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Par

SANOGO Tidiani

INFLUENCE OF CLIMATE RISK RELATED HAZARD ON PASTORAL RESOURCES AND RESPONSE STRATEGIES IN THE SOUTH-WEST OF MALI, WEST AFRICA

Soutenue publiquement le 12 mars 2025 devant le jury composé de :

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Specialty: Climate change and disaster risk management

By

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Publicly defended on 12th March 2025 before the jury composed of:

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DEDICATION

To my dearest mother **Salimata CISSE**,

who always sacrificed herself for my success and never failed in her role as a mother

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ACRONYMS AND ABBREVIATIONS

ACF	: Action Contre la Faim
ANR	: Assisted Natural Regeneration
AU	: African Union
BMBF	: German Federal Ministry of Education and Research
CC	: Climate Change
CCDRM	: Climate Change and Disaster Risks Management
CNRTL	: Centre National de Ressources Textuelles et Lexicales
CRA	: Centre Regional Agrhymet
DER	: Département d'Enseignement et de Recherche
DM	: Dry Mater
DNP	: Direction Nationale de la Population
DNPIA	: Direction Nationale des Productions et des Industries Animales
DRR	: Disaster Risk Reduction
ETM	: Enhanced Thematic Mapper
FAO	: Food and Agriculture Organization
GDP	: Gross Domestic Product
GPS	: Global Positioning System
GLCF	: Global Land Cover Facility
FGD	: Focus Group Discussion
GIZ	: Deutsche Gesellschaft für Internationale Zusammenarbeit
Ha	: Hectare
HFA	: Hyogo Framework for Action
IFAD	: International Fund for Agricultural Development
IMPD	: Initiative Mondiale pour un Pastoralisme Durable
INSTAT-Mali	: Institut National de la Statistique du Mali
IPCC	: International Panel on Climate Change
IRICS	: International Refugee and Immigrants Community Services
LDSP-M	: Livestock Development Support Project in Mali
LVI	: Livelihood Vulnerability Index
LTA	: Long Terme Average
MRD	: Ministry of Rural Development
NAM-M	: National Agency of Meteorology of Mali
NDVI	: Normalized Difference Vegetation Index
NDWF	: National Directorate of Water and Forests
PANA-Mali	: Programmes d'Action Nationaux aux fins de l'Adaptation du Mali
OLI	: Operational Land Image
PCM	: Pastoral Charte of Mali
PNDEM	: Programme National de l'Elevage au Mali
PRAPS	: Projet d'Appui au Pastoralisme au Sahel
PROGEBE	: Projet régional de Gestion durable du Bétail Endémique
PSPS-M	: Pastoralism Support Project in the Sahel in Mali
PV	: Pastoral Value
RGPH	: Recensement Générale de la Population et l'Habitat
RN	: République du Niger
SDGS	: Sustainable Development Goals
SDPLS	: Sustainable Development of Pastoral Livestock in the Sahel
SLPIA-B	: Service Local des Productions et des Industries Animales de Bougouni
SPI	: Standardized Precipitation Index

TLU	: Tropical Livestock Unit
TM	: Thematic Mapper
UL	: University of Lome
UNDP	: United Nations for Development Program
UNDRR	: United Nations International Strategy for Disaster Risk Reduction
UNEP	: United Nations Environment Programme
UNOWAS	: United Nations Office for West Africa and the Sahel
USAID	: United States Agency for International Development
USGS	: United States Geological Survey
UTTSB	: University of Technic and Technology Sciences of Bamako
UTM	: Universal Transverse Mercator
WASCAL	: West African Science Service Centre on Climate Change and Adapted Land Use
WGS	: World Geodetic System
WMO	: World Meteorological Organization
ZEF	: Zentrum für Entwicklungsforschung

ABSTRACT

Pastoral resources play an important role in the livestock production and reproduction system in the south-west of Mali. These pastoral resources are very sensitive to climatic hazards which are negatively affecting their availability in quantity and quality. This research aims to analyze the influence of climate hazards on pastoral resources and response strategies to strengthen agro-pastoral communities' resilience. To achieve this, meteorological data trends from 1950 to 2022, satellite images, and phyto-ecological data were analyzed. The socio-demographic data were collected through a semi-structured survey administered to 404 head households, from focus groups through discussion with local stakeholders by using a climatic risks matrix. The results obtained indicate a concordance between agropastoralists' perception of climate change and meteorological observations concerning the decrease of rainfall (-213 mm; agree (63.3 %)), the increase of maximum and minimum temperature (+1.33 °C, +1.24 °C; agree (93.1 %)), and the increase of wind speed (+0.59 m/s; agree (97 %)) over the past 70 years. The main climatic risk-related hazards are frequency of drought (RS=21.15) and increasing temperature (RS=17.60). Agro-pastoralists perceived depletion of pastoral resources due to these climatic hazards increasing their vulnerability. Thus, adopted strategies were collected including collection and storage of crop residues (49.5 %), regular drinking of animals (39.6 %), and changing of animals rhythms of driving (35.9 %). Agro-pastoralist communities adapt more easily to erratic rainfall and frequency of violent winds (mark 5) than the frequency of drought (mark 3) and increasing temperatures (mark 2). The influence of climatic risk-related hazards constitutes a real threat to agro-pastoral systems in the district of Bougouni. This research permitted the enhancement of agropastoralist adaptive capacity to climate hazards in the study area.

Keywords: Pastoral resources, climatic hazards, meteorological observations, adopted strategies, Bougouni

TITRE: Influence des risques reliés aux aléas climatiques sur les ressources pastorales et les stratégies de réponses dans le Sud-Ouest du Mali, Afrique de l'Ouest

RESUME

Les ressources pastorales jouent un rôle important dans le système de production et de reproduction du bétail dans le Sud-Ouest du Mali. Ces ressources pastorales sont très sensibles aux aléas climatiques qui affectent négativement leur disponibilité en quantité et en qualité. Cette recherche vise à analyser l'influence des aléas climatiques sur les ressources pastorales et les stratégies de réponses afin de renforcer la résilience des communautés agro-pastorales. Pour ce faire, les tendances des données météorologiques de 1950 à 2022, des données d'images satellitaires et phyto-ecologiques ont été analysées. Les données socio-démographiques ont été collectées à travers une enquête semi-structurée administrée à 404 chefs de ménages, des focus groups à travers des discussions avec les acteurs locaux en utilisant la matrice des risques climatiques. Les résultats obtenus indiquent une concordance entre la perception des agro-pasteurs sur le changement climatique et les observations météorologiques concernant la diminution des pluies (-213 mm; d'accord (63.3 %)), l'augmentation des températures maximales et minimales (+1.33 °C, +1.24 °C; d'accord (93.1 %)) et l'augmentation de la vitesse du vent (+0.59 m/s; d'accord (97 %)) au cours des 70 dernières années. Les principales risques reliés aux aléas climatiques sont la frequence de sécheresses (RS=21.15) et l'augmentation de la temperature (RS=17.60). Les agro-pasteurs ont perçu l'épuisement des ressources pastorales dû à ces aléas climatiques, ce qui accroit leur vulnérabilité. Ainsi, des stratégies adoptées ont été recueillies, notamment la collecte et le stockage des résidus de culture (49,5 %), l'abreuvement régulier des animaux (39,6 %), le changement des rythmes de conduite des animaux (35,9 %). Les communautés agropastorales s'adaptent plus facilement aux l'irrégularités de précipitations et aux fréquences de vents violents (note 5) qu'à la fréquence de sécheresses (note 3) et à l'augmentation des températures (note 2). L'influence des aléas climatiques constitue une menace réelle pour les systèmes agro-pastoraux dans le cercle de Bougouni. Cette recherche a permis de contribuer au renforcement de la capacité d'adaptation des agropasteurs face aux aléas climatiques dans la zone d'étude.

Mots-clés : Ressources pastorales, aléas climatiques, observations météorologiques, stratégies adoptées, Bougouni

GENERAL INTRODUCTION

Climate change is one of the major challenges facing mankind in the 21st century. That climate change including increases in frequency and intensity of extremes has reduced food and water security, hindering efforts to meet Sustainable Development Goals (IPCC, 2022b, p. 11). In addition, it is significantly increasing the likelihood of compound hazards and cascading impacts on society (R. Glasser, 2020, p. 152). Its negative impacts are more severely felt by poor people in developing countries who rely heavily on natural resources for their livelihoods. Rural poor communities rely greatly for their survival on agriculture and livestock keeping which are amongst the most climate-sensitive economic sectors (N. Aberman *et al.*, 2011, p. 1).

However, anthropogenic climate change has increased extreme sea-level events associated with some tropical cyclones, which have increased the intensity of other extreme events such as flooding and associated impacts (WMO, 2021, p. 15). Therefore, climate change and variability have exacerbated the frequency and intensity of hydro-meteorological hazards (AU, 2017, p. 6) and added greater uncertainty to the assessment of hazards and vulnerability (IPCC, 2012, p. 49). It is aggravating the costs of disasters and putting more people at risk from more powerful, more frequent, and more severe storms, floods, and droughts (World Bank, 2021, p. 1). Disasters are increasing worldwide with more devastating effects than ever before (F. Bousquet *et al.*, 2013, p. 1).

Therefore, the number of disasters has increased by a factor of five over the 50 years, driven by climate change, more extreme weather, and improved reporting; from 1970 to 2019, weather, climate, and water hazards accounted for 50 % of all disasters, 45 % of all reported deaths and 74 % of all reported economic losses; more than 91 % of these deaths occurred in developing countries (WMO, 2021, p. 16). Between 2010-2020, human mortality from floods, droughts, and storms was 15 times higher in highly vulnerable regions, compared to regions with very low vulnerability (IPCC, 2022a, p. 12). Each year, disasters result in the deaths of an average of 93,000 people mostly in developing countries and affect an average of 169 million people (A. A. Tawane & J. W. Wakhungu, 2018, p. 77). Climate change projections suggest many areas will experience droughts that are more frequent and more severe (UNDRR, 2021, p. 31).

Climate change is seen as a major threat to the survival of many species, and ecosystems and the sustainability of livestock production systems in many parts of the world (S. M. Naqvi & V. Sejian, 2011, p. 19).

It is predicted that Africa will be the hardest-hit region in terms of catastrophic natural disasters (A. A. Tawane *&* J. W. Wakhungu, 2018, p. 77) and the most vulnerable continents due to its high exposure and low adaptive capacity (IPCC, 2014, p. 1205). Climate change is projected to have an especially negative impact on Africa (C.C. Godson-Ibeji *et al.,* 2022, p. 18). Therefore, in Africa from 1970 to 2019, 1,695 recorded disasters caused the loss of economic damages 731,747 lives and US$ 38.5 billion (WMO, 2021, p. 22), consequently, the continent accounts for 15 % of weather, climate and water-related disasters, 35 % of associated deaths and 1 % of economic losses reported globally (WMO, 2021, p. 22).

Climate change is expected to heighten the vulnerability of livestock feed in terms of quality and quantity. The hot and dry seasons have induced the greatest reduction in biomass yield for different types of grass growing in low-land environments (D. Hidosa & M. Guyo, 2017, p. 1). Hence, in Ethiopia, cow milk yields remained at five (5) liters per day in a normal or good year to only one liter per day during the drought period. The average mortality during the drought was as high as 68 % of the herd, compared with a good rainfall year when on average 11 % of the herd dies (W. Patrick, R. Thomas, 1992, p. 235). Among the critical infectious diseases, rinderpest, pasteurellosis, contagious bovine pleuropneumonia, foot and mouse disease, anthrax, bloody diarrhea, skin and lung diseases and internal and external parasites are some of the critical infectious diseases and pests attacking livestock during drought and flood hazards (A. Chinasho, 2017, p. 70).

Every year, West African countries and the Sahel subregion are adversely affected by hazards, such as droughts and floods, as well as transboundary animal diseases, economic crises and civil conflicts (FAO, 2011, p. 8). Animal and human diseases, including zoonoses, are emerging in new areas (IPCC, 2022a, p. 13). These events result in losses of life, assets and livelihoods, consequently weakening the food and nutrition security of the populations (FAO, 2011, p. 8). According to various reports, climate change is responsible for the change in rainfall amount and pattern accompanied by the various degrees of extreme events in Sahelian West Africa in recent years (R. Kasei *et al.,* 2010, p. 89). In this regions, increase of temperatures has fluctuated between 0.2 and 0.8°C from 1961 to 2010 (B. Sarr *et al.,* 2015, p. 17). Therefore, climate hazards are a real concern for Sahelian people due to their adverse socio-economic and environmental impacts (UNEP, 2011, p. 5). The mainstream livestock-keeping system in the Sahelian region is the pastoral system characterized by a high dependence on natural resources. Currently, traditional practices are not able to buffer climate drivers (A. Kiema *et al.,* 2015, p. 1). Much pastoral land has been cultivated by small-scale farmers, taken for plantation agriculture, acquired by elites, or built on. Transhumance routes and access routes to water are frequently blocked or narrowed by farms and settlements, constraining pastoral mobility and leading to the destruction of crops by cattle (UNOWAS, 2018, p. 26).

Livestock system has long been recognized as a particular problem due to climate change mitigation. Therefore, it contributes to reducing farm pollution and building more productive food systems and security. Livestock products account for 17 % of world calorie consumption and 33 % of global protein consumption, making them an important agricultural commodity for global food security. Furthermore, the livestock sector contributes to the livelihoods of one billion of the world's poorest people and employs nearly 1.1 billion people (G. A. Bogaleaand & Z. B. Erena, 2022, p. 471). Livestock is the sole source of livelihood for at least 20 million pastoral families and an important source of income for at least 200 million stalk-holder farmer families (S. Bekele, 2014, p. 53).

This Livestock system in Africa faces multiple stressors that can interact with climate change and variability to amplify the vulnerability of livestock-keeping communities. These stressors include rangeland degradation, increased variability in access to water, and fragmentation of grazing areas (IPCC, 2014, p. 1219). The length of the pasture growing period is expected to decrease in many parts of the tropics and this may be accompanied by greater variability in rainfall patterns with more frequent droughts (D. Hidosa & M. Guyo, 2017, p. 1). In this drought year cattle died because pasture ran out, while many which were taken to boreholes consumed all the grass around them, so that other livestock taken there later starved. Thus, 'overgrazing', in a sense, killed livestock in the drought years. Cattle losses were estimated at between 20 and 40 percent in some Sahelian regions (J. Derrick, 1977, p. 555). The livestock numbers fluctuated heavily and many villages of "Fulbe" lost 62 percent of their cattle and 55 percent of their small ruminants during these droughts (H. V. Djik, 1997, p. 13). The 1970-1990 period experienced a rainfall deficit of 30 to 50 % compared to the 1950-1969 period (O. Marega & C. Mering, 2018, p. 2). Moreover, droughts will likely increase in the future due to climate change (J. Frischen *et al.*, 2020, p. 1).

Increasing temperatures in lowland areas of Africa could result in reduced stocking of dairy cows in favor of cattle, a shift from cattle to sheep and goats and decreasing reliance on poultry (IPCC, 2014, p. 1220). The carbon dioxide levels and nitrogen deposition decrease the primary production in pastures (D. Hidosa & M. Guyo, 2017, p. 1). Moreover, Increased temperatures increase the signification of plant tissues and thus reduce the digestibility and the rates of degradation of plant species (T. Garnett, 2013, p. 4). The climate change projections are predicting loss of livestock productivity, loss of rangelands and water sources (USAID, 2017, p. 1). The occurrence of droughts and floods all negatively affects forage and fodder production, water availability, and livestock productivity (USAID, 2017, p. 3). Drought is an environmental stress that is characterized by periods of limited or no water during the growing season and results in a decrease in forage production for grazing and haymaking. Prolonged drought forces livestock and hay producers to better manage their fields to minimize recovery after the drought ends (V. Sejian *et al.,* 2012, p. 449). Temperatures rising impacts negatively rangelands, pastures and cultivated forages; changing rainfall regimes, and the effect of increased atmospheric CO_2 (J. Morton, 2012, p. 18).

In addition, the rise in temperatures, the shortening of the rainy season, drought and high winds all have major impacts on animal health, loss of herbaceous seeds and availability of fodder and the organization of communities (C.C. Godson-Ibeji *et al.*, 2022, p. 20*;* I. Ali *et al.,* 2022, p. 9). To maintain flexibility in resource access, pastoralists have to engage in continuous negotiations with other resource users. Mobility represents an essential component of the herds' productivity. It allows it to benefit from fodder resources which vary in quantity and quality in different areas during the year (PRAPS, 2017, p. 6).

The pattern and availability of rainfall have a huge impact on the spatial distribution and availability of pasture and water. Changes in rainfall patterns and temperature ranges also have an impact on feed availability, grazing ranges, feed quality, weed, pest, and disease incidence. Climate change affects animal productivity in two ways, the quality and quantity of fodder from grasslands may change, and greater temperatures may have direct consequences on livestock (G. A. Bogale *et al*., 2022, p. 476). Climate change is projected to have the greatest impact on vulnerable pastoral communities that rely on huge livestock production systems in arid environments (S. Oseni & O. Bebe, 2010, p. 4). Warming is also expected to alter the feed intake, mortality, growth, reproduction, maintenance, and production of animals (T. Gashaw *et al.,* 2021, p. 40). In Borana (Ethiopia), climate change impacts on livestock production induce heavy infestation of invasive species has reduced the availability of herbaceous species and hence resulted in a critical shortage of feed, shortage of water supply for animal watering, changes in livestock genetics (Y. Zelalem *et al.,* 2009, p. 22). Increasing temperatures and decreasing rainfall reduce yields of rangelands and contribute to their degradation (S. Tiruneh & F. Tegene, 2018, p. 53). Higher temperatures tend to reduce animal feed intake and lower feed conversion rates (S. Tiruneh & F. Tegene, 2018, p. 53).

Livestock is the sole source of livelihood for at least 20 million pastoral families and an important source of income for at least 200 million stalk-holder farmer families in Africa (S. Bekele, 2014, p. 53).

Thus, it is very relevant to look at livestock farming in Mali. The under-sector of livestock breeding is very important for the Malian economy. Its contribution to Gross Domestic Product (GDP) is 15.2 % behind agriculture at 16.2 % (UNOWAS, 2018, p. 39; DNPIA, 2022, p. 7). This livestock population is very high and diverse in terms of breeds (PROGEBE, 2015, p. 17). The practiced livestock farming in Mali is pastoral type, which is estimated at 13,234,158 heads of cattle, 22,207,301 heads of sheep, 30,661,134 heads of goats, 619,942 heads of horses, 1,214,379 heads of donkeys, 1,317,057 heads of camels, 89,322 heads of pigs and 57,438,542 subjects of poultry (DNPIA, 2022, p. 25). The second source of income after agriculture (IMPD, 2007, p. 3), this sector employs 80 % of the rural population and constitutes an important source for their livelihood (PNDEM, 2004, p. 2).

Despite the economic importance of this sector, Mali has already felt the adverse influence of climate-related hazards since the drought episodes of the 1970s, resulting in a reduction in the quantity and quality of pastures (PANA-Mali, 2007, p. 17). The uneven distribution of rainfall and violent wind lead to early drying of the water point, water scarcity and increased degradation of pasture (T. Sanogo *et al.,* 2016, p. 57; T. Sanogo *et al.,* 2023, p. 263). Additionally, the vegetation cover in Mali is decreasing with 100,000 Ha per year as an average (D. Konaré *et al.,* 2019, p. 204).

However, In the South-West of Mali, due to the quality of climatic conditions compared to other areas of the country, pastoral resources are rich in nutritive components and constitute attractive sources of livestock herds coming from different areas throughout the country. In the Bougouni district, forage production was evaluated at 158,250 kg per year as an average (SLPIA-B, 2020, p. 31). Additionally, In the wake of the crisis located in the north and center regions (Tombouctou, Gao, Mopti, Segou..), the District of Bougouni has become a pastoral zone by excellence. The considerable number of livestock which reach in that zone each year added by the extension of cropland are putting pressure on the shared pastoral resources which leads to its rarefaction and degradation (D. Konare *et al.*, 2019, p. 205). Nowadays, that situation is aggravated by the adverse impact of climate-related hazards.

From these observations, the problem of the effect of climatic hazards on the degradation of pastoral resources arises. This problem raises a number of research questions, hypotheses and objectives including mains and secondaries respectively.

- **RESEARCH QUESTIONS**

The main question of this research is to know:

what are the influences of climate risk-related hazards on pastoral resources and response strategies to strengthen the resilience of agro-pastoral communities in South-West of Mali?

This main question leads to the following secondary questions:

- what are the major climate risk-related hazards according to the perception of agro-pastoral communities on climate change in the study area?
- what are the impacts of climate risk-related hazards on pastoral resources in the environment of study?
- how is the Livelihood Vulnerability Index (LVI) of agro-pastoral communities in the study area?
- what are the effective response strategies of agro-pastoral communities to climate risk-related hazards for Disaster Risk Reduction (DRR) in the research sites?

To answer the posed questions, the following research hypotheses have been raised.

- **RESEARCH HYPOTHESIS**

The main hypothesis of this research states that:

The influence of climate risk-related hazards on pastoral resources leads to its low availability in terms of both quality and quantity, and the methods of valorization of pastoral ecosystems are the response strategies for strengthening the resilience of agro-pastoral communities in South-West of Mali.

From this main hypothesis, the following secondary hypotheses emerge:

- drought and strong winds are some of the major climate risk-related hazards according to the perception of agro-pastoral communities on climate change in the study area;

- the degradation of pasture areas and the early drying up of water points are some of the impacts of climate risk-related hazards on pastoral resources in the study area;
- the Livelihood Vulnerability Index (LVI) of agro-pastoral communities is high in the study area;
- The protection of pasture areas and the promoting of forage crops are some of the effective response strategies of agro-pastoral communities to climate risk-related hazards for Disaster Risk Reduction (DRR).

In order to carry out this research, objectives are set.

- **RESEARCH OBJECTIVES**

The general objective of this research is to analyze the influence of climate risk-related hazards on pastoral resources and response strategies in order to strengthen the resilience of agro-pastoral communities in South-West of Mali.

Specifically, this research aims to:

- determine the major climate risk-related hazards according to the perception of agro-pastoral communities on climate change in the study area;
- assess the impacts of climate risks related-hazards on pastoral resources in the study area;
- assess the Livelihood Vulnerability Index (LVI) of agro-pastoral communities in the study area;
- elaborate the effective response strategies for agro-pastoral communities to climate risk-related hazards for Disaster Risk Reduction (DRR).

LITERATURE REVIEW

Terminologies and Definitions

Climate Change (CC) refers to a change in the state of the climate that can be identified (using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer (IPCC, 2012, p. 29). It is also defined as any change in climate over time, whether due to natural variability or as a result of human activity (IRICS, 2011, p. 11).

Risk is the probability that a hazard event will occur and cause damages or losses at a given place and time. It is a combination of the possibility of a hazard happening, the vulnerability of the target system to the hazard and the scale of damage that can occur (UNDP, 2016, p. 5; S. Schneiderbauer & D. Ehrlich, 2004, p. 9).

Hazard is defined as the potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environment resources (C. J. Van Westen, 2013, p. 2; IPCC, 2022a, p. 35; IPCC, 2022b. p. 7)**.** It is a potentially damaging physical event, phenomenon and/or human activity, which may cause loss of life or injury, property damage, social and economic disruption or environmental degradation. Hazards can be single, sequential or combined in their origin and effects (S. Schneiderbauer & D. Ehrlich, 2004, p. 10 ; HFA, 2008, p. 3). The term hazard usually refers to climate-related physical events or trends or their physical impacts (GIZ, 2017, p. 13).

Exposure is defined as the presence of people; livelihoods; species or ecosystems; environmental functions, services and resources; infrastructure; or economic, social or cultural assets in places and settings that could be adversely affected (IPCC, 2022b, p. 7)**.**

Drought, In general terms, drought is a 'prolonged absence or marked deficiency of precipitation', a 'deficiency that results in water shortage for some activity or for some group', or a 'period of abnormally dry weather sufficiently prolonged for the lack of precipitation to cause a serious hydrological imbalance (IPCC, 2007, p. 80). It is a period of abnormally dry weather long enough to cause a serious hydrological imbalance. It results from a shortfall of precipitation over a certain period, from the inadequate timing or the ineffectiveness of the precipitation, and/or from a negative water balance due to an increased atmospheric water demand following high temperatures or strong winds (IPCC, 2012b, p. 24).

Agriculturally, it is a shortage in soil moisture which is facilitated by hydrological and meteorological drought, lowering the supply of moisture for vegetation (M. A. Mothapo *et al.*, 2020, p. 13). It is also a period with abnormal soil moisture deficit, which results from a combined shortage of precipitation and excess evapotranspiration, and during the growing season impinges on crop production or ecosystem function in general (IPCC, 2021, p. 41). Drought is one of the components of weather climate extremes, and it occurs when the natural water supply is lower than normal, resulting in water-related difficulties (G. A. Bogaleaand & Z. B. Erena, 2022, p. 472).

Influence, according to the Ortolang dictionary of the Centre National de Resources Textuelles et Lexicales (CNRTL) is an action (usually slow and continuous) of a physical agent (on someone, something), causing changes of a material nature (website: https://www.cnrtl.fr/definition/influence, consulted 15th August 2023, 8:00 AM).

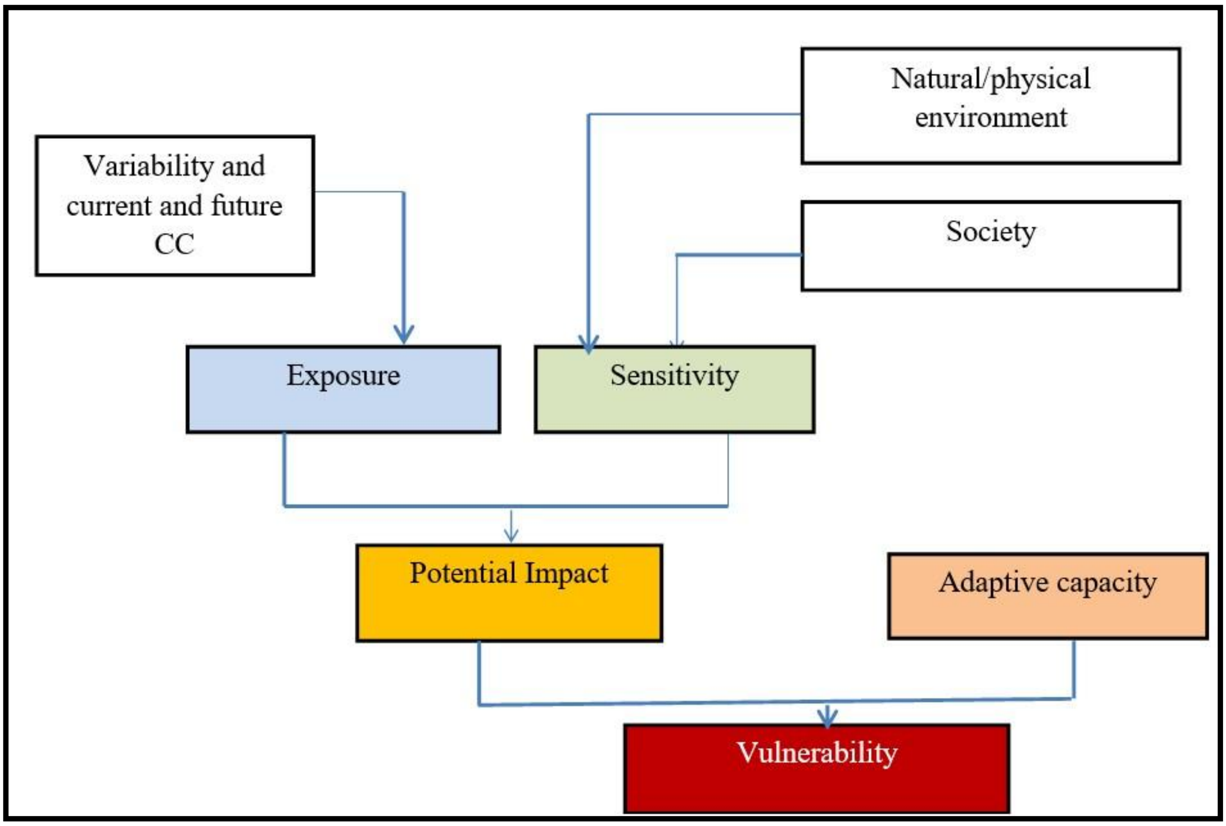
Human influence on the climate system refers to human-driven activities that lead to changes in the climate system due to perturbations of the earth's energy budget (also called anthropogenic forcing). Human influence results from emissions of greenhouse gases, aerosols and tropospheric ozone precursors, ozone-depleting substances, and land use change.(IPCC, 2021, p. 51). It refers to the effects of climate events or climate change on natural or human systems**.**

Vulnerability is defined as the propensity or predisposition to be adversely affected and encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt (IPCC, 2022a, p. 35). It means the degree to which a system, such as a community, is susceptible and exposed to the adverse effects of a given hazard. It is a condition that predisposes individuals, groups, communities or systems to hazard events. Vulnerability depends on the physical, socio-economic and environmental characteristics and circumstances that make the target system or community susceptible (UNDP, 2016, p. 5). It is a degree to which a system is susceptible to, and unable to cope with, the adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed its sensitivity, and its adaptive capacity (IPCC, 2007, p. 89 ; K. Sanogo *et al.*, 2020, p. 217).

Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt (GIZ, 2017, p. 16) (figure 1).

$$\text{VULNERABILITY} = \frac{EXPOSURE\ X\ SENSITIVITY}{ADAPTIVE\ CAPACITY} \qquad \text{Eq1}$$

Source: (Adger, 2006, p. 273; OXFAM, 2017, p. 9)



Source: GIZ, 2015, p. 20

Figure 1: Vulnerability assessment framework

Disaster is a serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its resources. Disaster is an outcome of a hazard event (UNDP, 2016, p. 3; S. Schneiderbauer & D. Ehrlich, 2004, p. 8).

Disaster risk refers to the scale of potential losses or damages that can affect a target community in the event of a disaster at a given time in the future. This can be quantified as the losses or damages in terms of lives, livelihoods, health, properties, facilities and services, among others. It is difficult to quantify all risks accurately, but it is important to identify and prioritize risks in disaster management (UNDP, 2016, p. 7).

Disaster risk management is a structured approach to manage uncertainty and potential adverse impacts from a natural hazard event, through a process of risk assessment and the development of strategies and specific actions to control and reduce risks. It is systematic, institutionalized, and covers both strategic and operational issues related to reducing vulnerability and exposure to hazards while increasing coping and response capacity (UNDP, 2016, p. 7).

Response strategies, is defined, in human systems, as the process of adjustment to actual or expected climate and its effects in order to moderate harm or take advantage of beneficial opportunities (IPCC, 2022b, p. 7). It means adopted strategies or measures to counter climate hazards.

Resilience is defined as the capacity of social, economic and ecosystems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure as well as biodiversity in case of ecosystems while also maintaining the capacity for adaptation, learning and transformation (IPCC, 2022a, p. 35). It is the ability of a community or system to resist, absorb, or recover from the effects of hazards in a timely and efficient manner, preserving or restoring its essential basic structures, functions and identity. It is the ability of the community to bounce back to normal functioning after suffering distress from a hazard event (UNDP, 2016, p. 9).

Population at risk is a well-defined population whose lives, property, and livelihoods are threatened by given hazards (UNDP, 2016, p. 10).

Pastoralism: Agricultural practice founded on extensive livestock breeding including systems where animal and/or human movement is significant: nomadism, transhumance, semi-transhumance (PRAPS, 2017, p. 2)**.** The pastoralism is understood as a production system based on the itinerant exploitation of natural resources by rearing of domestic animals of variable mobility. It contributes to the food and nutritional security of both rural and urban populations in West Africa (H. Nugteren & C. Le Come, 2016, p. 14).

Mobility: Refers to something likely to move. Regarding livestock breeding, it refers to herds moving seasonally or occasionally over small or long distances (PRAPS, 2017, p. 2)**.**

Pastoral resources are the whole of natural resources needed for the feeding of livestock. They are encompassed by water, pasture and salty land (PCM, 2001, p. 1). The term pastoral resources is a set of natural or artificial resources needed for animal feeding. They are constituted by water, pasture salty land and under agro-industrial products (RN, 2010, p. 5). They are natural resources allowing pastoral feeding of animals: water, pasture and salt marshes (PRAPS, 2017, p. 2).

Agropastoralist can be defined as someone or a person who is doing a combination of both agriculture and livestock herding activities that enables peasant societies to extensively produce the resources necessary for their needs (O. Marega & C. Mering, 2018, p. 1). An agropastoralist is a farmer who raises livestock by traditional methods and whose practices with regards to animals are similar to those of herders, as in transhumance (PRAPS, 2017. p. 2). Thus, agropastoralists are either sedentary farmers who have diversified into ruminant breeding, or pastoralists who have diversified into agriculture following the droughts of previous years (1970, 1974, 1984) or as a result of changes in individual strategies to adapt to local constraints (H. Abdou *et al.*, 2020, p. 83).

Transhumance is the livestock cycle and season movement in the custody of herdsmen according to precise itineraries in other to pastoral resources use of a given area (PCM, 2001, p. 1). It is breeding method including seasonal livestock migration. This system is very mobile and there is a return to seasonal bases each year. Farmers have a permanent residence. The calendar and itineraries are regular and the movements are mostly predictable. They are based on seasons and towards known pastures (PRAPS, 2017, p. 2).

Bowal is degraded land surface characterized by ferricrete exposure due to soil surface erosion (E. A. Padonou *et al.*, 2015, p. 45). It is also a shallow soil above lateritic crusts is often waterlogged during the rainy season and extremely dry during the dry season. The typical vegetation are grass savannahs, woody plants are usually absent from these habitats (M. Schmidt *et al.*, 2012, p. 107).

Shrubby savannah is a formations of vegetation where the height of the woody is between four and eight meters (K. K. Edouard & S. Y. Charles, 2014, p. 280). It is similar to wooded savannah but the tree layer is replaced by a shrub layer. The rate of shrub cover is less than 70 % (F. H. Hiol *et al.*, 1983, p. 171).

Wooded savannah is a vegetation formation in which trees and shrubs form a clear canopy (20-70 % cover) that provides ample light transmission (F. H. Hiol *et al.*, 1983, p. 170).

Biomass is a measure of vegetation production, specifically Dry Matter (DM) expressed in kilograms per day and per hectare. The term "dry matter" is used to describe any form of vegetation above ground level, without taking into account its water content. For an analysis of the pastoral situation, DM is an effective way of measuring the availability of fodder resources in a standardised way. (ACF, 2016, p. 3).

Impacts of climate hazards in the World and West Africa

The scientific understanding of climate change and its impacts has increased dramatically in recent years, but several interacting sources of uncertainty mean that future climate change and its impacts will not be known with precision for the foreseeable future (H. Kunreuther *et al.*, 2013, p. 447). The world has experienced an increasing impact of disasters in the past decades. Many regions are exposed to natural hazards, each with unique characteristics. The main causes for this increase can be attributed to a higher frequency of extreme hydro-meteorological events, most probably related to climate change, and to an increase in vulnerable populations (C. J. Van Westen, 2013, p. 1).

However, there is now wide recognition of the need to include disaster risk management concerns in dealing with to climate change (R. Glasser, 2020, p. 154). The Inter-Governmental Panel on Climate Change (IPCC) identified floods, drought, heat waves, desertification, violent winds, and outbreak of disease and food insecurity as top among the effects of climate change (IPCC, 2021, p. 221). The number of floods and other hydrological events have quadrupled since 1980 and have doubled since 2004. Climatological events, such as extreme temperatures, droughts, and forest fires, have more than doubled since 1980. Meteorological events, such as storms, have doubled since 1980 (R. Glasser, 2020, p. 152).

Moreover, between 1970 and 2019, there were more than 11,000 disasters attributed to weather, climate and water-related hazards, which accounted for just over 2 million deaths and US$ 3.64 trillion in losses (WMO, 2021, p. 7). The disaster loss recording process has involved compiling the loss and damage in terms of deaths and economic losses, and then attributing them to a hazard event based on various sources such as newspaper reports and other literature, as well as national scientific and technical agencies (WMO, 2021, p. 12).

This variability of climate has increased since the 1950s mainly because of the increased concentration of anthropogenic greenhouse gases in the atmosphere (M. Ly *et al.*, 2013, p. 19). Additionally, it has been predicted that by 2100 the increase in global average surface temperature may be between 1.8 °C and 4.0 °C. With increases of 1.5 °C to 2.5 °C, approximately 20 to 30 percent of plant and animal species are expected to be at risk of extinction with severe consequences for food security in developing countries (IFAD, 2010b, p. 4). This climate change affects most socioeconomic sectors in West Africa. Over the past 100 years, rainfall has declined by 20-30 % while the mean temperature increased by up to 1.3 °C in the West African Sahel. Furthermore, there is an uneven spatial and temporal distribution of the rainfall in this area of West Africa (K. Sanogo *et al.*, 2020, p. 213). The IPCC last report describes the Sahel as a hotspot of climate change with temperatures expected to increase by between 3 °C and 6 °C by the end of the 21st century compared to those in the late 20th century, while changes in precipitation are uncertain (D. Gautier *et al.*, 2016, p. 667).

Moreover, that's climate change is regarded as having a major impact on key sustainable socio-economic and environmental indicators in Sub-Saharan West Africa (B. Sarr *et al.*, 2015, p. 16). In West Africa, agriculture, essentially rainfed, is the most important economic sector and the one most vulnerable to climate change. It is an increasingly serious threat for West African countries through a whole of factors that include weak adaptive capacity, high dependence on ecosystem goods for livelihoods, and less developed agricultural production systems (K. Sanogo *et al.*, 2020, p. 214).

Impact of climate hazard based-drought on livestock system

Hazard is defined here as the potential occurrence of a natural or human-induced physical event that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, and environmental resources (IPCC, 2012, p. 32). The spatial distribution and availability of pasture and water are highly dependent on the pattern and availability of rainfall. Changes in the patterns of rainfall and ranges of temperature affect feed availability, grazing ranges, feed quality, weed, pest and disease incidence (T. Gashaw *et al.*, 2021, p. 40).

The weight of climatic conditions in the development process of pastoral livestock is therefore not negligible. The availability of fodder depends on rainfall and the same for watering points (K. Sokemawu, 2008, p. 252), while the livestock sector accounts for 40 % of the world's agricultural Gross Domestic Product (GDP) and 1.3 billion people depend upon livestock husbandry for their livelihood (V. Sejian *et al.*, 2012, p. 436).

The drought and delay of rainfall led to increased mortality of livestock, vulnerability to diseases, and physical deterioration due to long-distance travel for water and pastures (S. Bekele, 2014, p. 55). Drought affects almost all dimensions of the environment and society, and directly influences the achievement of sustainable development goals (SDGs). Drought conditions frequently remain unnoticed until water shortages become severe, and adverse impacts on the environment and society become evident (UNDRR, 2021, p. 42). Species richness decreased in the second half of the 20th century and both tree density and the plant cover decreased significantly during the droughts in the 1970s and 1980s but non climatic factors (such as changes in land use due to human activities) could also explain these trends (D. Gautier *et al.,* 2016, p. 670).

However, as shown by the droughts in the 1970s and the 1980s, the efficiency of these adaptation strategies may be limited. Since the early 1970s, international attention has focused on the impacts of drought on local populations in the Sahel and on the risks of famine and malnutrition (D. Gautier *et al.*, 2016, p. 666 and 667).

Most of the victims of animals are attributed to the many severe droughts in the early 1980s that, for example, in the Sahel region killed about 400,000 just in the year 1983 (U. Ranke, 2016, p. 38). The drought that took place in the year 1973/74 in the Afar pastoral region of Ethiopia had resulted in livestock mortalities of 90 %, 30 %, 50 %, and 30 % for cattle, camels, sheep, and goats respectively due to the shortage of forage supply and water (D. Hidosa & M. Guyo, 2017, p. 2).

The impacts of climate hazard lead to animal performance degradation in terms of milk and meat production due to high temperature, increasing of floods risk and droughts. Climate hazard impacts result also to forage and water availability reduction and wild spread of infectious diseases from climate conditions (A. Zaatra, 2022, p. 141). Higher temperatures reduce feed intake and lead to energy deficits and decreased milk production, fertility, fitness, and longevity, while drought can reduce calving rates from the normal 60-70 percent to 25-30 percent (USAID, 2017, p. 3). Crop production was the most affected subsector, accounting for 42 % of all agricultural losses, followed by livestock production with 36 %.

Almost 86 % of reported loss and damage was due to drought events (UNDRR, 2021, p. 48). Between 1990 and 2000, the World Bank estimated that in several developing countries, disasters had caused damage representing between 2 and 15 percent of their annual (IRICS, 2011, p. 6). Drought affects agricultural areas with loss of livestock and reduction in livestock production, decreased resistance of livestock to diseases and reduced yields or crop failure (UNDRR, 2021, p. 92).

Climate change impacts will have a substantial effect on global water availability in the future. This will not only influence livestock drinking water sources, but it also affect livestock feed production systems and pasture yield (T. Garnett, 2013, p. 2). Rivers have decreased as the area under cultivation has expanded, including for irrigated dry season farming.

However, it was perceived that since the 1984 drought, the number of livestock in the Timbuktu region has diminished, a situation worsened by the lack of education and professional training for nomads (whether men or women) and limited state support for pastoralism. Consequently, a large number of pastoralists have left the Timbuktu region (70 % according to informal estimates) (UNOWAS, 2018, p. 44).

Impact of livestock system on climate change reduction

The livestock system is held responsible for about 12 % -18 % of all anthropogenic greenhouse gas (GHG) emissions but while being associated with many critical environmental impacts, livestock reduces vulnerability to environmental risks for 600 million poor smallholder farmers (I. Weindl *et al.*, 2015, p. 1).

However, Animals provide energy by transforming plant energy into useful work and provide dung used for fuel through dung cakes or biogas to replace charcoal and wood. In an age in which energy demands are increasing, measures are needed to implement a more efficient use of biomass reducing pressures on natural resources.

Therefore, it is necessary to develop sustainable livestock manure management to control environmental losses and contaminant spreading (IFAD, 2010a, p. 13). In India, some strategies have been implemented to reduce methane emission from livestock such as improved genetic selection to produce low methane-producing animals, efforts to reduce livestock population, and improving grassland management.

The diet modification through ammonia and molasses feeding to reduce methane, increasing the proportion of concentrate feeding, and employing advanced technology like immunization and recombinant technology leads to a reduction of methane production (S. M. Naqvi & V. Sejian, 2011, p. 23).

In particular, the potential benefits of extensive livestock systems are highlighted, including supporting livelihoods, providing high-quality nutrition, enhancing biodiversity, protecting landscapes, and sequestering carbon. By failing to differentiate between livestock systems, global assessments may mislead (I. Scoones, 2023, p. 1). In the developing world, many low-producing animals could be replaced by fewer but better-fed animals of a higher potential to reduce total emissions while maintaining or increasing the supply of livestock products (P. Thorton *et al.,* 2011, p. 1).

The double bonus of energy and compost motivated poor people to adopt the technology of biogas as a source of household energy in significant numbers. More than 22,600 biogas tanks involving almost 30,000 households in more than 3,100 villages. As a result, 56,600 tonnes of firewood can be saved in the project area every year, equivalent to recovering 7,470 hectares of forest (IFAD, 2010b, p. 10).

- **Livestock system adaptation to climate hazard in West Africa**

An increase in temperature affects livelihood practices in the region, which remain uncertain, such as potential changes in evapotranspiration rates and water availability (UNEP, 2011, p. 34). Where rainfall is reduced, water availability for cattle and fodder production is affected, leading to changes in migratory patterns for pastoralists (UNEP, 2011, p. 38).

Therefore, the adverse effects of climate hazards compel livestock producers to build several adaptation strategies. Among the whole strategies, there is livestock mobility. This livestock mobility allows for a flexible response to ecological variability, which involves reducing pastoralist vulnerability to climate change and the likelihood of overgrazing (L. Brottem *et al.,* 2014, p. 351).

However, this adaptation is linked to the availability of socio-economic and environmental conditions in a given place. Agro-pastoralists develop supplementary agriculture during the rainy season and go on transhumance during the dry season to make use of pastoral resources (water, fodder) that are often randomly distributed in space and time (O. Marega & C. Mering, 2018, p. 1).

This practice of transhumance allows easy access to pastoral resources, the livestock market, and animal genetic/breed strengthened (D. Konaré *et al.,* 2019, p. 216). It permits to restoration of pasture areas and enhances the reproduction conditions (E. M. Moutari & F. Giraut, 2013, p. 310). In addition, identifying and strengthening the adapted local breeds to local climatic stress and feed sources are adaptive strategies (T. Garnett, 2013, p. 7). On the other hand, it was concluded that information available on the impact of climate change should be demonstrated to all pastoralists' communities and policymakers in order to design mitigation interventions (D. Hidosa & M. Guyo, 2017, p. 3).

