar results were obtained by Nepali & TAMANG (2022) who report that changing extreme climatic events directly affect the availability of forage, water, forest and pasture diseases for animals. According to Thornton et al. (2009) and Amole et al. (2022), the climate change impacts on livestock and livestock production systems in developing countries; and those of in West African Sahel concluded that climate change can alter the composition of pastures, such as changes in the ratio of grasses to legumes, dry matter (DM) yields. As a result, several woody or herbaceous species that are highly appetizing to animals are disappearing due to climatic risk-related hazards, including *Andropogon guyanus* (*Kunth*)*, Cymbopogon giganteus*, *Diheteropogon amplectens, Rottboellia exaltata, Digitaria horizontalis, and Sporobolus pyramidalis* for herbaceous species. For the woody plants, they are *Afzelia africana, Pterocarpus erinaceus, Khaya senegalensis, Ficus gnaphalocarpa, Securinega virosa, Baissea multiflora*. These results are related to that obtained by Idrissa et al. (2020) in the pastoral enclave of Dadaria, Diffa region in Niger, and by Kiema et al. (2014) in Burkinabe faso, who indicated that the area of vegetation cover is declining, reflecting a decline in certain species. Degradation of pastures resulting in a decrease in the availability of fodder biomass, a decrease in the diversity of fodder species, with well-favored species such as *Andropogon gayanus Kunth, Brachiaria lata* (*Schumach.*) *C. E. Hubbard, Alysicarpus ovalifolius* (*Schum. and Thonn.*)*Echinochloa stagnina.*

4.3. Diverse Strategies Adopted in Face to Multiples Climate Hazards

In the Bougouni district, agropastoralists have not remained inactive in face to negative effects of climate hazards. They have adopted strategies that allow them to be resilient to these climatic risks and hazards. The main strategies adopted are based on the collection and storage of crop residues, the practice of adapted fodder crops cultivation, the changing of animal rhythms driving, regular watering of animals, the practice of assisted natural generation, the protection of large species, the collection and storage of hay, the purchase of supplementary food, the digging of water reservoirs and the development of watering points, and the practice of transhumance. Results were obtained by Sabaï et al. (2014) in the Sudano-Sahelian zone of Benin reported that in order to adapt to climate change, agropastoralists practiced planting, multiplying watering points, storing hay, purchasing livestock feed, and using woody leaves as fodder. In the Sahel, research by Bonnet & Guibert (2014) reports that pastoralists purchase feed and secure fragile animals in times of scarcity, and that the mobility of animals allows them to save all or part of the herd. The mobility of pastoral communities is less vulnerable to livestock losses compared to those with sedentary livelihoods (Filho et al., 2020).

5. Conclusion

The main objective of this research was to analyze the risks and influences of climate hazards on pastoral resources and the adopted strategies by agropastoralists to cope with them. The results obtained indicated a concordance between agropastoralists' perception of climate change and meteorological observations concerning the decrease in rainfall, the increase in temperatures and wind speeds in the Bougouni district from 1950 to 2022. The respondents identified four climate risks related to hazards, including the frequency of dry spells, rising temperatures, the frequency of violent winds, and erratic rainfall. These climatic risks contribute to a deterioration of pastoral resources conditions (pastures, watering points and salty lands). These degradations are manifested by a low density of pastures, a reduction of the annual cycle of species, a decrease of herbaceous species (*Andropogon guyanus, Cymbopogon giganteus, Diheteropogon amplectens, Rottboellia exaltata, Digitaria horizontalis, Sporobolus pyramidalis*) and woody species (*Afzelia africana, Pterocarpus erinaceus, Khaya senegalensis, Ficus gnaphalocarpa, Securinega virosa, Baissea multiflora*) that are highly palatable to animals; early drying up of watering points and pollution of available water; collapse of salt land sites.

However, the agropastoralists have not remained inert in face to these climatic hazards. They have adopted response measures that allow them to be resilient. These include the collection and storage of crop residues, the practice of fodder crops, the mowing and conservation of green herbaceous biomass, the creation of water reservoirs and watering points, planting of appetizing woody species against the frequency of dry spells and erratic rainfall; regular watering of animals, modification of the rhythms of driving animal, reforestation of shaded species against temperature increases; protection of pruned species, the practice of assisted natural regeneration and concerted reforestation against the frequency of violent winds.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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