- **Impact of climate hazard on pastoral resources in Mali**

Climate-related hazards in Mali include droughts, floods, and crop pests. These hazards are a natural occurrence in Mali, which nevertheless pose serious constraints on development and food security, and their intensity and frequency are likely to increase under a changing climate (World Bank, 2010, p. 5).

The years of extreme deficit (1973, 1983 and 1984) correspond to major droughts that sometimes had dramatic consequences for humans and their herds (O. Marega & C. Mering, 2018, p. 2). During this long period of drought, fodder availability was much lower than in the more humid Sudanese regions, as crop production in the Sahel, is closely correlated to the amount of rainfall.

For this reason, Sahelian agro-pastoralists in general and particularly Malians were forced to push the boundaries of dry season pastures further south (O. Marega & C. Mering, 2018, p. 5). Additionally, the 2004 drought across the north, brought about by rainfall deficits, seriously affected transhumant populations, forcing pastoralists to remain near permanent water sources and leading to considerable overgrazing. Crop losses in and around Mopti, Segou, and Tombouctou are often the result of extended dry spells, poor rainfall and dry conditions (World Bank, 2010, p. 7).

However, water resources dry up early following the phenomena of temperature rise / strong sunstroke and strong winds. The water table level continues to drop compared to previous years. Some very rich plant species (woody and herbaceous) which are popular with animals are endangered because they are no longer able to adjust to current climatic conditions (T. Sanogo *et al.,* 2016, p. 57).

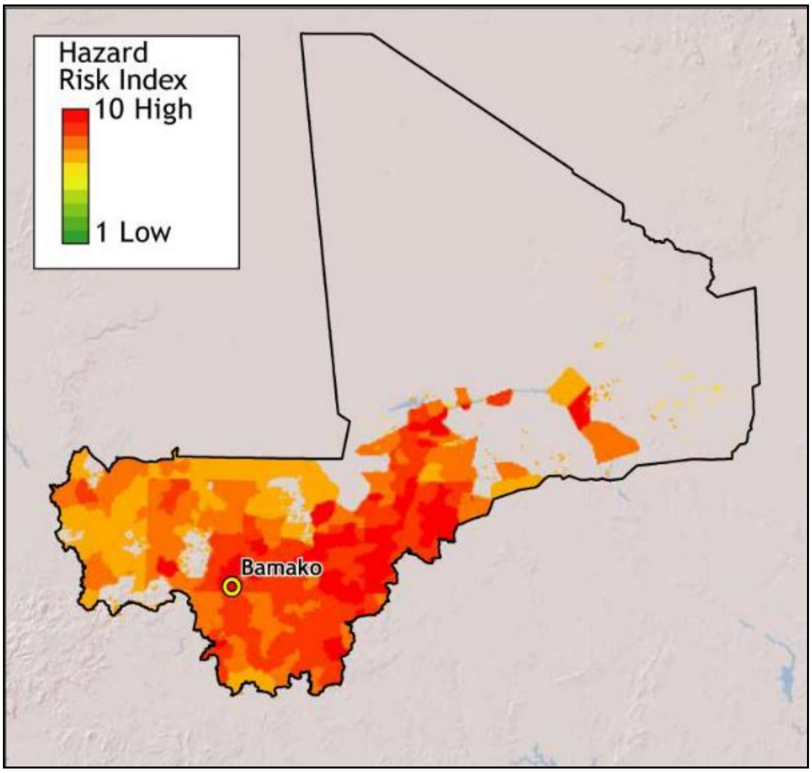
Variations in the volume and distribution of rainfall are a major factors in the dynamics of pastoral resources. Indeed, they determine the storage of runoff water and the recharge of water tables, the herbaceous plant production and that of the foliage of woody plants.

Moreover, the relationships between rainfall and crop production are not linear, as they are constrained by the processes of population dynamics. This plant formation is a function of the dispersal of seeds, the conservation of the seed stock in the soils and of germination.

Plant productivity also depends on the functional groups that make up the vegetation and on the fertility of soils, whether they are rangelands or fields (P. Hiernaux *et al.,* 2014, p. 22).

Moreover, climate-related hazard patterns such as significant rainfall variability or the increase of temperatures induce to less water, less pasture, crop failure, failure in livestock's productivity, and health issues leading to an increase of their vulnerability (A. Sanfo et al., 2015, p. 96).

According to a World Bank report in 2004, the hazard risk index was high from the south to the east part of Mali globally (figure 2). That hazard-related drought has affected seriously transhumance population forcing pastoralists to remain near permanent water sources and leading to considerable overgrazing. Crop losses in and around Mopti, Segou, and Tombouctou are often the result of extended dry spells, poor rainfall, and dry conditions (World Bank, 2010, p. 7).



Source: World Bank (2010, p. 6)

Figure 2: Exposure to climate hazard-related drought across Mali in 2004

METHODOLOGY

❖ **Literature review**

The first method used in this research was the literature review. It focused on research information in documentation services. Thus, researchs have made through internet sites (Google scholar and others links) , some libraries in Mali, work structures and intitutions.

Researchs have been carrying out at the Ministry of Rural Development (MRD), the National Directorate of Animal Productions and Industries (NDAPI), the National Directorate of Water and Forests (NDWF), the Pastoralism Support Project in the Sahel of Mali (PSPS-M). Public services based rural development as agriculture, livestock production, forestry and fisheries have been investigated. The purpose was to define the framework of the research topic, to collecte secondary data, to define criteria the study areas choice (communes and villages) where primary data have been collected. Certains research have been implemented with the Livestock Development Support Project in Mali (LDSP-M), with the Sustainable Development of Pastoral Livestock in the Sahel (SDPLS) project, with the Institute of Rural Economics of Sikasso, with the Center of Development Research at the University of Bonn (Germany).

Moreover, techniques used by most researchers have been noted and adapted for this study context. These secondary data contribute to making a state of knowledge on the research topic. Several scientific papers, master and doctoral thesis, books, reports at the national level, periodicals, and reviews were read and used where there was a need. Following secondary data collection, a panoply of criteria was established leading to the collection of primary data in the field using the questionnaire method. Similar methods were used by K. Sokemawu, (2016, p. 160) in the savannah region of Togo; by P. T. Sewando *et al.,* (2016, p. 14) in Northern and central Tanzania; by M. Coulibaly *et al.*, (2022, p. 28) in the region of Kayes (Mali) and by M. L. Katilé *et al.*, (2024, p. 46) in the southwest of Mali;

✓ **Criteria applied for study area choice**

District of Bougouni

The main criteria that motivated the choice of Bougouni’s District as the study area are: zone of pastoralism, easy accessibility, availability of livestock data around ten years, high size of livestock population, security conditions, transhumance track areas, and the geographical position regarding neighboring countries.

✓ ***Communes and villages***

This research is carried out in four (4) communes such as Dogo, Koumantou, Faragouaran and Garalo for the survey data and two communes (Faragouaran and Koumantou) concerning the satellite and phyto-ecological data. These communes have been selected according to the following requirements: livestock population size, geo-spatial repartition, easy accessibility, stability in terms of security, the geographic position regarding the border countries, frequency of conflicts related to pastoral resources management, transhumance track area, frequency of pastoral resources scarcity and availability of pastoral resources data. These requirements have been also used for the choice of phyto-ecological survey and satellite data sites. The results from the exploratory survey allow to validate communes and the village's choice.

SURVEY DATA COLLECTION AND ANALYSIS

The method was devoted to gathering data-based perceptions of agro-pastoralist communities on the effect of climatic risk-related hazards on pastoral resources in the four communes (table 1). This method was applied to the overall specific objectives. The Chi-square test was applied to assess the significant relation between variables.

✓ **Exploratory survey**

The implementation of this study required an exploratory survey phase which has been carried out over ten (10) days in the study area (photo 1). Implemented is August 2022, this phase was divided in two (2) stages.

The first stage was based on primary data collection at the level of technical services in the study areas (local service of agriculture, local livestock husbandry service, fisheries local services, and local statistic services). The data collected at this step were related to the perception of climate change, existing pastoral resources and climate risk-related hazards, and experiences in terms of adopted strategies. This step allows to contextualize and to validate the choice of the study area, survey communes and villages.

The second stage consists of carrying out village assemblies in each study area. It permits to testing questionnaires through individual interviews, focus group discussions and exchanges with some resource persons who have been living in the study area for more than 40 years.

A small sample size per zone allows the questionnaire to be tested for its validation. This test highlights some shortcomings of the survey tool that have been taking account in the final questionnaire. A survey-specific period has been proposed and validated by respondents. All these activities resulted to the determination of survey administration villages. A field observation has been done after each village assembly.

Source: Traoré M., photo taken in August 2022.

Photo 1: Case of assembly in the village of Faragouaran

✓ **Field observation**

The field observation aims to witness agropastoral communities' perceptions regarding the influence of climate risk-related hazards on pastoral resources. However, field observation shows:

- a continuous degradation of herbaceous pastures due to the influence of climate hazards;
- a disappearance of palatable herbaceous species such as *Andropogon gayanus, Pterocarpus lucens ; Digitaria argillacea, Brachiaria ramosa ……;*
- a colonization of rangeland by some herbaceous species with low pastoral value such as *Sida cordifolia, Cassia tora, Hyptis suaveolens, Waltheria indica, ……;*
- a delayed installation of grass cover due to dry spell long term at the beginning of the rainy season;
- an early drying up of the natural water points causes enormous pressure on the artificial ones during the lean period;

- an existence of many seasonal watering points that dry up after the wintering period;
- an erratic rainfall, decrease of rainfall, frequency of dry spells high variability of temperature, and violent wind;
- an existence of response strategies collections in face to climate hazard at agro-pastoral communities level.

✓ **Sample size procedure**

The sample size was drawn based on the 2022 population data of Bougouni's District provided by the National Population Directorate (NPD) of Mali.

The number of household heads to survey (size of this sample) has been determined through the formula of D. O. Nyangweso & M. Gede, (2022, p. 10)

$$n = \frac{N}{1+N(e)^{2}} \qquad \text{Eq1}$$

When **n** is the sample size, **N** is the population size, **e** is the accuracy level or limit of tolerable error and **1** is a unit or a constant.

The simple random sampling method has been used for selecting random respondents from a sampling frame (A. Bhattacherjee, 2012, p. 67). The level of accuracy taken into consideration is 5 % regarding limited financial means and difficulties related to the time and access of certain villages. The sampling of the surveyed villages was based on some specific criteria that were determined during the exploratory survey in the field.

The number of surveyed household heads is obtained by dividing the number of a household over the overall total, the whole multiplied by sampling size. The relative weight is obtained by dividing the number of households over the overall total (table 1).

For instance, Koumantou's number of household heads to survey: 76 475/192 122*400=**159**

For instance Dogo's relative weight: 51 005/192 122=**0.27**

Table 1: Description of households sampling selection procedure in study areas

N°	Districts	Number of households	Sampling size with e=5 %	Relative weight	Number of household heads expected to survey	Number of household heads surveyed	Number and Gender of household heads surveyed	
1	Dogo	51,005	**400**	0.27	**106**	**106**	Male:	74
							Female:	32
2	Faragouaran	15,718		0.08	**33**	**34**	Male:	28
							Female:	6
3	Garalo	48,924		0.25	**102**	**104**	Male:	87
							Female:	17
4	Koumantou	76,475		0.40	**159**	**160**	Male:	126
							Female:	34
Total		192,122		1	**400**	**404**	**Male:**	**315**
							Female:	**89**

Source of household number: DNP of Mali (2022); Source of relative weight and Number of household heads to survey approach: (F. Konaté *et al*., 2021, p. 341)

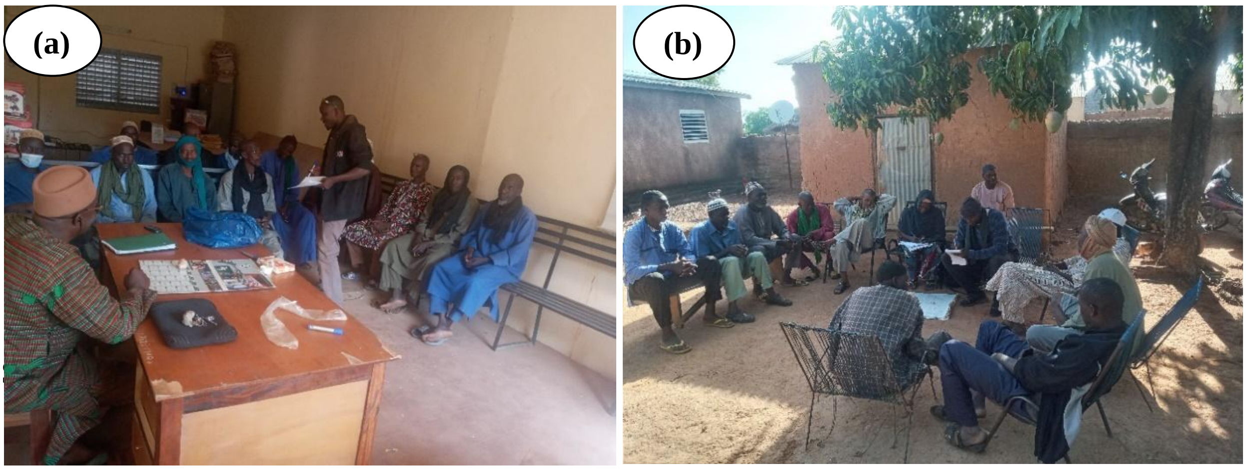
✓ **Survey/sampling techniques**

The survey of this study started on December 1st, 2022, and ended on December 30th, 2022. The respondents were agropastoralists aged at least 30 years to respect the climate change dimension. In this present research, three (3) phases of the survey have been implemented. They are about technical service surveys, focus group discussions and individual interviews.

- **Technical services survey**: A specific questionnaire was designed for the local technical services in the livestock sector located in the survey areas. This approach aims to document actors' experiences about livestock production in the climate change context. The information collected was based essentially on questions regarding the frequency of climatic risks, adverse impacts of these climatic risks, most climatic hazards recorded in the 30 past years, and adaption measures used in the face to climatic risks.

- **Focus group Discussion**: This method was used in the study area. It concerns the village where the survey population is upper or equal to 25 persons. Men and women have separate focus group discussions to make the activities more rich and participative. The focus group discussions were constituted from six (6) to twelve (12) agro-pastoralists as size for questionnaire administration (photo 2). They were all at least thirty ages old and possessed much experience in livestock production activities.

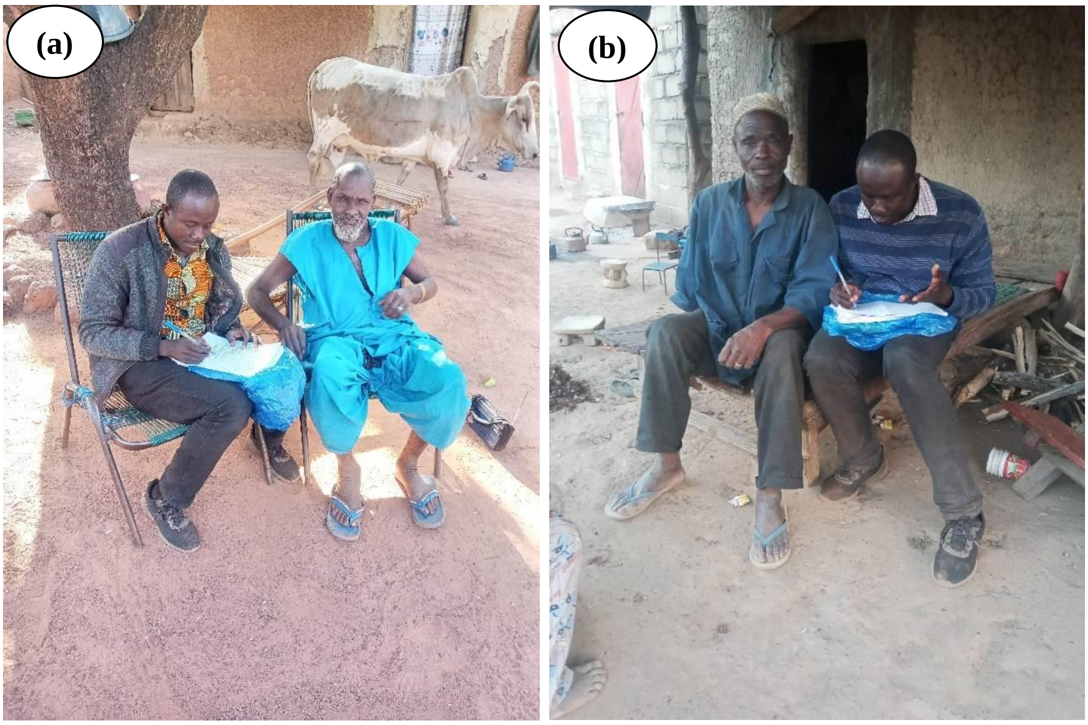
  The parameters that covered this tool were based on the climatic risks related to hazards; perception on the rainfall, on temperatures, and on wind speed; matrix of impacts and adaptation, inventory on existence pastoral resources, and adapations measures used agro-pastoralist communities.



Source: Sanogo T., photo taken in December 2022.
Photo 2: Case of focus group discussion activities in the communes of Garalo (a) and Faragouaran (b)

- **Individual survey**: The last and third method of survey has been the individual interview of the head of household. This phase has concerned the household head (men or women) aged 30 years at least taking into account the perception before the last thirty years) (photo 3).

  A questionnaire tool allows to collect the individual survey data. These data were collected by face-to-face interview. Online tools were also used to assess some keyword variables. The main questions of this tool were structured around: perception on existing climatic risks; rainfall, temperatures, and wind speed evolution; livestock resources; existing pastoral resources; negative impacts of climatic risks related-hazards on livestock production; existing climate extreme events, and adaptation strategies. Certain questions concerned with the socio-economic and environmental impacts related to climate change, the major climate events that have marked the history of the study area over the past thirty years …



Source: Diarra F., photo taken in December 2022.

Photo 3: Case of individual survey activities in the village of Garalo (a) and Dogo (b)

- **Climate Risk-related hazard impacts on pastoral resources and adaptation measures methods**

This method is based on the agro-pastoralist communities' perception through impact matrix and adaptation measures implementation.

Impact matrix

This method consists to determine through the impact matrix (table 2), the climatic hazard and their prioritization in terms of efficiency as well as their impacts on pastoral resources. The combination of exposure and sensitivity induces to the potential impact of climate change (IPCC, 2007, p. 53; T. Sanogo *et al.*, 2016, p. 47).

Table 2: Example of impact matrix

Climate Risk related-hazard	Variables impacted		
	Resource 1	Resource 2	Resource 3
CRH1			
CRH 2			
CRH3			
CRH4			

Adaptation measures matrix

The adaptation matrix tool (table 3) is putting in place for determining agro-pastoralist adaptation measures to climate risk-related hazards through each impacted variable (IPCC, 2007, p. 53; T. Sanogo *et al.*, 2016, p. 47).

Table 3: Example of adaptation measures matrix

Climate Risk-related Hazard	Adaptation measures		
	Resource 1	Resource 2	Resource 3
CRH1			
CRH2			
CRH3			
CRH4			

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 (Chi-square test), allowing 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 (WMO, 2017, p. 12).

- **Climate Risk-related Hazard Assessment**

Climate risk assessment

This method, which is based on a participative approach, contributes to assessing and identifying current and future climate risks. It contributes also to determining their probability of occurrence and the variables affected by climatic factors as well as the analysis of the impacts. Thus, the impact and adaptation matrix and the prioritization of current and future adaptation measures have been developed. The probabilities of occurrence (level of certainty) of each climatic factor are determined by referring to the work of IPCC (2007, p. 83), T. Sanogo *et al.,* (2016, p. 39) and then assigning different colours to each level of probability of occurrence (table 4).

Table 4: Definition of probabilities of occurrence for climatic factors

Climate information	Probability level
Disruption of the rainfall regime	Unlikely (probability> 50%)
Severe drought	Likely (> 66%)
Increased occurrence of high winds	Very likely (> 90%)
Increased minimum and maximum temperatures	Extremely likely (> 95)

Source: IPCC, 2007, p. 83; T. Sanogo *et al.*, (2016, p. 39)

The degree of impact is determined by crossing the level of severity of the consequence (minor, moderate, major or severe) which determines the degree of impact of climate risk according to its probability of occurrence. This value of the risk or degree of impact depending on the colour can be low, moderate, high, or extreme (table 5).

Table 5: Illustration of the different values attributed to climate risks

Likelihood occurrence of risk	**Consequences**			
	Degree of severity			
	Minor	**Moderate**	**Major**	**Severe**
Unlikely	Low	Low	Low	Low
Likely	Low	Medium	Medium	High
Very probable	Low	Medium	High	High
Extremely likely	Low	Medium	High	Very high

Source: IPCC, 2007, p. 83; T. Sanogo *et al.*, 2016, p. 39

For example, when the likelihood of occurrence of risk is very probable and the degree of severity is moderate, the consequence is medium. Risks cited are used to assess the climatic risk related hazards

Climatic Risk Hazard Assessment

This method involved qualitative descriptions of risk in terms of high, moderate and low (table 6). It is used when the hazard information does not allow us to express the probability of occurrence, or it is not possible to estimate the magnitude. This approach has widespread application in the profiling of vulnerability using participatory methodologies (UNDP, 2016, p. 31, 32, and 33). In This methodology, the hazards are listed and a score from 0 to 5 is attributed to them. The scores include the impacts on livelihood and the vulnerability of resources (table 7). While the probability of risk is moderate and the severity (risk level) is high the potential of losses is medium (table 8). This method involves the qualitative data of the matrix of impact and vulnerability. This method led to determining the climatic risk-related hazard in the district of Bougouni. It leads to achieving the objective specific one.

Table 6: Description of the hazard risk assessment

<table>
<tr><td colspan="6">In column B. the likelihood of occurrence of this event (between 0 low to 5 high)</td></tr>
<tr><td>Hazards</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td>B. Likelihood</td><td>very low</td><td>low</td><td>medium</td><td>high</td><td>very high</td></tr>
<tr><td colspan="6">In the column, C. entered the severity of the impact expected. This would be based on your understanding of the various vulnerabilities and the measures your community has already taken to reduce them</td></tr>
<tr><td>Vulnerability</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td>C. Impact severity</td><td>minor</td><td>controllable</td><td>critical</td><td>devastating</td><td>terminal</td></tr>
<tr><td colspan="6">In column D, likelihood is multiplied by the impact rating. column B x C. This would give the risk score</td></tr>
<tr><td>Risk score</td><td>1-3</td><td>4-8</td><td>9-14</td><td>15-19</td><td>20-25</td></tr>
<tr><td>Description</td><td>very low</td><td>low</td><td>medium</td><td>high</td><td>very high</td></tr>
<tr><td colspan="6">In Column E, the conversion of risk scores into simple priority scores
3=Low; 2=Medium; 1=High</td></tr>
<tr><td>Risk score</td><td>1-3</td><td>4-8</td><td>9-14</td><td>15-19</td><td>20-25</td></tr>
<tr><td>Priority level</td><td>3</td><td>3</td><td>2</td><td>1</td><td>1</td></tr>
<tr><td>Description</td><td colspan="2">low</td><td>medium</td><td colspan="2">high</td></tr>
</table>

Source : (UNDP, 2016, p. 33)

Table 7: Hazard risk assessment matrix

A. Hazards	B. Hazard likelihood (0 low-5 is high	C. Impact severity (Vulnerabilities /resources) low-5 is high	D. Risk score BxCE. Priority	E. Priority
1				
2				
3				

Source: UNDP, (2016, p. 32)

Table 8: Qualitative method illustrating hazard risk assessment

RISK MATRIX

Probability				
High	C	B	A	A
Medium	C	B	B	A
Low	D	C	B	B
Very low	D	D	C	C
	Low	Medium	High	Very high
	Potential loss			

LOSS

Based on the potential by taking into account elements at risk:

- ✓ Fatalities;
- ✓ Injuries;
- ✓ impacts on facilities;
- ✓ critical services and infrastructure;
- ✓ property damage;
- ✓ business interruption;
- ✓ environment/Economic impact

RISK LEVELS

A: Very high. Frequent events causing very high losses or moderate frequent events causing very high losses
B: High. Frequent events with moderate losses/moderate & low frequent events causing (very) high losses
C: Moderate. Frequent events with low losses or very low-frequency events causing (very) high losses
D: Low. frequency events with low losses

PROBABILITY

High	**Events that occur more frequently than once in 10 years**
Moderate	**Events that occur from once in 10 years to once in 100 years**
Low	**Events that occur from once in 100 years to once in 1,000 years**
Very low	**Events that occur less frequently than once in 1,000 years**

Source : (UNDP, 2016, p. 31)

This method has led to determining the climatic risk-related hazard in the district of Bougouni, the adverse impacts of climatic risk-related hazards on pastoral resources, agropastoralist vulnerability assessment, and adopted strategies of agropastoralist to alleviate climate change impacts. It applied to all the specific objectives

METEOROLOGICAL DATA COLLECTION AND ANALYSIS

The data types collected were rainfall daily, annual maximum, minimum, and wind speed data. The time series of daily data was from 1950 to 2010 and from 1950 to 2022 for annual data. These data have been collected at the Regional Center of Agrhymet in Niger (2010) and Mali-Meteo (2022).

This data series refers to the last normal climatic standard (1991-2020) of the World Meteorological Organization (WMO, 2017, p. 12) for taking a count that covers thirty periods.

- **Data analysis**

Rainfall variability

The measurement of rainfall variability was focused on five (5) elements: Lamb Index Standardized (LIS), Standardized Precipitation Index (SPI), statistics test, rainy season and dry spell frequency analysis.

- ***Lamb Index Standardized or Rainfall Variability Index:*** is a method used for determining the characteristics of rainfall variability in the study area. It allows to show trends in chronological series and to estimate the deficit and surplus periods in the annual scale (A. Dao *et al.*, 2010, p. 438; E. Alamou & G. Quenum, 2016, p. 317). It is calculated by the following equation:

$$V_{cr} = \frac{x_i - \bar{x}}{\sigma} \qquad \text{Eq2}$$

x_i = data i for the annual data series ;

$\bar{x}$ = Serie means of annual data on the referring period;

σ = Standard deviation of annual data series on the referring period.

- ***Standard Precipitation Index:*** This is calculated using the arithmetic average and the standard deviation of the precipitation series. It allows 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). Four different drought categories are defined by B.T. McKee *et al.*, (1993, p. 2) (table 9). It is calculated from the following equation:

$$SP_i = \frac{X_{i-\bar{X}}}{S_x} \quad \text{Eq3}$$

$\mathbf{x}_i$ is the cumulative rainfall for the year i;

$\bar{\mathbf{x}}$ is the average cumulative rainfall

S_x is the standard deviation of the precipitation series.

Table 9: Classification and evaluation of different standardized precipitation indices

N°	SPI Values	Drought category	Colour
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 : (B. T. McKee *et al.*, 1993, p. 2)

➢ **Statistical tests used*:*** This method is based on three statistical tests:

✓ **Mann-Kendall trend test (1945)**

This non-parametric test allows to characterize a trend or an abrupt jump. It is based on the 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 yi and yj, where i > j, the test looks at whether yi > yj (P) or whether yi < yj (M). Its statistics are equal to the sum of the difference between two observations, it means S = P - M. The significance of a trend can be tested by comparing the standardized value U with the test variable at the desired significance level (C. Cédric, 2008, p. 12; K. Hamed, 2008, p. 3).

✓ **Pettitt test (A. N. Pettitt, 1979, p. 3)**

Pettitt's test is defined as the point at which a sudden change or jump occurs in a given data series. It is used to determine the year of the rainfall, the temperatures or wind speed break for a station under consideration. Pettitt approach is non-parametric and is derived from the Mann-Whitney test. The absence of a break (rupture) in the series (Xj) of size N constitutes the null hypothesis. The implementation of the test assumes that for any time t between 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 in the absolute value of the variable Ut N defined by:

$$U_{t,N} = \sum_{i=1}^{t} \sum_{J=t+1}^{N} Dij \qquad \text{Eq4}$$

Where Dij = sgn (Xj - Xj) with sgn{x) = 1 if x > 0, 0 if x = 0 and - 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 of the week (E. Servat *et al.,* 1998, p. 7). Its null hypothesis is the non-breakage (J. E. Paturel *et al*., 1998, p. 4)

- ✓ **Student's Means Comparison Test**

  The student test was used to compare two means. It tests the equality of two independent samples and thus allows to prove whether the difference between the two averages is significant or not. The *T* follows a Student's law with *v* degrees of freedom where v= n1+n2 – 2 where n1 and n2 are respectively the sizes of the first and second samples (C. Cédric, 2008, p. 12).

- ➢ **Rainy season analysis:** The analysis of the characteristic parameters of the season (onset date, end date, and length) has been carried out using the INSTAT+ v3.36 software according to the criteria retained for the Sudano-Sahelian zone. The criteria are as follows:
  - ✓ ***The date of onset of rains***, when receiving 20 millimeters (mm) as rain quantity collected in one (1) or two (2) consecutive days after 1^{st} May, without a dry period exceeding 20 days in the 30 days that follow (R. D. Stern, 1981, p. 3).
  - ✓ ***The date of ending of rains,*** based on water balance as a criterion, for example, the first day after 1^{st} September, when the water balance is less than or equal to 0.05 mm. So when the plant's water consumption and climatic demand deplete the soil's water reserve (R. D. Stern *et al.,* 1982, p. 8; R. D. Stern *et al.*, 2006, p. 96). The date of ending of rains (Y) is taken as that date after 1^{st} September following which no rain occurs over a period of 20 days (M. K. Sivakumar, 1988, p. 298).
  - ✓ ***The length of the rainy season*** is obtained by calculating the difference between the date of onset of rains and the date of ending of rains (M. K. Sivakumar, 1988, p. 298; R.D. Stern *et al.*, 2006, p. 96).

- **Dry spells frequency analysis:** A dry spell for a given period is defined as the maximum number of consecutive days without rain after the rainy season onset. For the analysis of this risk, the INSTAT + v3.36 software has been explored. The frequency and length of the dry spells have been calculated for the months of May, June, July, August and September. The chosen threshold is 0.85 mm (R. D. Stern *et al.*, 1982, p. 7; 2006, p. 85).

Temperature and wind speed Analysis Methods

The interannual evolution of minimum and maximum temperatures was studied initially for the analysis of this risk. The chronological series was observed to see if there were any climatic ruptures/breaks. When there is an apparition of rupture/break, a comparison of the means before and after the years of rupture to statistically see whether the two means on both sides of the year of rupture are different and entail to identify when there is an increasing or a decreasing of temperatures.

The wind speed interannual variation during the rainy and dry season has been analyzed. This method allows for analyzing the risk of a violent wind. This situation has led to determining the increasing or decreasing of the average wind speed through meters per second (m/s). Similar methods were used by N. Debela *et al.,* (2015, p. 12) in South Ethiopia, by B. Sarr *et al.,* (2015, p. 18) in Burkina Faso, Chad, and Niger, and by T. Sanogo *et al.,* (2016, p. 38) in Mali.
The interpretation process is while H0: The data are homogeneous and Ha: There is a date from which there is a change in the data. Given that the calculated p-value is below the significance level alpha=0.05, we must reject the null hypothesis H0, and accept the alternative hypothesis Ha. This applied method contributes to achieving the specific objective 2 at the meteorological observation scale.

- **SATELLITE DATA COLLECTION AND ANALYSIS**

The method applied in this satellite data led to achieving the specific objective 2. It aims to evaluate the pressure of climatic-related hazards on pastures and watering points area.

The collected Satellite data covered the years 1990, 2002, 2012, and 2022. Data from the sensors Landsat 5 Thematic Mapper (TM) acquired in 1990. Landsat 7 Enhanced Thematic Mapper (ETM) and Landsat 7 Enhanced Thematic Mapper plus (ETM+) were acquired in 2002 and 2012 respectively. Landsat 8 and 9 Operational Land Imager (OLI) acquired in 2022. These data have been downloaded from the Global Land Cover Facility (GLCF), http://glcfapp.glcf.umd.edu:8080/esdi/ and the United States Geological Survey (USGS) data archives (http://glovis.usgs.gov; accessed from 06 to 26 November 2023). The study area of Bougouni’s District is covered by the following paths and rows: 199-52; 198-52. According to the high level of the cloud for the image, Landsat 7 ETM+ for the two sites, six bands were used to increase the accuracy (table 10).

These data as the phyto ecological data were collected in two sites (Faragouaran and Koumantou commune)

Table 10: Characteristics of satellite images used for the Faragouaran and Koumantou communes

City	Satellites	Sensors	Resolution (m)	Number of bands	Cloud Cover (%)	Aquiered dates	Path	Row
FARAGOUARAN	Landsat 5	TM	30	3	0	November 09, 1990	199	52
	Landsat 7	ETM	30	3	0	November 18, 2002	199	52
	Landsat 7	ETM+	30	6	60	November 13, 2012	199	52
	Landsat 8 and 9	OLI	30	3	0	November 09, 2022	199	52
KOUMANTOU	Landsat 5	TM	30	3	0	November 26, 1990	198	52
	Landsat 7	ETM	30	3	0	November 11, 2002	198	52
	Landsat 7	ETM+	30	6	60	November 06, 2012	198	52
	Landsat 8 and 9	OLI	30	3	0	November 10, 2022	198	52

Source: Author construction, November 2023.

- **Data analysis**

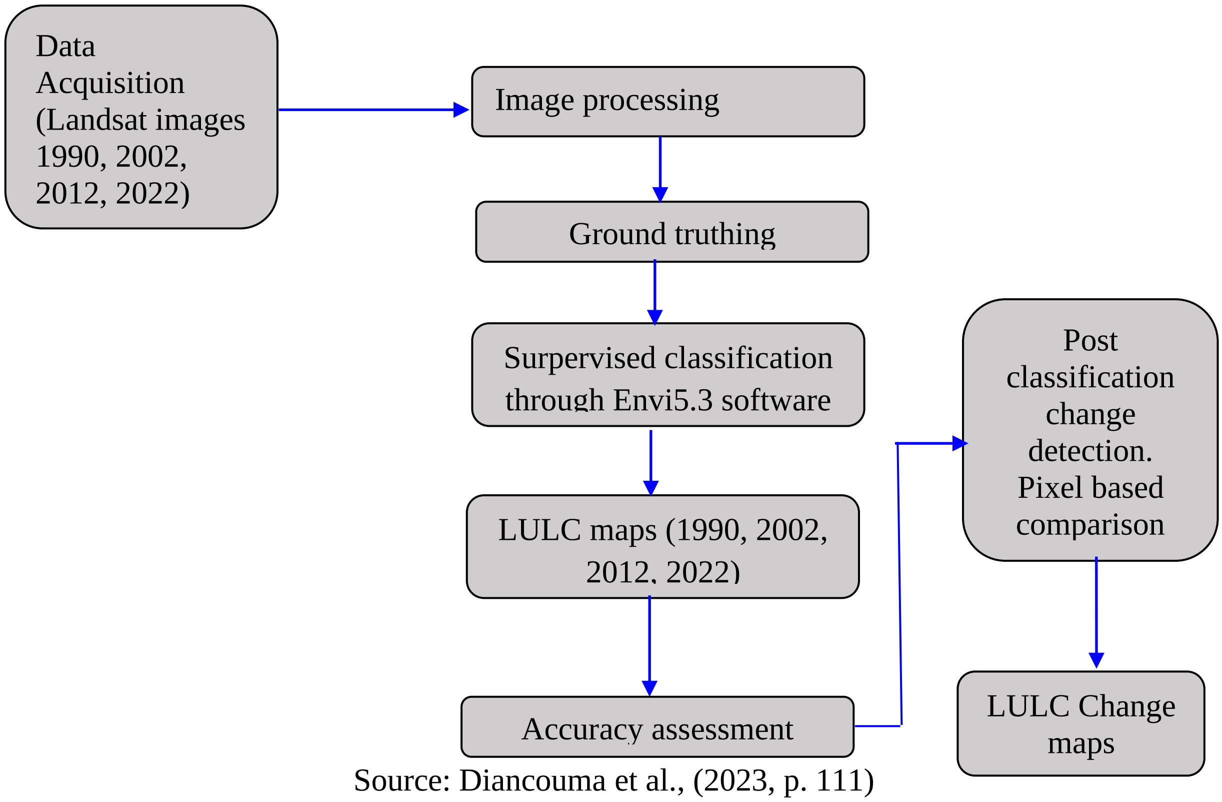
Image pre-processing

The Supervised Classification method, was applied to subset Landsat images from 1990 To 2022 (figure 3). Therefore, Landsat5 Thematic Mapper (TM), Landsat7 Enhanced Thematic Mapper (ETM), Landsat7 Enhanced Thematic Mapper plus (ETM+), and the Landsat8 and 9 Operational Land Imager (OLI) images have been processed before analysis by using the software Envi (version 5.3) coupled with QGIS (version 3.22.5) and excel 2016. These images were downloaded over the 30 years from 1990 to 2022. The soil and topographic map of Mali (PIRT, 1986) acquired from the IGM, and available vegetation map of the district of Bougouni were explored documents.

The purpose of pre-processing satellite images prior to change detection is to directly associate the biophysical phenomena on the ground with the acquired data. In image classification, the main objective is to place the set of pixels in an image into the land use/land cover (LULC) classes in order to derive useful thematic information based on the reflectance characteristics of the different LULC types (Fomba et al., 2024, p. 5). The ground truth of the sites was assessed in order to ameliorate the classification accuracy for each year.

In this analysis, the Bands 5, 4, and 3 (RGB, Red, Green, Blue) have been combined to generate land use land cover change classes. The analysis of land cover implied the classification of main patterns. The conventional supervised Maximum Likelihood Classification was used for the eight images, whose four per site. The random sampling approach was used (B. A. DIALLO Boubacar & Z. BAO, 2010, p. 9).

The six land cover classes defined in the classification were Bowal/bare land, cultivated area, settlement, water body, shrubby savannah, and wooded savannah.



Source: Diancouma et al., (2023, p. 111)

Figure 3: Flow chart of the methodology of LULC units analysis

This Landsat image dataset period of years refers to the last normal climatic standard of the World Meteorological Organization (OMM, 2017, p. 12). Thus, this method allows to evaluate the dynamic process of land use/land cover in the research sites over the following units: Bowal/bare land, cultivated area (farmland), settlement (build area), water body, shrubby savannah, wooded savannah (table 11). This method contributes to highlighting factors of pressure on pastoral resources through human and climatic aspects. Similar methods were utilized by S. Traoré *et al.*, (2012, p. 4) in Bougouni and Koutiala and by O. Diancoumba *et al.*, (2023, p. 111) in the southern part of Mali.

Table 11: Description of the land used and land cover classes for supervised classification

N◦	LULC Classes	Descriptions
1	Bowal/Bare Land	Bowal, is also a shallow soil above lateritic crusts is often waterlogged during the rainy season and extremely dry during the dry season. The typical vegetation is grass savannahs, woody plants are usually absent from these habitats; Bare land, an eroded area devoid of vegetation cover as a result of soil degradation and its usage as an unpaved road.
2	Cultivated area	An area used specifically for agriculture practice (food crops: maize, green, beans, sorghum, millet, rice…..). It means farmland area.
3	Settlement	Places where, people have constructed for their installation (Habitat, routes, work services, trade, factories….). it also means the building up area.
4	Water Body	Zones covered by water (river, backwater, shallows, affluents…) either along the river or riverbed or by artificial dams or haphazard constructions, temporarily filled dams and ponds during the rainy season.
5	Shrubby savannah	Formations of vegetation where the height of the woody is between four and eight meters in height.
6	Wooded Savannah	Vegetation formation in which trees and shrubs form a clear canopy (20-70 % cover) that provides ample light transmission.

Source: (B. Barnieh *et al.*, 2020, p. 8 ; M. Fomba *et al.*, 2024, p. 6)

PHYTO-ECOLOGICAL DATA COLLECTION AND ANALYSIS

The data collected were devoted to the biomass, the pastoral value, the specific contribution of species (grass and tree), palatable and non-palatable species, and the carrying capacity. The method was applied to achieve the specific objective 2. The Data were collected in the two sites (Faragouaran and Koumantou commune). This data collection started November 1st, 2022, and ended November 30, 2022. It is about:

Herbaceous and woody species Data

This research was carried out in two sites (Faragouaran and Koumantou commune). It was focused on field surveys and realized in November 2022 considered as the corresponding period of the maximum standing biomass in the Sudanian region (J. M. Ouadba, 1974, p. 333; M. Grouzis & P. Levang, 1980, p. 234; L. Sawadogo, 2009, p. 48; P. Hiernaux *et al.,* 2011, p. 5).

- **Inventory of herbaceous vegetation**

The inventory method used is that of point quadrat aligned of P. Daget & J. Poissonnet (1971, p. 234). This method consists of stretching a ribbon or measuring rope in centimeters (cm) over a distance of twenty meters (20 m) above the grass cover, and every 20 cm, an iron thin stem ’’baguette’’ is driven vertically into the grass. All present species and their contact (stubbles, leaves, fruits, flowers..) with the stem are recorded on a pre-established sheet. However, whether there is no plant touching the metal rod, it is noted the presence of bare soil (O. F. Saidou *et al.,* 2010, p. 155). By convention, each species is noted only once at each of the reading points in order to give a better image of the proportion of species projected on the ground. It allows quantifying the floristic composition of a route by measuring, the frequency of all the species listed and by expressing, in particular, these frequencies in terms of cover (L. Sawadogo, 2009, p. 46; S. Santi, 2011, p. 45) (photo 4). GPS coordinates are taken for each survey at the purpose to satellite data analysis accuracy. Thus, for each plot hundred (100) measures are achieved in the length of the 20 m stretched ribbon (L. Sawadogo, 2009, p. 46). At the total six hundred (600) reading points have been done in the two sites. The identified species *in situ* and its nomenclature followed the International Plant Names Index[1].

This method allows for determining the Pastoral Value. It is obtained by multiplying the specific contributions of diverse species by the Specific quality Index and adding the obtained

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[1] IPI : International Plant Names Index, https://www.ipni.org/ (November 11, 2023)

values. The results are expressed in percentages (P. Daget & J. Poissonnet, 1971, p. 33; O. F. Saidou *et al.*, 2010, p. 157).

The Specific Contribution (CS) is calculated by using this formula:

$$\boldsymbol{CS}i = \boldsymbol{FS}i / \sum \boldsymbol{Si} * 100 \qquad \text{Eq5}$$

CS*i*= Specific contribution of specie *i*, FS*i*=*Specific Frequency of specie i,*

The pastoral value is computed by using the following formula:

$$VP = 0{,}2 \sum_{i=1}^{n} CS_{t} \times Is_{t} \qquad \text{Eq6}$$

VP: Pastoral value, CS is the specific contribution of species, Is is Specific quality Index.

The Pastoral value is defined by assigning to each species a specific quality index (SI). This specific index (Is) is obtained by considering the zootechnical and bromatological values of the species, and agropastoralist perception and established on a scale of scoring from 0 to 5:

- ✓ very good pastoral value, species whose specific index (SI) is equal to 5;
- ✓ good pastoral value, species whose specific index (SI) is equal to 4;
- ✓ fairly good pastoral value, species whose specific index (SI) is equal to 3;
- ✓ medium pastoral value, species whose specific index (SI) is equal to 2;
- ✓ low pastoral value, les espèces, species whom specific index (SI) is egal to 1;
- ✓ without pastoral value, species whose specific index (SI) is equal to 0 (F. Ouattara, 2004, p. 41; O.F. Saidou *et al.*, 2010, p. 156; B. Kanambaye *et al.*, 2022, p. 172).

Source Bagayoko A., photo taken in November 2022.
Photo 4: Herbaceous inventory method by using quadrat point aligned in the village of Faragouaran

Herbaceous biomass estimate method

The yield square method was used to estimate herbaceous production in the research sites (N. Coulibaly, *et al.,* 2022, p. 196). It consisted in taking phytomass samples in three different classes (low, medium and high) on each type of vegetation (shrubby savannah, wooded savannah and bowal). On each type of substrate 36 samples of 1 m x 1 m of which 9 in the low class, 18 in the medium class and 9 in the high class are described (floristic list and visual cover) before proceeding to the integral harvest (P. Hiernaux *et al.,* 2011, p. 1). The mowed phytomass is put in cretonne bags, and then weighed with an electronic balance to determine the green weight. The dry weight in kg of DM is determined after air drying until a constant Dry Weight (DW) is obtained (W. Ouedraogo *et al.,* 2019, p. 3279) (photo 5). Herbaceous phytomass productions by soil type were made with the comparison of averages. Theoretical carrying capacity was estimated on the basis of dry matter production. The empirical formula established by G. Boudet, (1977, p. 175) was used for this purpose:

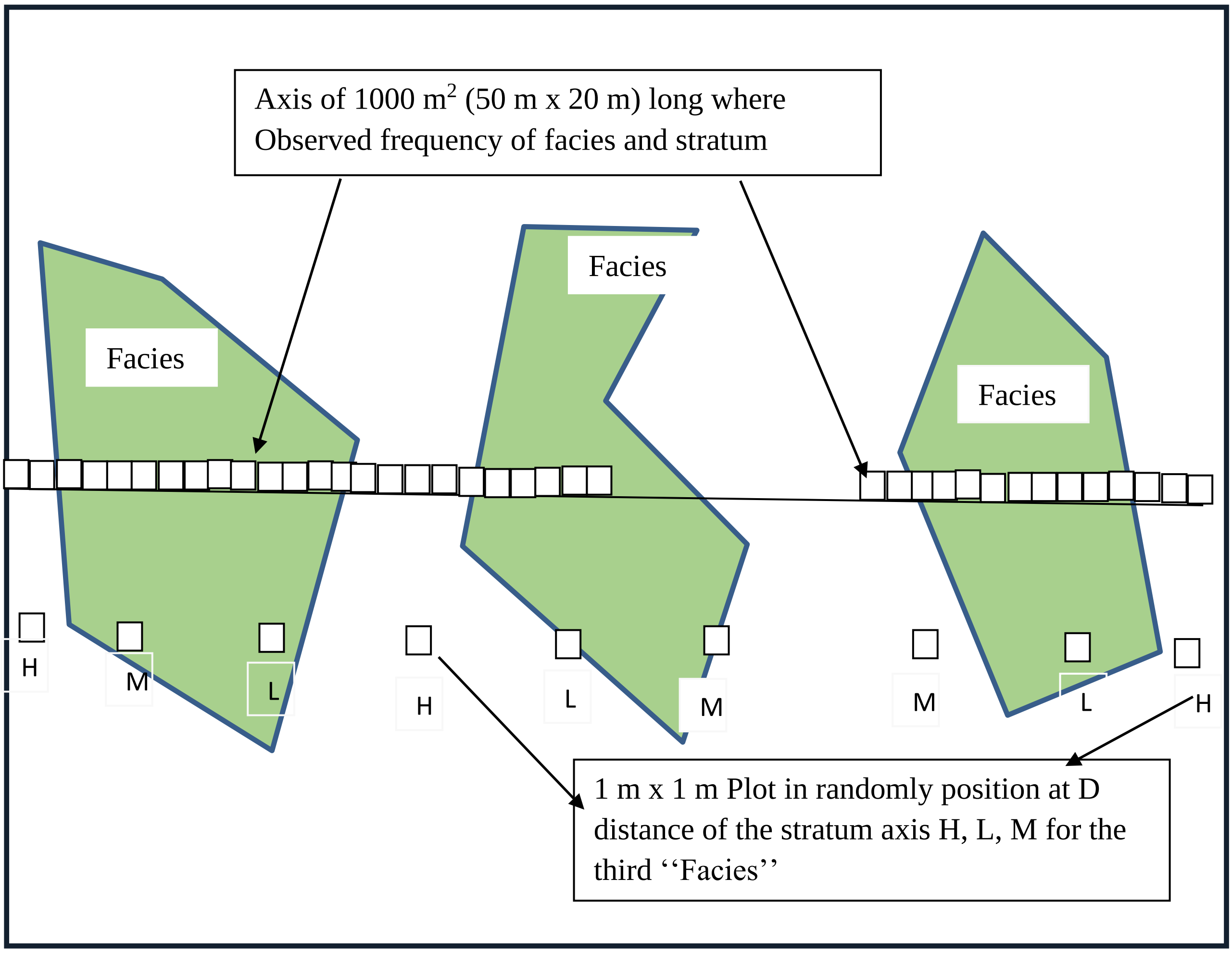
Number of days (Nd) = phytomass production (kg DM/Ha) /3*6.25
Quantity of forage per LU/Ha/year (Qf) = NJ*250/365
Number of LU/ha/year (NA) = Qf/250 Eq7
Number of ha/TBU/year = 250/NJ

Photo 5: Demonstration process of biomass estimate in the villages of Faragouaran and Koumantou from the mowing (a), weighing (b), sample composite constitution (c) and drying under the sun (d).

Source: Coulibaly N., photo taken in November 2022.

❖ **Device of stratified random sampling**

The biomass estimate assessment was implemented by using stratified random sampling procedures. The type of vegetation communities are constituted to multiple phases named ‘‘Facies’’. In each‘‘Facies’’ a sample of high, medium and low of the‘‘Facies’’ were assessed. The stratum L, M, H are sampled randomly through three ‘’Plot” for the L and H, and six for M (figure 4). A similar method was used by P. Hiernaux *et al.*, (2011, p. 5) in sub-saharian area of Africa.



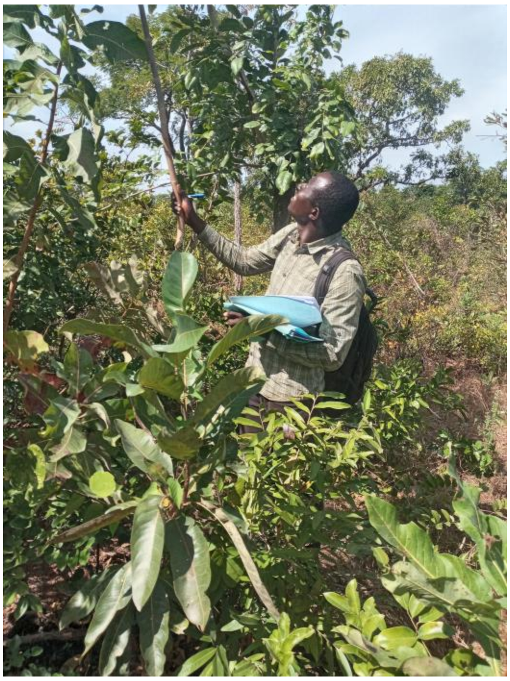
Source: Author construction, November 2023; L=Low; M= Medium; H=high,

Figure 4: Sampling randomly dispositive stratified at two levels: ‘’Facies and Stratum of annual herbaceous

❖ **Woody vegetation inventory**

The inventory was conducted in 1,000 m^2 (50 m x 20 m) plots delineated in each site (S. F. Traoré *et al.*, 2022, p. 22; B. Kanambaye *et al.*, 2022, p. 170). On each plot, the geographic coordinates have been recorded using a GPS.

The measurements were based on the counting of existing species, on the measurements of the circumference of the trunk at the height of the chest about 130 cm from the ground through calipers, on the height and the projection of the crown using a graduated perch (M. Karembe, 2014, p. 43) (photo 6). This method focused on the phenological state of individuals (leaves, flowering, fruiting), physical (living, dead) and the information gathering on pasture situation to resource users (period of use as crop, transhumant paths, herbaceous and woody species diversity).



Source: Coulibaly N., photo taken in November 2022.

Photo 6: Woody vegetation inventory process in the village of Guérékélé (commune of Koumantou)

❖ **AGRO-PASTORALIST VULNERABILITY ASSESSMENT DATA COLLECTION AND ANALYSIS**

- **Livelihood Vulnerability Index (LVI) assessment method of agro-pastoralist communities**

The Livelihood Vulnerability Index (LVI) method is analyzed and adapted following the composite index approach (M. B. Hahn *et al.*, 2009, p. 74; C. Laitae *et al.*, 2014, p. 2; U. C. Nkwunonwo, 2017, p. 4). This method is used in the pastoralism field. It considers two types of data (secondary and primary). The method applied leads to achieving the specific objective 3. It contributes to assessing the most vulnerable communities in the study area.

- ✓ The Secondary data have encompassed climate data (average annual rainfall; average annual temperature). They have been collected through the National Meteorological Agency of Mali, Regional Meteorological Agency of the District of Bougouni and compared to those obtained by the Online climatic Data. website: (https://beaumont.tamu.edu/climaticdata/CountryMap.aspx?index=4_30&name=MALI). The reference series considered for the research site is from 1950-2022.
- ✓ The Primary data was obtained by surveying agro-pastoralist communities in the study area. They focused on the following items: socio-demographics, social networks, pasture, water points, and livestock. A similar method has been applied by C. U. Nkwunonwo, (2017, p. 4 and 5) for assessing social vulnerability for efficient management of urban pluvial flooding in the Lagos Metropolis of Nigeria and by P. T. Sewando *et al*., (2016, p. 15) for assessing vulnerability of agro-pastoral farmers to climate in the northern and central Tanzania.

The approach has consisted to determine the major component and each of them has been comprised by several indicators. It explains how each sub-component has been quantified, the survey question used to gather the data, the source of the survey question, and potential limitations (table 12).

Table 12: Characterisation of the major component for LVI

N°	**Major components**	**Sub-major components**	**Explanation of sub-major components**	**Survey questions**	**Source of data**	**Potential limitations**
1						
2						
3						
4						

The sub-components were measured on different scale (Percents, numbers and millimeters) and was necessary to standardize each as an index. The equation used for this conversion was adapted from that used in the Human Development Index to calculate the life expectancy index, which is the ratio of the difference between the actual life expectancy and a preselected minimum, and the range of pre-determined maximum and minimum life expectancy (UNDP, 2007, p. 356 ; P. Sewando *et al.*, 2016, p. 15)

$$index_{sd} = \frac{S_d - S_{min}}{S_{max} - S_{min}} \qquad \text{Eq8}$$

sd is the original sub-component value for locality *d* and *Smin* and *Smax* are the minimum and maximum values, respectively, for each sub-component determined using data (secondary or primary). For each sub-component attributes value (d) from data and the maximum and minimum measured according to its whole.

After standardization, the sub-components were averaged using Eq. (7) to calculate the value of each major component:

$$M_d = \frac{\sum_{i=1}^{n} index_{sd^i}}{n} \qquad \text{Eq9}$$

Md = one of the major components for a locality *d* index di represents the

sub-components, indexed by *i*, that make up each major component, and *n* is the number of sub-components in each major component.

Once values for each of the major components for a locality have been calculated. Each of major component were averaged using Eq. (8) to obtain the locality Livelihood Vulnerability Index level (LVI):

$$\text{LVId} = \frac{\sum_{i=1}^{n} W_{Mi} Mdi}{\sum_{i=1}^{n} WMi} \qquad \text{Eq10}$$

LVId, the Livelihood Vulnerability Index for district *d*, equals the weighted average of the major components. The weights of each major component, *WMi*, are determined by the number of sub-components that make up each major component and are included to ensure that all sub-components contribute equally to the overall *LVI* (C. Sullivan, 2002, p. 1203). In this study, the LVI is scaled from 0 (least vulnerable) to 0.5 (most vulnerable).

Calculating the LVI–IPCC: IPCC framework approach

The method for calculating the LVI-IPCC was based on the categorization of major components into contributing factors from the IPCC (Intergovernmental Panel on Climate Change) vulnerability definition (table 13).

Table 13: Example of major components categorization into contributing factors from the IPCC

IPCC contributing factors to vulnerability Major components	
Exposure	Climate hazard
Adaptive capacity	Socio-demographic, social network
Sensitivity	Pasture, water points, Livestock

Source : M. Hahn *et al., (*2009, p. 80)

following equation:

$$CF_d = \frac{\sum_{i=1}^{n} {}_{WMi}\ M_{di}}{\sum_{i=1}^{n} W_{M_i}} \qquad \text{Eq11}$$

where *CF*d is an IPCC-defined contributing factor (exposure, sensitivity, or adaptive capacity) for district *d*, *Mdi* are the major components for locality *d* indexed by *i*, WM_i is the weight of each major component, and *n* is the number of major components in each contributing factor. Once exposure, sensitivity, and adaptive capacity were calculated, the three contributing factors were combined using the following equation:

$$\text{LVI} - IPCC_d = \ (e_{d\ -}a_d) * S_d \qquad \text{Eq12}$$

where *LVI–IPCCd* is the LVI for Locality *d* expressed using the IPCC vulnerability framework, ***e*** is the calculated exposure score for locality *d* (equivalent to the climate hazard major component), *a* is the calculated adaptive capacity score for locality *d* (weighted average of the Socio-demographic profile and social network), and *s* is the calculated sensitivity score for locality *d* (weighted average of the pasture, water point, livestock, major components). The LVI–IPCC, is scaled from -1 (least vulnerable) to 1 (most vulnerable).

❖ EFFECTIVE RESPONSE STRATEGIES ASSESSMENT TO CLIMATE HAZARD DATA AND ANALYSIS

The main objective of this method is to document the adopted strategies by agropastoralist communities to alleviate climate hazards negative impacts. It leads to achieving the specific objective 4.

✓ Identification of response strategies

During the Focus Group Discussion phase, the adopted response strategies were identified. The process was to discuss and mentioned the most adopted strategies by the agro-pastoralist communities in face to identified climate risk-related hazards. The same method has been deployed in all surveyed villages. The most relevant strategies were identified and raised on a survey sheet. This method leads to attributing marks to each climatic risk-related hazard to assess the most hazards impacting pastoral livelihood.

✓ Prioritization of response strategies by using multicriteria analysis

A participatory approach with the various actors operating in the livestock sector and decentralized service executives allows priority response strategies to be implemented. This prioritization is focused on the multi-criteria analysis taking into account of:

- cost of the adopted response strategies implementation;
- efficiency of adopted response strategies and measures for reducing the vulnerability to climate hazards;
- facility which encompasses questions of deeds and the necessity to adjust others' implementation politics;
- rapidity of the realization;
- capacity to hold the system;
- technical feasibility by the local actors;
- social acceptability for the local actors.

It is accompanied by a scale at three levels for each criterion, namely: 3 = high, 2 = medium, 1 = low. The score assigned is all greater, more the criterion contributes to or facilitates the implementation of the adopted response strategies.

An accumulation of the different scores obtained by response strategies is mentioned in the total column (table 14). Prioritization, therefore, consists of classifying them in order of magnitude on the rank column. A similar method was used by E. K. Daku & B. Sarr (2014, p. 23) in the plateau region of Togo, by I. Mballo *et al.,* (2020, p. 584) in Casamance (Senegal) and by M. Coulibaly *et al.,* (2022, p. 35) in the rural commune of Diéma (Mali)

Table 14: Multicriteria analysis matrix of response strategies in the face to climate risk-related Hazards

Response strategies	**Cost**	**Efficiency**	**Facility**	**Rapidity**	**Capacity**	**Technical feasibility**	**Social acceptability**	**Total**	**Rank**

DATA ANALYSIS TOOLS

Data processing and analysis tools include:

- Mapping and image processing software (QGis.v3.22.5, ENVI v5.3, MS Excel 2013);
- Climate data analysis software (Instat + v3.36, XLSTAT 2016, Khronostat.v1.01, fast statistics v2.0.4 and Rclimdex; R.v4.1.3; maxent v3.4.4);
- Socio-economic and Phyto-ecological survey data analysis software (SPSS (Statistical Package for Social Sciences) v23, Excel 2010, R.4.1.3; Jamovi 2.3; JASPI 0.16.1.0, fast statistics;
- Online collecting data (Kobocollect or questionPro for implementing an online dataset)
- Reference tool (MendeleyV2.66.0).

A Synoptic chart of the research site has been elaborated (table 15). It aims to show an overview of the whole thesis activities in terms of questions, objectives, hypothesis, methodology, tool and plan.

Considering the whole difficulties experienced, quantitative and qualitative data were gathered which allow structured this thesis report in three (3) parts, each part has two chapters:

- ✓ The first part, entitled ‘‘generality of the study area’’. It has two chapters. This first chapter describes the presentation of physical and human framework; the second is documenting dense pastoral resources in degradation with a strong growth of livestock size in the study environment

- ✓ The second part is devoted to analysing ‘‘characterisation of climatitic risks determinants and their influences on pastoral resources’’. The first chapter is reporting the determinants of climatics risk-related hazards and the second based on the influence of climate conditions on the variability, availability, the nutritional quality of pastoral resources and agro-pastoral communities’ perception of climate change.
- ✓ the third section, entitled ‘‘assessment of Agro-pastoralist Livelihood Vulnerability Index and Adopted Strategies of Agro-pastoral Communities in face to Climate Hazards’’. It is structured around two chapters too. The first chapter reports the assessment of the Livelihood Vulnerability Index of agro-pastoralist communities and the second on adopted response strategies of agro-pastoralist communities in the face of climate risks related-hazards.

To make this work easier to understand, a synoptic table has been drawn up (Table 15)

❖ Synoptic chart of the research in the District of Bougouni

The table 15 is structuring this research in terms of research questions, objectives, hypothesis, methodology, tools and plans deployed.

Table 15: Synoptic chart of the research

Questions	Objectives	Hypothesis	Methodology	Tools	Plan
what are the major climate risk-related hazards according to the perception of agro-pastoral communities on climate change in the study area?	determine the major climate risk-related hazards according to the perception of agro-pastoral communities on climate change in the study area	Drought and strong winds are some of the major climate risk-related hazards according to the perception of agro-pastoral communities on climate change in the study area	-Literature review -Focus group discussion -Individual interview -technical service interview Climate data analysis	-Maps -Photos -Graphics -Questionnaire sheet - Tables -SPSS -Mendelay 2.66	Part I : the south west zone of Mali, a favorable area for pastoral activities; Part II: Dense pastoral resources in degradation with a strongly growing livestock
what are the impacts of climate risk-related hazards on pastoral resources in the study area?	assess the impacts of climate risk-related hazards on pastoral resources in the study area	The degradation of pasture areas and the early drying up of water points are some of the impacts of climate risk-related hazards on pastoral resources in the study area	-Phyto-ecological survey sheets -Climatic data analysis (rainfall, temperature, vind, insolataion relative humidity	-Ribbon, 20 meters of length, iron, GPS, metal quadrat, sickle, cretonne bag, electronic balance, numeric photographer	Part II : Dense pastoral resources in degradation with a strongly growing livestock

			-Focus group discussion -Individual interview -Landsat satellites images analysis	Questionnaire sheet - Excel 2013, R3.5, Instat+ 3.36 -Vegetation Map.	
how is the Livelihood Vulnerability Index (LVI) of agro-pastoral communities in the study area?	assess the Livelihood Vulnerability Index (LVI) of agro-pastoral communities in the study area	The Livelihood Vulnerability Index (LVI) of agro-pastoral communities is high in the study area	-Climatic data analysis (rainfall, temperature) -Livestock secondary data -Focus group discussion -Individual nterview	-R 3.5 - Excel 2013 -SPSS v23 Questionnaire sheet	Part III: Evaluation de la vulnérabilité et Elaboration des stratégies de réponses des communautés agro-pastorale
what are the effective response strategies of agro-pastoral communities to climate related-	elaborate the effective response strategies for agro-pastoral communities to climate related	The protection of pasture areas and the promoting of forage crops are some of the effective response strategies of agro-pastoral communities	-Focus group discussion -Individual nterview - Technical service	Maps -Photos -Graphics -Questionnaire sheets	Part III : Evaluation de la vulnérabilité et Elaboration des stratégies de réponses des

hazards for Disaster Risk Reduction (DRR) in the study area	hazards for Disaster Risk Reduction (DRR) purposes.	to climate related hazards for Disaster Risk Reduction (DRR).	interview	-Tables -SPSSv23 -R 3.5 - Excel 2013 -Jamovi 2.3; -JASP 0.16.1.0, -Kobo collect	communautés agro-pastorale

Source: Author construction, December 2022

FIRST PART:

GENERALITY OF THE STUDY AREA

The physical and human conditions of the District of Bougouni constitute an important factor for livestock production. The annual average of precipitation is high favouring the vegetation condition. The main socio-demographic activities are based on agriculture, livestock production and fisheries.

However, this situation contributes to increase pastoral resources wellbeing including woody and herbaceous cover and watering points. Due to these conditions, the study area is attracting a lot of livestock producers coming from the central and northern of the country entailing the overgrazing, frequency of conflict based-pastoral resources, degradation of natural resources, and increasing of livestock population size. This degradation is amplified by climate risks through changing of climate parameters.

The first part of this research is focused on two chapters. The first chapter is presenting the physical and human framework and the second is documenting dense pastoral resources in degradation with a strongly growing of livestock size in the study environment**.**

CHAPTER 1:

PRESENTATION OF PHYSICAL AND HUMAN FRAMEWORK

The first chapter of this research is composed by the presentation of the study area, relief and soil, climate parameters, hydrography, vegetation, population, socio-economic activities.

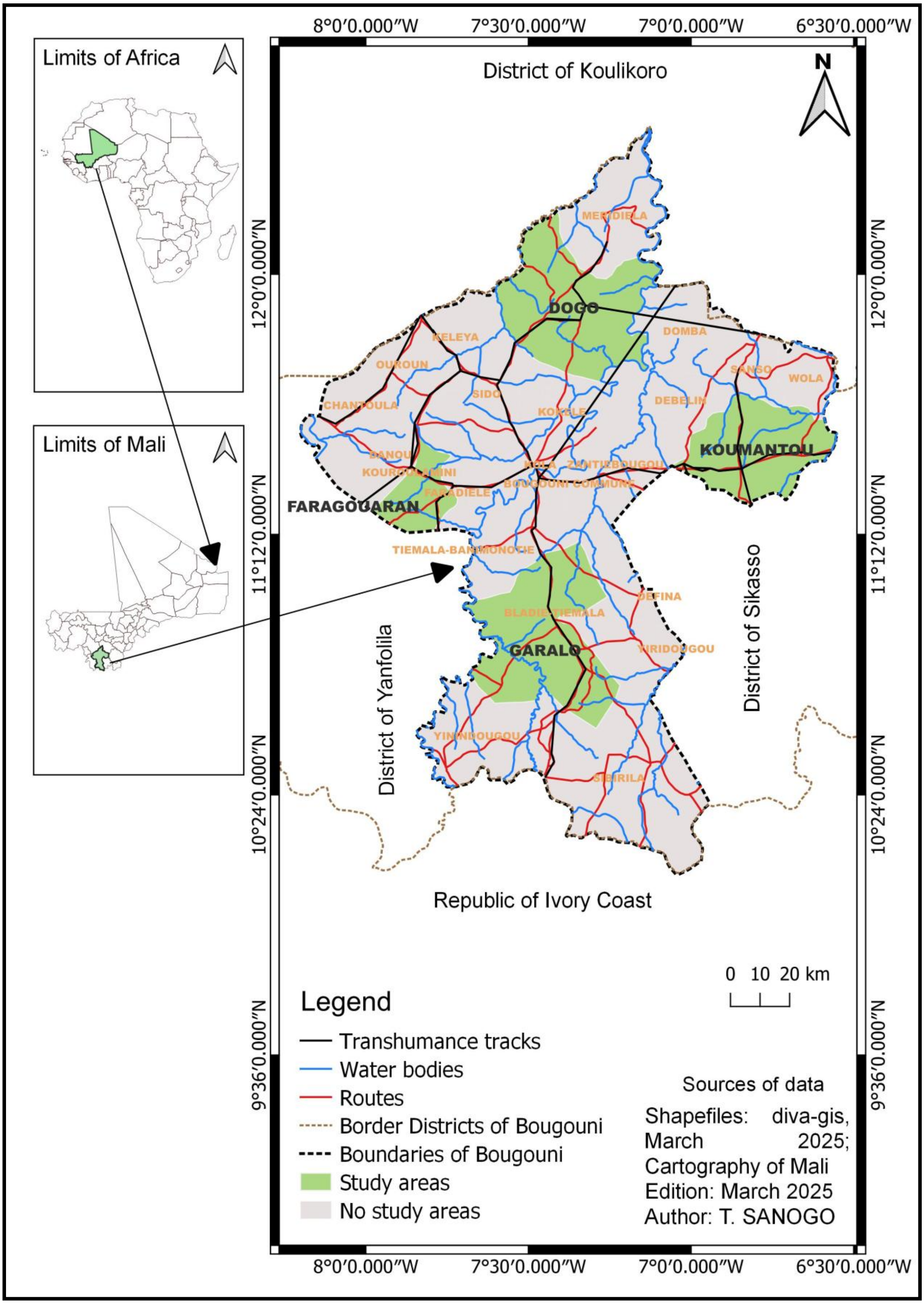
The investigation zone of this research is located in the south west part of Mali. It is bounded in the south with Ivory Coast Republic. The relief is characterized essentially by hills and plains and the soils are poor and exposed to high erosion.

The climate of the study area is sudanian with an important annual rainfall. The temperatures increases during the month of March and April and the frequency of violent wind too. The hydrography network is very rich with many rivers and backwaters.

The vegetation cover is characterized by large tree and several variety of herbaceous stratum. The population is numerous and so much diversified. The socio-economic activities are based on agriculture, livestock farming, fisheries, trade, gold mining and handicrafts.

1.1. Presentation of the study area physical framework

The study environment of this research is the District of Bougouni administratively part of the region of Sikasso. Located in Sudano-Guinea zone in the south-west of Mali, between the latitudes 10°00′ and 12°40′ north and the longitudes 06°20′ and 08°20′ west, the District of Bougouni has been created in the years 1956 (M. Dembélé *et al.*, 2013, p. 5096) and constitutes a real crossroads. It is composed administratively by five hundred forty (540) villages, twenty-six (26) communes including one urban and twenty five (25) rural distributed in nine (9) under-districts (B. Sanogo, 2006, p. 29). Covered approximately by 20, 028 km^2 area surface or 1.6 % of Malian territory, the District of Bougouni is crossed by National Route number 7 (RN7) which allows to join the district for one part at Bamako (170 km) and another part at Sikasso (210 km). Bougouni’s District is part of the "Haut Bani Niger" zone located at medium altitude of 350 m above mean sea level (S. Traore *et al*., 2021, p. 2). It is bounded at the north by the district of Kati and Dïola (Koulikoro Region); at the north-west by the district of Yanfolila (Sikasso Region); at the south by the Ivory Coast Republic and at the south west by the district of Sikasso and Kolondieba (Sikasso Region) (M. Keïta, 2009, p. 37; Z. Doumbia, 2009, p. 29). This study has been conducted in the District of Bougouni over four (4) communes, namely Dogo, Koumantou, Garalo and Faragouaran (map 1).



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

1.2. An environment at hill relief and ferruginous soil

The relief of Bougouni is a little uneven characterized by the presence of hills and plains. The main hills are Kokoun in the rural commune of Dogo, Kouroulamini in the rural commune of Madina-Kouroulamini, Keïkoro in the rural commune of Sanso. The most useful plains are Baoulé and Mono which are used mainly for the rice, legume cultivation and for the animal watering (F. Coulibaly, 2008, p. 53).

The types of soil encountered are tropical ferruginous soils that are very sensitive to water erosion (F. Coulibaly, 2008, p. 53). This soil is poor in fertility levels and is exposed to a high rate of erosion, low water storage capacity, and poor drainage conditions (S. Traore *et al*., 2021, p. 2).

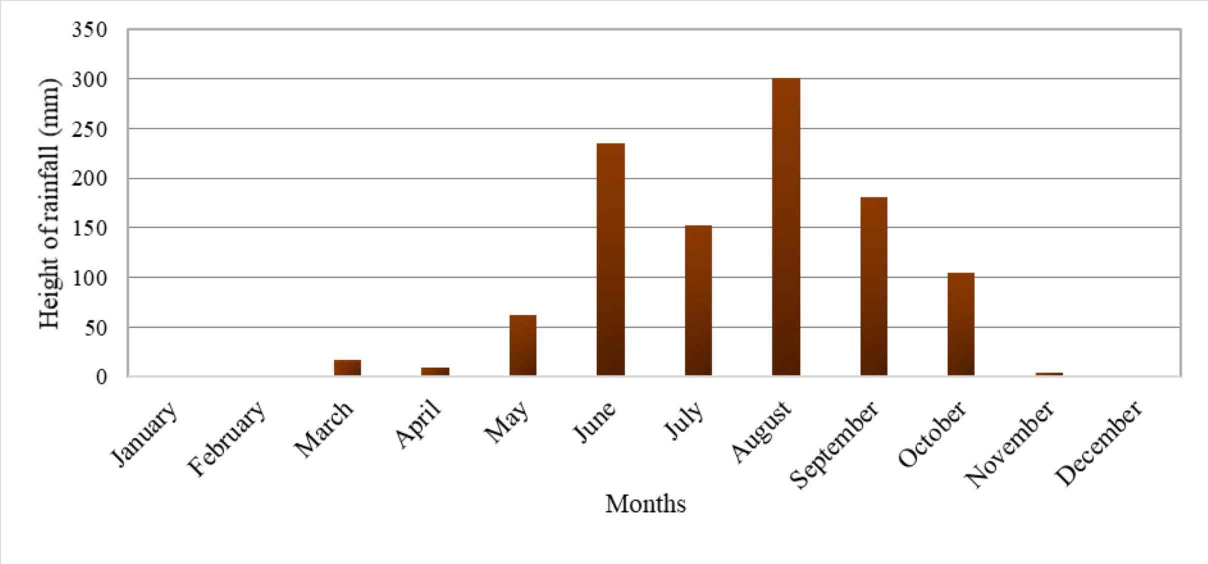
1.3. A Space at sudano-guinean climate

1.3.1. A zone with a high rainfall level

Located in the Sudano-Guinea zone, the District of Bougouni has a favorable climate and good rainfall. It possesses two larges climatic zones. It is about:

- ✓ the Sudano-Guinean zone occupies the southern part of the District between isohyets 1,200 mm and 1,500 mm. This zone is for the heavy rainfall.
- ✓ the southern Sudanian zone occupies the northern slope with annual rainfall varying from 900 mm to 1,200 mm.

The District of Bougouni has a dry season of 5 to 6 months (from November to April) and six months of rainy season (from May to October). The average annual rainfall is around 1,300 mm (Z. Doumbia, 2009, p. 30 ; F. Coulibaly, 2008, p. 53). The extent of rainfall and the speed of rainwater runoff favor soil degradation, especially in the plateau areas, through increasingly increased and scouring water erosion. Nowadays, due to many environmental problems aggravated by climate hazards, this high level of rainfall is decreasing (T. Sanogo *et al.,* 2021, p. 170). In the year 2019, the rainiest months was June (230 mm) and August (300 mm) and for the same year, the months of July and September are comparable in terms of rainfall height (figure 5).

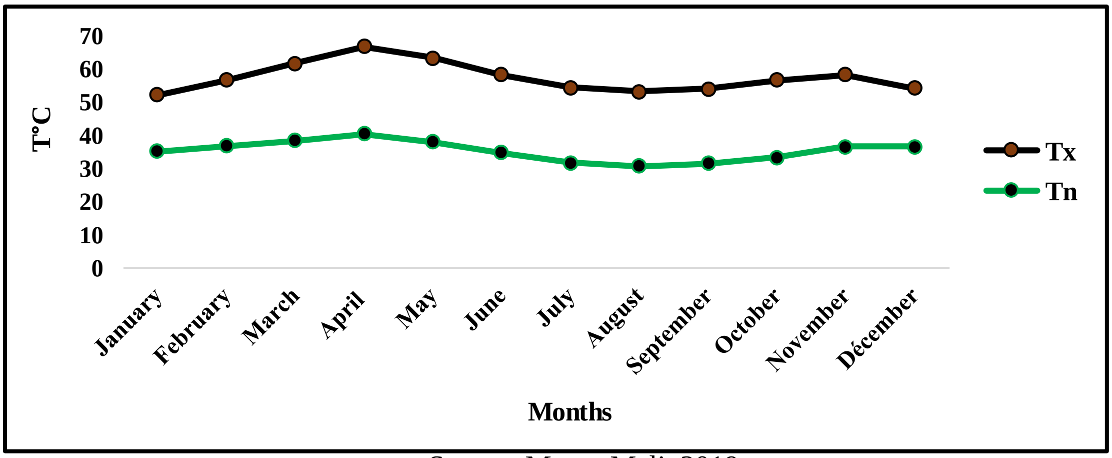


Source: Meteo-Mali, 2019

Figure 5: Monthly variation of Rainfall in the District of Bougouni in 2019

1.3.2. A temperature related to geographical location

The geographical location of the District of Bougouni makes that the temperatures are less uppermost compared to those areas in the Sahel-Saharan regions of the country. However, these temperatures are very high in certain months (April and May). In the year 2019, the temperatures show an important monthly variation. For the maximum and minimum temperatures, April is the hottest month (figure 6). Thus, when the maximum temperature increases, the minimum increases also except in December where the minimum temperature is stable.



Source: Meteo-Mali, 2019

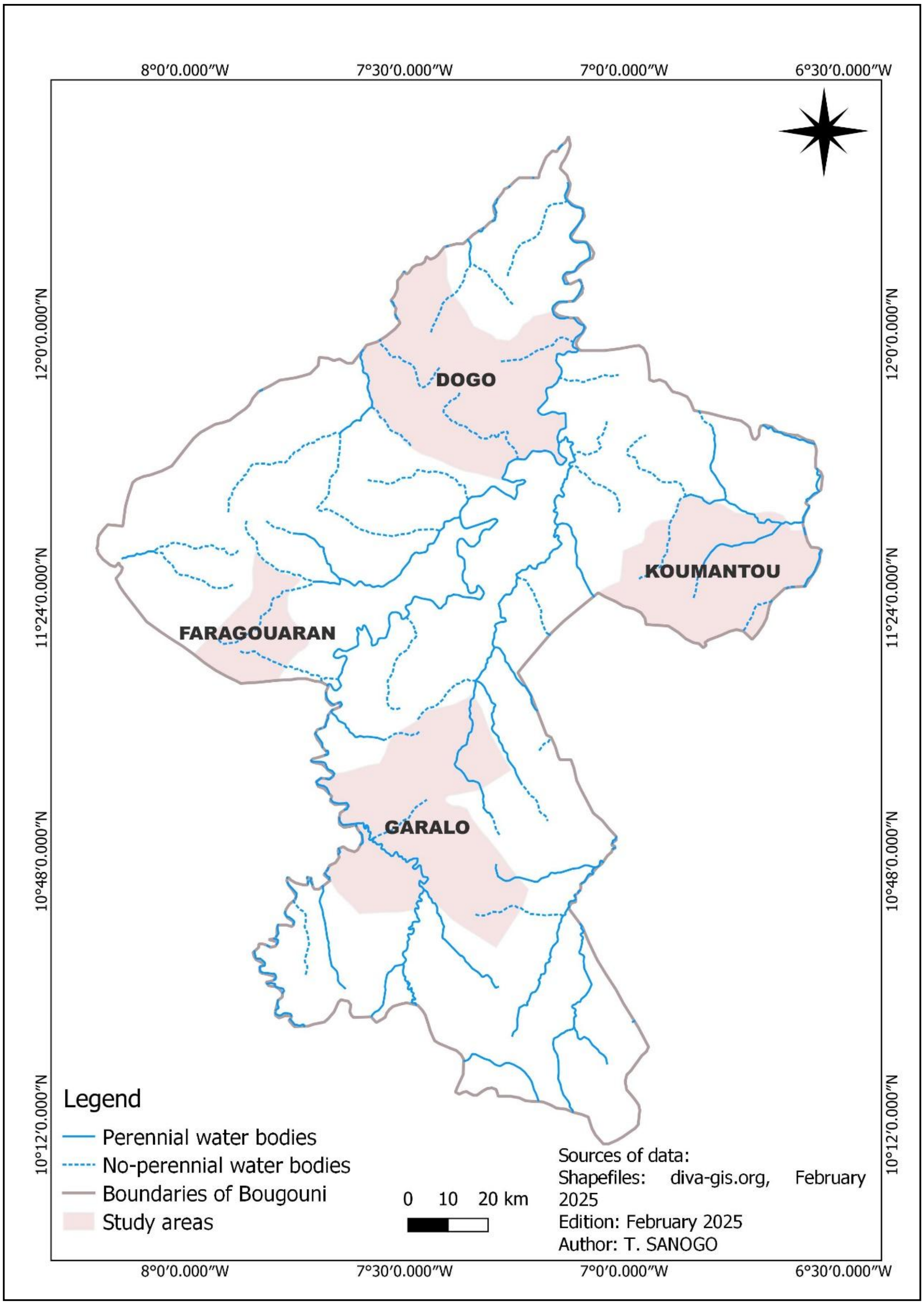
Figure 6: Monthly variation of Maximun Temperature (Tx) and Minimum Temperature (Tn) in the district of Bougouni in 2019

1.3.3 A resources-destroying wind speed

In the District of Bougouni, the winds are very strong. These are generally harmattan winds. In addition to the regular winds, monsoon or harmattan, which blow for several hours, there are very short gales that precede tornadoes; they give rise to very high speeds and have a much more devastating effect than these regular winds (M. Diabaté, 1995, p. 18). This devastation is manifested by the degradation of ligneous plants, the wind erosion of the seeds of the gramineae, and the amplification of the phenomenon of bushfires….

1.3. 4. A hydrographic network well-extended

The district of Bougouni is spanned by three (3) tributaries of the Niger River such as the ’’Baoulé’’; the ’’Bafing’’ and the ’’Bagoé’’. Alongside these are large backwaters such as the ’’Mono’’ and the ’’Dégou’’. The rains are very regular during the successive months: August-September and they end in October (F. Coulibaly, 2008, p. 53). However, the hydrographic network of Bougouni is classified as perennial and non-perennial water bodies. Those perennials are concentrated in the center and the south part while the non-perennials are located in the west and the north part of the district (map 2). This hydrographic network permits easy access of animal watering conditions.



Map 2: Hydrography resources map of Bougouni

1.4. A favorable zone for the Vegetation and fauna resources

The District of Bougouni abounds in enormous potentialities in terms of natural resources. Therefore, its geographical position confers to it abundant vegetation and provides in species presenting various types of formations and fauna resources such as:

- **Wooded and arboreal savannahs:** these plant formations are composed of trees and shrubs disseminated in a fairly dense herbaceous carpet, whose height varies between 6 to 8 m. They are essentially characterized by fallow land in the process of reconstitution whose cover is open and letting penetrate the light. The main dominant species are: *Bombax costatum* ‘‘Boumboum’’, *Afzelia africana* ‘‘Lingué’’, *Daniellia olveri* ‘‘Sanan’’, *Isoberlinia doka* ‘‘Chò’’, *Pterocarpus erinaceus* ‘‘Guénou’’, *Parkia biglobosa* ‘‘Néré’’, *Vitellaria paradoxa* ‘‘Shi’’, *Adansonia digitata* ‘‘Zira’’, *Tamarindus indica* ‘‘Tomi’’ (F. Coulibaly, 2008, p. 54).
- **Forest galleries:** These are rice-growing formations where the vegetation cover is entirely made up of fairly large trees that are distinguished from other formations by a narrow fringe 30 to 100 m wide, with a transversally uninterrupted canopy and uninterrupted and with specific floristic vaults. The dominant species are: *Carapa procera* ‘‘Kòbi’’, *Berlinia sp* ‘‘kòchò’’, *Elaeis guineensis* ‘‘N'té’’, *Raphia sudanica* ‘‘N'Pan’’ with a height generally greater than or equal to 17 m (F. Coulibaly, 2008, p. 54).
- **Open forests:** They are deciduous formations characterized by trees of medium size with a discontinuous undergrowth. The tree stratum is dominated by *Isoberlinia doka*, characterized by the presence of some economic species such as *Khaya senegalensis*, *Afzelia africana, Pterocarpus, erinaceus*. The dominant height is superior to 12 m.

The District of Bougouni has six classified forests, namely:

- The classified forest of Dialakoro at Garalo: 33,200 Ha;
- The classified forest of Siankandougou at Zantièbougou: 11,600 Ha;
- The classified forest of Keikoro at Sanso: 52,000 Ha;
- The Classified Forest of Banifing Baoulé at Dogo: 13,880 Ha;
- Classified forest of Tièmedougoula at Dogo : 28,640 Ha;
- The classified forest of Foulaboula in the urban commune of Bougouni: 200 Ha.

The classified forests remain the only reserves of fertile land and wood resources in the resources of the District which, nowadays, are subject to strong human pressures related to illegal occupation and excessive clearing, which constitute serious threats to the survival of these classified forests (F. Coulibaly, 2008, p. 5).

- ✓ **Fauna resources:** The geographical location of the District offers to animals a suitable habitat to their development. Thus, one can encounter: the Buffon's Cob ‘‘N'Kongoron’’, the Sylvicapagruma ‘‘Mangalan’’, the Guib harnessed ‘‘Minan’’, The Hippopotamus ‘‘Mali’’ and the Hypotrague ‘‘Dadjè’’. More than ¾ of the fauna's numbers have disappeared as a result of the combined action of harsh climatic conditions, bushfires and wild poaching. These actions have led to the migration of certain species to other countries in the sub-region (F. Coulibaly, 2008, p. 55).

1.5. A densely populated geographical space

The general population of the District of Bougouni in 2009 was 458, 546 inhabitants according to the ‘‘Recensement General de la Population et de l’Habitat (RGPH) du Mali’’ either 225, 430 for men and 233, 116 for women, with a density of 22 inhabitants per km².

The number of persons per household was estimated at 6,6 (INSTAT-Mali, 2013, p. 106). According to the ‘’Direction National de la Population (DNP)’’, from 2014 to 2022, the population of the District of Bougouni per communes is growing. This growing of population creates more needs which causes pressure on existing pastoral resources among agro-pastoralist communities. The most populated communes are Bougouni, Koumamtou, Zantiebougou, Dogo, Garalo, Sibirila and Keleya (table 16). More and more, the District is attracting many immigrants through Mali notably from the regions of Segou, Mopti and Gao and from neighboring countries because of gold mining activities. Emigration is in the direction of coastal countries, particularly the Ivory Coast Republic.

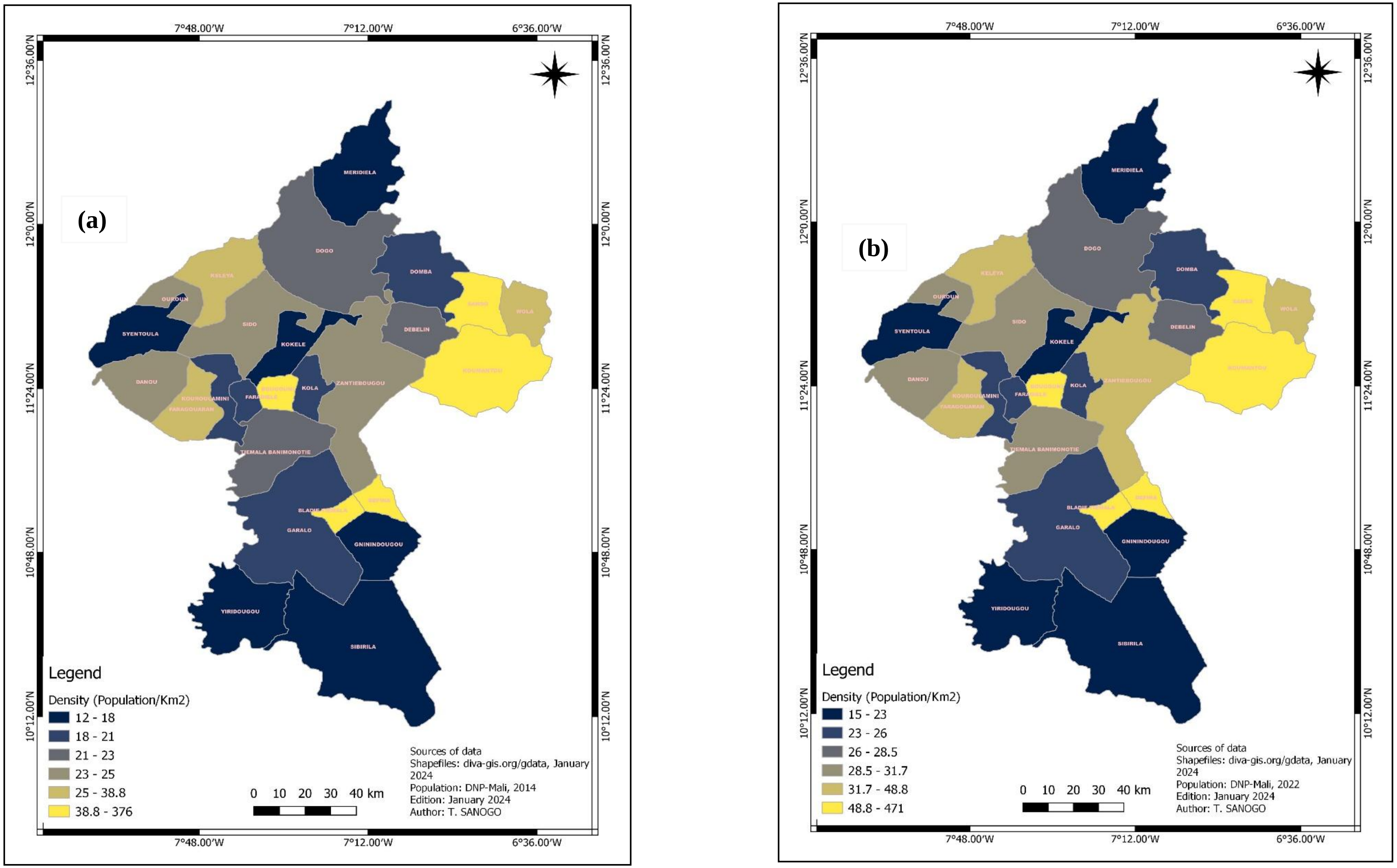
However, in recent years, the District has seen a massive return of emigrants from the district and from other parts of the country because of the conflicts taking place in Ivory Coast Republic (B. Sanogo, 2006, p. 28). In the District of Bougouni, there are several ethnic groups, the main ones being are the Peulhs, the Bambara, the Senoufos, the Miniankas, the Bozos, the Somonos, the Sonrhaïs, the Sarakolés, the Bobos and the Dogons. This population practices religions such as Islam, Christianity and animism. The customs are almost identical and tend to join the Muslim religion (B. Sanogo, 2006, p. 29).

Table 16: Evolution of Bougouni District annual population from 2014 to 2022

COMUNNES	2014	2015	2016	2017	2018	2019	2020	2021	2022
BOUGOUNI	69,740	71,800	73,904	76,052	4,604	80,470	82,746	85,063	87,420
BLADIE-TIEMALA	5,485	5,647	5,813	5,981	13,464	6,329	6,508	6,690	6,876
DANOU	16,041	16,515	16,998	17,492	8,281	18,508	19,032	19,565	20,107
DEBELIN	9,866	10,157	10,455	10,759	8,019	11,384	11,706	12,033	12,367
DEFINA	9,554	9,835	10,124	10,418	34,154	11,023	11,335	11,653	11,976
DOGO	40,690	41,892	43,119	44,373	13,847	46,950	48,278	49,630	51,005
DOMBA	16,497	16,984	17,482	17,990	2,689	19,035	19,573	20,121	20,679
FARADIELE	3,204	3,298	3,395	3,494	10,525	3,696	3,801	3,907	4,016
FARAGOUARAN	12,539	12,910	13,288	13,674	32,760	14,468	14,878	15,294	15,718
GARALO	39,029	40,182	41,359	42,562	20,529	45,034	46,308	47,604	48,924
KELEYA	24,458	25,180	25,918	26,671	6,477	28,220	29,019	29,831	30,658
KOKELE	7,716	7,945	8,177	8,415	4,488	8,904	9,156	9,412	9,673
KOLA	5,347	5,504	5,666	5,831	51,209	6,169	6,344	6,522	6,702
KOUMANTOU	61,009	62,811	64,651	66,530	6,245	70,395	72,387	74,413	76,475
KOUROULAMINI	7,440	7,660	7,884	8,113	13,858	8,585	8,828	9,075	9,326
MERIDIELA	16,510	16,998	17,496	18,004	5,545	19,050	19,589	20,137	20,695
OUROUN	6,606	6,801	7,001	7,204	19,834	7,623	7,838	8,058	8,281
SANSO	23,630	24,327	25,040	25,768	30,837	27,265	28,036	28,821	29,620
SIBIRILA	36,738	37,823	38,932	40,063	20,822	42,390	43,590	44,810	46,052
SIDO	24,807	25,539	26,288	27,052	9,455	28,623	29,433	30,257	31,095
SYEN TOULA	11,264	11,597	11,937	12,284	16,773	12,997	13,365	13,739	14,120
TIEMALA BANIMONOTIE	19,983	20,573	21,176	21,791	11,382	23,057	23,709	24,373	25,049
WOLA	13,560	13,961	14,370	14,787	8,966	15,646	16,089	16,539	16,998
YININDOUGOU	10,682	10,997	11,320	11,649	9,478	12,325	12,674	13,029	13,390
YIRIDOUGOU	11,292	11,625	11,966	12,314	35,767	13,029	13,398	13,773	14,154
ZANTIEBOUGOU	42,612	43,871	45,156	46,468	17,636	49,168	50,558	51,974	53,414
Total	**546,299**	**562,432**	**578,915**	**595,739**	**417,644**	**630,343**	**648,178**	**666,326**	**684,789**

Source: National Directorate of Population of Mali (2022)

The density per square kilometers of this population is varying from 12 to 376 for the year 2014 and from 15 to 471 for 2022 (map 3). From the 2014 to 2022, it reaveals a high decreasing of density for the commune of Tiémala banimonotié and Zantiébougou.



Map 3: Density map of the population of Bougouni District in 2014 (a) and 2022 (b)

1.6. Socio-economics activities focused on Pastoralism

The main socio-economics activities practiced by the population living in the District of Bougouni are agriculture, livestock farming and other secondary activities such as, fisheries, handicrafts and socio-cultural (S. Traore *et al.*, 2021, p. 2).

- ✓ The agriculture sector based on cereal and cotton production related to favorable climatic conditions is greatly productive. The main cereals of production are maize, rice, sorghum, millet, fonio and bean. From 2011 to 2021, according the statistics of the Regional Directorate of Agriculture in Bougouni, the farmlands areas are increasing for rice and bean, with greatly reduction for the sorghum, maize, millet and fonio (table 17). He semi-arid climatic conditions and the fragile soils of Mali have until now supported production of maize ‘‘*Zea mays*’’, cotton ‘‘*Gossypium hirsutum*’’, sorghum ‘‘*Sorghum bicolor*’’, millet ‘‘*Pennisetum glaucum*’’, fonio ‘‘*Digitaria exilis*’’, cowpeas ‘‘*Vigna unguiculata*’’ and peanuts ‘‘*Arachis hypogaea*’’ as field crops. That situation is contributing to rangeland area reduction. Agricultural pressure on land resources has gradually increased. According to the National Programme of Adaptation to climate change of Mali (2007, p. 15), the area of cultivated land at national level increased from 1,967,000 Ha in 1970/71 to 3,472,000 Ha in 1994/95, which represents an increase of 15 % in terms of land clearing. The growing of areas under cultivation is an important crop residues production for livestock feeding but constitutes pasture area reducing factor. The District is increasingly involved in industrial activities that contribute to the economic development of the population. The cotton ginning factories employ young people for at least six months of the year. The gathering of ‘‘shea nuts’’ *(vitellaria paradoxa)* and ‘‘nere’’ (*Parkia biglobosa)* is an important source of income for women. There is a shea nut *(vitellaria paradoxa)* processing plant in Zantièbougou, located 30 kilometers from Bougouni. The exploitation of the Morila gold mine began in the year 2000, resulting in a massive influx of young people from the interior of the country and from other African countries (Z. Doumbia, 2009, p. 30).

Table 17: Evolution of the farmlands/cultivated area of the main cereals (ha) in the District of Bougouni from 2011 to 2021

Years	Main Cereals (Ha)					
	Maize	**Rice**	**Sorghum**	**Millet**	**Fonio**	**Bean**
2011	60,495	23,845	62,020	22,085	5,000	6,850
2012	67,442	28,433	61,510	25,834	5,025	6,265
2013	116,223	27,230	68,424	30,153	4,975	6,370
2014	70,516	24,330	60,345	27,844	4,042	4,275
2015	16,046	23,279	10,750	6,161	2,823	5,671
2016	19,404.5	19,987	74,475	4,075.2	1,912	6,793
2017	19,707	24,517	3,923	4,342.5	700	6,780
2018	35,825.5	12,005.5	6,081	3,406	1,067.5	1,356
2019	40,762	26,840	17,672	5,533.5	1,281.5	8,916
2020	42,677	26,323.8	18,283	6,781.7	1,305	8,934
2021	43,614	30,182	19,936.5	5,964	1,004	13,064

Source: Regional Directorate of Agriculture of Bougouni (2021)

- ✓ The livestock farming sector is growing. The District of Bougouni possesses seven (7) livestock market, twenty five (25) pastoral wells, deux (2) Slaughterhouse, eight (8) air slaughter for the big and small ruminants, one poultry slaughterhouse center (SLPIA-B, 2021, p. 9). The most important livestock market are those from Bougouni (Kola and Dalabani), Koumantou and Garalo/Manakoro. These markets are well supplied according to the statistics of 2020 annual report of the livestock farming sector, the controlled meat production was estimated at 1,278,155 kg an increase of 15 % compared to those of the year 2019. The controlled number of animals in fattening was approximately 930 heat for the cattle, 555 heat for the sheep and 365 heat for goat (SLPIA-B, 2020, p. 16). These markets constitute an important source of income of the population. They are more well supplied from May to December than other months. Exceptionally well supplied on the eve of some Muslim holidays like Ramadan, Tabaski, the first day of the Muslim year. The animals as big ruminants are categorized by bulls, steers, young bull/bullocks, cows and heifers. For most of the markets, the whole heat of animal categories presented are almost all sold for the large and small ruminants. This animal presented size is globally in high variation (table 18).

Table 18: Large ruminants controlled movement in the livestock markets of Bougouni's District from 2014 to 2021

Years	Animal Categories											
	Bulls		Steers		Young Bull/Bullocks		Cows		Heifers		Total	
	P	S	P	S	P	S	P	S	P	S	P	S
2014	3,077	2,994	5,690	5,210	3,975	3,565	8,219	7,698	3,820	3,375	**24,781**	**22,842**
2015	2,164	2,190	4,985	4,185	3,352	2,979	7,146	6,490	3,011	2,700	**20,658**	**18,544**
2016	4,628	4,548	6,800	5,983	5,675	4,914	10,962	9,560	4,763	4,177	**32,828**	**29,182**
2017	3,685	3,563	6,174	5,386	5,373	4,414	8,666	7,494	4,260	3,339	**28,158**	**24,196**
2018	3,680	3,560	6,160	5,377	6,373	5,311	8,530	8,490	5,200	4,899	**29,943**	**27,637**
2019	10,403	10,176	8,436	8,045	6,889	6,580	8,989	8,557	5,471	5,126	**40,188**	**38,484**
2020	7,120	6,720	9,213	8,541	8,535	8,496	10,397	9,361	7,576	6,715	**42,841**	**39,833**
2021	9,033	8,527	8,997	7,933	8,422	7,658	11,830	10,932	7,567	6,504	**45,849**	**41,554**

P=*Presented;* ***S***= *Sold*

Source: SLPIA-B (2021)

The sheep and goats' controlled movement in markets of Bougouni's District from 2014 to 2021 shows that the animal size presented was almost sold. The year 2014 and 2014 were globally less provided markets compared to the rest of years. However, the year 2021 was the most provided market (table 19).

Table 19: Small ruminants controlled movement in the livestock markets of Bougouni's District from 2014 to 2021

Years	Sheep		Goat		Total	
	P	S	P	S	P	S
2014	20,222	16,467	22,860	19,175	43,082	35,642
2015	8,521	6,776	13,849	11,677	22,370	18,453
2016	30,616	24,994	33,957	27,890	64,573	52,884
2017	34,715	28,270	39,362	38,806	74,077	67,076
2018	34,700	31,250	39,367	39,215	74,067	70,465
2019	22,031	17,740	32,686	25,770	54,717	43,510
2020	53,869	46,094	46,900	32,404	100,769	78,498
2021	61,319	50,282	68,024	59,111	129,343	109,393

P=*Presented;* ***S***= *Sold*

Source: SLPIA-B (2021)

- ✓ The milk production in the recent ten years (from 2010 to 2020) was estimated at 507,730 liters for the controlled quantity collected and 505,104 liters transformed (table 20). This milk production is increasing for the years 2017 and 2018. These increasing can be explaned by the high quantity of forage production, capacity building of producers, sensitization, promoting of forage crop production, selection improved breeds.

Table 20: Variation of the milk production in the District of Bougouni from 2011 to 2021

Years	**Milk Quantity (Liters)**	
	Collected	**Transformed**
2010	164,000	38,190
2011	59,507.5	58,257.5
2012	46,259.5	38,328.5
2013	103,094	102,660
2014	95,321	95,321
2015	90,157	90,157
2016	116,317.5	116,317.5
2017	219,158.25	216,966.67
2018	219,158	216,966
2019	210,161	205,957
2020	148,436	145,467
2021	144,964	142,065
Total	**1,616,534**	**1,466,653**

Source: SLPIA-B (2021)

The egg production from 2015 to 2020 in the District of Bougouni was approximately 54,000 of the number of laying hen for egg production estimated at 15,768,000. This production is very important for fighting food insecurity in the district of Bougouni and his neighbor's localities (table 21).

Table 21: Variation of modern eggs production in Bougouni's District from 2015 to 2021

Years	Number of laying hen	Number of Eggs
2015	10,434	2,629,368
2016	28,484	1,189,564
2017	78,389	2,496,460
2018	78,355	2,486,464
2019	73,475	17,598,330
2020	54,000	15,768,000
2021	63,250	17,314,687
Total	**375,953**	**56,853,505**

Source: SLPIA-B (2015-2021)

1.7. Other activities or opportunities in Bougouni

They are about fisheries, handicrafts, socio-culture….

- ✓ Fishing is practiced in all seasons in the District of Bougouni. The fisheries activities are practiced through the natural and artificial ways. The natural way is implemented over the rivers and backwaters. This production is originate from the Niger Rivers which crossed the District. The artificial production is on above-ground ring and fishpond.
- ✓ Handicrafts are not well developed. The different group of handicraft activities are: blacksmiths, jewelers, potters, metal and wood carpenters, sculptors, dyers, seamstresses, upholsterers, shoemakers, toy makers, masons, car and motorcycle repairers, food processors, soap makers. Most of the artisans have their work area located in the rights-of-way of the main roads and inside the concessions.
- ✓ On the socio-cultural level, the District of Bougouni, is a crossroads of several peoples and civilizations is an area where cultures and traditions mix per excellence. The predominant ethnic group is the Bambara, followed by the Peulh of Wassoulou. Social relations respect the gerontocracy. Inter-village and inter-ethnic solidarity exists in most of the villages. Other food crops were grown during the agricultural season. However, other food crops are grown during the agricultural season (B. Sanogo, 2006, p. 29; Z. Doumbia, 2009, p. 30).

Despite, the whole activities and opportunities, the livestock sector has started experiencing pastoral resources degradation with a growth in livestock population size.

CHAPTER 2:

DENSE PASTORAL RESOURCES IN DEGRADATION WITH A STRONG GROWTH OF LIVESTOCK SIZE

The chapter two of is focused on the rich and diversified pastures in degradation, the watering points and the salty land, the livestock breed growing and land use/land cover accuracy assessment.

According to the favorable climatic conditions, the pastures are dense and diversified for animal long period feeding. The hydrography network is very large and constitutes an easy access for animal watering.

However, these resources are on high degradation due to human actions and adverse behaviors of rainfall. Animal breeds are diverses and richs. During the dry season, these animal breeds are suffering from the early dry of watering points and scarcity of forage availability. The Land Use and Land Cover (LU/LC) accuracy is showing a greater pressure from human and climatic patterns on pastoral resources areas. The extention of build up/settlement areas and farmland/cultivated areas are leading to pastoral areas reduction. The reduction of water body and pasture areas constitute a real threat for the livestock production system in the study area.

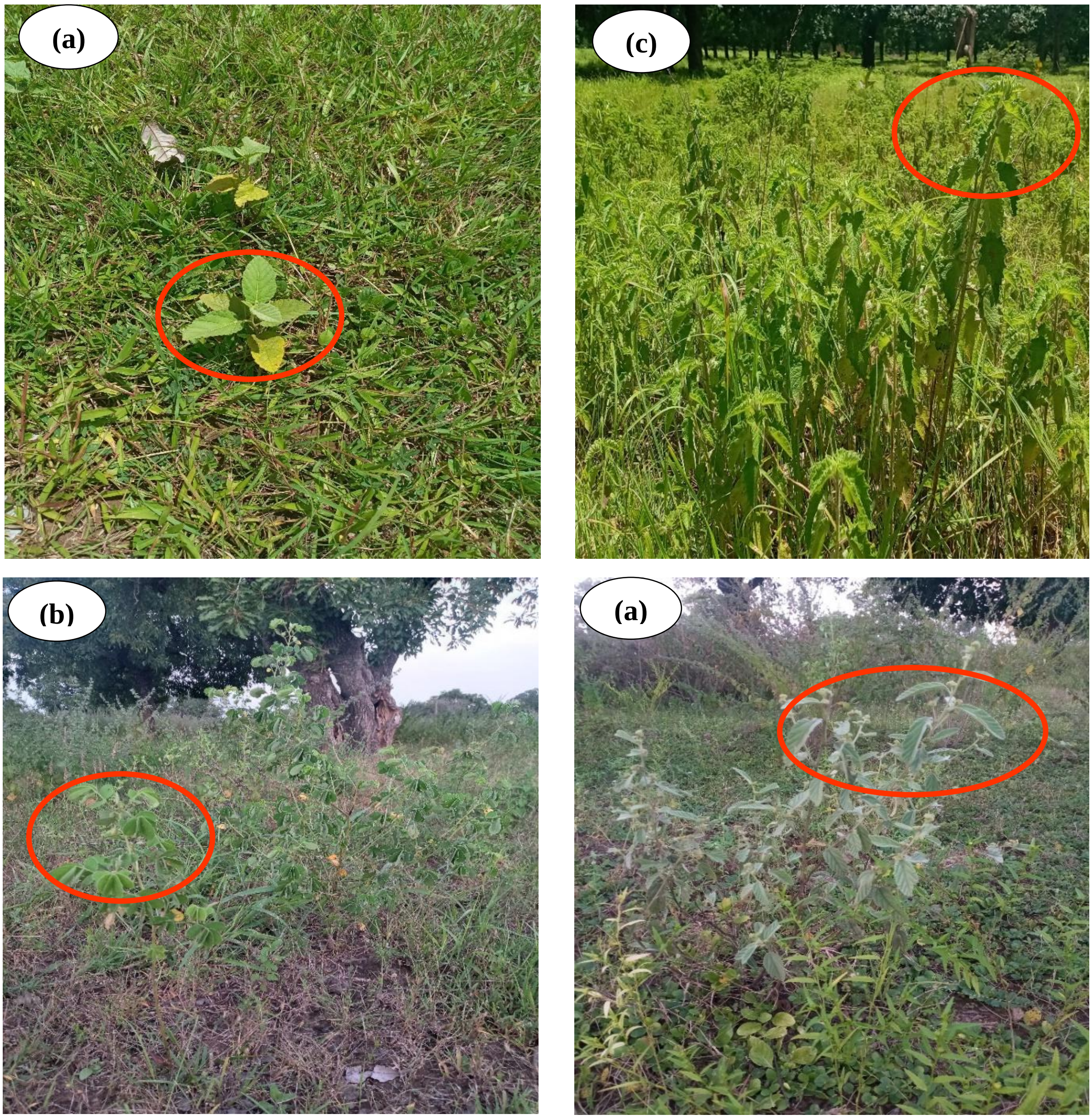
2.1. Riched and diversified pasture areas in high degradation

2.1.1. Herbaceous species

The pastures in the District of Bougouni are constituted by several herbaceous species. These herbaceous species are most of them gramineae (annual or perennial). The dense forests, the gallery forests and the fallow land are the main areas where these species are well growing. In fallow land, herbaceous species grow rapidly than others areas due to its resting time and not experienced by any agricultural activities.

They encompasses of *Digitaria horizontalis, Digitaria sanguinalis, Andropogon gayanus, Andropogon pseudapricus, Zornia glochidiata, Euphorbia hirta, Cyperus esculentus, Diheteropogon hagerupii, Loudetia togoensis, Tripogon minimus, Sporobolus pyramidalis, Boreria radiata*. Since the Sahelian zone drought' year 1970, the herbaceous cover has decreased due to one part of human activities through the late bushfire practices, increasing the cultivated area and other part to climate adverse impacts (PANA-Mali, 2007, p. 17).

According to a recent study carried out by S. Traoré *et al.,* (2022, p. 129), the onset of the rainy season is getting late with an early end. However, many species are not able to end the cycle production for a given year. That situation leads to the disappearance of certain species, reduction in species yield, low density of species, appearing of some species with less pastoral value. However, since many years ago the rangelands in the District of Bougouni are experiencing a decreasing in the number of palatable species at the expense of unpalatable species with less pastoral value. The most important species are *Waltheria indica* (a), *Cassia Tora* (b), *Hyptis souaveolens* (c) (photo 7). Due to its high level of resitance to droughts and its aptitude colonizing pasture areas, these species constitute a real threat for the pastoral value quality in the study area.



Source: Sanogo T., photo kaken in August 2022.

Photo 7: Case of species with less pastoral value in the district of Bougouni based on *Waltheria indica* (a), *Cassia tora* (b), *Hyptis suaveolens* (c)

2.1.2. Woody species

The woody stratum of the District Bougouni is composed essentially of bushes, trees with high height located in the dense forests, open forests, and gallery forests (S. Traoré *et al.*, 2021, p. 2). They are mainly constituted by *Khaya senegalensis*, *Ficus gnalocarpa*, *Pterocarpus lucens*, *Puterocarpus erenaceus*, *Acacia albida*, *Acacia nilotica, Afzelia africana, Manguifera indica*. They are used as the main of small ruminants feed during the dry season and are considered as an income for a portion of the population.

At the scale of local knowledge, certain species are playing a medicinal role for livestock health including *Khaya senegelenis* (leaves), *Pteleopsis suberosa* (leaves), *Ximenia americana* (fruit), *Prosopis africana* (leaves and fruit), *Guieria senegalensis* (leaves), Gardenia erubescens(fruit).

2.1.3. An extended pastures areas in the study environment

The table 22 reveals a wide and diverse pastures zone in the District of Bougouni. They constitute by ponds, watering points, transhumance areas, patoral wells, and pastoral spaces, transhumance tracks, pastoral tracks. The communes of Dogo, Sibirila, Sanso, have the widest pastoral zones of the District of Bougouni.

Currently, most of these pasture areas are blocked by farmland and build up areas which entailing its spaces reduction. These resources mostly affected by the occurrence of droughts, the reduction of rainy season length, the increasing of wind speed adverse impacts…..

Table 22: Situation of main developed and undeveloped pastures in the District of Bougouni

N°	COMMUNES	PASTURES AREAS	SURFACE AREAS/NUMBER	DISTANCE (KM) FROM BOUGOUNI CITY	CONCERNED LOCALITIES
1	Kéléya	Ponds and developable spaces	610 Ha		Tiessana, Sagala, Dialakoro, Gouanalé, Diala, N'téna, Soulouba, Siembougou, Ouré (Faraba), Donséla, Makana, Sémana, Faradié.
		Transhumance track,	-	40 km	Bassa, Kéléya, Diala, et Tiérou.
		Pastoral wells	-		, Bassa, Kéléya, Diala, et Tiérou.
2	Sanso	Ponds and development spaces	800 Ha		18 Villages
		A Transhumance track,		75 km	Sanso, Sinsin, Diamakolé.
		Pastoral wells	05	-	Finkoua, Sounsounkoro, Koroféréla, N'tjila, Sokéla.
3	Sibirila	Ponds and developable spaces	-	-	Sofarani to Manankoro Dalada to Fangala Diarako to Diondiala Bani to Kolé Sagani to Ouogona Kobolo to Diossan Tènèko to Kabandiè Baboloni to Soromba
		Developable pastoral areas	5,000 Ha	-	Banzana, Koroko, Minzanga, Diendio, Manankoro, N'gorola, Bamba, Ouoman, Ouogona, Kabandiè, Sirakoro.
		3 Transhumance tracks	-	110 km	Garalo, Soromba, Torola, Debela, Diondiala, Ouogona, Ouoman, Nikamala, Komina.
			-	180 km	Sirakourou (Garalo), Sanakourouni, N' Gorola, Manankoro.

			-	80 km	Foulalaba (Garalo), Diossan, Sanakourouni, N’ Gorola, Manankoro.
		Pastoral ponds developable Pastoral spaces developable	50 Ha	-	Solaba, Blaba, Doumoutou, Bofara, Djinè, Garalo, Banko. Fara, Nagnola, Sirakoroblé, Kora, Dialakoro, Tabakorolé, Solabougouda , Foulalaba, Ouena Sokoro et Séna.
4	Garalo	Pastoral wells	03	-	Djinè, Garalo, Tabakorolé,
		7 Transhumance tracks	-	135 km	Djinè, Banko, Garalo, Sorona, Kolobé, Solobougouda, Solaba, Tanhala, Tiékoumala, Kodiougou, N’pagnala, Foulalaba.
				12 km	Tanhala, Tabakorolé, Sirakoroblé.
				10 km	N’pagnala, Kora.
				15 km	Garalo, Djinè.
				28 km	Djinè, Kotiè, Nagnola, Banifing Fleuve, Garalo.
				14 km	Ouéna Sokoro, Sèna, Kérékoumala, Garalo.
				21 km	Fara, Sienré, Tienko, Dialakoro, Sorona Kolobé.
5	Sido	Pastoral spaces developable	09	-	Tomba, Sido, Sido (Banco), Sido, Farabakoro, Sakoro, Siratogo, Djerila, Banankoro, Bougoula.
		Pastoral wells developable	08	-	Tomba, Sido, Farabakoro, Sakoro, Siratogo, Djerila, Banankoro, Bougoula.
		Transhumance track	-	-	Tomba , Sido, Sakoro, Siratogo , Banankoro , Bougoula
		Transhumance track	-	-	
		Ponds and developable	1,665 Ha	-	Belekan , Feretou , N’vogokoro , Famambougou , Bindjougoula , Soumoudji ,Lasso, Fiana , Nèrèkôrô Tyan , Totiguila , Nani , Sagala (Koula) , Diran Tabakoro, N’tianyirila , Diran Massafala , Tietiguila Massala ,

		spaces			Kemedougou
6	Dogo	Pastoral wells developable	14	-	Feretou, Soumoudji, Lasso, Fiana, Totiguila, Nani, Diran Tabakoro, N'tianyirila, Diran Massafala, Tietiguila Massala, Kemedougou
		3 Transhumance tracks	-	147 km	Dogo, Belekan, Sido (45 Km) ; Dogo, Bougouni Par Le Mono (81 Km), Belekan Fiana, Soumoudji, Faradie (21 Km)
7	Koumantou	Ponds and developable spaces	04	-	Guérékélé, Kô Tenkô, Boumou, Winkala
		Pastoral spaces developable	05	-	Banko-Zanfina, Konza, Guérekele, Sodioula, Tienkongoba
		Pastoral wells developable	02	-	Nonthô (Banko-Zanfina), Konza
		3 Transhumance tracks	-	71 km	Sanso, Dèbèlin, Konza, Kébila
			-	75 km	Sanso, Nèrèkôrô, Zambala, Mèna, Koumantou, Winkala
			-	65 km	Sanso, Diamakoli, Kégnérila, Mèna, Kolondiéba
8	Danou	Pastoral track	-	10 Km	Dièba

Source: DRPIA-Bougouni, 2023

2.2. Watering points and salty land affecting by climate drivers in the study area

The livestock watering point network of Bougouni's District is varied and important. It is composed by the crossed tributaries of Niger River (‘‘bafing, baoulé, and bagoe’’), lakes, waterholes, backwaters, wells. In the dry season period, most of wells are very deep of level and lead to low access of animal drinking water. According to the conclusions of a research implemented in the Bougouni' district, the mean depth of wells was estimated at 11.48 meters in the dry season (B. Z. Birhanu & R. Tabo, 2016, p. 7).

During the rainy season the most used watering points are lakes, waterholes, backwaters. In the dry season, livestock producers use the tributaries of Niger River and certain wells for animal watering. Therefore, due to the adverse effects of climate hazard most of these water point are becoming increasingly dry than the normal period (T. Sanogo *et al.,* 2016, p. 41).

The alteration of the endoreism and the strong evaporation allow the formation of salty lands. These are particular sites where the ground has a salty taste and which, of this fact, has a great power of attraction on the animals which inevitably come to lick them (M. Aguilhon, 2009, p. 10). In the District of Bougouni, these pastoral resources are disappearing due to climate hazards through the high intensity of rainfall and the erosion. The zones as the village of Kassela and Blaba are some regions where salty land has been discovered.

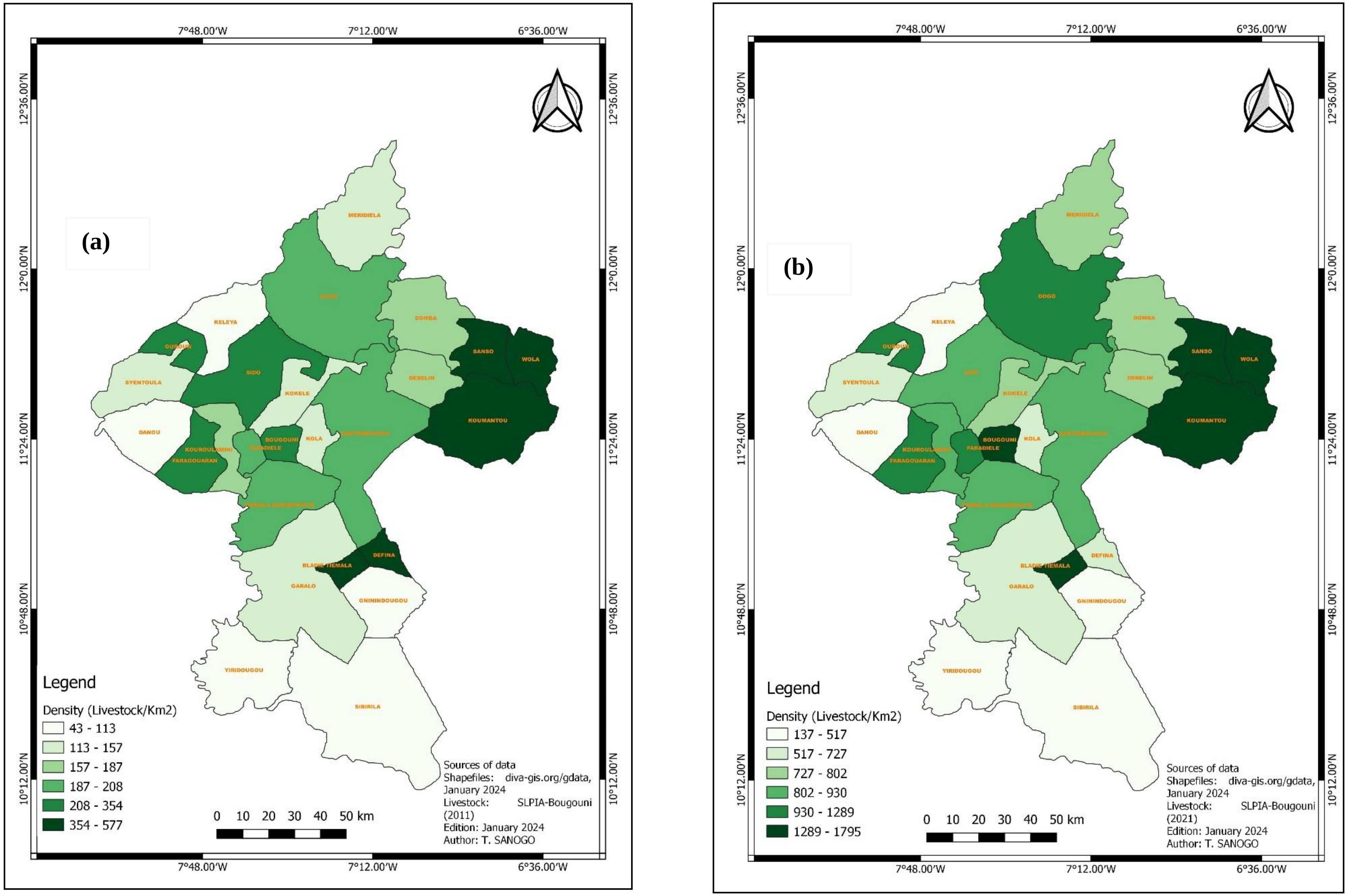
2.3. A livestock of various breeds growing

The District of Bougouni is one of the greatest zones of Mali in terms of animal population size. Bougouni's livestock is constituted by Cattle, sheep, goats, horses, donkeys, pigs, and poultry (table 23). This livestock is riched and diversified in breed. The main breeds are: ‘‘Zebu peulh’’, ‘‘Ndama’’, ‘‘zebu maure’’, ‘‘zebu borrorrow’’, ‘‘zebu azawak’’. From the statistics of 2021, the livestock population is estimated by 574,003 heats of cattle; 282,050 heats of sheep; 481,385 heats of goat; 118 heats of horse; 32,984 heats of donkey; 4,582 heats of pig and 16,724,765 subjets for poultry. This livestock population is higher in the localities of Bougouni, Koumantou, Dogo, Zantiebougou, Garalo, and Faragouaran than others (map 4). From 2011 to 2020, the livestock population is increasing (table 24). This incrasing is very important for the poultry, cattle, goat and sheep. Concerning the Horse and Pig, the population size is not much varying. This situation can be explained by the fact where population is less interesting to Horse and Pig breeding. There is a religious factor which explains for the Pig case.

Table 23: Livestock Population of 2021 per communes in the District of Bougouni

Communes	Cattle	Sheep	Goat	Horse	Donkey	Pig	Poultry	Total
Bougouni	63,337	32,819	55,120	20	2,241	592	2,311,668	**2,465,797**
Bladiè Tièmala	70,579	1,775	2,979	5	117	28	125,303	**200,786**
Faradielé	3,761	1,983	3,270	2	5,816	38	137,243	**152,113**
Danou	2,377	8,826	14,837	6	598	147	65,450	**92,241**
Dèbèlin	8,721	4,510	7,574	3	303	75	317,637	**338,823**
Défina	12,140	6,286	10,560	2	428	114	87,022	**116,552**
Dogo	43,353	22,453	37,729	8	1,527	397	1,581,873	**1,687,340**
Domba	15,164	7,856	13,193	3	532	138	553,430	**590,316**
Syentoula	11,474	5,945	9,505	2	407	206	418,697	**446,236**
Faragouaran	13,491	6,986	11,727	4	473	128	492,457	**525,266**
Garalo	34,570	30,083	17,909	6	1,217	320	1,261,731	**1,345,836**
Kéléya	29,780	15,425	25,923	4	1,047	283	118,748	**191,210**
Kokélé	8,553	4,426	7,440	2	303	70	312,205	**332,999**
Kola	4,622	2,270	4,005	4	162	38	138,775	**149,876**
Kouroulamini	7,794	4,038	6,775	3	278	75	279,236	**298,199**
Méridièla	15,488	8,019	13,470	4	545	138	708,876	**746,540**
Ouroun	7,228	3,745	6,282	3	256	62	263,770	**281,346**
Sanso	18,544	9,608	16,140	5	659	165	676,903	**722,024**
Sibirila	29,363	15,214	25,553	4	10,337	275	535,750	**616,496**
Sido	21,902	11,351	59,346	5	770	62	799,366	**892,802**
Tièmala Banimonotié	19,524	10,113	16,987	4	687	28	712,501	**759,844**
Wola	15,694	8,125	13,646	3	553	138	572,617	**610,776**
Gninindougou	7,577	3,734	6,587	4	262	62	276,442	**294,668**
Yiridougou	11,630	6,024	10,113	3	38	103	424,392	**452,303**
Koumantou	57,625	29,856	50,151	5	2,028	542	2,103,161	**2,243,368**
Zantièbougou	39,712	20,580	34,564	4	1,400	358	1,449,512	**1,546,130**
Total	**574,003**	**282,050**	**481,385**	**118**	**32,984**	**4,582**	**16,724,765**	**18,099,887**

Source : SLPIA-B (2021, p. 13)



Map 4: Livestock size density map in 2011(a) and 2021 (b) per communes in Bougouni District

Table 24: Evolution of livestock population from 2011 to 2020 in the Bougouni's District

Years	Animals Species						
	Cattle	**Sheep**	**Goat**	**Horse**	**Donkey**	**Pig**	**Poultry**
2011	380,000	165,875	284,922	34	13,677	1,800	3,154,666
2012	439,963	182,011	310,644	32	14,088	1,940	3,563,227
2013	453,160	191,110	326,175	32	14,510	2,095	3,990,814
2014	453,148	191,099	326,166	32	21,989	2,082	3,990,802
2015	466,730	200,694	342,459	32	22,636	2,231	4,469,686
2016	480,732	210,729	359,582	33	23,315	2,403	5,006,048
2017	510,010	232,050	388,722	100	25,334	2,510	6,753,430
2018	530,010	230,150	392,720	100	27,327	2,542	6,850,457
2019	541,069	255,839	428,566	120	31,104	3,662	10,703,849
2020	557,298	268,631	449,996	120	32,036	4,100	13,379,816
2021	574,003	282,050	481,385	118	32,984	4,582	16,724,765
2022	591,223	296,153	505,456	118	33,975	12,0017	20,840,509
Total	**5,977,346**	**2,410,238**	**4,091,337**	**871**	**259,000**	**29,947**	**78,587,560**

Source: SLPIA-B (2022)

2.4. Land use/land cover map and accuracy evaluation in the study area

2.4.1. Assessment in the commune of Faragouaran

The land use /land cover assessment was focused on the following classes: bowal/bare land, settlement, water bodies, shrubby savannah, wooded savannah, and cultivated area. The overall area of interest is 47, 636 hectares in Faragouaran.

The land use /land cover analysis for 1990 reports that the unit ranged 30,537 Ha for wooded savannah, 6,080 Ha for shrubby savannah, 4,799 Ha for bowal/bare land, 3,687 Ha for cultivated areas, 1,557 Ha for settlement, 976 Ha for water bodies. Thus, the widest unit were woody and shrubby savannah areas and the least were settlement and water body areas.

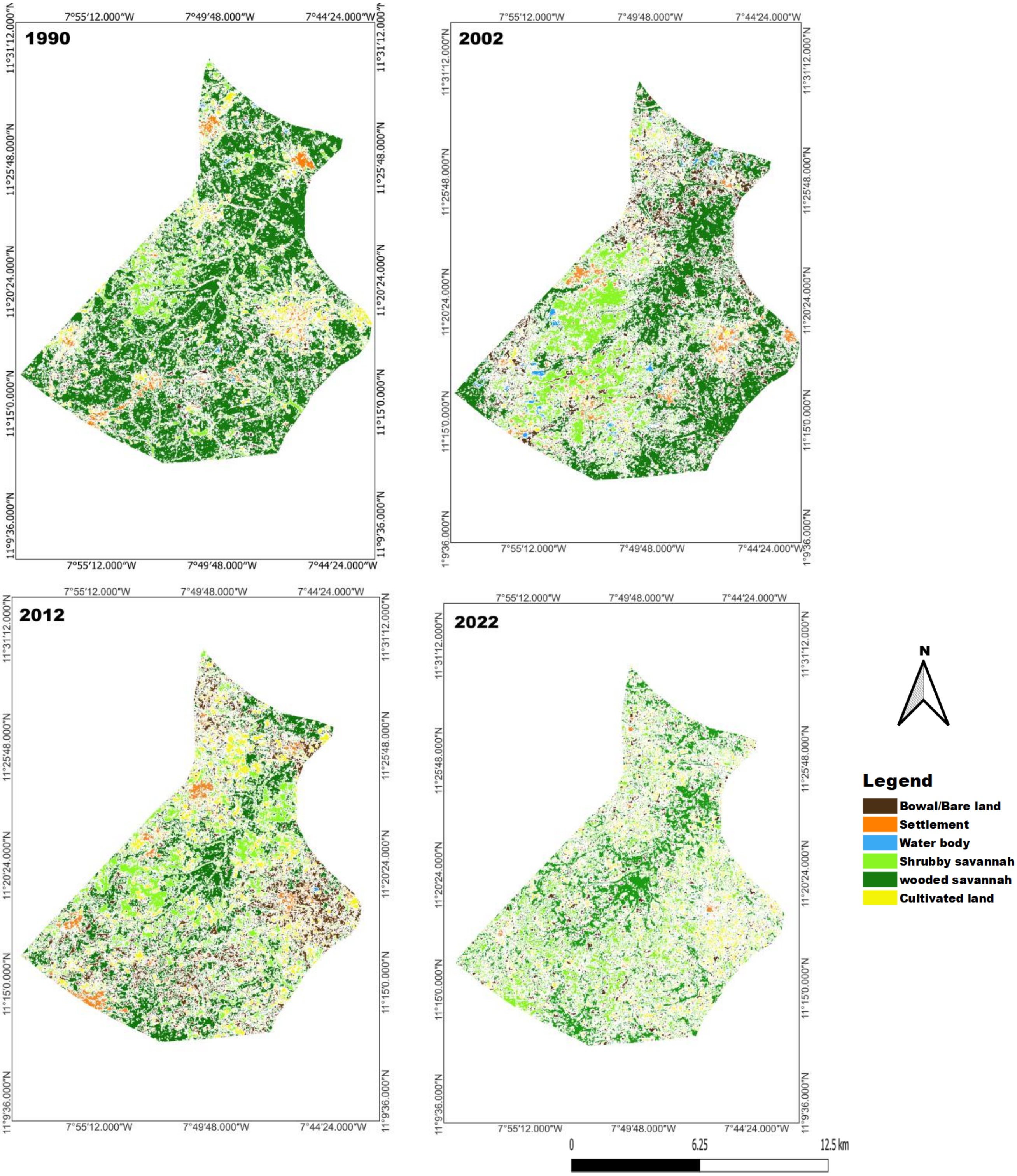
The land use /land cover analysis for 2002 reports that the unit ranged 21,438 Ha for wooded savannah, 10,638 Ha for shrubby savannah, 10,385 Ha for bowal/bare land, 2,998 Ha for settlement, 1,513 Ha for cultivated areas and 664 Ha for water bodies. Thus, the widest units were woody and shrubby savannah areas and the least were cultivated areas and water body areas.

The land use /land cover analysis for 2012 reports that the unit ranged 17,180 Ha for wooded savannah, 12,063 Ha for bowal/bare land, 10,466 Ha for shrubby savannah, 10,385 Ha, 5,535 Ha for cultivated areas, 2,175 Ha for settlement and 217 Ha for water bodies. Thus, the widest units were woody savannah and bowal/bare land areas and the least were settlement areas and water body areas.

The land use /land cover analysis for 2022 reports that the unit ranged 15,608 Ha for shruby savannah, 15,564 Ha for wooded savannah, 7,419 Ha for bowal/bare land, 6,753 Ha for cultivated areas, 2,047 Ha for settlement and 245 Ha for water bodies. However, the widest units were shrubby and woody savannah areas and the least were settlement areas and water body areas.

The LULC change analysis by comparing m1 and m2, reveals a rate of decreasing of wooded savannah (20.19%) and water bodies (1.24%). While an increase of bowal/bare land (4.51%) and cultivated area (7.44%) is observed (map 5 and table 25).

These statistics announce a real threat to livestock production in the future in Faragouaran’s commune. There is a need to undertake actions that can lead to support livestock producers notably promoting palatable species reforestation in bare land areas, securing and developing watering points areas, and policy controlling farmland extension.



Source: USGS, Landsat5 TM image November 1990, Landast7 ETM+ images November 2002 and 2012, Landsat OLI image November 2022; WGS 84 UTM projection, WGS 84 area 29N; Cartography of Mali

Map 5: Land use/land cover change in the commune Faragouaran for the year 2002 (Envi version 5.3

Table 25: Land Use/Land Cover change of Faragouaran Commune from 1990 to 2022

LULC Classes	Area (ha)	Area (ha)	Area (ha)	Area (ha)	M1	M2	Df	R(%)
	1990	**2002**	**2012**	**2022**	**1990-2002**	**2012-2022**	**M1-M1**	
Bowal/Bare land	4,799	10,385	12,063	7,419	7,592	9,741	-2,149	+4.51
Settlement	1,557	2,998	2,175	2,047	2,277.5	2,111	166.5	-0.35
Water bodies	976	664	217	245	820	231	589	-1.24
Shrubby savannah	6,080	10,638	10,466	15,608	8,359	13,037	-4,678	+9.82
Wooded Savannah	30,537	21,438	17,180	15,564	25,987.5	16,372	9,615.5	-20.19
Cultivated areas	3,687	1,513	5,535	6,753	2,600	6,144	-3,544	+7.44
Total	**47,636**	**47,636**	**47,636**	**47,636**	**47,636**	**47,636**		

M1: mean1; **M2:** .men2; **Df:** difference; **R:** Rate of increasing (+) or decreasing (-), **Ha:** Hectare

Source: Personal work

The overall accuracy ranges 88.11 % for 2012, 87.58 % for 2002, 82.08 % for 1990, and 80.69 for 2022. It ranges from 88.11% to 80.69 %.

The kappa coefficient range of 0.69 for 1990, 0.80 for 2002 and 2012, and 0.70 for 2022. Thus it was very low for the year 1990 (0.69) and 2022 (0.7) (table 26).

Table 26: Accuracy Assessment of the LULC in the commune of Faragouran

Years	Overall accuracy (%)	Rank	Kappa Coefficient	Rank
1990	82.08	3	0.69	3
2002	87.58	2	0.80	1
2012	88.11	1	0.80	1
2022	80.69	4	0.70	2

Source : Author construction, November 2023

2.4.2. Assessment in the Commune of Koumantou

The land use /land cover assessment was focused on the following classes: bowal/bare land, settlement, water bodies, shrubby savannah, wooded savannah, and cultivated area. The overall area of interest 125,149 hectares in Koumantou.

The land use /land cover analysis for 1990 reports that the unit was ordered 47,548 Ha for wooded savannah, 44,605 Ha for shrubby savannah, 21,000 Ha for bowal/bare land, 9,286 Ha for cultivated areas, 2,265 Ha for settlement, and 444 ha for water bodies.

Moreover, the widest units were woody and shrubby savannah areas and the least were settlement and water body areas

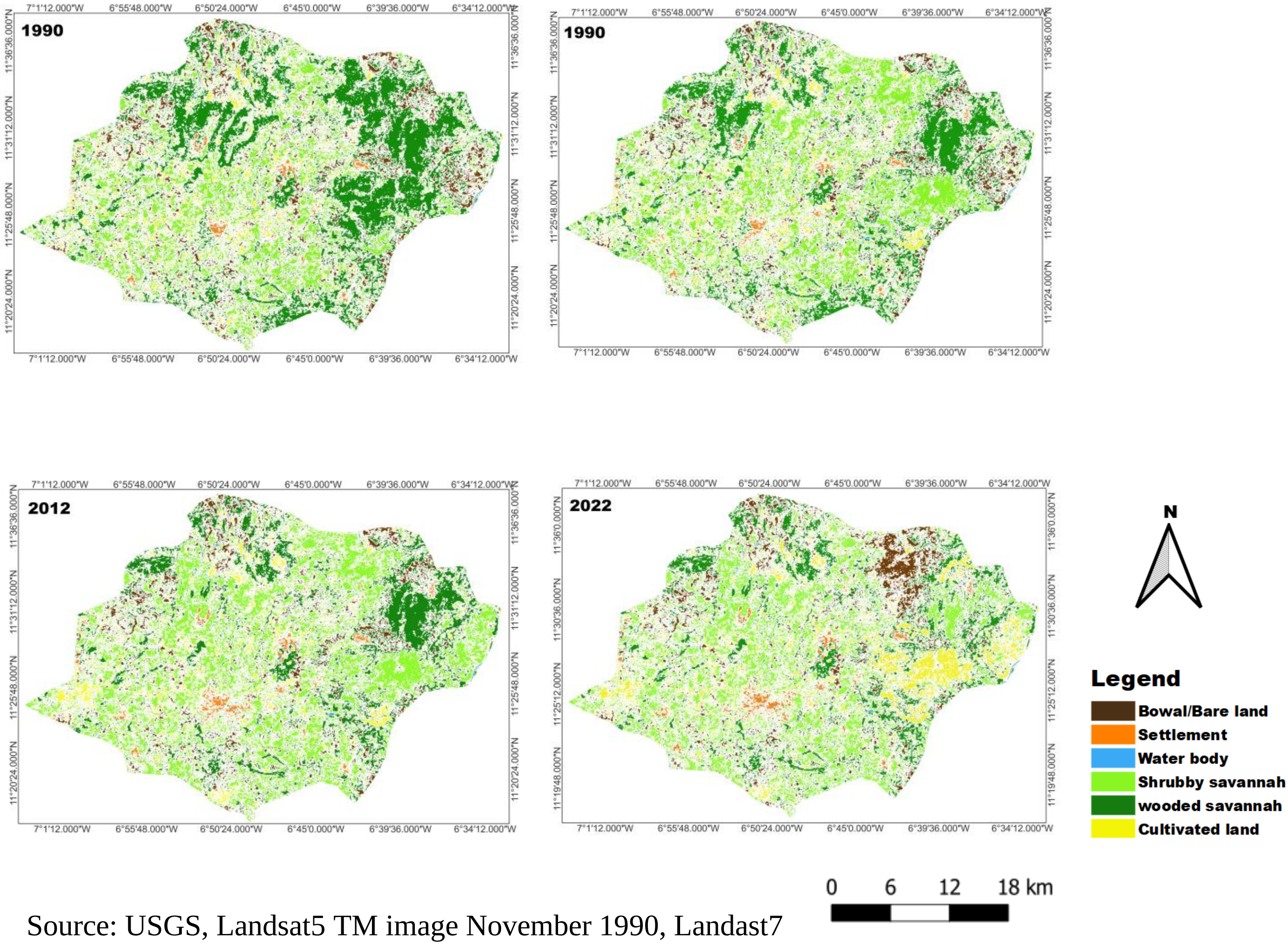
The land use /land cover analysis for 2002 reports that the unit was ordered 52,551 Ha for shrubby savannah, 38,940 Ha for wooded savannah, 20,673 Ha for bowal/bare land, 9,821 Ha for cultivated areas, 2,699 Ha for settlement and 466 Ha for water bodies. Moreover, the largest units were shrubby and woody savannah areas and the least were settlement and water body areas.

The land use /land cover analysis for 2012 reports that the unit was ordered 59,049 Ha for shrubby savannah, 33,645 Ha for wooded savannah, 18,474 H for bowal/bare land, 10,281 Ha for cultivated areas, 3,214 Ha for settlement and 485 Ha for water bodies. Moreover, the largest units were shrubby and woody savannah areas and the least were settlement and water body areas.

The land use /land cover analysis for 2022 reports that the unit was ordered 52,668 Ha for shrubby savannah, 31,428 Ha for wooded savannah, 20,756 Ha for bowal/bare land, 16,265 Ha for cultivated areas, 3,546 Ha for settlement and 485 Ha for water bodies. Moreover, the largest units were shrubby and woody savannah areas and the least were settlement and water body areas (map 6 and table 27).

The LULC change analysis by comparing m1 and m2 for Koumantou commune has revealed a rate of decrease of wooded savannah (8.56%) while an increase of settlement (0.72%) and cultivated area (2.97%) is observed (map 6 and table 25).

These statistics announce a real threat to livestock production in the future in Koumantou's commune. There is a need to undertake actions that can lead to support producers like promoting reforestation, and policy control on building up area extension.



Source: USGS, Landsat5 TM image November 1990, Landast7 ETM+ images November 2002 and 2012, Landsat OLI image November 2022; WGS 84 UTM projection, WGS 84 area 29N; Cartography of Mali

Map 6 : Classified LULC map of Koumantou commune from 1990 to 2022 (Envi Version 5.3)

Table 27: Land Use/Land Cover change of Koumantou Commune from 1990 to 2022

LULC Classes	**Area (ha)**	**Area (ha)**	**Area (ha)**	**Area (ha)**	**M1**	**M2**	**Df**	**R(%)**
	1990	**2002**	**2012**	**2022**	**1990-2002**	**2012-2022**	**M1-M2**	
Bowal/Bare land	21,000	20,673	18,474	20,756	20,836.5	19615	1,221.5	-0.98
Settlement	2,265	2,699	3,214	3,546	2,482	3,380	-898	+0.72
Water bodies	444	466	485	485	455	485	-30	+0.02
Shrubby savannah	44,605	52,551	59,049	52,668	48,578	5,5858.5	-7,280.5	+5.82
Wooded Savannah	47,548	38,940	33,645	31,428	43,244	32,536.5	10,707.5	-8.56
Cultivated areas	9,286	9,821	10,281	16,265	9,553.5	13,273	-3719.5	+2.97
Total	**12,5149**	**12,5149**	**12,5149**	**12,5149**	**12,5149**	**12,5149**		

M1: mean1; **M2:** .men2; **Df:** difference; **R:** Rate of increasing or decreasing, **Ha:** Hectare

Source: Personal work

The overall accuracy ranges 87.23 % for 2012, 84.32 % for 2002, 78.82 % for 2022 and 77.26 for 1990. It ranges from 87.23 % to 77.26 %.

The kappa coefficient range of 0.66 for 1990, 0.78 for 2002, 0.83 for 2012 and 0.73 for 2022. Thus, it was very low for the year 1990 (0.66) and 2022 (0.73) (table 28).

Table 28: Accuracy Assessment of the LULC in the Commune of Koumantou

Years	Overall accuracy (%)	Rank	Kappa Coefficient	Rank
1990	77.26	4	0.66	4
2002	84.32	2	0.78	2
2012	87.23	1	0.83	1
2022	78.82	3	0.73	3

Source : Author construction, November 2023

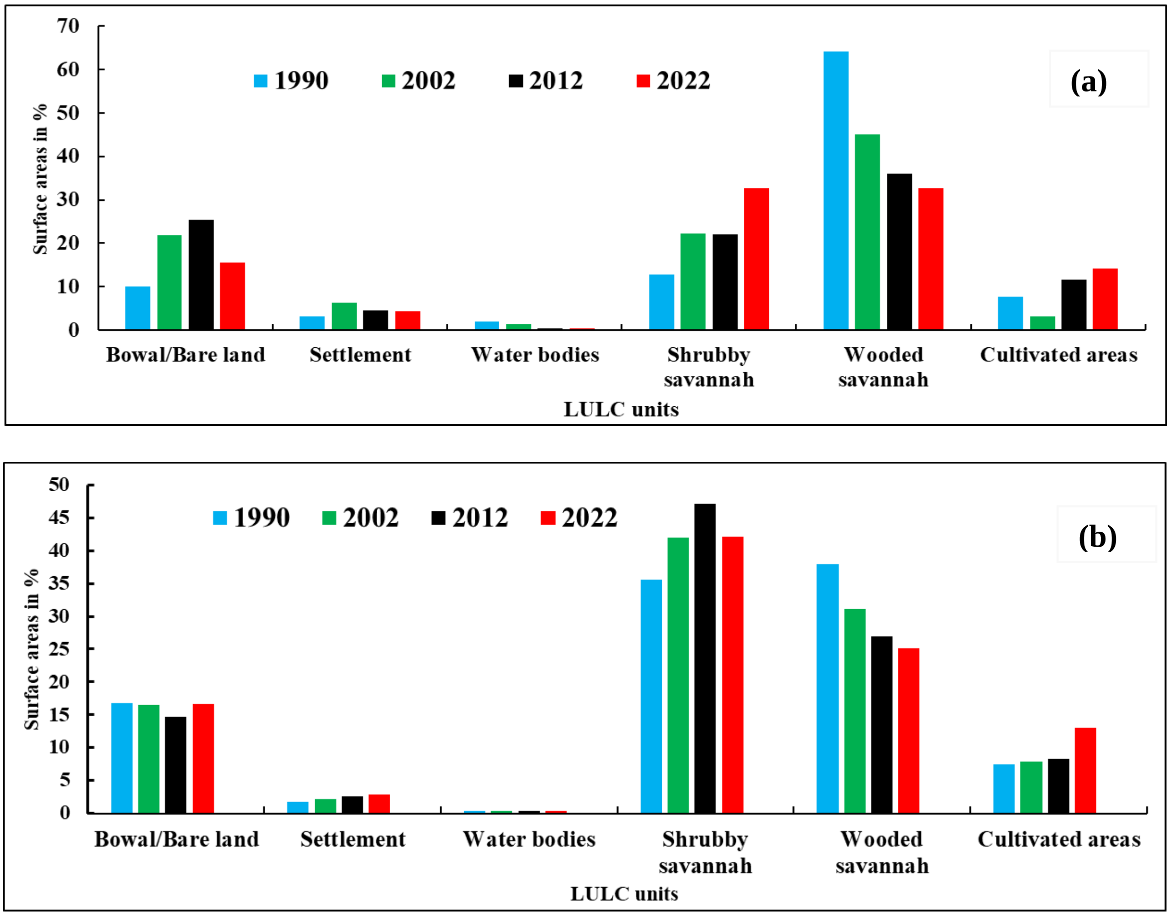
2.4.3. LU/LC analysis comparison between both research sites (Faragouaran and Koumantou)

The main land use /land cover classes were bowal/bare land, settlement, water bodies, shrubby savannah, wooded savannah, and cultivated area. The overall area of interest is 47, 636 hectares in Faragouaran and 125,149 hectares in Koumantou. In the research sites during the analyzed period (1990, 2002, 2012, 2022), the analysis has shown an increase in cultivated area and a decrease in wooded savannah area for both sites (figure 7).

These results are supported by M. Fomba *et al.*, (2024, p. 9) in the district of Bamako and Sikasso Region showing that the built-up area of Bamako more than doubled from 5,421 hectares in 1990 to 13,350 hectares in 2020 and increased in Sikasso from 20.5 %. These results share similarities with the conclusion of O. Diancoumba *et al.*, (2023, p. 114) in the Southern part of Mali illustrating that the cultivated land has increased from 1990 (2.55 %) to 2016 (17.40 %). In West Africa generally, Cropland increased significantly from about 11.5 % in 1975 to 18 % in 2000 and 23.8 % in 2013 in the total mapped area (B. Barnieh *et al.*, 2020, p. 13). The overall decrease of the wooded and shrubby savannah area has risen. This decrease in resources constitutes a real threat to livestock natural feed availability. According to A. A. Tawane & J. W. Wakhungu, (2018, p. 91), shrubs hence reduction in shrub-land indicates a reduction in livestock production and productivity hence leading to a vulnerable society endangering human security.

The settlement increased in 2002 but started to reduce from 2012 in Faragouaran but it is increasing in Koumantou from 1990 to 2022. In Different Spatiotemporal Scales of West Africa, from the land use land cover assessment, the Settlements increased substantially from 0.3 % in 1975 to 0.5 % in 2000 and 0.7 % in 2013 (B. Barnieh *et al.*, 2020, p. 12).

This situation is affecting negatively pastoral activities through the pressure on the pasture area in terms of space and quantity existing. Koumantou commune is more affected by pasture space reduction through the increasing of the settlement area, cultivated area and climate hazards frequency. This is in agreement with the research conclusions obtained by F. Belete *et al.*, (2023, p. 10) in south western Ethiopia reporting that cropland showed a sharp rise in all the study periods at the expense of main forests, grasslands and shrublands, respectively. The grassland was almost lost over the study periods (1973-2018).



Source: author construction, november 2023.

Figure 7: LULC analysis statistics in Faragouaran commune (a) and Koumantou commune (b) for 1990, 2002, 2012, 2022

PARTIAL CONCLUSION

The District of Bougouni is located in the Sudanian zone between the latitudes 10°00′ and 12°40′ north and the longitudes 06°20′ and 08°20′ west. It is one of the most important areas of the country in terms of livestock production size. This situation is linked to favorable climatic conditions (annual rainfall height and distribution) compared to other areas in the country. The annual average of the rainfall is 1,300 mm with August as the rainiest month.

This high quantity of rainfall per year allows richness of pasture qualities (density and variety of species), watering points supply, and good cereal production for crop residues. The District of Bougouni is covered by tributaries of the Niger River including ‘‘Baoulé’’, ‘‘Bafing’’ and ‘‘Bagoé’’which are important animal water drinking resources. With animal breeds varied, these climatic conditions contribute to livestock population size increasing.

The District of Bougouni abounds in enormous potentialities in terms of natural resources based on its geographical position confering abundant vegetation and providing species presenting various types of formations. According to statistics of ‘’Direction National de la Population’’, from 2014 to 2022, the population of the District of Bougouni is growing over the whole communes. This population is living from agriculture, livestock farming, and fisheries as main socio-economies activities.

The main species entailing pasture richness for herbaceous are *Digitaria horizontalis, Digitaria sanguinalis, Andropogon gayanus, Andropogon pseudapricus, Zornia glochidiata, Euphorbia hirta, Cyperus esculentus, Diheteropogon hagerupii, Loudetia togoensis, Tripogon minimus, Sporobolus pyramidalis, Boreria radiata.* For the woody cover, it is about *Khaya senegalensis, Ficus gnalocarpa, Pterocarpus lucens, Puterocarpus erenaceus, Acacia albida, Acacia nilotica, Afzelia africana, Manguifera indica.* The pasture areas of the District are experiencing so many invasive species less palatable by animals including *Waltheria indica, Cassia tora, Hyptis souaveolens.*

The land use /land cover classes of interest were bowal/bare land, settlement, water bodies, shrubby savannah, wooded savannah, and cultivated area. From 1990 to 2022, the analysis has shown that Koumantou commune is the largest area compared to Faragouaran commune. The wooded savannah areas and cultivated areas are increasing in both sites. Globally the settlement and shruby savannah areas are also increasing in both sites. This fact is affecting adversely pastures resources in the research sites.

SECOND PART:

CHARACTERISATION OF CLIMATIC RISK DETERMINANTS AND THEIR INFLUENCES ON PASTORAL RESOURCES

Local communities possess valuable perception knowledge about climate changes and its avderse effects on livelihood. In many scientific researchs, researchers used constructing links between local perception and meteorological observations. In this type of studies, the ages and great experiences of the respondents are necessary.

The second part of this research is divided in two chapters. The first chapter is reporting the determinants of climatics risks related hazards and the second based on the influence of climate conditions on the variability, availability, the nutritional quality of pastoral resources and agro-pastoral communities' perception on climate change.

CHAPTER 3:

DETERMINANTS OF CLIMATIC RISKS RELATED-HAZARDS

This chapter is announcing the situation of the sociodemographic characteristics of agro-pastoralists (respondents), climate risks related-hazards identified through multiple manifestations and the general overview, local knowledge of agropastoralist on climatic risks related-hazards identified on their livelihood.

Most of the respondents were male showing that the livestock farming is male-dominated who are in majority married, and practicing agropastoralism as the main activities. Agro-pastoralists identified and ranked four (4) climate risks related-hazards, notably the frequency of droughts, rising of temperatures, the frequency of violent winds and erratic rainfall.

According to agro-pastoralist local knowledge, the frequency of drought can lead to decrease in the nutritive quality of herbaceous plants, reduction in woody and herbaceous biomass, drying out of first herbaceous plants, delay in the formation of the herbaceous mat, forage deficit, low density of pastures.

3.1. Situation of the sociodemographic characteristics of agro-pastoralists

The sociodemographic characteristics are presented in the table 29. Most of the respondents were male (78 %) showing that the livestock farming is male-dominated who are in majority married (96 %). Only 2 % of respondents were single and widowed and 1 % have divorced. About 50% of agropastoralist were illiterated, 24 % and 17 % have primary level and koranic education level respectively. The 7 % and 2 % of the respondents have reached secondary and university level of study. Overall, 337 (83 %) of respondents reported agro-pastoralism as their main occupation and while 270 (67 %) of agro-pastoralist were practicing animal trade as secondary occupation. The 310 (77 %) agro-pastoralists did not get any training on pasture managements.

In the northern of Cape Province of South Africa, concordant results has been reported by R. Matlou *et al.,* (2021, p. 8) showing that the livestock farming is male-dominated (81.2 %) and the respondents were in the majority married (67.1 %). According K. Sanogo *et al.,* (2016, p. 453) through his research in the southern Mali, most the respondents were illiterated, married and are 40 years old. In Borana zone (North of Ethiopia), the livestock farming is male-dominated and the respondents were in the majority married. (D. A. Tofu *et al.,* 2023, p. 6).

The Chi square test indicate that there is a significant relationship between the respondents tranches of ages and the level of study, secondary occupations and traning on pastures management. Therefore, this relationship do not differ with the gender, the marital status and the main occupations.

Table 29: Socio-demographic characteristics of the respondents

Variables	Sub-variables	Frequency	%	X^2
Gender	Male	315	78	0.090
	Female	89	22	
Marital status	Married	386	96	0.082
	Single	7	2	
	Divorce	3	1	
	Window	8	2	
Level of study	Illiterate	200	50	0.000
	Primary	95	24	
	Secondary	30	7	
	Koranic education	70	17	
	University	9	2	
Main occupations	Transhumance	63	15	0.082
	Nomadism	4	1	
	Agro-pastoralism	337	83	
Secondary occupations	Animal trade	270	67	0.000
	Butcher	10	2	
	Carpenter	24	6	
	General trade	100	25	
Training on pastures management	Yes (have got training)	94	23	0.000
	No (have not got training)	310	77	

Source: Author construction, December 2022

3.2. Climate risk-related hazards identified through multiple manifestations

During the semi-structured interview and focud group discussions, agro-pastoralists identified and ranked four (4) climate risks related-hazards:

- ✓ the frequency of droughts with risk score of 21.15 (high level), is the first climate risks related-hazards raised by the respondents related to its effects on livestock livelihood. According to respondents, this climate risks related-hazards is affecting livestock production through early drying up of water points, strong livestock pressure around permanent water points, reduction in the nutritional quality of herbaceous plants, reduction in woody and herbaceous biomass, drying out of the first herbaceous plants, delay in the constitution of the herbaceous carpet, frequency of fodder shortages, reduction in the life cycle of herbaceous species, reliable reproduction and production (milk, meat).

- ✓ the increasing of temperatures with 17.50 (high level) as risk score, is the second climate risks related-hazards recognized by the agropastoralist communities. The main impacts this hazards perceived the respondents are the increasingly warm nights, shortening of the cold season period at the expense of the warm season, increasingly warm winters; diminution of herbaceous regeneration; genetic change and species physiognomy, delayed flowering of species, delayed growth of species, reduction in the life cycle of species, early drying up of wells, intensification of the process of drying up of wells reduction in ground water level.

- ✓ the frequency of violent winds has assessed with 12.80 as a risk score (medium level) is the third raised the agro-pastoralists. It is manifesting by increase in average wind speed, increasingly violent winds, destruction of large trees, silting up of natural watering points, degradation of galerite forests, decrease in the amount of water available, silting up of rivers, heating of rivers, acceleration of the bushfire phenomenon.

- ✓ The erratic rainfall with 7.50 as risk score (low level) has been the last risks related-hazards recognized by the agropastoralist communities. It is the less threatening risk of agropastoralist livelihood. The respondents perceive it through poor distribution of rainfall in time and space, poor reconstitution of the grass cover, erratic onset and end of the rainy season, proliferation of weeds and parasites, delayed reconstitution of wells, lowering of the water table, degradation by water erosion of saline land sites, frequency of out-of-season rainfall (table 30).

This result is supported by the finding of B. Diarra, (2020, p. 24) in Mali at the national scale and M. Coulilbaly *et al.,* (2022, p. 34) in the rural commune of Diéma which reporting drought, floods, violent winds, sand winds, increasing of temperature as climate risks and as climatics hazards. According to D. A. Tofu *et al.,* (2023, p. 7), through researchs implemented in the in the Borana zone (south Ethiopia), the commonly experienced climate change induced risks are based on drought, flood, high temperature, rainfall reduction. In the Sahel regions, the increased temperatures, the erratic precipitation, increased incidence of drought and flooding and desertication are climate risks and potential impacts on livestock production (USAID, 2017, p. 3).

The findings of K. A. Daiba *et al.,* (2021, p. 8653) in the Chadian part of the lake chad, reveal that the main climatic hazards cited by agro-pastoralists were drought, maldistribution of rainfall, temperature increasing, vilont wind, flood. Thus, 45 % were attributed to drought occurrence.

Table 30: Climate risks related-hazards perceived by agro-pastoralists' in the study area

CRH	HL	IS/VR	RS	DH	R
Frequency of drought	4.5	4.7	21.15		1
Increasing of temperatures	4.0	4.4	17.60		2
Frequency of violent wind	3.2	4.0	12.80		4
Erratic rainfall	2.5	3.0	7.50		3

Scale and LHS

Low (1-8) **Medium (9-14)** **High (15-25)**

HL: Hazard Likelihood; IS/VR: Impact Severity/Vulnerabilities Resources; RS: Risk Score; LHS: Level Hazard Severity; R: Rank

3.3. A general overview of agropastoralist local knowledge on climatic risk-related hazards identified impacting their livelihoods

The identified climatic risks related-hazards are assessed throughout impact matrix on pastures, wells, backwaters, saltyland and livestocks resources (table 31). From this assessment, agropastorlists have inventoried adverses impacts per each climatic hazards.

The frequency of drought impacts on pastures areas are experiencing through decrease in the nutritive quality of herbaceous plants, reduction in woody and herbaceous biomass, drying out of first herbaceous plants, delay in the formation of the herbaceous mat, forage deficit, low density of pastures. Regarding to livestock resources, the respondends have revealed low availability of feed resources for animals, reliable reproduction and production (milk, meat,), frequency of disease, animal emaciation, animals welfare degraded, reliable overweight of animal.

Table 31: Impact matrix of of agro-pastoralist livelihood to climatics risks related-hazards

Climate risks relate-Hazards	Pastoral Resources and livestock				
	Pastures	Wells	Backwater	Saltyland	Livestock
Frequency of Drought	Decrease in the nutritive quality of herbaceous plants, reduction in woody and herbaceous biomass, drying out of 1st herbaceous plants, delay in the formation of the herbaceous mat, forage deficit, low density of pastures	Poor water replenishment, early drying up of wells, well pollution, very deep level of water	Low water replenishment, drying up of watercourses, exposure of galerite pastures to bush fires, disappearance of watercourses	Low resistance of the resource, scarcity of salty land, degradation of nutritive value of resource	Low availability of feed resources for animals, Reliable reproduction and production (milk, meat,), Frequency of disease, animal emaciation, animals welfare degraded, reliable overweight of animal
Increasing temperature	Reduced regeneration of herbaceous plants, genetic and physiognomic changes in species, delayed flowering of species, delayed growth of species, reduced life cycle of species,	Early drying-up of wells, intensification of the well-drying process, reduction in water levels	Intensified drying-up of wells, reduction in water levels, warming of watercourses	Quality resources for animals degraded, disappereance of salty land	Frequency of morbidity and mortality, low animal reproduction, frequency of disease, reduced animal fertility,

Frequency of violent wind	Destruction of large trees, acceleration of bush fires	Intensified deterioration in watering conditions, silting up of wells	Addition of solid particles to river beds, degradation of galerite forests, reduction in water availability, silting up of watercourses.	High risk of covering the resource with sand,	Viral disease frequency, vector-borne
Erratic Rainfall	Poor reconstitution of large grass cover, acceleration of bush fires, proliferation of weeds and parasites.	Delayed replenishment of wells, lower water table	Delayed river replenishment, low river recharge	Site collapse, degradation by water erosion,	Degradation of watering conditions, long calving intervals, poor reproduction, low milk production, frequency of water-borne diseases.

Source: Author construction, December 2022

The identified climatic risks related-hazards are assessed throughout adaptation matrix on pastures, wells, backwaters, saltyland and livestocks resources (table 32). From this assessment, agropastorlists have inventoried diverses adaptation strategies per each climatic hazards. The extension of adapted forage crops, fight against bushfires, delimit grazing areas, control early bushfires, mow grasses called for stock, collecte harvest residues, develop bourgou cultivation in wetlands are some adapted strategies used by agropastoralist communities aigainst drought hazards. Others adopted strategies notced were restore grazing lands, develop forage crops, variety of genetically resilient species, prevalence of transhumance, artificial insemination, encouraging animal mobility to other areas.

Table 32: Adaptation Matrix of agro-pastoralist livelihood to climatics risks related-hazards

Climate risks relate-Hazards	**Pastoral resources and livestock**				
	Pastures	**Wells**	**Backwater**	**Saltyland**	**Livestock**
Frequency of drought	Extension of adapted forage crops, fight against bush fires, delimit grazing areas, control early bush fires, mow grasses called for stock, Collect harvest residues, Develop Bourgou cultivation in wetlands, restore grazing lands, Develop forage crops	Digging large-diameter wells, constructing large-diameter wells, building the interior of the well, digging to great depths, developing watering points, digging to desired depths,	Construction of reservoir dams, overflowing of ponds, management of reservoir perimeters, prevention of gallery forest deforestation	Protecting sites with moisture-conserving species	Variety of genetically resilient species, prevalence of transhumance, artificial insemination, Encouraging animal mobility to other areas
Increasing temperature	Choosing forage resistant crops ,	Development of wells with windbreaks, reforestation of	Development of reservoir perimeters, reforestation	Protecting sites with moisture-conserving species	Heat-adapted breed,

		well surroundings	around watercourses		
Frequency of violent wind	Practice of firebreaks, reforestation, reforestation of called species, Practice of reforestation that serves as a living hedge,	Well protection, site selection, well site prospection	Development of the river banks, Landscaping the interior of the well, respecting the 25 to 30 m standard between the field and the river bed, Ploughing perpendicular to the water slope in relation to the river bed,	Protection by live hedges	vaccination and regular health monitoring of animals
Erratic rainfall	Cultivation of adapted forage crop , reforestation, fighting of abusive exploitation of the green tree	Backfilling of wells	Creating reservoirs and upgrading existing ones	Reforestation practice	Collection and storage of fodder and crop residues

Source: Author construction, December 2022

CHAPTER 4:

INFLUENCE OF CLIMATE CONDITIONS ON THE VARIABILITY, THE AVAILABILITY, THE NUTRIENT QUALITY OF PASTORAL RESOURCES AND AGRO-PASTORAL COMMUNITIES PERCEPTION ON CLIMATE CHANGE

The Fouth chapter of this research is treating the agro-pastoralists with good endogenous perceptions of climate parameters, the climate conditions highly influencing the variability and availability of pastoral resources, the local perception of drought negative impacts on patoral resources. It also focused on the meteorological data evidence on risk drought related-hazards and the riched pastures nutritionnaly in quantity and quality.

The endogenous perceptions of agro-pastoralists on climatic parameters reveals a decreasing of rainy season length, an increasing of temperatures and wind speed. The drought has adverse impacts on pastoral resources.

The meteorological data observation reveals also a reduction of rainfall, increasing of temperatures and average wind speed. The herbaceous and ligneous pastures are riched in termes of palatable species but these pastures areas are suffering to the pressure from human activities and climate drivers.

4.1. Agropastoralists with good endogenous perceptions of climate parameters

The table 33 reports the endogenous perceptions of agro-pastoralists regarding rainfall, temperatures and wind speed. It indicates that the rainy season is increasingly dry (63.4 %). The onset of the rainy season before (years < 1990) was the onset of May (62.4 %) and actual (years ≥1990), it is the 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 survey communities have noted that it is getting hotter (93.1 %) and the winds are increasingly violent (97 %).

These results are corroborating with those found by M. Doumbia *et al.*, 2013, (p. 4826) in the West-Centre of Ivory Coast; by T. Sanogo *et al.*, (2022, p. 141) in the rural commune of Tioribougou (south of Mali) and by S. Nepali & R. Tamang, (2022, p. 378) in India which reports that livestock farmers perceived a decrease of rainfall, an increase of temperatures, late onset and early end of rainy season, a frequency of violent wind speed, an increasing of the hottest days.

Table 33: Observation of agro-pastoralists' endogenous perceptions of rainfall, temperatures and wind speed

Parameters	Frequency	%	Rank
Rainy season is more and more			
Rainy	90	22.3	2nd
Dry	256	63.4	1st
Normal	25	6.2	4th
Erratic	33	8.2	3rd
Onset of rainy season before			
Onset of April	10	2.5	5th
Middle of April	5	1.2	7th
End of April	7	1.7	6th
Onset of May	252	62.4	1st
Middle of Mai	93	23	2nd
End of May	24	5.9	3rd
Onset of June	11	2.7	4th
Middle of June	1	0.2	8th
End of June	1	0.2	9th
Onset of rainy season actual			
Onset of April	2	0.5	7th
Middle of April	1	0.2	9th
End of April	3	0.7	8th
Onset of May	41	10.1	3rd
Middle of May	37	9.2	4th
End of May	69	17.1	2nd
Onset of June	206	51.0	1st
Middle of June	31	7.7	5th
End of June	14	3.5	6th
End of rainy season before			
Onset of September	7	1.7	9th
Middle of September	13	3.2	8th
End of September	73	18.1	3rd

Onset of October	43	10.6	4th
Middle of October	28	6.9	5th
End of October	125	30.9	1st
Onset of November	16	4.0	7th
Middle of November	22	5.4	6th
End of November	77	19.0	2nd
End of rainy season actual			
Onset of September	13	3.2	9th
Middle of September	24	5.9	8th
End of September	44	10.9	4th
Onset of October	72	17.8	3rd
Middle of October	28	6.9	7th
End of October	82	20.2	1st
Onset of November	75	18.6	2nd
Middle of November	32	7.9	6th
End of November	34	8.4	5th
Length of rainy season			
Long	34	8.4	4th
Short	110	27.2	2nd
Normal	36	8.9	3rd
Erratic	224	55.4	1st
Increasingly hot			
Yes	376	93.1	1st
No	28	69.0	2nd
Increasingly violent wind			
Yes	392	97.0	1st
No	12	3.0	2nd

Source: Individual Survey, December, 2022.

The Chi square test analysis reveals that agropastoralist perception's of climate hazards are varying from one site to another site (table 34). This findings are not corroborating with those from K. Sanogo et al., (2016, p.10) that have illustrated farmers' perceptions of climate change do not differ between the two research sites.

Table 34: Chi square test (x2) between agro-pastoralist perception in the four sites of study area

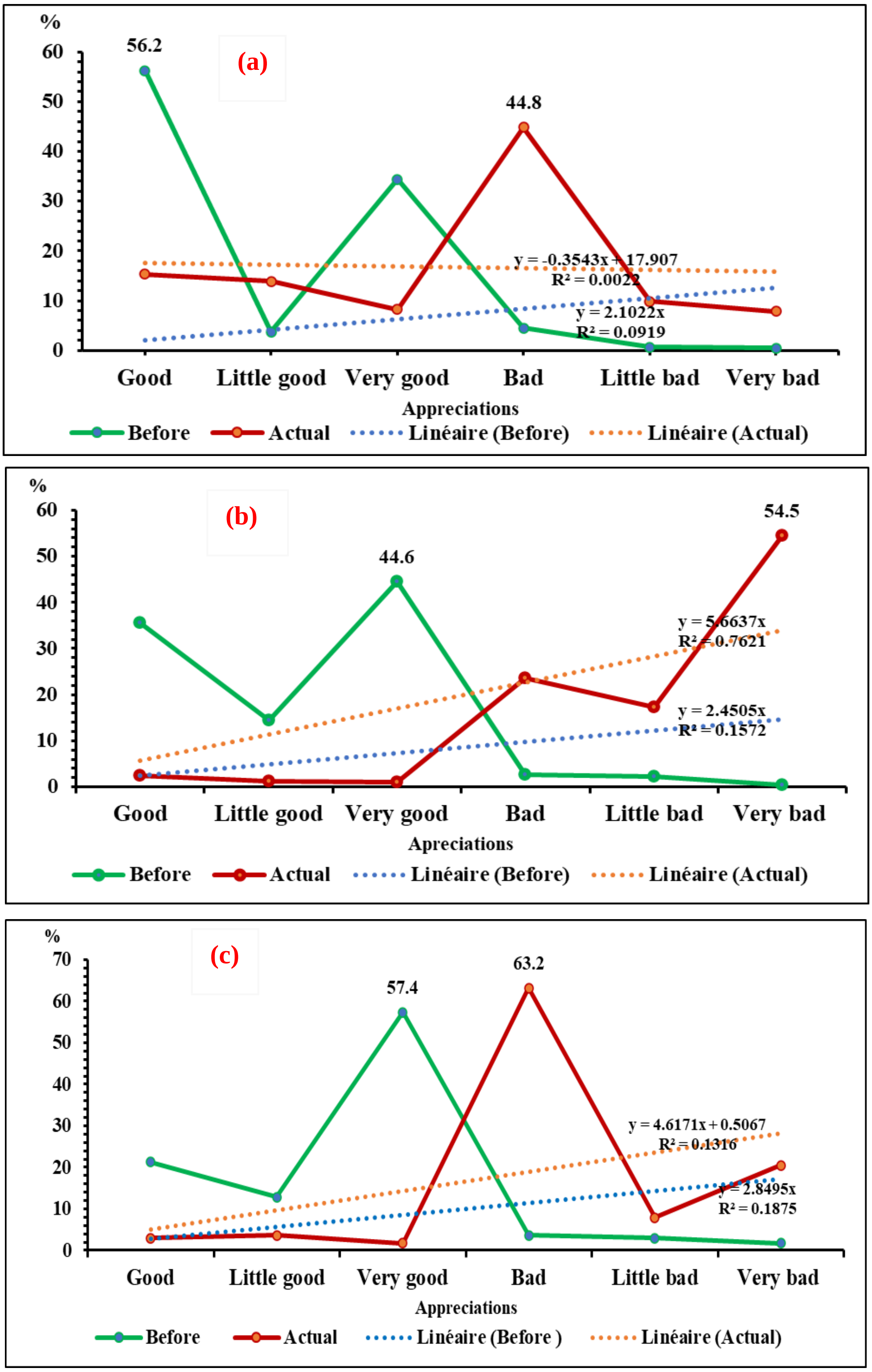
Parameters test	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	8.411[a]	3	.038
Likelihood Ratio	8.631	3	.035
N of Valid Cases	404		

a. 4 cells (50.0%) have expected count less than 5. The minimum expected count is .50.

4.2. Climate conditions highly influencing the variability and availability of pastoral resources

4.2.1. Degradation of pastoral resources due to the negative effects of climatic hazards

The figure 8 is based on the effects of climate hazards on pastoral resources before (years < 1990) and actual (years ≥1990). It shows that the conditions of watering points for animals were good before (56.2 %) compared to poor at present (44.8 %). The conditions of pastures were similar to watering points (44.6 %), but very poor at the moment (54.5 %). The 57.4 % of agro-pastoralists perceived that the salty lands were in very good condition before, but are in poor conditions currently (63.1 %). In the Borana area (Ethiopia), the major effects of climate change on livestock production cited by pastoralist include feed shortage, shortage of water, reduced productivity, and decreased mature weight and/or longer time to reach mature weight in their order of importance (Y. Zelalem *et al.,* 2009, p. 13; S. Tiruneh & F. Tegene, 2018, p. 53). The climate change might lead to shortage of water which could reduce livestock feed and pasture yield (S. Bekele, 2014, p. 54). Similar results were obtained by S. Nepali *et al,* (2022, p. 381) who reports that changing extreme climatic events directly affect the availability of forage, water, forest and pasture diseases for animals. According to P. K. Thornton *et al,* (2009, p. 113) and T. Amole *et al.* (2022, p. 35), 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.



Source: Individual Survey, December, 2022.

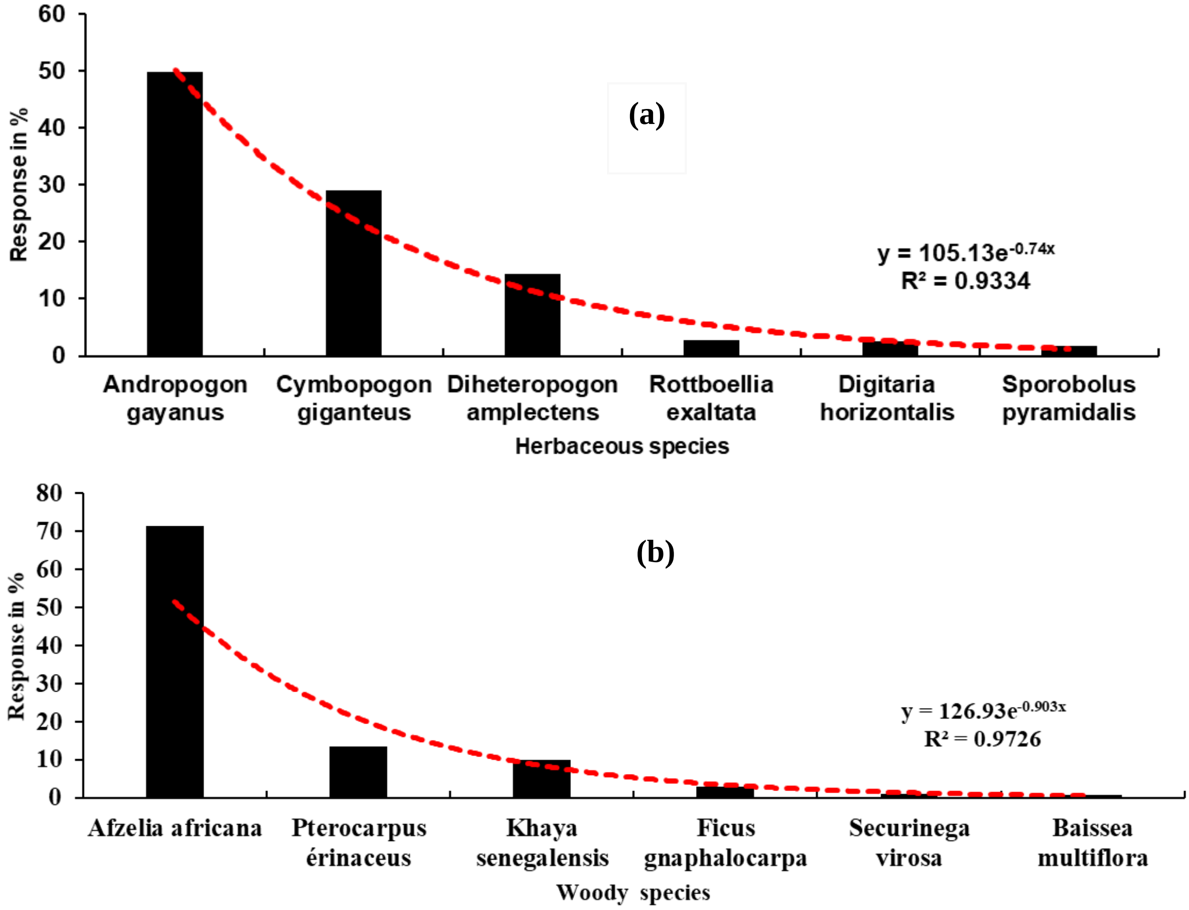
Figure 8: Agro-pastoralists' perception of the effects of climatic hazards on waterings points (a); pastures (b) and salty land (c)

In the Bougouni's District, agro-pastoralists' observations showed 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 (figure 9). In particular for the herbaceous species, it is about *Andropogon gayanus* (Kunth), *Cymbopogon giganteus* (Chiovenda, Kerhar), *Diheteropogon amplectens* (Nees), *Rottboellia exaltata* (Robuta hook), *Digitaria horizontalis* (Willd), *Sporobolus pyramidalis* (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).

These results are related to those obtained by I. Idrissa *et al.,* (2020, p. 181) in the pastoral enclave of Dadaria, Diffa region in Niger, and by Kiema *et al.*, (2014, p. 8) in Burkinabe faso, who indicated that the area of vegetation cover is declining, reflecting a decline in certain species.

However, the 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.) and *Echinochloa stagnina* (Retz.) P. Beauv.



Source : Personal work

Figure 9: The six (6) main herbaceous (a) and woody (b) species highly palatable by animal but endangered of disappearing in the research sites

4.2.2. Climate change as the main cause of degradation of pastoral resources

The main causes of degradation of pastoral resources cited by agro-pastoralists are the increase in long dry spells (55.4 %), agricultural pressure (25.2 %), erratic rainfall (10.6 %), and livestock pressure (overgrazing….) (4.2 %). Those respondents have noticed land degradation and late bushfires as factors with negative impacts on pastural resources even with low percentage (table 41). Thus, these results are supported by those obtained by G. Bogale & Z. Erena, (2022, p. 474) in ecological zone of Ethiopia showing the seasonal rainfall failure (meteorological drought) is mostly caused by climate variability, and its consequences include widespread failure of seasonal crops, pasture, and forage, as well as significant livestock deaths in pastoralist areas, as well as widespread starvation among the affected population.

Table 35: Main causes of these changes cited by agropastoralists on pastoral resources in the four research sites

Main causes	Dogo	Faragouaran	Garalo	Koumantou	average	SD
	n=106	n=34	n=104	n=160		
Increasing of dry spell length	40(37.700	10(29.4)	35(33.7)	55(34.4)	35.0	7.7
Erratic rainfall	23(21.7)	4(11.8)	11(10.6)	30(18.8)	17.0	4.7
Agricultural pressure	30(28.3)	5(14.7)	12(11.5)	20(12.5)	16.8	3.8
Abandonment of tradition	2(1.9)	1(2.9)	30(28.8)	11(6.9)	11.0	1.8
Livestock pressure	5(4.7)	2(5.9)	5(4.8)	12(7.5)	6.0	0.3
Land degradation	2(1.9)	4(11.8)	3(2.9)	12(7.5)	5.3	0.1
Late bush fires	2(1.9)	3(8.8)	5(4.80	10(6.3)	5.0	0.0
Herbicide	2(1.9)	5(14.7)	3(2.9)	10(6.3)	5.0	0.0

Source: Individual Survey, December, 2022

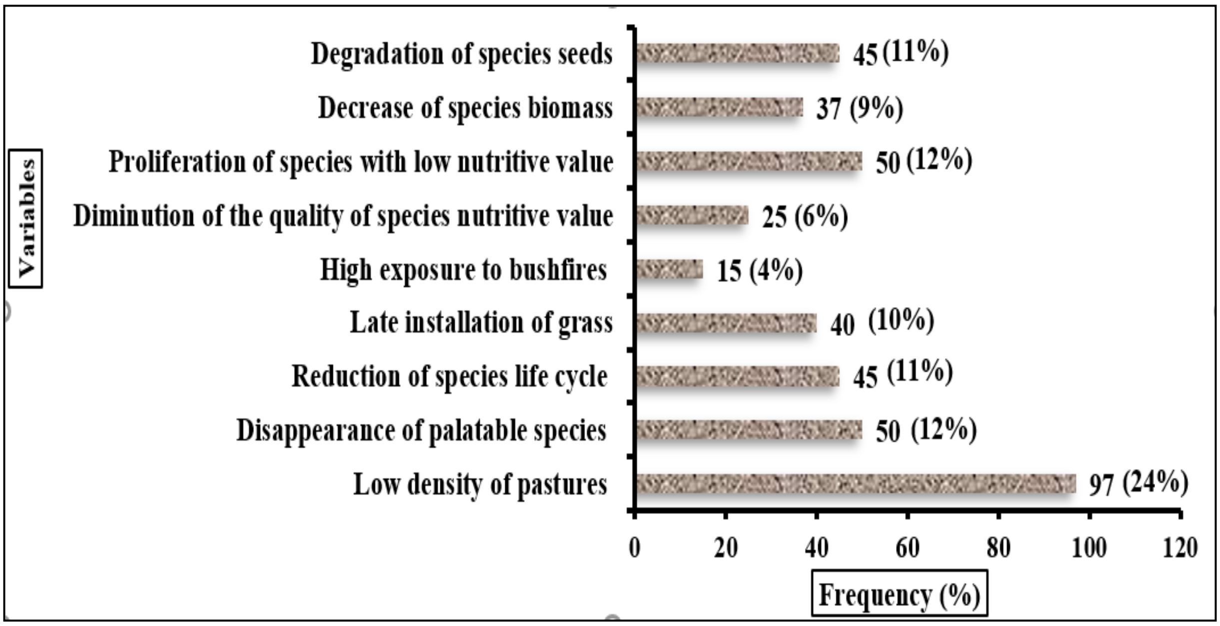
4.3. Local perception of drought negative impacts on pastoral resources

The local perception of agropastoralist commuties of drought adverse impacts is assessed cross the pastures, livestock and watering points.

4.3.1. Impacts on pastures, livestock and watering points

In the District of Bougouni, agro-pastoralists perceive drought impacts on pastures, watering points and livestock which lead to their degradation.

However on the pastures, seven (7) factors has been raised including low density of pastures (24 %) (photo 8b), disappearance of palatable species and proliferation of species with low nutritive value (12 %), reducing species life cycle and degradation of species seeds (11 %), low installation of grass (10 %) (figure 10). In South Africa, The majority of livestock producers use any available type of feed during drought periods, so as to sustain basic maintenance that will keep their livestock alive, this is facilitated by a huge decline in natural grazing and reduced crop residue (M. A. Mothapo, 2020, p. 27).

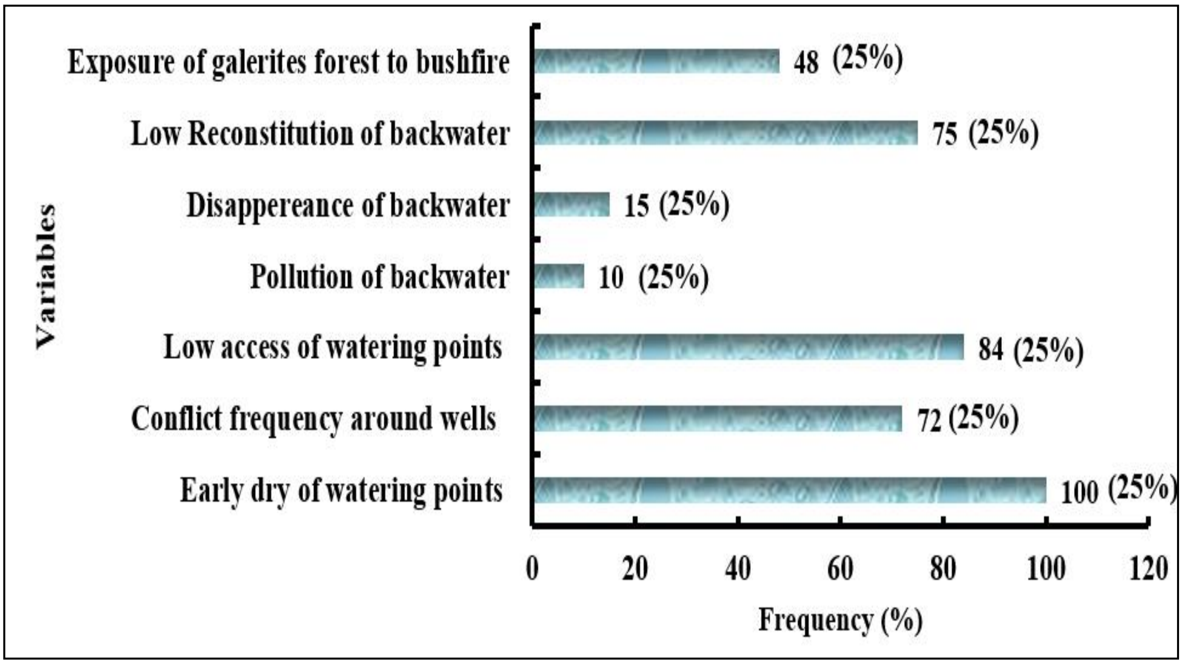


Source: Individual Survey, December, 2022.

Figure 10: Agropastoralism local perception of drought impact on pastures

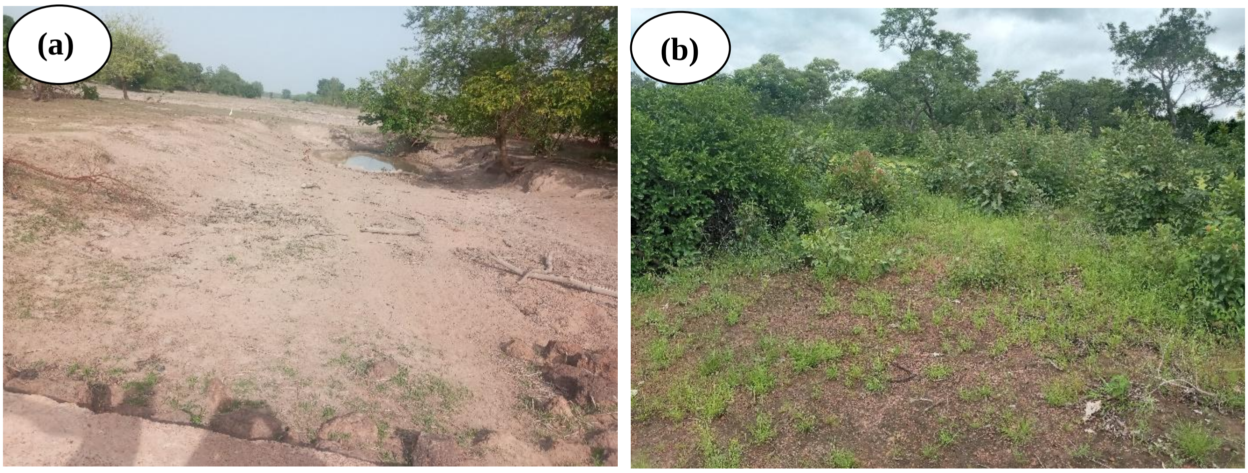
The figure 11 is showing drought impacts on watering points. The majority of the respondents noticed that the most important impacts of drought were early dry of watering points (25 %) (photo 8a), low access of watering points (21 %), low reconstitution of backwater (19 %) and conflicts frequency around wells (18 %) . This research realize that drought constitute a real threat for livestock waterning point in the study area.

Researchs from S.K. Singh S. K *et al.,* (2012, p. 409) indicated that climate adverse impact to livestock lead to negative impacts on milk production, animal reproductive performance, feed and fodder resources are decreasing, shortage of dry fodder, decreased water resources. Specific climate change in West Africa, as reported by IFAD, (2017, p. 3) and T. Amole *et al.,* (2022, p. 35) may include changes in livestock drinking water sources, bearing on livestock feed production systems and pasture yields, in herbage growth, changes in floristic composition of vegetation, changes in herbage quality, and changes in importance of crop residues as animal feed.



Source: Individual Survey, December, 2022.

Figure 11: Agro-pastoralism local perception of drought impact on watering points



Source: Sanogo T., photo taken in November 2022.

Photo 8: Early dry condition of watering point in the village of Garalo (a), Low density of pastures in the village of Faragouaran (b)

The livestock itself is experiencing drought impact hardly. These impacts are noticed through changes in the first giving birth, interval between two giving births, in the abortion frequency, livestock mortality and diseases, and cow milk production (table 36). The Chi square test indicate that the perception of agropastoralist do not differ according the tranches of ages exept changes in the livestock deseases (0,004) less than 0,05.

Most of the respondents reported a reduction livestock population due to drought hazards occurrence. In Ethiopia, cow milk yields obtained by upper tercile households remained at five liters per day in normal and drought years, but lower households remained at five liters per day in normal and drought years. but lower tercile households saw their yields drop from 4.8 liters in the good year to only one tercile households saw their yields drop from 4.8 liters in the good year to only one liter per day during the drought (W. Patrick, R. Thomas, 1992, p. 231).

In Matuu (Kenya), pastoral communities have reported that milk from cows has become scarce as many cows have died during the drought of 2009 and 2010 (B. Njiru, 2012, p. 519).

According to D. Campbell, (1984, p. 43) in drought years in the department of Maasai (Kenya), animal numbers declined due to death caused by disease and starvation and as herders sold stock to raise cash to buy food.

Table 36: Agro-pastoralism local perception of drought impact on livestock

Drought related to livestock production		**Frequency**	**%**	X^2
Changes in first giving birth of livestock				
	Long	365	90.0	0.344
	Short	9	2.0	
	Normal	30	7.0	
Changes in the interval between two giving births of livestock				
	Long	367	91.0	0.171
	Short	7	2.0	
	Normal	30	7.0	
Changes in abortion frequency of livestock				
	Yes	350	87.0	0,777
	No	54	13.0	
Changes in livestock mortality				
	Yes	269	67.0	0.283
	No	135	33.0	
Changes in livestock diseases				
	Yes	272	67.0	0.004
	No	132	33.0	
Changes in cow milk production				
	Yes	371	92.0	0.232
	No	33	8.0	

Source: Individual Survey, December, 2022.

4.3.2. Agro-pastoralist Local Perception of Dry Spell

The agro-pastoralist of the study area perceived dry spell in termes of its frequency, average duration and period. The respondents have illustrated a frequency of dry spell (94 %) and its average duration per days is lower or equal to 20 days (56 %).

The probable dry spell period is the onset of the rainy season (65 %). The Chi square test applied indicate that perceptions of agropastoralist per tranches of ages do differ (table 37). These results are supported by research of S. Traore *et al.*, (2022, p. 129) in the commune of Benguene (Mali); of K. Sabaï *et al.*, (2014, p. 7423) in the Commune of Banikoara, North of Benin, and of P. Gnangle *et al.*, (2012, p. 142) in the north of benin reporting that the respondents have noticed an frequency of dry spell during the rainy season. A total of 54 % of the respondents indicated the duration of drought periods being an entire year, with 27 % stating it lasted between four and six months and 19 % indicated the duration to be one month. About 70 % of the respondents noticed the occurrence of droughts were more frequent (R. Matlou *et al.*, 2021, p. 10).

Table 37: Local perception of agro-pastoralist on dry spell patterns

Dry spell frequency	Frequency	%	X^2
Yes	378	94.0	0.995
No	26	6.0	
Average duration of dry spell per days			
≥5	13	3.0	0.514
≥10	82	20.0	
≥15	84	21.0	
≥20	225	56.0	
Dry spell period			
Onset of rainy season	262	65.0	0.325
Middle of rainy season	95	24.0	
End of rainy season	39	10.0	
All time in rainy season	8	2.0	

Source: Individual Survey, December, 2022.

4.4. Meteorological data evidence in climate risk-related hazards

This meteorological data evidence in climate risk-related hazards has been evaluatated through the rainfall, temperatures and wind speed patterns.

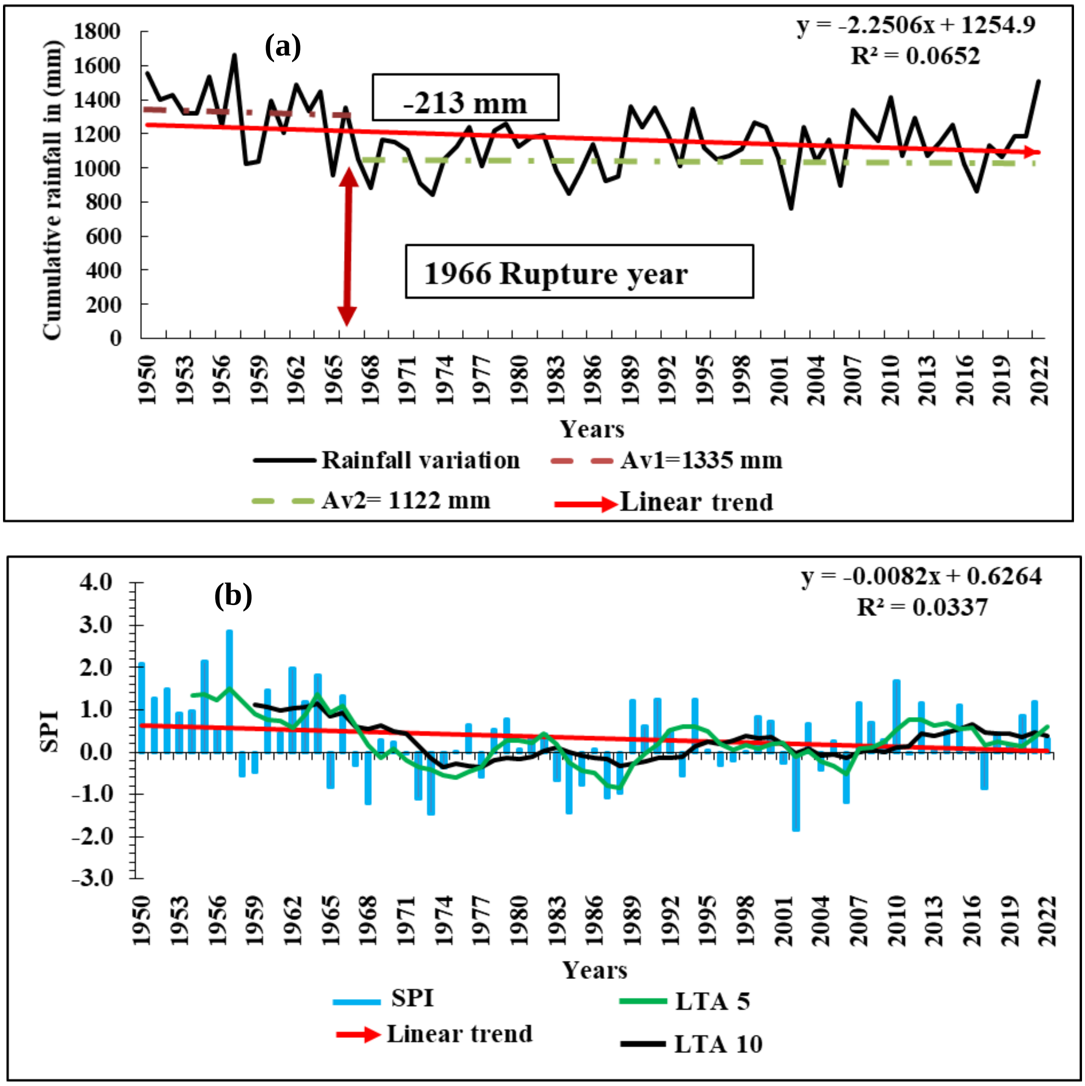
4.4.1. A Seasonal rainfall with a downward trend and variable parameters and increasingly long dry spells

The analysis of the Mann Kendall test on rainfall data from 1950 to 2022 shows a decreasing trend. This decreasing is significant with a p-value of 0.05. However, analysis of the Pettitt test reported a negative break/rupture occurred in 1966 with a significant p-value (0.023).

A comparison of the two means using Student's t Test reveals a decrease of rainfall of 213 mm (y:-2.25) from 1950 to 2022 either 8.66 % (figure 12a). 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 occurred in 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 illustrate a high alternation of wet and dry years after the 1970s (figure 12b). This result is contradictory to that obtained by S. Traore *et al.*, (2022, p. 132) in the Sudanian zone of Mali which shows a general increase of rainfall since 1997 throughout meteorological observations from 1983 to 2018. Research from I. Yaya *et al*, (2020, p. 6) in the dry and sub-humid tropical zone of Benin and those obtained by C. Y. Alle, (2014. p. 65), in southern Benin illustrate an agreement between climatic data and the perception of herders regarding later dates of installation of the rainy season.

With respect to the date of the end of the rains, there is a slight contradiction between the climatic data and the perception of herders regarding the dates of the end of the rainy season.



Source: Personal work

Figure 12: Rainfall interannual variation (a) and SPI evidence (b) in the station of Bougouni District from 1950 to 2022

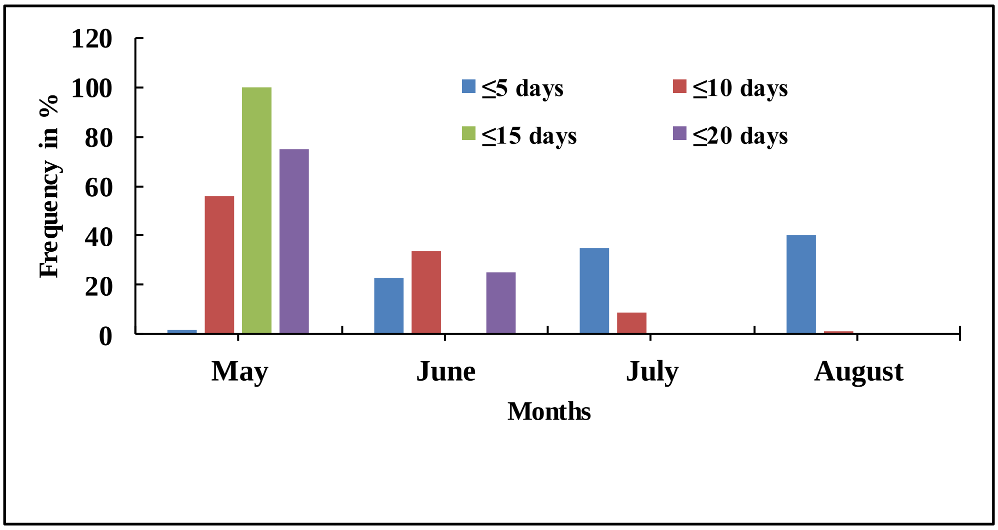
The Analysis of the season's parameters shows that the two recent 30-year periods (1950-1979; 1980-2009) were marked by a delay in the start of the rainy season (on average of 6 days), an early cessation of the rainy season (on average of 4 days) and a reduction in the number of rainy days (on average of 10 days) (table 38).

Table 38: 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[2]	15th May	21st May	6 days late
AERS[3]	15th November	11th November	4 days early
ALRS[4]	184 days	174 days	10 days reduction

Source: Personal work

The dry spell of May, June, July and August were analyzed. The figure 13 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 is very high for the month of May. This summarizes that July and August constitute the rainiest months. This result is corroborating with those obtained by T. Sanogo *et al.*, (2016, p. 53) in the rural commune of Tioribougou illustrating that only May was covered by dry sequences of twenty (20) days or more and the month of August was the rainiest.



Source: Personal work

Figure 13: Dry spells frequency analysis in Bougouni station from 1950 to 2010

[2] **Average Onset of Rainy Season**
[3] **Average End of Rainy Season**
[4] **Average Length of Rainy Season**

4.4.2. A short rainfall analysis of synoptic station in the research site

The table 39 reveals the annual variation of rainfall in the research site. From 2010 to 2011, the average rainfall was most important for the year 2022 (1, 411 mm), 2016 (1, 337 mm), 2021 (1, 196 mm), 2010 (1, 192 mm), 2020 (1, 212 mm). However the year 2017, 2011 were dry. The commune of Garalo and Faragouaran were the rainiest areas throughout the thirteen past years assessement with 1,570 mm and 1,516 mm respectively.

Table 39: Evolution of rainfall in the four study area

Study zones	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Dogo	1,334	855	1,126	560	847	987.67	1,060	893	845	870	1,091	1,167	1,394
Faragouaran	1,061	949	1,068	1,116	1,044	1,162	1,405	826	1,261	1,204	1,021	1,252	1,516
Garalo	1,268	944	1,159	1,264	1,122	1,229	1,574	835	1,132	1,137	1,437	1,259	1,570
Koumantou	1,104	1,189	1,225	804	1,073	1,052	1,309	821	936	993	1,179	1,076	1,163
Average	**1,192**	**984**	**1,145**	**936**	**1,022**	**1,126**	**1,337**	**844**	**1,044**	**1,051**	**1,182**	**1,189**	**1,411**

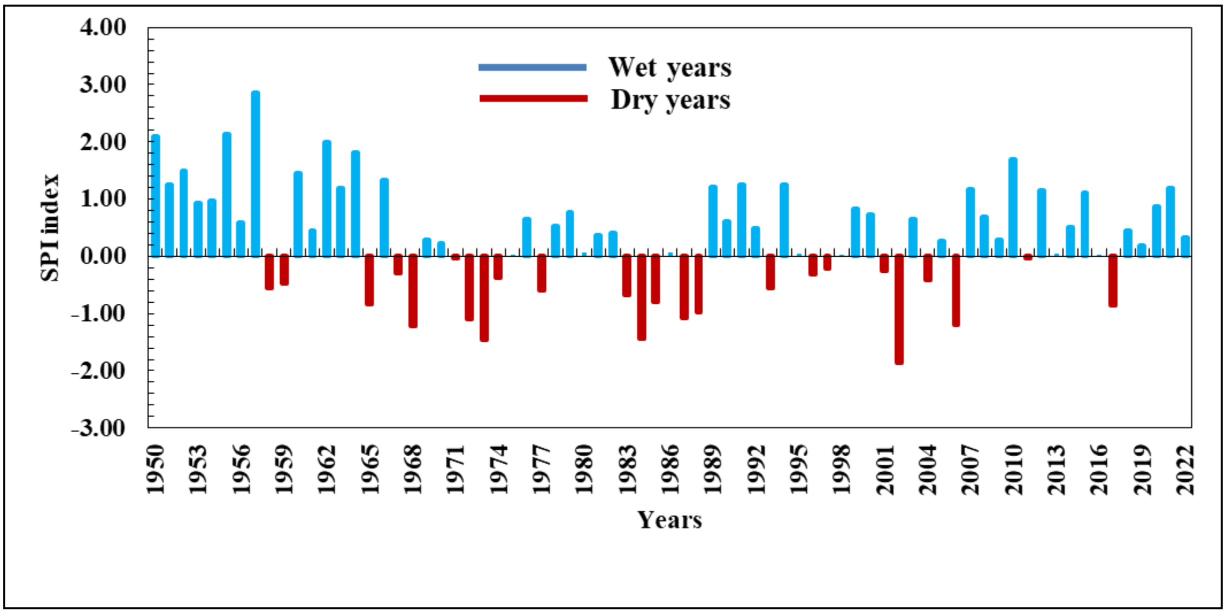
Source: Local service of agriculture based in Bougouni (2022)

4.4.3. Standardized Precipitation Index Test analysis

The Standardized Precipitation Index (SPI) stated that the period from 1950 to 1965 and from 2008 to 2022 were globally wet years and from 1966 to 2007 were also dry years globally. Therefore, SPI illustrated a severe drought for the years 2002 (-1.9) and 1973 (-1.5); moderate drought for 1968 (-1.2), 1984 (-1.4), 1987 (-1.1), 2006 (-1.2); mild drought for 1985 (-0.8) and 1993 (-0.6) (figure 14).

Similar results have been obtained by V. Markantonis *et al.*, (2018, p. 1285) in Mekrou River Basin (West Africa) reporting that generally, rainfall is highly variable in time and space and follows a cyclical trend of wet and dry periods from 1981 to 2016 and the SPI analyses highlighted a period of moderate to extreme droughts during the earlier part of the 1980s.

Concordant results have been reported by D. Diarra *et al.*, (2022, p. 236) which show a continuous evolution of SPEI at different levels in the Koutiala district, during the period from 1989 to 2019, there was an exceptional wet condition that occurred in 1994 (+2.53), and extreme wet conditions were observed in 1996 (+1.62) and 2010 (+1.62). While in 2013 (-1.52), 2017 (-1.63), 2002 (-1.80), and 2001 (-1.99) an exceptional dry condition was observed.



Source: Personal work

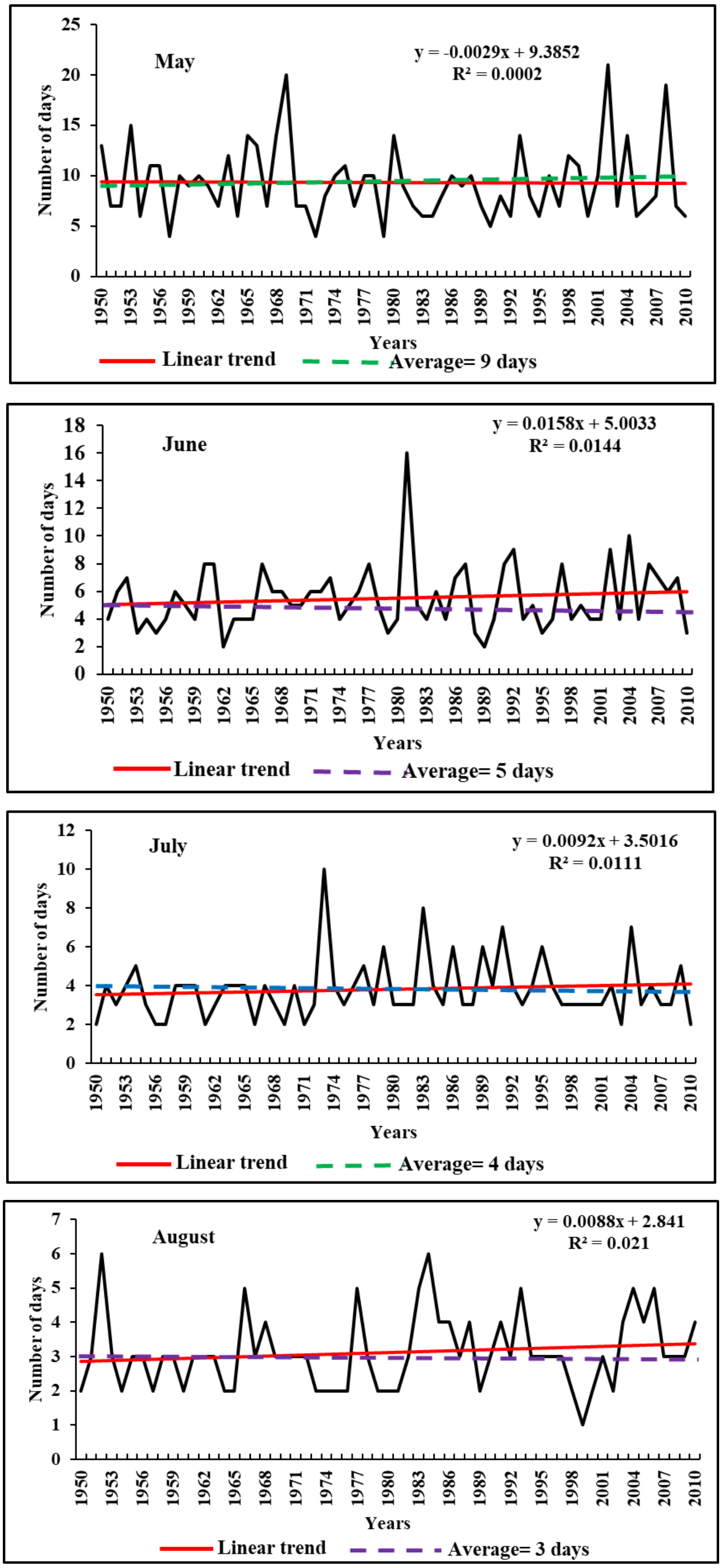
Figure 14: Standardized Precipitation Index (SPI) analysis of the rainfall in the District of Bougouni from 1950 to 2022

4.4.4. A dry spell high variation monthly

The figure 15 shows the monthly (May, June, July, August) dry spell in the District of Bougouni from 1950 to 2010. The average days of dry spell were 9 days for May, 5 days for June, 4 and 3 for July and August. From this analysis, the dry spell days were more important in May than others months. While, the equation of the line is negative it means a downward trend and upward trend in positive way.

A concordance of results has been reported by T. Sanogo *et al.*, (2016, p. 53) in the commune of Tioribougou (Mali), showing that may is the most month affected by dry spell as an average of 15 days and with the following month (June, July, August), the length of dry is spell is decreasing. According to B. Sarr (2012, p. 109), the precipitation deficit during the dry periods in West Africa was essentially due to a deficit in the number of rainfall events during the rainy season.

Thus, over the Sahel region, rainfall decrease has been about from 0.8 to 1 mm per day in July-August. This result are corroborating with those found by T. Sanogo *et al.*, (2023) in the southwest of Mali, showing that frequent of dry spells greater than or equal to five days was present in all months (May, June, July, August) but very low in May.



Source: Agrhymet-Niger (2010)

Figure 15: Average days of monthly dry spell in the district of Bougouni from 1950 to 2010

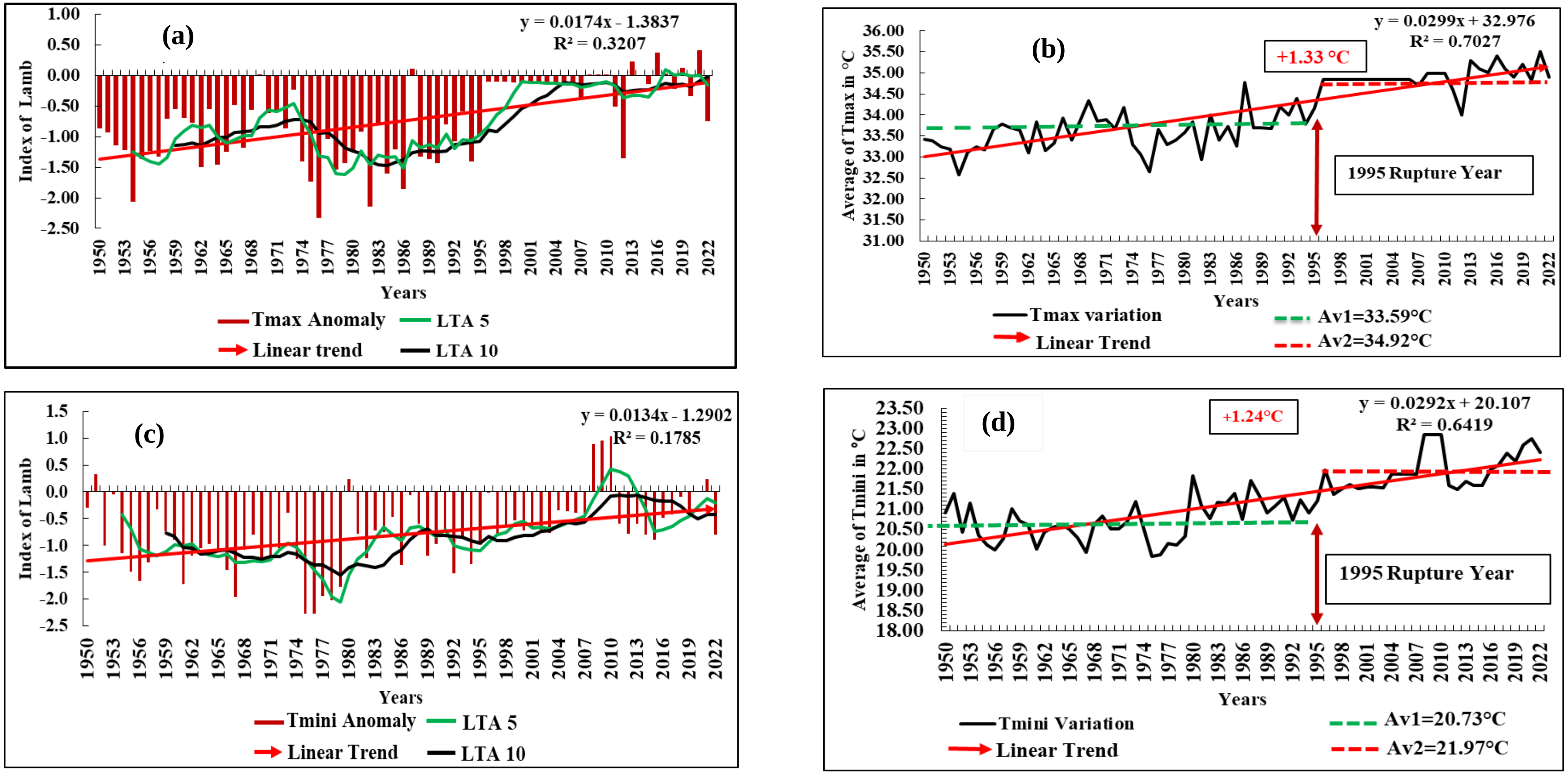
4.4.5. Maximum and minimum temperatures trending upwards

The standardized maximum temperature anomalies indicate 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). The positive way of equation of the line means an upward trend in the time serie.

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 16a). 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. A 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 16b). 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; and 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 16c).

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 16d). Similar studies were conducted by M. Coulilbaly, *et al.,* (2022, p. 23) in Diéma in Mali and Borana in southern Ethiopia (N. Debela *et al.,* 2015, p. 5), 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 have been observed by surveys in the Sahelo-Sudanian zone of Burkina Faso (D. Bambara *et al.,* 2013, p. 9). According to P. Gnanglè *et al., (*2005, p. 2), farmers' perceptions of climate change are consistent with trends of meteorological observations data.



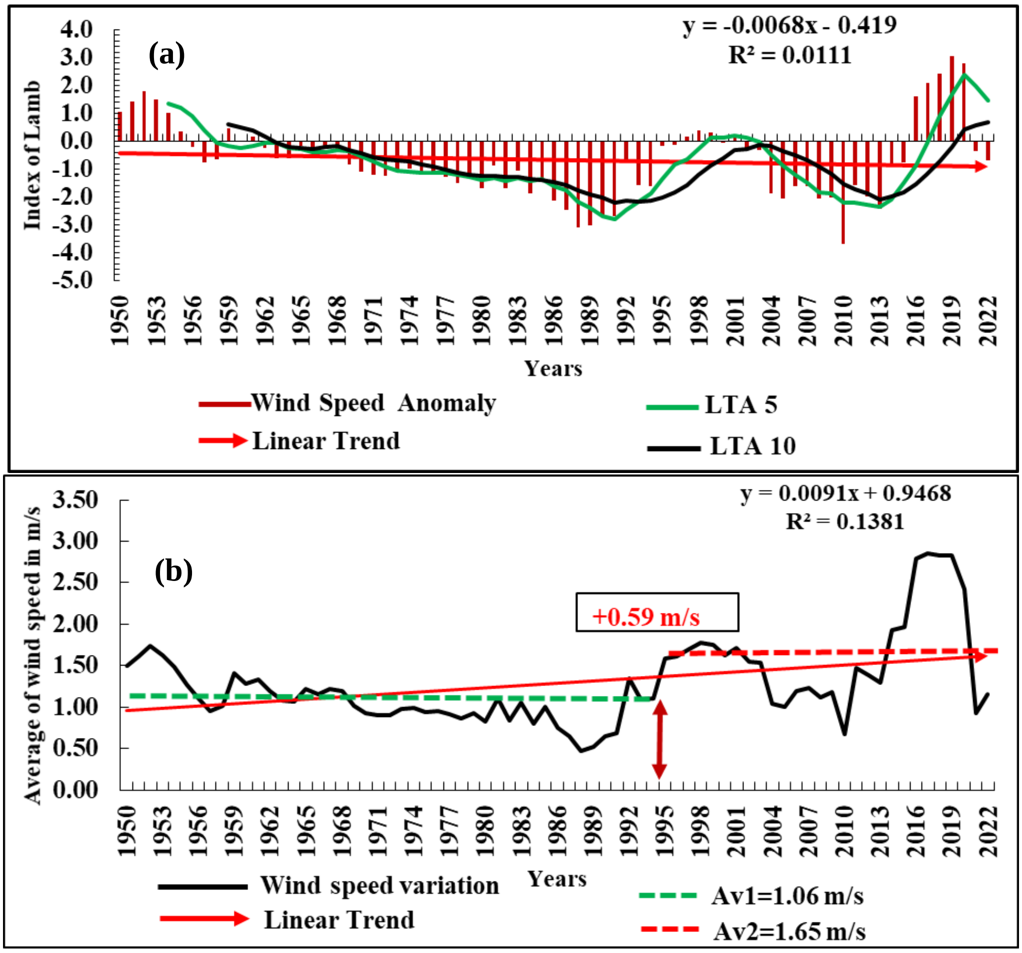
Source: Personal work

Figure 16: 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's District from 1950 to 2022

4.4.6. Wind Speed trending upwards

The normalized average wind speed anomalies indicate that the years 1950 to 1954; and 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 17a).

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 17b).



Source: Personal work

Figure 17: Anomalies Interannual variation (a) and evidence of statistic tests (b) of wind speed in the station of Bougouni's District from 1950 to 2022

4.5. Riched pasturages nutritionnaly in quantity and quality

4.5.1. Richness of herbaceous production

The table 40 is illustrating the average specific contribution of herbaceous species carpet per type of vegetation in the research sites.

At the total forty (40) species have been inventoried for the year 2022 in the research sites. The most dominant species are the *Andropogon pseudapricus* (43.68 %), *Microchloa indica* (28.72 %), *Loudetia Togoensis* (19.09 %), *Eragrostis aspera* (15.27 %), *Schizachyrium exile* (11.04 %), *Andropogon gayanus* (9.71 %).

However, certain most palatable species have a low contribution particularly *Panicum leatum* (2.24 %), *Brachiaria ramosa* (1.12 %), *Brachiaria xantholeuca* (1.1 %), *Stylosanthes erecta* (0.59%), *Borreria scabra* (0.28 %), *Sporobolus pyramidalis* (0.29 %). This results are not corroborated with those fund by N. Coulibaly *et al.,* (2022, p. 199) in Niono ranch (West of Mali) reporting that the most dominant species were *Zornia glochidiata* (38.80 %), *Schenofeldia gracilis* and *Brachiaria xantholeuca* (16.89 %; 16.34 %). According to I. Zerbo *et al.,* (2016, p. 5), In the protected area of West African Savanna Ecosystems, the most important species were *Andropogon gayanus, Andropogon pseudapricus, Hyparrhenia involucrata, Chamaecrista pratensis* and *Sorghastrum bipennatum. Andropogon gayanus* is one of the most palatable species in the research site that has high contribution (26.2 %) in the shrubby savannah than those vegetation type. This result is corroborating with those obtained by H. Sanon *et al.,* (2014, p. 8) in the soudanian zone of Burkina Faso, reporting that the contribution of *Andropogon gayanus* is the most important species in shrubby savannah.

Table 40: Specific contribution of herbaceous species (%) in the study area

Species	**Bowal**	**Shrubby savannah**	**Wooded Savannah**	**Average**	**SD**
Alysicarpus ovalifolius (Schumach & Thonn.) J.Léonard.	11.61	2.54	7.98	7.38	8.65
Andropogon gayanus Kunth.	0.40	26.2	2.53	9.71	8.75
Andropogon pseudapricus Stapf	40.83	53.85	36.36	43.68	8.83
Aristida mutabilis Trin. & Rupr.	23.14	0.00	0.00	7.71	6.09
Borreria scabra K.Schum.	0.83	0.00	0.00	0.28	6.14
Borreria stachydea (DC.) Hutch. &	1.66	0.77	7.54	3.32	6.20

Dalziel					
Brachiaria ramosa Stapf,	0.83	2.54	0.00	1.12	6.30
Eragrostis aspera Nees	34.71	8.58	2.53	15.27	6.38
Eragrostis pilosa (L.) P.Beauv	0.83	0.00	0.00	0.28	6.14
Eragrostis tremula Hochst. ex Steud.	0.83	0.77	0.00	0.53	6.21
Fimbristylis hispidula (Cherm.) Napper	3.33	0.00	0.00	1.11	6.29
Fimbristylis littoralis Gaudich.	0.83	0.00	0.00	0.28	6.38
Indigofera hirsuta Jacq.	0.83	2.42	0.00	1.09	6.46
Loudetia togoensis (Pilg.) C.E.Hubb.	33.31	0.00	23.97	19.09	6.56
Microchloa indica Hack. & Stuck.	28.14	14.16	43.86	28.72	5.94
Panicum leatum Kunth	4.96	1.77	0.00	2.24	3.02
Paspalum scrobiculatum bispicatum Hack. ex Merr	0.83	2.65	0.00	1.16	3.08
Pennisetum pedicellatum Trin.	0.83	10.12	11.39	7.44	3.14
Polycarpaea corymbosa (F.Muell.) Domin	5.83	0.00	0.00	1.94	3.02
Schizachyrium rupestre Stapf	0.83	2.31	0.00	1.05	3.09
Setaria pallide-fusca (Schumach.) Stapf & C.E.Hubb.	0.83	5.19	0.00	2.01	3.16
Sporobolus festivus Hochst. ex A.Rich.	1.67	0.00	2.48	1.38	3.24
Tephrosia bracteolata Guill. & Perr.	0.83	2.65	0.83	1.44	3.33
Waltheria indica L.,	2.49	0.00	0.00	0.83	3.42
Borreria chaetocephala (DC.) Hepper	0.00	8.73	15.19	7.97	3.51
Aspilia bussei O.Hoffm. & Muschl.	0.00	1.77	0.00	0.59	3.31
Cassia tora (L.) Roxb.	0.00	1.54	0.00	0.51	3.40
Crotalaria retusa (L.) Sp.	0.00	0.77	0.00	0.26	3.50

Digitaria horizontalis Willd.	0.00	18.12	7.59	8.57	3.59
Hyptis suaveolens (L.) Poit.	0.00	10.12	2.09	4.07	3.22
Merremia tridentata hastata Ooststr.	0.00	0.88	0.00	0.29	3.32
Phyllanthus amarus Schumach. & Thonn.	0.00	1.77	0.00	0.59	3.47
Schizachyrium exile (Hochst.) Pilg.	0.00	7.39	25.72	11.04	3.66
Schizachyrium sanguineum (Retz.) Alston	0.00	2.65	6.61	3.09	1.05
Schoenefeldia gracilis Kunth	0.00	0.88	0.00	0.29	0.60
Sida rhombifolia (L.) Sp.	0.00	0.88	0.00	0.29	0.63
Sporobolus pyramidalis P.Beauv.	0.00	0.88	0.00	0.29	0.65
Stylosanthes erecta P.Beauv.	0.00	1.77	0.00	0.59	0.59
Zornia glochidiata Rohb. ex DC.	0.00	5.31	0.00	1.77	0.47
Brachiaria xantholeuca Stapf	0.00	0.00	3.31	1.10	4.23

Source: Author construction, November 2022.

The average of dry master biomass is more important in Faragouaran (1 595.92 Kg/Ha) than Koumantou (1 216.40 Kg/Ha) for the overall and particularly more important in the shrubby savannah, followed by bowal and wooded savannah. The pastures have good pastorale value in Koumantou at the rate of 54.04 % compared Faragouaran with 48. 69 %. Concerning the both research sites, the richness of pasture is very high for the wooded savannah, followed by the bowal and shrubby savannah (table 41).

According to D. Konaré & M. Coulibaly, (2019, p. 215) in the rural commune of Dabia (south of Mali), the pastoral value was fluctuating from 35 to 64.61 %. These results are in accordance with those of A. Alhassane *et al.,* (2018, p. 1711) (Niger), who observed that in the Maradi Region of Niger, the herbaceous Biomass were varying between 1.06 Tonne/ha and 0.43 Tonne/Ha particularly for the north soudanian and south soudanian bioclimatic scale.

Similar results were fund by D. Konaré & M. Coulibaly, (2019, p. 215) in the rural commune of Dabia (south of Mali) illustrating that the dry mater are varying between 2,74 Tonne/Ha for silty-sandy soils vegetation compared with 1.63 Tonne/Ha for vegetation on leathery knoll soils.

This reveal that the dry mater biomass can be high level of production for a specific pasturage but its pastoral value is low. The Anova one factor test was applied on the biomass estimates production and the test shows no significant difference between the two sites.

Table 41: Estimates Biomass of Dry Master (DM) per Ha and Pastoral Value (PV) in research sites

Sites	Bowal		Shrubby savannah		Wooded Savannah		Averages	
	DM (Kg/Ha)	PV (%)	DM (Kg/Ha)	PV (%)	DM (Kg/Ha)	PV (%)	DM (Kg/Ha)	PV (%)
Faragouaran	1,197.15	48.83	1,972.00	43.85	1,618.62	53.39	1,595.92	48.69
Koumantou	1,273.00	44.20	1,415.70	64.25	960.50	53.67	1,216.40	54.04

Source: Author construction, November 2022

4.5.2. A decreasing carrying capacity in the study area

The carrying capacity per type of vegetation of the livestock has reported through the table 42. The carrying capacity is not greatly varying from type of vegetation to other. However, the average number of Tropical Livestock Unit (TLU) is slightly high for the shrubby savannah (0.25 TLU/Ha/year) and for the bowal slightly low (0.18 TLU/Ha/year).

The average number of days per year of livestock for pastures exploitation is 90.34 days for the shrubby savannah, 68.78 days for the wooded savannah and 65.87 days for the bowal. The general average is 75 days from the assessment of the year 2022 in the research sites. In the soudanian zone of Burkina Faso, results obtained by H. Sanon *et al.*, (2014, p. 9) announced that in the shrubby savannah the carrying capacity were 1,559.44 TLU per year for an area of 2,823.4 Ha per year either 1.81 TLU/year/Ha.

Table 42: Carrying capacity per type of vegetations

Sites	DM (Kg/ha)	Average number of HA/TLU/year	Average number/TLU/ HA/year	Average of QF/year (Kg)	Average number of days/year
Bowal	1,235.08	4.69	0.18	45.12	65.87
Shrubby Savannah	1,693.85	3.14	0.25	61.88	90.34
Wooded Savannah	1,289.56	4.83	0.19	47.11	68.78
Average	**1,406.16**	**4.22**	**0.21**	**51.37**	**75.00**

Source: Author construction, November 2022.

4.5.3. A ligneous stratum riched and getting highly degraded

The vegetation cover of wooded species is very riched and composed by sixteen (16) families of species: Anacardiaceae, Annonaceae, Apocynaceae, Asteraceae, Caesalpiniaceae, Celastraceae, Combretaceae, Ebenaceae, Fabaceae, Lamiaceae, Malvaceae, Mimosaceae, Olacaceae, Phyllanthaceae, Rubiaceae, Sapotaceae (table 43).

From the overall families, the Fabaceae is the most important with 13 species either 29.55 %, followed by the Combretaceae with 8 species either 18.18 %, Malvaceae with 4 species either 9.09 %, Anacardiaceae and Rubiaceae with 3 species either 6.82 %. This results are supported by those found by F. S. Traoré *et al.,* (2022, p. 23) illustrating that in West Sahel of Mali (District of Niono), the most important family of species was the Fabaceae with 9 species followed by the Combretaceae with 5 species.

Table 43: Repartition of wooded species per families

Families	Species	Number of species /family	Dominance (%)
Anacardiaceae	*Lannea acida* A. Rich. *Lannea microcarpa* Engl. & K.Krause *Lannea velutina* A. Rich.	3	6.82
Annonaceae	*Annona senegalensis* Pers. *Hexalobus monopetalus* Engl. & Diels	2	4.55
Apocynaceae	*Saba senegalensis* (A.DC.) Pichon	1	2.27
Asteraceae	*Vernonia amygdalina* Delile.	1	2.27
Caesalpiniaceae	*Cassia sieberiana* (DC) Jacques-Félix	1	2.27
Celastraceae	*Gymnosporia senegalensis* (Lam.) Loes.	1	2.27
Combretaceae	*Anogeissus leiocarpa* (DC.) Guil. & Perr. *Combretum fragrans* F.Hoffm. *Combretum glutinosum* Perr. *Combretum sp* *Guiera senegalensis* J.F.Gmel. *Pteleopsis suberosa* Engl. & Diels. *Terminalia laxiflora* Engl. *Terminalia macroptera* Guill. & Perr.	8	18.18
Ebenaceae	*Diospyros mespiliformis Hochst. ex A.DC.*	1	2.27
Fabaceae	*Acacia macrostachya* Rchb. ex G.Don. *Acacia raddiana* Savi. *Acacia seyal* Del. *Afrormosia laxiflora* Harms. *Burkea africana* Hook. *Daniellia oliveri* (Rolfe) Hutch. & Dalziel. *Detarium microcarpum* Guill. & Perr. *Dichrostachys glomerata* Chiov. *Entada sudanica* Schweinf. *Isoberlinia doka* Craib & Stapf. *Piliostigima reticulatum* (DC.) Hochst.	13	29.55

	Prosopis africana Taub. *Pterocarpus erinaceus* Poir.		
Lamiaceae	*Vitex barbata ex Baker*.	1	2.27
Malvaceae	*Bombax costatum* Pellegr. & Vuillet. *Grewia bicolor* Juss. *Grewia mollis* Juss. *Sterculia setigera* Delile.	4	9.09
Mimosaceae	*Parkia biglobosa* Benth.	1	2.27
Olacaceae	*Ximenia americana* f. inermis (Aubl.) Engl.	1	2.27
Phyllanthaceae	*Hymenocardia acida* Tul. *Securinega virosa* (Roxb. ex Willd.) Baill.	2	4.55
Rubiaceae	*Crossopteryx febrifuga* Benth. *Gardenia erubescens* Stapf & Hutch. *Sarcocephalus latifolius* (Sm.) E.A.Bruce.	3	6.82
Sapotaceae	*Vitellaria paradoxa* C.F.Gaertn.	1	2.27
Total		44	100.00

Source: Author construction, November 2022.

The table 44 is announcing the dominance of wooded species per Ha in the research site for the assessment of 2022. The most dominant species are *Afrormosia laxiflora* (3,990 tree/Ha either 33.61 %), *Detarium microcarpum* (1,820 tree/Ha either 15.33 %), *Terminalia laxiflora* (1,630 tree/Ha either 13.73 %), *Pteleopsis suberosa* (640 tree/Ha either 5.39 %), *Annona Senegalensis* (570 tree/Ha either 4.80 %). In the soudanian zone of Burkina-faso, similar results were obtained by H. O. Sanon *et al.,* (2014, p. 10) reporting that the *Detarium microcarpum* (632 tree/Ha) and the *Pteleopsis suberosa* (482 tree/Ha) are the most important tree.

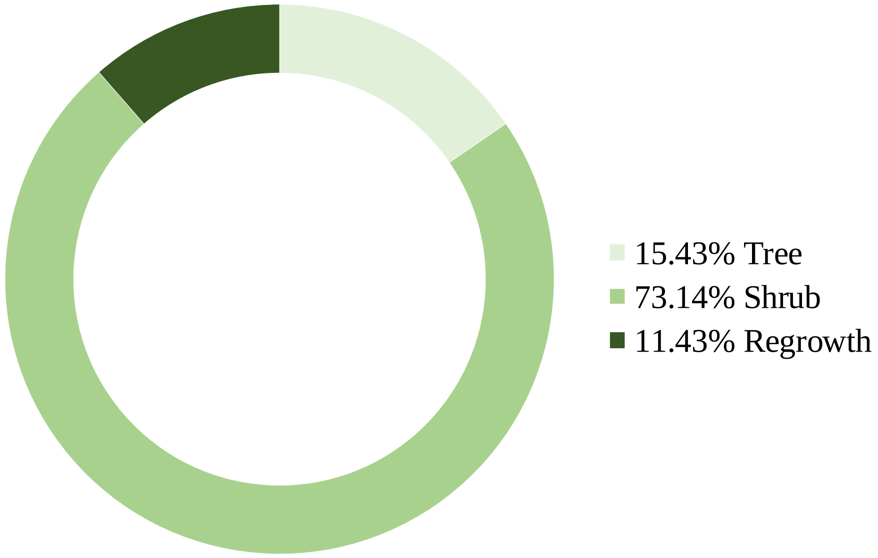
Table 44: Dominance of woody species per Ha

Species	Number of Tree/Ha	Relative Dominance (%)
Acacia macrostachya	40	0.34
Acacia raddiana	10	0.08
Acacia seyal	10	0.08
Afrormosia laxiflora	3,990	33.61
Annona senegalensis	570	4.80
Anogeissus leiocarpa	10	0.08
Bombax costatum	20	0.17
Burkea Africana	20	0.17
Cassia sieberiana	300	2.53
Combretum fragrans	440	3.71
Combretum glutinosum	110	0.93
Combretum sp	20	0.17
Crossopteryx febrifuga	250	2.11
Daniellia oliveri	30	0.25
Detarium microcarpum	1,820	15.33
Dichrostachys glomerata	40	0.34
Diospyros mespiliformis	20	0.17
Entada sudanica	10	0.08
Gardenia erubescens	430	3.62
Grewia bicolor	20	0.17
Grewia mollis	20	0.17
Guiera senegalensis	200	1.68
Gymnosporia senegalensis	40	0.34
Hexalobus monopetalus	10	0.08
Hymenocardia acida	10	0.08
Isoberlinia doka	130	1.10
Lannea acida	240	2.02
Lannea microcarpa	10	0.08
Lannea velutina	10	0.08
Parkia biglobosa	20	0.17
Piliostigima reticulatum	120	1.01
Prosopis africana	70	0.59

Pteleopsis suberosa	640	5.39
Pterocarpus erinaceus	20	0.17
Saba senegalensis	80	0.67
Sarcocephalus latifolius	10	0.08
Securinega virosa	140	1.18
Sterculia setigera	10	0.08
Terminalia laxiflora	1,630	13.73
Terminalia macroptera	100	0.84
Vernonia amygdalina	10	0.08
Vitellaria paradoxa	160	1.35
Vitex barbata	10	0.08
Ximenia americana	20	0.17
Total	**11,870**	**100.00**

Source: Author construction, November 2022

The structure of wooded plants has divided in three part that are tree, shrub, and regrowth. This structure has showed that the majority of plants is shrubs (73.14 %) and only 15.43 % are tree(figure 18). This situation is explained through human pressure and climate hazards based drought on the available resources.



Source: Author construction, November 2022.

Figure 18: Characterization of Woody plant structure

PARTIAL CONCLUSION

The second part of this research revealed in the District of Bougouni, a concordance between agro-pastoralists' perception of climate change and meteorological observations concerning the decrease in rainfall, the increase in temperatures and wind speed from 1950 to 2022. The respondents identified four (4) climate risks related-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 gayanus, 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*). These species are highly palatable for animals. Others adverses effect are early drying up of watering points and pollution of available water; collapse of salt land sites.

At the total forty herbaceous species have been inventoried for the year 2022 in the research sites. The most dominant species are the *Andropogon pseudapricus, Microchloa indica, Loudetia togoensis, Eragrostis aspera, Schizachyrium exile, and Andropogon gayanus*. The average of dry master biomass is more important in Faragouaran than Koumantou for the overall and particularly more important in the shrubby savannah, followed by bowal and wooded savannah. The pastoral value refereeing to the quality pastures is more good in Koumantou than Faragouaran. Concerning the both research sites, the richness of pasture is very high for the wooded savannah, followed by the bowal and shrubby savannah. Moreover, a dry mater biomass is not correlated to pastoral value in research sites.

The vegetation cover of wooded species is very riched and composed by sixteen (16) families of species: Anacardiaceae, Annonaceae, Apocynaceae, Asteraceae, Caesalpiniaceae, Celastraceae, Combretaceae, Ebenaceae, Fabaceae, Lamiaceae, Malvaceae, Mimosaceae, Olacaceae, Phyllanthaceae, Rubiaceae, Sapotaceae. The Fabaceae is the most important (13 species), followed by the Combretaceae (8 species), Malvaceae (4 species), Anacardiaceae and Rubiaceae (3 species). The most dominant species are *Afrormosia laxiflora, Detarium microcarpum, Terminalia laxiflora, Pteleopsis suberosa, and Annona senegalensis*. The wooded plant structure has showed that the majority of plant is shrubs followed by tree and regrowth.

THIRD PART:

VULNERABILITY ASSESSMENT AND ADOPTED STRATEGIES ELABORATION OF AGRO-PASTORAL COMMUNITIES

The third part of this thesis is structured around chapters five and six. The fifth chapter reports the assessment of the Livelihood Vulnerability Index of agro-pastoralist communities and the six chapter on adopted response strategies of agro-pastoralist communities in the face of climate risks related-hazards.

The assessmsnt of agro-pastoral communities vulnerability was structured around human factors, pastoral resource factors and climatic factors. This vulnerability is usually considered to be the product of three elements: sensitivity, exposure and adaptive capacity (O. F. Godber &W. Richard, 2014, p. 3093). Thus the vulnerability equal to risk plus response. The response factor include the degree of sentivity, adaptive capacity and exposure.

CHAPTER 5:

ASSESSMENT OF AGRO-PASTORALIST LIVELIHOOD VULNERABILITY INDEX

This chapter is treating the assessment of agro-pastoralist Livelihood Vulnerability Index (LVI) based on major components and sub-components variable and the assessment of Climatic Vulnerability Index based on contributing factors.

The major components of the LVI are the sociodemographic, social network, livestock, pastures, watering points, climatic hazards. The LVI-IPCC computing announce that Koumantou and Dogo are least vulnerable whereas Faragouaran and Dogo are most vulnerable.

5.1. Assessment of agro-pastoralist Livelihood Vulnerability Index based on major component and sub-component variable

Data on agro-pastoralist Livelihood Vulnerability Index assessment were collected in November 2022. It is about demographic data, livestock data, temperature data, rainfall data, and survey data (table 45).

The sample size has been computed by using recent dataset from the national directorate of the population. The livestock population data was gathered at the technical service of the livestock production of the District of Bougouni. It aims to raise the number of head animal in square kilometers. The climatic data (rainfall and temperature) was collected from tree types of sources which the Agency of National Meteorology, Agency of Regional Meteorological of Bougouni and Beaumont weeb site link. The tree sources of climatic data used and compared aim to apply for good quality of data.

Survey data were collected using semi-structrure questionnaire in face-to-face interviews and focus group discussions adoption. These interviews and focus group discussions addressed information about sociodemograpic profile and social network of the household, the livestock wellbeing characteristics, the degradation of pastures areas, the degradation of watering points, climatic risks related-hazards, impact and adapatation matrix. The Four communes concerned by this data collection were Dogo, Faragouaran, Garalo and Koumantou. At the total of 404 valid questionnaires were administrated from agropastoralists. A field guides were recruited in each research site for introducing to local communities in order to avoid misunderstanding of agropastoralist during questionnaire administration.

Silimar data used in the Evaluation of livelihood vulnerability of agropastoral households in Mozambique (M. B. Hahn *et al.*, 2009, p. 76) , in Northern China (W. Ding *et al.,* (2014, p. 536), in the Sahelian part of Mali (T. Sanogo *et al.*, 2016, p. 38) and in the North Eastern of

Kenya (A. A. Twane & J. W. Wakhungu, 2018, p. 79) to natural disasters and climate change were implemented focusing on the survey data collection, livestock data and meteorological data.

Table 45: Dataset describing the format, use and source for this vulnerability assessment

N°	Data	Use	Sources
1	Demographic data	Sample size calculation	DNP, 2022
2	Livestock population	Number of heads/km^2	SLPIA-B, 2021
3	Temperature data	Average annual	ANM, 2021; Meteo-Bougouni, 2023; https://beaumont.tamu.edu/climaticdata
4	Rainfall data	Average annual	ANM, 2021; Meteo-Bougouni, 2023; https://beaumont.tamu.edu/climaticdata (2023)
5	Survey data	Descriptive statistics	Sanogo T., Nonember 2022

Source: Author construction, December, 2022.

The table 46 announces the major-component, sub-component and maximum (Max) and minimum (Mini) values for Dogo, Faragouaran, Garalo, and Koumantou communes. The major components take account in this vulnerability assessment were sociodemographic with four sub-components, social network and water points with three components, livestock with five sub-components, pastures with six components and climatic hazards with two sub-components.

However, the percent of each sub-component reveals more important globally for Dogo and Koumantou communes. However, the main units noted were percentage (%), millimeters (mm), Celsius degree (°C) and the number of livestock population. The number of livestock population in the year 2021 per square kilometers is more important in Koumantou (1,794.0 km^2) followed by Faragouaran (1,107.0 km^2) and Dogo (935 km^2). The average of annual rainfall from 2010 to 2021 is higher in Garalo (1,229 mm) and very low in Dogo (987.7 mm). The maximum temperature was 35.2 °C and the minimum 35 °C.

The sociodemographic was focused the population in load, the active person, the study level and the training received on livestock field. The literacy, professionals, more than four persons in a room weresomes of family structure and socioeconomiques indicators for assessing social vulnerability for efficient management of urban pluvial flooding in the Lagos

Metropolis of Nigeria (C. U. Nkwunonwo, 2017, p. 4). Concerning the social network, it raises the conditions under which population are living in peace in the communities. The livestock encmopsses on the the transhumance practice; the weight, mortality and feed of animal. The major component of pastures refers to the level of degradation of pastures in termes of woody and herbaceous species related to climatic hazards and human drivers. The size of the livestock population was used in pasture major component for assessing the pressure on pasture areas in termes of overgrazing and others types of impacts. In the Livestock and food security vulnerability assessment to population growth and climate change, the sensitivity score was composed of a nation's level of self-sufficiency with regard to grazing animal-based food products, the nutritional contribution of animal-based food products to diet (O. F. Godber & W. Richard, 2014, p. 3094).

The water points were referencing to the availability of water resources for animal watering during the whole season of the year. Its develops how drought can be a main factor of degradation of water point, the length of water crisis period and water bad condition currently comparing to the past time. Similar results have been obtain by A. Sanfo *et al.,* (2015, p. 95) in the eastern part of Burkina Faso, showing that the main factor involved in the pastoralist and agro-pastoralists vulverability assessment were water, livestock health issue, animal productivity, pastures and conflucts.

The climatic hazards were focused on the average of annual rainfall and temperatures from 2010 to 2021 collected in each research sites. Each research sites vulnerability score has been measured according to the average annual rainfall and temperatures it was experiencing in the twelve year serie. In the northern and central Tanzania, the indicators of exposure used by P. T. Sewando *et al*., (2016, p. 15) for assessing vulnerability of agro-pastoral farmers to climate risks were the rate change in average annual minimum temperatures, the rate of change in average annual maximum temperature and the rate of change in average annual precipitation.

Table 46: Major-component, sub-component and maximum (Max) and minimum (Mini) values for Bougouni's Districts

Major components	Sub-Components	Units	Dogo	Faragouaran	Garalo	Koumantou	Max	Mini
Sociodemographic	percent of people who have more than 20 persons in load	%	41.0	3.8	21.8	33.3	100	0
	percent of people who have less than or equal to 5 active persons	%	20.9	9.0	29.2	40.8	100	0
	percent of people who have a high level of study (Secondary)	%	38.9	13.9	13.9	33.3	100	0
	percent of people having training in livestock field	%	23.4	20.2	18.1	38.3	100	0
Social network	Percent of people using social assistance	%	25.7	7.9	24.8	41.6	100	0
	Percent of people belong to socioprofessional organization	%	26.4	8.5	16.9	48.3	100	0
	Percent of people reported amicable conflict management cases	%	25.5	8.5	26.1	39.8	100	0
Livestock	Percent of people practicing livestock transhumance	%	12.9	11.3	27.4	48.4	100	0
	Percent of people on decrease of livestock weight	%	24.8	8.6	26.7	40.0	100	0
	Percent of people on frequency of livestock mortality	%	27.7	6.6	25.8	39.9	100	0
	Percent of people on frequency of livestock mortality related diseases	%	28.3	8.6	24.2	39.0	100	0
	Percent of people who have built house for livestock feed storage	%	36.7	8.3	18.3	36.7	100	0
Pastures	Percent of people on the pastures currently bad condition	%	31.8	6.4	24.7	37.1	100	0
	Percent of people on disappearance of woody appetizing species by livestock	%	25.3	10.0	29.8	34.9	100	0
	Percent of people on disappeared appetizing species in pastures	%	23.4	7.5	25.9	43.3	100	0
	Percent of people on disappearance of herbaceous appetizing species by livestock	%	24.1	7.8	27.8	40.3	100	0
	Percent of people on pastoral resource management training	%	29.7	4.6	22.8	42.9	100	0
	Percent of people on frequency of bushfires	%	27.7	8.3	23.7	40.3	100	0
	Livestock density per square kilometer in 2021	Livestock/km2	935.0	1,107.0	726.0	1,794.0	13,287	137
Water points	Percent of people on drought as a factor in the degradation of water points	%	28.5	4.7	22.9	43.9	100	0
	Percent of people on the length of water crisis period	%	10.3	13.8	20.7	55.2	100	0
	Percent of people on the watering points currently bad condition	%	37.0	6.6	28.7	27.6	100	0
Climatic hazards	Annual average Rainfall of research sites from 2010-2021	mm	987.7	1,161.7	1,229.0	1,052.3	1,229	988
	Annual average Temperature of research sites from 2010 to 2021	°C	35.1	35.1	35.1	35.1	35.2	35

Source: Personal work, December 2022 (%), Livestock density (SLPIA-B, 2021) , climatic data (Mali-Meteo, 2021)

The sub-component index varies from 0.04 to 0.41 for the household who have more than 20 person in load, from 0.09 to 0.41 for household who have less than or equal to 5 active persons and from 0.14 to 0.39 for people who have a high level of study (Secondary). The index remains between 0.18-0.38 for the people who have got training in livestock, 0.08-0.48 for those relying on social assistance, 0.08-0.48 for people belong to socio-professional organization, 0.09-0.26 for people reporting amicable conflicts management cases, 0.11-0.48 for those who practicing transhumance activites. It is ranging from 0.09 to 0.40 for the decrease of livestock weigt, from 0.07 to 0.40 for the livestock mortality, from 0.09 to 0.39 for the frequency of livestock mortality related deseases, from 0.08 to 0.37 for people who have constructed house for livestock feed storage.

The sub-component index is about 0.06-0.37 concerning the pasture currently bad in condition, 0.10-0.35 for the disappearance of woody appetizing species, 0.07-0.43 for disappearance of appetizing species in the pastures, 0.08-0.40 for disappearance of herbaceous appetizing species, 0.05-0.43 for people having training on pastoral resources management. With the frequency of bushfires, the density of livestock per square km^2, drought impacts on water points, the index is fluctuating between 0.05 and 0.44. The length of water crisis period, the water points in bad condition have index between 0.07 and 0.55. Concerning the rainfall and temperature, the indesx ranges from 0.00 to 0.72.

The LVI of sub-components are very high in Koumantou and Dogo than other areas. The index for the person in load and active person reveals that the communes with large size of household and small size of active person are most vulnerable. The amicable conflict management has low index in Faragouaran (0.09) but in high in Koumantou (0.40). The currently bad condition of pastures is very low in Faragouaran (0.06) than those in Garalo (0.25), in Dogo (0.32) and in Koumantou (0.37) According the people on disappeared appetizing herbaceous species in pastures, the pasture areas in commune of Faragouaran and Dogo are most vulnerable. The Concerning the climatic risks related rainfall variability, the commune of Dogo and Garalo are more affected with index relatively low (0.00; 0.1) (table 47).

Table 47: Livelihood Vunerability Index of sub-component in Dogo, Faragouaran Garalo, Koumantou

Sub-Components	Dogo	Faragouaran	Garalo	Koumantou
percent of households who have more than 20 persons in load	0.41	0.04	0.22	0.33
percent of households who have less than or equal to 5 active persons	0.21	0.09	0.29	0.41
percent of people who have a high level of study (Secondary)	0.39	0.14	0.14	0.33
percent of people having training in the livestock field	0.23	0.20	0.18	0.38
Percent of people using social assistance	0.26	0.08	0.25	0.42
Percent of people belong to a socio-professional organization	0.26	0.08	0.17	0.48
Percent of people reported amicable conflict management cases	0.26	0.09	0.26	0.40
Percent of people practicing livestock transhumance	0.13	0.11	0.27	0.48
Percent of people on decrease of livestock weight	0.25	0.09	0.27	0.40
Percent of people on the frequency of livestock mortality	0.28	0.07	0.26	0.40
Percent of people on the frequency of livestock mortality-related diseases	0.28	0.09	0.24	0.39
Percent of people who have built house for livestock feed storage	0.37	0.08	0.18	0.37
Percent of people in the pastures currently in bad condition	0.32	0.06	0.25	0.37
Percent of people on disappearance of woody appetizing species by livestock	0.25	0.10	0.30	0.35
Percent of people on disappeared appetizing species in pastures	0.23	0.07	0.26	0.43
Percent of people on disappearance of herbaceous appetizing species by livestock	0.24	0.08	0.28	0.40
Percent of people on pastoral resource management training	0.30	0.05	0.23	0.43
Percent of people on frequency of bushfires	0.28	0.08	0.24	0.40
Livestock density per square kilometer in 2021	0.06	0.07	0.04	0.12
Percent of people on drought as a factor in the degradation of water points	0.28	0.05	0.23	0.44
Percent of people on the length of water crisis period	0.10	0.14	0.21	0.55
Percent of people on the watering points currently bad condition	0.37	0.07	0.29	0.28
Average annual Rainfall of research sites from 2010-2021	0.00	0.72	1.00	0.26
Average annual Temperature of research sites from 2010 to 2021	0.50	0.50	0.50	0.50

Source: Personal work, December 2022.

The table 48 evokes LVI of Major-component in Dogo, Faragouaran Garalo, Koumantou communes. The Major component of pasture has the most important number of sub-component (7), follow by the livestock (5), sociodemographic and watering points (4), social network (3), and climatics (2). The index ranges from 0.118 to 0.365 for the sociodemographic, from 0.083 to 0.433 for the social network, and from 0.086 to 0.408 for the livestock. It also varies form 0.074 to 0.359 for the pastures, from 0.083 to 0.423 for the watering points, and from 0.250 to 0.380 for the climatic hazards.

The index is globally high in Koumantou and Dogo for the whole major component. For the sociodemographic, the index is low for faragouaran (0.118) and garalo (0.208) in contrast high with Dogo (0.320) and koumantou (0.365). This situation can explained be by the study level and size of active person that are is more important in Dogo and Koumantou. Concerning these two communes, the household less load intermes of number person. However, about level of social assistance, the index is 0.086 and 0.227 for Faragouaran and Garalo respectively but 0.260 and 0.433 for Dogo and Koumantou. So, this contrast reveals that the communes of Dogo and Koumantou people are more intersting to socioprofessional organization. Most of the conflicts are solved amicably and while hazards occurred the level of assistance is very high in these two communes. The livestock index is low for the communes of Faragouaran and Garalo whereas high for Dogo and Koumantou communes. According the respondents, the persons who are practing transhumance activities and building livestock fee storage bank are important in Dogo and koumantou communes than the others. It appears that these two communes (Dogo, Koumantou) are sharing borders with transhumance tracks. Rgarding, the livestock mortality form deseases, the access of veterinary product is low in Garalo commune.

The vulnerability of pastures areas in faragouaran is due the high frequency of bushfires during the crisis period (from January to May), the disappereance of woody and herbaceous palatable species. The density of livestock population per square kiliometers is very high in Faragouaran commune than the others. This situation exposes pastures zone on overgrazing condition. The number of people who has reported having traning of livestock resources management is very low for Faragouaran compared to the others zones. The The index of pastures is globally low for overall areas. The water points, the index is high for Koumantou commune due the availability of the Guérékélé dam's which can retain water during the whole period of the year. This communes is crossed by many river. The early dry of water areas is more frequent in the others commune than Koumantou. The commune of Dogo and Garalo are most vulnerable to climatic risks rekated hazards than Koumantou and Faragouaran where the average of annual rainfall is high. Pastoralists in the Borana area said climate change had an impact on their livelihoods through a variety of ways and the four principal effects of climate change on livestock production, are feed shortage, water shortage, reduced productivity, and decreased mature weight and/or longer time to achieve mature weight (G. A. Bogale & Z. B. Erena, 2022, p. 447). For the overall, the index is high for climatic hazards (0.440) in contrast very low with pastures (0.225).

Table 48: Livelihood Vunerability Index of Major-component in Dogo, Faragouaran Garalo, Koumantou

Major Component	Number of Sub-component	Dogo	Faragouaran	Garalo	Koumantou	Mean
Socio-demographic	4	0.310	0.118	0.208	0.365	0.250
Social Network	3	0.260	0.083	0.227	0.433	0.251
Livestock	5	0.260	0.086	0.244	0.408	0.250
Pastures	7	0.240	0.074	0.227	0.359	0.225
Watering points	4	0.253	0.083	0.240	0.423	0.250
Climatic Hazards	2	0.250	0.380	0.750	0.380	0.440

Source: Personal work, December 2022.

5.2. Assessment of Climatic Vulnerability Index based on contributing factors

The LVI of Agro-pastoraloist per Major component for Dogo, Faragouaran, Garalo and Koumantou is composed by twenty four sub-components. However, these sub-components are splited in seven (7) sub-components for the adaptive capacity, fifteen (15) sub-components for the sensitivity and two (2) for the exposure (table 49).

The adaptive capacity index was assessed through the sociodemographic and social network component. The adopted factors for the sensitivity were based on the livestock, pastures and watering points. The exposure contributing factor was assessed on the climatic hazards focusing rainfall and temperature patterns. The findinds from assessment of vulnerability index on climate variability in the east of thailland has indicated that the exposure component includes rainfall and maximum and minimum temperature, drought risks; the sentitivity includes incomes of household, crop diversity, water resources; the adaptive capacity has concerned proportion of the working age in a household, proportion of people who participated in training related to environment and natural resources (C. Laitae *et al.,* 2014, p. 3). The indices range from 0.103 to 0.394 for the adaptive capacity, from 0.080 to 0.388 for the sensitivity, and from 0.250 to 0.380 for the exposure. The adaptive capacity has the greatest index (0.394). A similar result was reported by C. Laitae *et al.,* (2014, p. 3) in the east of Thailand, showing that the adaptation capacity contributed the greatest vulnerability index ranging from 0.34 to 0.62.

Table 49: LVI of Agropastoraloist per Major component for Dogo, Faragouaran, Garalo and Koumantou

Contributing factors	**Major component values**	**Number of sub-component**	**Dogo**	**Faragouaran**	**Garalo**	**Koumantou**
Adaptive Capacity	Sociodemographics	4	0.288	0.103	0.216	0.394
	Social Network	3				
Sensitivity	Livestock	5	0.249	0.080	0.235	0.388
	Pastures	7				
	Watering points	3				
Exposure	Climatic Hazards	2	0.250	0.380	0.750	0.380

Source: Personal work, December 2022.

However, the adaptive capacity and sensitivity index is high for Koumantou (0.3940; 0.388) and low for Faragouaran (0.103; 0.080). Concerning the exposure index, which is high for Koumantou (0.380) and low for Dogo (0.250). The LVI-IPCC computing announce that Koumantou and Dogo are least vulnerable (-0.005; -0.009 respectively) against Faragouaran and Garlo that are most vulnerable (0.022; 0.125 respectively) (table 49). However, the most vulnerable agro-pastoralist communities are those from Faragouaran. This situation is explained through importance of livestock size per square kilometers due to high on available resources, high percent of those people who have not got any training on pastoral resources management, high frequency conflicts over pastoral resources management.

The pasture areas are mostly affected by the high frequency of bushfires in Faragouaran commune compared to others research sites. From January to Mai, potential period of dry season, pasture areas are regulary experiencing bushfires. This situation lead to destruction of herbaceous and woody species cover entailling early animal departure to transhumance. More than half of the respondent noticed that the watering points are becoming early dry due to drought hazards. Due to geographical position where, Faragouaran is crossed by one the biggest transhumance track of the country and poushed pressure on pastures areas and watering points resources.

This results are corroborating with those obtain by M. Hahn *et al.*, (2009, p.83) in Moma and Mabote district (Mozambique), Based on demographics, livelihoods, and social networks, Moma showed a higher adaptive capacity (0.522 versus 0.388 for Mabote). The overall LVI–IPCC scores indicate that Mabote households may be more vulnerable than Moma house-holds (0.005 versus 0.074, respectively). In the eastern of Thailand, similar results have been found by C. Laitae *et al.*, (2014, p. 4) reporting that the LIV of agro-pastoralist communities was varying between 0.04 and 0.07 respectively for Tha-Mai and Khoakitchakut District; and Khoa kitchakut also showed greater vulnerability on the Livelihood component than Tha mai.

Moreover, in Tanzania, the vulnerability index revealed that agro-pastoral farmers in the northern zone were more vulnerable than in central Tanzania, while the agro-pastoral farmers in Arusha, Mwanga, and Ikungi were more vulnerable than those from Kongwa and Babati districts (P. Sewando *et al.*, 2016, p. 20).

Table 50: LVI-IPCC of agropastoralis per Contribution factors for Dogo, Faragouaran, Garalo and Koumantou

Contribution Factors	Dogo	Faragouaran	Garalo	Koumantou
Adaptive capacity	0.288	0.103	0.216	0.394
Sensitivity	0.249	0.080	0.235	0.388
Exposure	0.250	0.380	0.75	0.380
LVI-IPCC	**-0.009**	**0.022**	**0.125**	**-0.005**

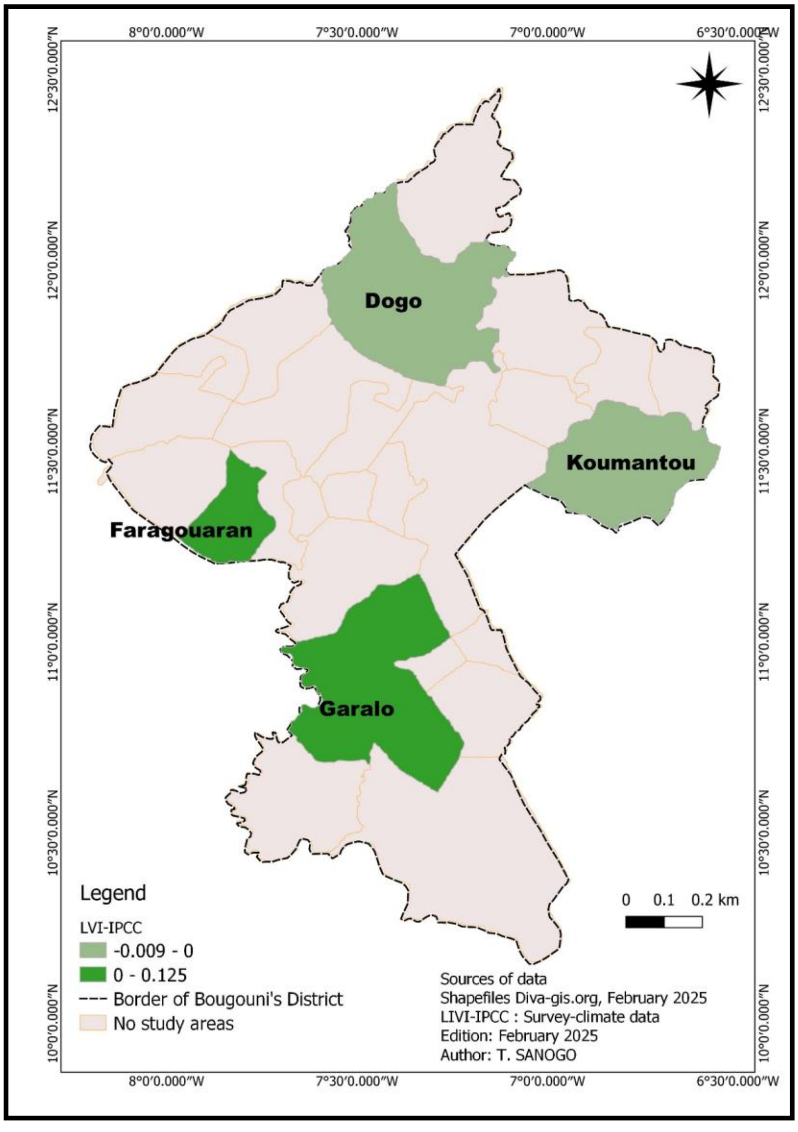
Source: Personal work, December 2022;
The LVI–IPCC is on a scale from -1 (least vulnerable) to 1 (most vulnerable)

However, data from focus group discussion were collected in each research sites to illuminate individual interview face-to-face. It was done with the resource persons in agro-pastoralism field who are at least 30 years old (photo 9).

Source: Bagayoko A., photo taken in November 2022.

Photo 9: Livelihood Vulnerability Index assessment method deploying focus group discussions in the village of Faragouaran

The map 7 is presenting the vulnerable zones in the District of Bougouni throughout the LVI-IPCC. From this analysis the communes at the north eastern part Bougouni are least vulnerable and those at the South western are most vulnerable according to the definition of the assessment scale. Field observations and the survey reveal that the pasture areas are more degraded in the south western part than the north eastern part. Moreover, the watering points condition are good due to some watering points development in the north eastern zone compared to the south western zone of the District where these conditions are severe.



The LVI–IPCC is on a scale from -1 (least vulnerable) to 1 (most vulnerable)

Source : Author construction, December 2022.

Map 7 : Map showing the vulnerable zones in the District of Bougouni

However, agro-pastoralist communities have adopted strategies to deal with climatic hazards.

CHAPTER 6:

ADOPTED STRATEGIES OF AGROPASTORALIST COMMUNITIES IN FACE TO CLIMATIC HAZARDS

The last chapter of this thesis is about the precaution against future drought, the main adopted strategies and perception based on marks attribution in face of climatic hazards and the prioritisation of the main adopted strategies for coping climatic risks related hazard.

Agro-pastoralist communities in the study environment have adopted responses measures which allow them to raise their resilience and to better conditions in face of climatic risks related hazards. In the District of Bougouni, the Agro-pastoralists have implemented precaution against future drought, adopted strategies and perception based on marks attribution in face of climatic hazards.

The three most prioritized strategies through multi-criteria analysis raised agropastoralists were collection and storage of crop residues, practice of adapted forage cultivation, sale of livestock to buy feed.

6.1. Precaution against future drought

The local perception of drought hazards and its adverse effects on pastoral, watering points and livestock wellbeing led to agro-pastoralist coommunities in the District of Bougouni to implement precaution against future drought as adaptive response to drought.

The most important are accounted at twenty (20). However, there are about collection and storage of crop residues in a shed (14 %); practice of adapted forage crop cultivation and big transhumance practice (11 %); purchase of supplementary feed (cereal bran, cotton meal..) and bushfire control policy (10 %); creation of water reservoirs and development of watering points (9%) (table 51). Similar results have been shown in Southern Kajiado District, Kenya, by D. J. Campbell, (1984, p. 54) which stated that the precautions against drought impacts emphasize economic activities and many represent divergence from existing ones, and thus may alter their way of life to adapt to changing circumstances. The prolonged dryness with high temperatures that lead to complete drying up of pasture and to water scarcity. This drought has forced pastoral communities to leave their homes in search of water and food for their animals (B. Njiru, 2012, p. 520). According to H. Abdou *et al.*, (2020, p. 85), as response to drought in falingué commune (Niger), livestock herders practice transhumance, purchase animal feeds, animal selling, and fodder storage. In addition, the livestock producers *fulani* in the savannah regions of Togo used transhumance practice as adopted strategies to alleviate climate hazards impacts (K. Sokemawu, 2026, p. 174).

To reduce vulnerability to future drought in West African Sahel, the respondents suggest expansion of cultivated land, small ruminant husbandry, adoption of improved and drought-tolerant crop varieties, and reclamation of degraded land, digging of wells for off-season farming, supply of feed supplements (A. Ayantunde *et al.*, 2015, p. 8). A concordance results have been fund by G. A. Bogale & Z. B. Erena (2022, p. 477) illustrating that pastoralists use a variety of coping and adaptation tactics to protect livestock assets during droughts, including transferring animals to places with better fodder and water, selling some animals, separating or trading herds, and changing the species makeup of herds over time.

The respondents have araised others adapation measures to drought adverse impacts including the reduction of livestock size and pastoral resources management practice, catle and small ruminnats fattening practice, afforestation practice around watering points, mowing and storage of grass biomass on shed. Studies conducted by A. B. Sikiru *et al.*, (2023, p. 250) support that changing the pattern of grazing management, such as reducing the number of animals per pasture land area, the use of crop residues and feeding of animals with fodder crops are leading adaptation strategies employed by smallholder agro-pastoralists in Africa to climate risks related-hazards as drought.

Moreover, as measures and practices with potential for enhancing adaptive capacity of communities in Ethiopia to climate drivers in pastoral areas was the reducing livestock numbers to match carrying capacity of grazing lands through increased commercial off- take rates (S. Tiruneh & F. Tegene, p. 56).

Table 51: Precautions against future drought impacts

Adopted strategies for frequent droughts	**Frequency**	**%**	**Rank**
Practice of adapted forage crop cultivation	45	11	2nd
Collection and storage of crop residues in a shed	55	14	1st
Aerial grazing	10	2	9th
Small transhumance practice	5	1	10th
Cattle fattening practice	15	4	7th
Creation of water reservoirs and development of watering points	35	9	4th
Small ruminant's fattening practice	12	3	8th
Purchase of supplementary feed (cereal bran, cotton meal..)	40	10	3rd
Cleaning of wells	7	2	9th
Cleaning of backwater	8	2	9th
Sale of livestock to buy feed	11	3	8th
Mowing and storage of grass biomass on shed	20	5	6th
Plantation appetizing species	5	1	10th
Bushfire control policy	42	10	3rd
Big transhumance practice	43	11	2nd
Promotion of "*Echinochloa stagnina* cultivation	6	1	10th
Defense of grazing areas	7	2	9th
Afforestation around watering points	13	3	8th
Livestock size reduction and pastoral resource management training	25	6	5th

Source: Individual Survey, December 2022.

6.2. Main adopted strategies and perception based on marks attribution in face to each climatic risk-related hazards

Agropastoralists in the research sites have adopted various response strategies to counter impacts of each climate risks related to hazards as shown in the figure 19. The climatic risks-related hazards opined by the respondents were based on the frenquency of drought occurrence, increase of temperature, increase of violent wind and erratic rainfall.

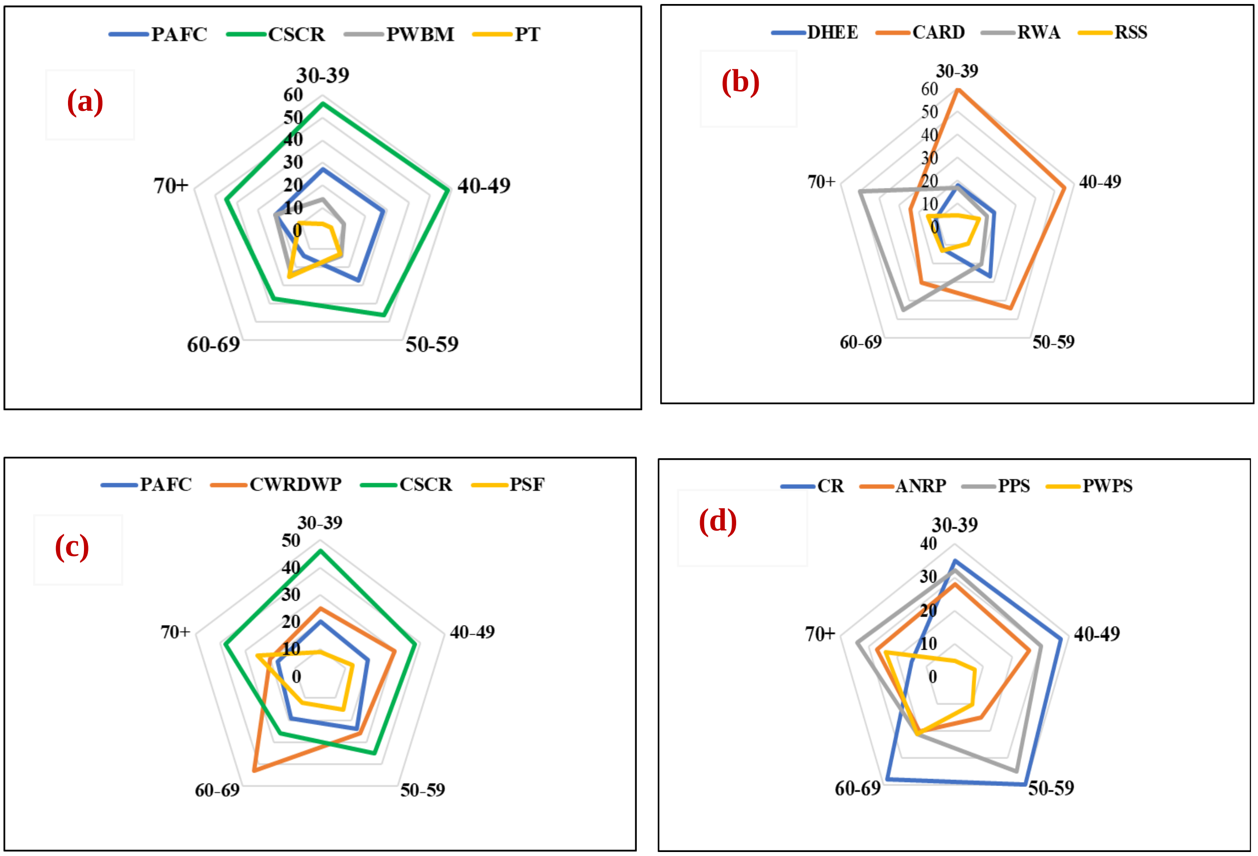
Thus, to adapt to the frequency of droughts, agro-pastoralists practice collection and storage of crop residues (52 %), practice of adapted forage cultivation (25.7 %), practice mowing of wood biomass (17.3 %) and practice of transhumance (5 %). Similar findings were reported by A. Sanfo *et al.,* (2015, p. 295) in the Eastern and Plateau Central Regions of Burkina Faso, by L. Filho *et al.,* (2020, p. 7) over Africa and recently by F. Tarekegn, *et al.,* (2024, p. 68) in Southern Ethiopia, showing that the mobility of pastoral communities is less vulnerable to livestock losses compared to those with sedentary livelihoods. By moving livestock to areas with better forage and water availability, agro-pastoralists can optimize their livestock production and reduce their vulnerability to resource scarcity due to the impact of climate change. Moreover, in the Western Himalayan region and Middle Gangetic plain region of India, Majority of livestock producers (90%) preserve fodder crop in form of hay, stored wheat straw, paddy straw, and crop residues to feed their animals for adverse climatic condition (S. K. Singh *et al.,* 2012, p. 410). In order to respond to uncertain climate, in livestoctock systems, herds migrate in search of water, grasses and look for better environment devoid of pests/diseases attack, look for new breeding ground, food on lush green succulent grasses and legumes (C. C. Godson-Ibeji *et al.,* 2022, p. 20).

In face to temperatures increasing, as adopted response strategies, 39.6 % of agropastoralists opted for regular watering of animals, 35.9 % opined to changing animal rhythm driving, 19.6 % noticed driving herds in the early evening and only 5 % apply for reforestation of shaded species. Thus, the animal must drink water regularly, drive in a place of shade and in the early evening, shaded species must be panted to reduce the risk of increasing temperature. According to C. C. Godson-Ibeji *et al.,* (2022, p. 20) in the southeast of Nigeria, the agro-pastoralist provide water constantly to the animals to avoid the deaths of the animals. This water is provided frequently to aid good health digestion and optimum performances of farms and work animals.

Concerning the frequency of violent winds, the respondents have mentioned as main adopted responses concerted reforestation (37.9 %), protection of pruning species (31.6 %), Assisted Natural Renegeration based palatable species (28 %) and planting of wood palatable species (2.5 %) for animal feeding and proction against violent wind. Results were obtained by S. Sabaï *et al.,* (2014, p. 7428) 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.

The Erratic rainfall means irregular distribution of the rainfall constitues a climatic risks related-hazards raised by the agro-pastoralists. They also build various strategies to counter this risk including collection and storage of crop residues (38.4 %), practice of adapted forage cultivation (29.7 %), purchasse of supplementary feed (16.3 %), and creation of water reservoirs and development of watering points (15.6 %). In the Sahel, researchs from B. Bonnet & B. Guibert, (2014, p. 44 and 46) argued that pastoralists purchase feed and secure fragile animals in times of scarcity. Moreover, in the rural commune of ‘‘Diéma’’ (Region of Kayes, Mali), researchs concducted by M. Coulibaly *et al.,* (2022, p. 36) concluded to adapt to climate change agro-pastoralists have implemented strategies including purchase of supplementary feed, destocking, use of harvest residues, storage of dry grass, improving breeds and seed and transhumance practice.

This research fund better these adopted strategies by the respondent to face climatic risk related hazards but, needed to be reinforced for increasing the resilience of agro-pastoralist communities.



Source: Personal work

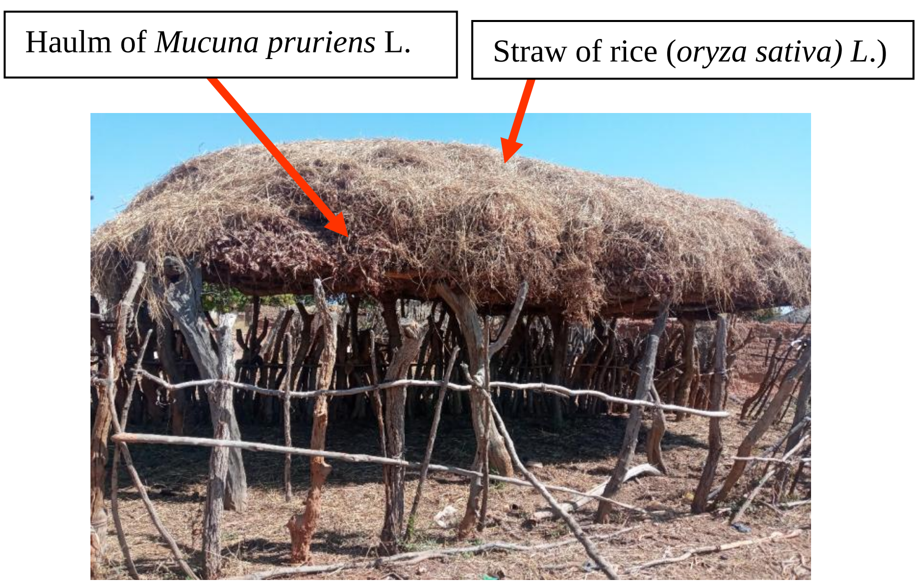
PAFC: Practice of adapted forage cultivation; CSCR: Collection and storage of crop residues; PWBM: Practice of woody biomass Mowing; PT: Practice of Transhumance; DHEE: Driving the herds in the early evening; CARD: Changing animals rhythms of driving; RWA: Regular watering of the animals, RSS: Reforestation of shaded species; CWRDWP: Creation of water reservoirs and development of watering points PSF: Purchase of supplementary feed; CR: Concerted reforestation; ANRP: Assisted Natural Regeneration practice, PPS: Protection of pruning species, PWPS: Planting of woody palatable species

Figure 19: Agropastoralists' response strategies per age group in the face to frequency of droughts (a); to increase of temperatures (b); erratic rainfall (c) and frequency of violent winds (d)

Collection and storage of crop residus is the most spreaded response strategies adopted by agro-pastoralists communities. However, a particular strategy has discover in the commune of Faragouaran where agro-pastoralists collecte and store the haulms of *mucuna pruriens L.* in a shed (photo 10). These haulms are covered by the straw of rice (*oryza sativa L.*) which is also forage palatable by animal. The strategy allow to protect and dry haums without its exposition to the sun which entail the degradation of the nutrivtive value of forage. This forage is utilized for animal feeding during the lean period of the dry season (from February to June).

During this critical times, the pasture areas lacking herbaceous cover due to no rains, overgrazing by transhumance animal on the way and high frequency of bushfires. In this period, certain agro-pastoralists apply for stabilization the livestock under the shed for feeding. Most the animal stabilized are cow and those due to loss of weight have difficulties of movement. This strategies for the forage storage help much for the activies of cattle and small ruminnats fattening which some very gainfull.

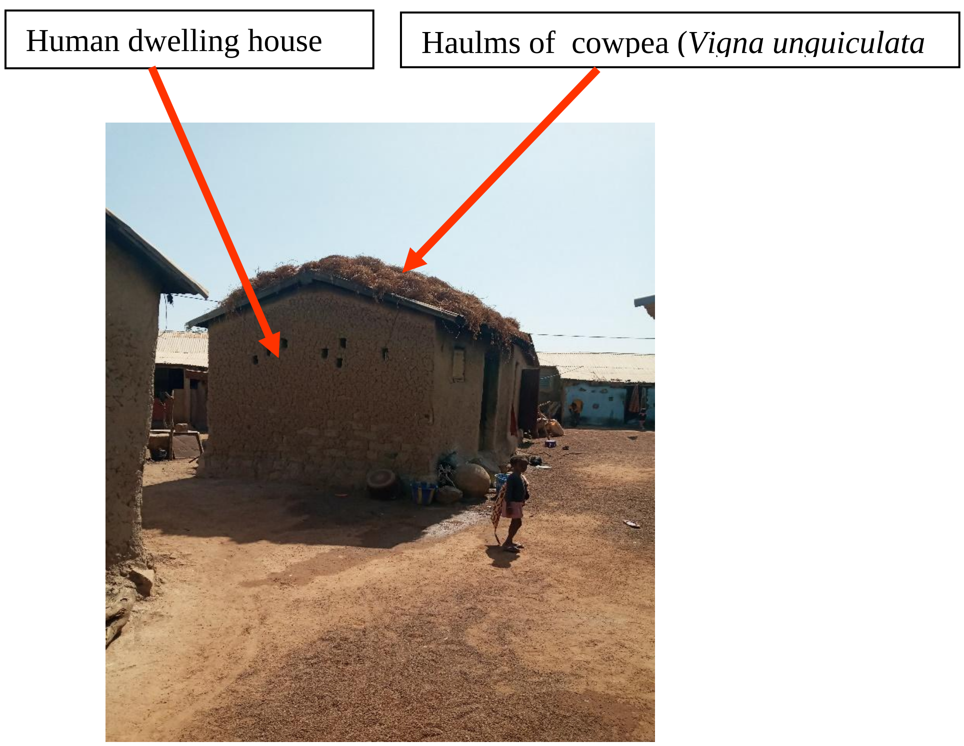
A stutdy on the Behavior of Sahelian herders in Mali in the face of climate variability, has reported that one part of the cereal straw and all of the legume haulms are collected and stored by farmer-breeders to feed their draught and fattening animals (P. Cissé, 20214, p. 114).



Source: Sanogo T., November 2022.

Photo 10: Collection and storage of crop residues of *Mucuna pruriens L.* in the village of Faragouaran

However, in the commune of Garalo, mostly, the whole collection and storge crop residues are exposed to sun at the top of human dwelling house (photo 11). In this condition, the nutrive value of the forage become more and more low as well as it remain long due to the open air condition of the forage compared to photo 11 strategy. This practice is common one in the research sites. Most the time due to forage richness low level it is mixted by another agricultural by-product (ceral brans) and weeds. This procedure lead to increase the richness quality of forage. These stratrategies lead to substitute the species biomass losses due to the frequency of bushfires. Consequently, while losses due to occasional fires is excluded, pastoral management recycles at least two-thirds of plant production *in situ*, as shown by the balance sheet drawn up for a Gourma rangeland subject to heavy grazing during the dry season (P. Hiernaux *et al.*, 2014, p. 28).



Source: Sanogo T., November 2022.

Photo 11: Collection and storage of crop residues of cowpea (*Vigna unguiculata (L.*) in the village of Garalo

For solving difficulties access to perennial water resources related to animal drinking, one of important strategies is to create and develop water reservoir. In this context agro-pastorlists with the partnership of NGO, the agro-pastoral Dam of ‘‘Guérékélé’’ in the commune of Koumnantou has been created (photo 12).

During the whole period of the year, this insfracture contain water for animal watering and make end all crisis related shortfall of animal drinking water based on livectock watering. Similar results were found by T. Sanogo *et al.*, (2022, p. 146) in the rural commune of Tioribougou (Mali) showing that agro-pastoralists have adopted various strategies for addressing to climate change impacts including watering points improvements, afforestation/reforestation around watering points, Assisted Natural Regeneration of palatable species.

The agro-pastoralist communities of Koumantou are in this context less vulnerable compare to others where there is low avalaibility of drinking water for animal fron february to May. Despite the role play this infrastructure in livestock wellbeing in the lean period, it is source of conflicts between users coming from everywhere looking for source of water for animal watering.

According to conducted study of S. Tiruneh & F. Tegene, (2018, p. 54) in the Ethiopia, the movement of animal populations out of drought-affected areas can lead to problems of overgrazing in neighboring areas and to problems of conflict over access to grazing land and water.

Source: Sanogo T., photo taken in November 2022.

Photo 12: Creation of water reservoirs and development of watering points in the village of Koumantou (dam of ‘‘Guérékélé’’)

Collection of survey data raised Four climatic reisks related-hazards including the frequency of droughts, increasing of temperatures, the frequency of violent winds and erratic rainfall. To assess which climatic risks related-hazards is easy to adapt, agro-pastoralist communities have attributed marks. This procedure lead to appreciate the level of strategies in face to each climatic risks related-hazards. These marks are varying from 0 (null/weak) to 10 (very good). The mean of marks is 5. More the percentage is low around the 5 marks, it is harsh to adapt to the concerned climatic risks related-hazards.

For the the frequency of violent winds, the 20 % and 23 % of respondents have attributed marks 4 and 5 to their strategies, 22 % and 23 % have raised marks 3 and 2 respectively. Only the 6 % and 2 % of the respondents have mentioned marks 6 and 2. The 5 mark ranges 23 % (figure 9a).

In face to erratic rainfall, the 25 % of respondents have given mark 5, 22 % for the mark 2, 15 % for the mark 3 and 6. Only 3 % opined the mark 7. The 5 mark have been given by 25 % (figure 9b).

Concerning the increasing of temperatures, most respondents (42 %) have attributed the mark 2, 27 % for the mark 3, 15 % for the marks 4 and only 8 % for the mark 5 (figure 9c).

For the frequency of drought, 26 % of respondents have attributed mark 3, 20 % for the mark 2, 18 % for the mark 4, 17 % for the marks 5, 10 % for the mark 6 and only 4 % for the mark 7 (figure 9d).

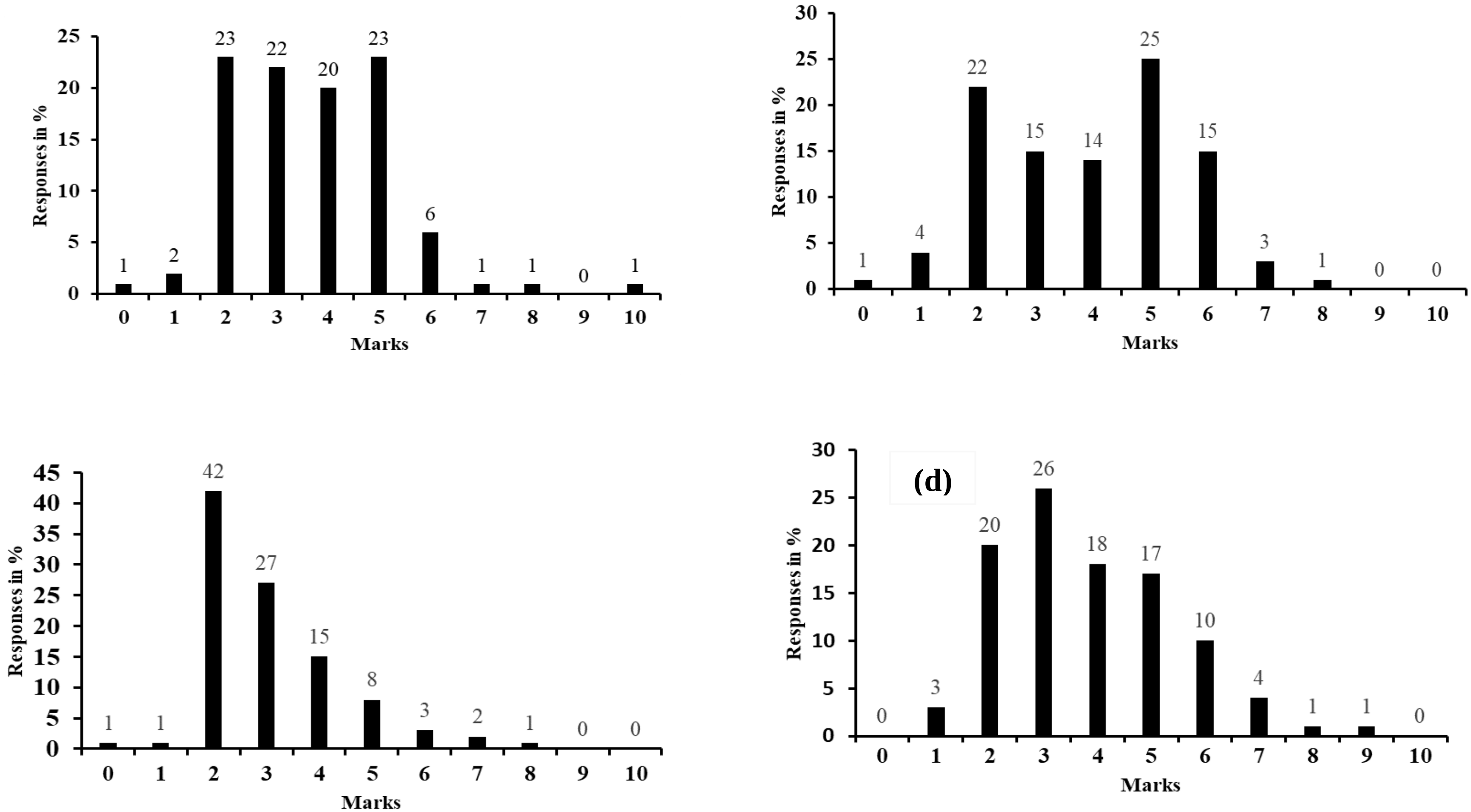
The highest perecentage for the mark 5 are 25 % for erratic rainfall, 23 % for the frequency of violent winds, 17 % for the frequency of drought and 8 % for the increasing of temperatures.

From the overall analysis, the assessment reveals that agro-pastoralists strategies in face to climatic risks related-hazards are better for erratic rainfall and the frequency of violent winds with high percentage for the mean of the mark. In addition, agropastoralist recognised that strategies deployed to counter erratic and frequency of violent are good. These strategies contribute to minimized adverses impacts based climatic hazards.

However, frequency of drought and increasing of temperatures reserve less strong strategies for adaptation with low percentage for the mean mark. It means that most of the agro-pastoralists are stuggling to adapt when facing to incrising of temperature and frequency of drought.

Moreover, at the level of agro-pastoralists communities, it is easy to adapt to erratic rainfall and frequency of violent winds than frequency of drought and increasing temperatures.

The findings of N. Zampaligré *et al.*, (2014, p. 773) in agro-ecological zones of Burkina Faso, have concluded that the traditional land management systems and related livelihoods of agro-pastoralists have been affected by the observed changes in rainfall and temperature. Hence, 20 % of the respondents mentioned that they did not have any adaptation strategy when facing changes in rainfall and temperature. According to H. Abdou *et al.*, (2020, p. 88), the increasing frequency of droughts attests the vulnerability of animal resources to environmental change. Despite their importance, these coping strategies were not enough to meet farmers' expectations.



Source: Individual Survey, December, 2022.

Figure 20: Marks attributed based-response strategies to the frequency of violent winds (a), to erratic rainfall (b), to increasing of temperature (c) and to frequency of drought (d)

6.3. Priorisation of Main adopted strategies for coping climatic risk-related hazards

The application of multi-criteria analysis on main adopted strategies of agro-pastoralist communities in the district of Bougouni is described by the table 51. However, this analysis reveals thirty five (35) main adopted strategies in the environment study. Among these strategies, agro-pastoralists have proceeded to their prioritization. This step allow to determine the most important coping strategies in face to climatic risks related-hazard for disaster risk reduction. Thus, three level of strategies were raised.

Firstly, it is about collection and storage of crop residues, practice of transhumance with part of the herds (1st). Secondly, they are about practicing of adapted forage cultivation, creation of water reservoirs and development of watering points, mowing and drying grass in the shade (2nd). The third strategies are based on sale of livestock to buy feed, bovine fattening practice, ovine and caprine fattening practice, purchase of supplementary feed (cereal bran, cotton meal..) (3rd).

Moreover, this priorization can be different from one study area to another. Findings of F. Diarra *et al.*, (2023, p. 128) in the region of Mopti (Mali) reporting that, agro-pastoralists have retained by priorization adoption local convention, protection of grazing areas, practice of erosion control, assised natural regeneration as handling strategies to climate drivers.

Therefore, there are those strategies important particularly defense of grazing areas, adoption of improved breeds, regular cleaning of wells, practice of transhumance with all livestock, regular watering of the animals, assisted natural regeneration practice, protection of pruning species, planting of woody appetizing species, mowing and storage grass on shed, livestock size reduction, afforestation around watering points, sale of livestock for other livestock treatment.

In the Districts of Sidama Region (Southern Ethiopia), F. Lomiso, (2020, p. 125) has concluded researchs reporting that farmers have adopted reducing the number of animals, supplementary feed, income diversification as adaptation mesures prioritized to climate hazards. According to D. Barton *et al.*, (2001, p. 14), livestock sales as a short-term coping strategy need to be understood within his context, but while regular adaptive livestock sales concentrate on surplus males and cull females, drought-time livestock sales may, as drought impact worsens, include breeding females, thus eroding households' coreassets. For regular livestock sales pastoralists have some freedom to choose time of sale according to livestock condition, season and other market conditions, whereas drought-time livestock sales occur when livestock prices are lowest and when animals are rapidly losing condition.

The agro-pastoralists have priorized others strategies which can lead to buffer climate drivers entailing disaster risk reduction. It is about defense of grazing area, adoption of improved breeds, reugular cleaning of wells (4^{th}).

At the Fifth level, the strategies concerned practice of transhumance with the whole livestock population size, regular watering of animal, assisted natural regeneration practice, protection of pruning species, planting of woody appetizing species, mowing and storage grass on shed, livestock size reduction, afforestation around watering points, sale of livestock for other livestock treatment.

For sixth level, it is about driving the herds early in the evening, changing animal rhythms of driving, reforestation of shaded species, bushfire control policy, purchase of a mill for industrializing cereal by-product and hay collection and storage. Concerning the seventh and eighth step, strategies include respectively seeding bourgou (*Echinochloa stagnina P.Beauv*) in lowland area and practice of woody biomass mowing.

Similar results were obtain by M. Coulibaly *et al.*, (2022, p. 35) in the sahelian part of Mali reporting that the most important strategies priorized by livestock producers were assisted natural regeneration, practice of transhumance, reconstitution of livestock population reforestion, implementation of early warning system.

Table 52: Multi-criteria analysis applied on the main adopted strategies

Adopted strategies	Criteria							Total score	Rank
	Cost	**Efficiency**	**Facility**	**Rapidity**	**Capacity**	**Technical Feasibility**	**Social acceptability**		
Practice of adapted forage cultivation	1	2	3	3	3	3	3	**18**	**2nd**
Collection and storage of crop residues	1	3	3	3	3	3	3	**19**	**1st**
Practice of woody biomass Mowing	1	2	1	1	3	3	1	**12**	**8th**
Practice of transhumance with all Livestock	2	3	2	1	2	3	2	**15**	**5th**
Driving the herds early in the evening	1	2	2	1	3	2	3	**14**	**6th**
Changing animals rhythms of driving	1	2	2	1	3	2	3	**14**	**6th**
Regular watering of the animals	3	3	1	2	2	2	2	**15**	**5th**
Reforestation of shaded species	3	3	2	1	2	2	1	**14**	**6th**
Assisted Natural Regeneration practice	1	2	2	2	3	3	2	**15**	**5th**
Protection of pruning species	1	2	2	2	3	3	2	**15**	**5th**
Planting of woody appetizing species	1	2	2	1	3	3	3	**15**	**5th**
Creation of water reservoirs and development of watering points	3	3	2	2	2	3	3	**18**	**2nd**
Sale of livestock to buy feed	2	3	2	2	3	2	3	**17**	**3rd**
Bovine fattening practice	3	3	1	2	2	3	3	**17**	**3rd**
Ovine and caprine fattening practice	2	3	2	3	2	2	3	**17**	**3rd**
Mowing and storage grass on shed	1	2	2	2	2	3	3	**15**	**5th**
Mowing and drying grass in the shade	1	3	3	2	3	3	3	**18**	**2nd**
Bushfire control policy	2	1	2	2	2	2	3	**14**	**6th**
Defense of grazing areas	1	2	3	3	2	3	2	**16**	**4th**
Livestock size Reduction	2	2	2	2	2	2	3	**15**	**5th**
Afforestation around watering points	1	2	2	1	3	3	3	**15**	**5th**

Purchase of supplementary feed (cereal bran, cotton meal..)	2	2	2	3	3	3	2	**17**	**3rd**
Purchase of a mill to industrialize cereal by-products	3	2	1	2	2	2	2	**14**	**6th**
Practice of Transhumance with part of the livestock	1	3	3	3	3	3	3	**19**	**1st**
Adoption of improved breeds	3	2	2	3	2	2	2	**16**	**4th**
Regular cleaning of wells	1	2	2	2	3	3	3	**16**	**4th**
Hay collection and storage	1	1	3	2	2	2	3	**14**	**6th**
Sale of livestock for other livestock treatment	2	2	2	1	2	3	3	**15**	**5th**
Seeding *Echinochloa stagnina P.Beauv* in lowland area	1	2	1	1	2	3	3	**13**	**7th**

Source: Individual Survey, December 2022.

PARTIAL CONCLUSION

The LVI of of Agro-pastoraloist per Major component for Dogo, Faragouaran, Garalo and Koumantou reveals seven (7) sub-components for the adaptive capacity, fifteen (15) sub-components for the sensitivity and two (2) for the exposure.

However, the adaptive capacity and sentivity index is high for Koumantou (0.3940; 0.388) and low for Faragouaran (0.103; 0.080). Concerning the exposure index, that is high for Koumantou (0.380) and low for Dodo (0.250). The LVI-IPCC computing announce that Koumantou and Dogo are least vulnerables (-0.005; -0.009 respectively) against Faragouaran and Garalo are most vulnerables (0.022; 0.125 respectively). The most vulnerable agro-pastoralist communities are those from Faragouaran. This situation is explaining through importance of livestock size per square kilometers, high percent of those people who have not got any training on pastoral resources management, high frequency conflicts over pastoral resources management.

Drought hazards and its adverse effects on pastoral, watering points and livestock wellbeing led to agro-pastoralist to implement precaution against future drought as a response to drought. The most important are accounted at twenty (20). These adopted responses are about collection and storage of crop residues in a shed; practice of adapted forage crop cultivation and big transhumance practice; purchase of supplementary feed (cereal bran, cotton meal..) and bushfire control policy; creation of water reservoirs and development of watering points.

To adapt to the frequency of drought and erratic rainfall, most of the respondents practice collection and storage of crop residues and practice adapted forage cultivation. In face to temperatures increasing the most strategies used respondents comunities were regular watering of animals and changing of animal rhythm driving. Concerning the frequency of violend wind, they were reforestation and the practice of protection and pruning species. Agro-pastoralist have high adaptation level to erratic rainfall than frequency of drought and increasing of temperatures. The multi-criteria analysis has been applied on the main adopted strategies of agro-pastoralist communities in the District of Bougouni. This analysis reveals thirty five (35) main adopted prioritized strategies in the environment study. This step allow to determine the most important coping strategies in face to climatic risks-related hazards. It is about collection and storage of crop residues, practice of transhumance with part of the livestock, practice of adapted forage cultivation, creation of water reservoirs and development of watering points, purchase of supplementary feed, sale of livestock to buy feed, bovine fattening practice, ovine and caprine fattening practice, feed.

GENERAL CONCLUSION

The District of Bougouni located in the sudanian zone, is one of the most important District of the country in termes of its livestock production. This situation is linked to favorable climatic condition (annual rainfall size and its well distribution). The high quantity of rainfall allow a rich production of pastures (density and variety of species), a great watering points, a good cereal production with an animal breeds varied, this climatic conditions contribute to livestock population size increasing.

The analysis revealed in the District of Bougouni, a concordance between agro-pastoralists' perception of climate change and meteorological observations concerning the decrease in rainfall, the increase in temperatures and wind speeds from 1950 to 2022. The respondents identified and ranked four (4) climate risks related-hazards, including the frequency of drought, increasing of 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 gayanus, 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*). Most of these species cited are highly palatable to animals. Those daverse impacts lead to early drying up of watering points and pollution of available water, collapse of salty land sites.

At the total forty (40) herbaceous species have been inventoried for the year 2022 in the research sites. The most dominant species are the *Andropogon pseudapricus*, *Microchloa indica*, *Loudetia togoensis*, *Eragrostis aspera*, *Schizachyrium exile*, and *Andropogon gayanus*. The average of dry master biomass is more important in Faragouaran than Koumantou for the overall and particularly more important in the shrubby savannah, followed by bowal and wooded savannah. However, the pasture have good pastorale value in Koumantou than Faragouaran. Concerning the both research sites, the richness of pasture is very high for the wooded savannah, followed by the bowal and shrubby savannah.

The vegetation cover of wooded species is very riched and composed by sixteen (16) families of species: Anacardiaceae, Annonaceae, Apocynaceae, Asteraceae, Caesalpiniaceae, Celastraceae, Combretaceae, Ebenaceae, Fabaceae, Lamiaceae, Malvaceae, Mimosaceae, Olacaceae, Phyllanthaceae, Rubiaceae, Sapotaceae. The Fabaceae is the most important (13 species), followed by the Combretaceae (8 species), Malvaceae (4 species), Anacardiaceae and Rubiaceae (3 species). The most dominant species are *Afrormosia laxiflora, Detarium microcarpum, Terminalia laxiflora, Pteleopsis suberosa, Annona senegalensis*. The wooded plant structure has showed that the majority of plant is shrubs followed by tree and regrowth.

The LVI of sub-component are very high in Koumantou and Dogo than the other areas. The index for the sub-component on percent of the people on the pastures currently bad condition is very low in Faragouaran (0.06) compared to those in Garalo (0.25), in Dogo (0.32) and in Koumantou (0.37). The Major component of pasture has the most important number of sub-component (7), follow by the livestock (5), sociodemographic and watering points (4), social network (3), and climate hazards (2). The index is globally high in Koumantou and Dogo for the whole major components. The index of pastures is globally low for overall areas. The annual rainfall is higher in Garalo and very low in Dogo.

The LVI of of Agro-pastoralist per Major component for Dogo, Faragouaran, Garalo and Koumantou reveals seven (7) sub-components for the adaptive capacity, fifteen (15) sub-components for the sensitivity and two (2) for the exposure. However, the adaptive capacity and sentivity index is high for Koumantou (0.3940; 0.388) and low for Faragouaran (0.103; 0.080). Concerning the exposure index, that is high for Koumantou (0.380) and low for Dogo (0.250). The LVI-IPCC computing announce that Koumantou and Dogo are least vulnerables (-0.005; -0.009 respectively) against Faragouaran and Garalo are most vulnerables (0.022; 0.125 respectively).

The most vulnerable agro-pastoralist communities are those from Faragouaran. This situation is explained through importance of livestock size per square kilometers, high percent of those people who have not got any training on pastoral resources management, high frequency conflicts over pastoral resources management.

The local perception of drought hazards and its adverse effects on pastoral, watering points and livestock wellbeing led to agro-pastoralists to implement precaution against future drought as responses to drought. The most important are accounted at twenty (20).

However, there are about collection and storage of crop residues in a shed; practice of adapted forage crop cultivation and big transhumance practice; purchase of supplementary feed and bushfire control policy; creation of water reservoirs and development of watering points.

Agro-pastoralists 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 increasing of temperatures, 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.

The Agro-pastoralist communities have attributed marks allowing to appreciate the level of strategies in face to climatic risks related hazards. These marks are varying from 0 (very weak) to 10 (very good). From the overall analysis, agro-pastoralist strategies in face to climate risks related-hazards are good for erratic rainfall, followed by the frequency of violent winds and very weak for frequency of drought and increasing of temperatures. Thus, at agro-pastoralist level, it is easy to adapt to erratic rainfall and frequency of violent winds than frequency of drought and increasing of temperatures.

The multi-criteria analysis has been applied on main adopted strategies of agro-pastoralist communities in the District of Bougouni. It is about assessment of the most important adaptation strategies to implement for reinforncing and enhancing agro-pastoral production systems. However, this analysis reveals thirty five (35) main adopted strategies in the environment study. Among these strategies, agro-pastoralists have proceeded to their prioritization. This step allow to determine the most important coping strategies in face to climatic risks related-hazard.

Firstly, it is about collection and storage of crop residues, practice of transhumance with part of the livestock. Secondly, these strategies are practice of adapted forage cultivation, creation of water reservoirs and development of watering points, mowing and drying grass in the shade. The third strategies are based on sale of livestock to buy feed, bovine fattening practice, ovine and caprine fattening practice, purchase of supplementary feed.

The agropastoralists have priorized additional strategies including defense of grazing areas, adoption of improved breeds, practice of transhumance, regular watering of animal, livestock size reduction, afforestation around watering points, sale of livestock for other livestock treatment, changing animal rhythms of driving, reforestation of shaded species, bushfires control policy, seeding bourougou (*Echinochloa stagnina,* P.Beauv) in lowland area and practice of woody biomass mowing.

RECOMMENDATIONS

This research aims to assess the influences of climate risks related-hazards on pastoral resources and agro-pastoralist communities adopted response strategies in the southwest of Mali, West Africa through the whole findings, recommend:

- ✓ promoting of adapted forage crop cultivation to increase production of animal feed during the whole season of years;
- ✓ training of agro-pastoralist communities on the best technics of collection and storage of crop residues for enhancing the nutrients quality of species for facing livestock feed shortage during the leam period;
- ✓ creation of water reservoirs and develop watering points for making easier animal access to water resources during the two season of the year and promoting water harvesting technologies;
- ✓ promoting practices of reforestation of shaded species, palatable species with high pastoral value on the banks of water points as for animal resting;
- ✓ encouragement intensive livestock system practice throughout bovine, ovine and caprine fattening practice;
- ✓ encouragement fodder bank construction of animal feed storage;
- ✓ adoption improved breeds, protect the endemic breeds and create and defend animal grazing areas/pastoral zones;
- ✓ promoting *echinochloa stagnina* (Bourougou) in the lowland area for multiplying animal source of feed;
- ✓ strengthening the mechanisms of traditional conflict resolution within differents communities;
- ✓ development of forage crop production such as elephant grass *(Miscanthus sinensis)* by enhancing pastoral areas;
- ✓ implementation of warning system base-livestock livelihood crisis for disaster risk reduction;
- ✓ promoting politics contributing to enhance the adaptive capacity of agro-pastoralist communities particularly to the frequency of drought and increasing of temperature for disaster risk reduction;
- ✓ implementing a regular exchange framework between authorities and to agro-pastoralist communities for sustainable development of livestock production system.

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APPENDIX

Appendix 1: List of Tables

Appendix 2 : List of Figures

Appendix 3: List of Photos

Appendix 4: List of Maps

Appendix 5: Questionnaire Wascal, December 2022

I. individual household head survey sheet

Agropastoralist perception of climate and adaptation strategies in Mali

Number…… Date of the survey....../…../ Cercle of BOUGOUNI
Climate zone: Sudanian; Village of ………………………………

A. General information of the respondent and his activities

N°	Indicators	codes
1	**Last name**…………………. **First name**………………….	
2	**Age**…………………………	
3	**Study level** **1= Primary ; 2= Fondamental 3= seconadry ; 4 = University ;** **5= Koranic** 6=Uneducated	/____/
4	**Ethnic group** **1**= Peulh 2= Bambara 3=Malinké 4 = Senoufo 5= Others	/____/
5	**Gender 1**=Male; 2=Female	/____/
6	**Marital status** **1**=married; 2=single; 3= divorced; 4=widowed	/____/
7	**What farming system do you practice?** **1**=extensive 2=intensive 3= both	/____/
8	**What type of livestock farming do you practice?** **1**=Transhumance 2=nomadism 3=both 4= Others	/____//____//____/
9	**How conflicts related agropastoralism are managed** **1=amicable ; 2= Justice ; 3= local institution**	/____//____//____/
10	**Do you have secondary activities** **1**=Agriculture 2=Trade of animal 3=big ruminant Fattening; 4= Small Ruminant fattening; 5= others	/____//____//____/
11	**Are you a member of a socio-Professional organization?**1=Yes 2=No	/____/
10	**Do you have a salaried workforce? 1**=Yes; 2= No	/____/
11	**Do you use mutual aid? 1**=Yes 2= No	/____/
12	**How many people are you in charge? 1**=>10 **2**= 10-20 **3**= <20	/____/
13	**How many active people are you in charge?** 1=>5 2= 5-10 3= <10	/____/
14	**Which ownership mode of livestock do you use?** 1=Owner; 2=Trusted; 3=Shepherd. 4=Mixed	/____//____//____/
15	**Have you been trained in the livestock farming field? 1= Yes 2=No**	/____/

Perception of climate variability Before = (<1990) ; Actual =10 years (≥1990)

B.1 Rainfall

16	**Are the rainy seasons more and more** **1**=Rainy 2=Dry 3=Normal	/____/
17	**Are the rains more and more variable from one year to another?** **1**= Yes 2=No	/____/
18	**Are there significant changes in the accumulation of the rainiest months?** **1**=July; 2=August; 3=September	/____/

B.2 Season parameters

19	**What is the start date of rainy season?** **Before Actual** April : Start□ Mid□ End□ — April: Start□ Middle□ End□ May: Start□ Mid□ End□ — May: Start□ Middle□ End □ June: Start□ Mid□ End□ — June: Start□ Middle□ End □ July: Start□ Mid□ End□ — July: Start□ Middle□ End □	
20	**Is the start of wintering from more to more** **1=Early 2=Late 3=Normal**	/___/
21	**What is the end date of rainy season?** Before **Actual** September: Start□ Middle□ End□ — September: Start□ Middle□ End □ October: Start□ Middle□ End□ — October:: Start□ Middle□ End □ November: Start□ Middle□ End□ — November: Start□ Middle□ End □	
22	**Is the end of wintering from more and more** **1**=Early 2= Late 3= Normal	/____/
23	**Is the length of the season from more and more** 1=long 2=short 3=Normal	/____/
24	**Specify length (in months)** Before…………… Current……………	
25	**Are the dry spelts longer and longer after the onset of wintering? 1**=Yes 2=No	/____/
26	**If yes specify the average length** **1**= ≤ 7 days ; 2= ≤ 10 days ; 3=≤ 15 days ; 4=more than one month	/___/
27	**When do they occur?** **1**=Beginning of season 2=Middle of season 3=End of season 4=All time	/____//____//____/

B.3 Temperature

27	**Is it getting hotter and hotter? 1**= Yes 2=No	/____/
28	**Are the nights getting hotter and hotter?** **1**= Yes 2=No	/____/
29	**the winters are warmer and warmer** **1**=Yes 2=No	/____/
30	**the cold season is getting hotter and hotter?** **1**=Yes 2=No	/____/

B.4 Wind

31	**Are there changes in the wind regime during the monsoon (rainy season)?** **1=**Yes 2=No If yes Which ones? …………………………………………………
32	**Are there any changes in the wind regime during harmattan (dry season)?**

	1=Yes 2=No	/____/
	If yes, which ones ?...	

B.5 Extreme events

33	**Are the rains more and more intense?** 1=Yes 2=No	/____/
34	**If yes, when do these heavy rains occur? ....**	
35	**Are the winds more and more violent?** 1=Yes 2= No	/____/
36	**What types of winds are the strongest?** **1=**Monsoon 2=Harmattan	/____//____/
37	**Are there more and more Drought ?** **1**= Yes 2=No	/____/
38	**If so, what explains this? upsurge** **…………………………………………………………………...**	
39	**Has the number of floods per year increased?** 1=Yes 2=No	/____/
40	**When do they occur? 1**=Beginning of Season 2=Middle of Season 3=End of Season 4=Anytime	/___//___//___/
	Are violent winds more and more frequent 1= Yes ; 2= No	/____/

B.6 Indicators

41	**What are your indicators of the start dates of the rainy season?** **1**=Vegetation (species of plants); 2=Birds; 3=Insects; 4=Stars (types) 5= others	/___//___//___//___/
42	**What are your indicators of the end dates of the rainy season?** **1**=Vegetation (species of plants); 2=Birds; 3=Insects; 4=Stars (types	/___//___//___//___/
43	**What are the indicators of a rainy winter?** **1**=Stars 2=Vegetation (species of plants) **3**=Fauna (birds) 4=Insects ; 5= others	/___//___//___//___/
44	**What are the indicators of a dry winter?** **1=**Stars 2=Vegetation (species of plants) 3=Fauna (birds); 4=Insects ; 5= others	/___//___//___//___/

C. Socio-economic and environmental impacts related to climate change

C.1 on pastoral resources

45	**What are your different livestock watering points?** **1**= River 2=Well 3= Ponds; 4=Boreholes; 5=Mixed;	/___//___//___//___/
46	**What was the condition of these different watering points before ?** **1**=bad; 2= good; 3= very good	/____/
47	**What is the current status of these different watering points?** **1**= Good; 2=very good ; 3=bad ; 4=very bad	/____/
48	**What explains this change? 1**=drought; 2: poor rainfall; 3=high winds, 4=Others	/___//___//___//___/
49	**What is the period of water crisis for animals watering before ?** **1=February, 2=March, 3=April, 4=May, 5=June, 6=July**	/____/

50	**What is the period of water crisis for currently animals watering?** **1=February, 2=March, 3=April, 4=May, 5=June, 6=July**	/____/
51	**What is the current state of the vegetation? 1**=more dense 2=less dense 3= stable	/___//___//___/
52	**Have you noticed a disappearance of plant species eaten by animals? 1**=Yes 2= No	/____/
53	**If yes, please name ……………………………………………………………………..**	
54	**What is the state of the pasture before ?** **1**=Good and abundant ; 2=Stable and satisfactory 3=Degraded	/___//___//___//___/
55	**What is the current state of the pasture?** **1**=Good and abundant ; 2=Stable and satisfactory 3=Degraded	/___//___//___//___/
56	**Do you notice a pasture invasion by unpalatable species?** **1**=yes 2=No	/____/
57	**If yes, specify………………………………………………………………….**	
58	**Have you noticed frequency of bushfires ?** 1= Yes ; 2= No /____/	
59	**If yes, what are the adverse impacts these bushfire ?** 1= destroying of pasture ; 2= detroying of soil ; 3= disapperance of herbaceous seeds 4= others /____/	

C.2 on animals

	C.2.1. Reproduction	
60	**Have you noticed any changes in the age of 1st parturition?** **1**=Yes 2=No	/____ /
61	**If yes, which ones ? ……………………………………………………………………….**	
62	**Have you noticed any changes in the interval between farrowing? 1**=Yes 2= No	/____ /
63	**If yes, which ones ? ……………………………………………………………………….**	
64	**Have you noticed any changes in abortion frequencies? 1=**Yes 2=No	/____ /
65	**If yes, which ones ? ……………………………………………………………………….**	
66	**What explains this change? ....**	
67	**What solution do you have in the face of these reproduction problems?** **...**	
68	**C.2.2. Morbidity**	
69	**Have you noticed any changes in the frequencies of diseases in your livestock?** **1=**Yes 2=Name	/______/
70	**If so why ? ………………………………………………………………………….**	
71	**What explains the frequency of these diseases…………………………………**	
72	**How do you deal with these mobility problems? ....**	
	C.2.3. Mortality	
73	**Are there frequencies of animal mortalities?**1=Yes 2= No	/____/
74	**If so, at what level ? 1=**during parturition 2=in young 3=in adults 4=Other (specify)…………………………………………………………	/___/___/___/___/

75	**What explains these problems?................ ………………………………………… …**	
76	**How do you deal with these mortality issues?.. ....**	
	C.2.4.Milk production	
77	**Have you noticed any changes in milk production? 1=**Yes 2=No	/______/
78	**If yes, which ones ?.. ....**	
79	**What are the causes of these changes? ………………………………………………**	
80	**How do you deal with these problems in milk production?...**	
	C.2.5.Meat production	
82	**Has the average weight (ALU) of livestock 1= decreased? 2=increased?**	/____/
	C.3. About breeders	
83	**Are there conflicts between the actors involved in the sector?** **1=**breeders-breeders, 2=breeders-farmers, 3=breeders-technical services, 4=mixed	/___/___/___/___/
84	**If yes, what are the causes ………………………………………………………………**	
85	**What difficulties do you face in carrying out your activity?** **1=**early drying up of water points 2= remote grazing 3= Mixed 4=Other (specify) ………………………………..	/___/___/___/___/
86	**How do you deal with these problems? ....**	

D. Socio-economic vulnerability

	D.1 Financial	
87	**How big is your herd?** **1=**Nb Cattle……………… 3= Nb Goats………………… 5= Others ……… **2**=Nb Sheep……………………….. 4=Poultry …………………………	
88	**Do you have difficulty accessing markets?** 1=Yes 2=No	/_____/
89	**If so why………………………………………………………………………………………**	
90	**Do you use the services of intermediaries to sell your animals? 1**=Yes 2=No	/_____/

91	**If yes, why ?.. ....** **...**	
92	**How do you judge the price of your livestock?..................................** **... ......**	
93	**Does your farming income manage to cover all the needs of the family? 1**=yes 2=No	/_____/
94	**If not what are the solutions? ………..**	
95	**What is your annual income?**	
	D.2 Infrastructure	
96	**What basic infrastructure do you have?** **1=**Health center 2=Market 3=School 4=Boreholes 5=Electricity 6=Bank 7=Vaccination center 8=Others ………………………..	/__//__//__//__//__/
97	**Do you have stores for the stock of animal feed? 1=**Yes 2=No	/____/
98	**If not, how do you do it? ....**	
	D.3 Human	
99	**What is your level of education? 1=**Uneducated 2=Primary 3=Secondary 4=Higher 5=Other	/___/
100	**Do you have any knowledge of traditional animal care? 1**=Yes 2=No	/___/
101	**Are you helped by someone in the activities (herding)? 1=**Yes 2=No	/___/
102	**If yes, specify. 1=**Family 2=Contract 3=Mutual assistance 4=Others	/___/___/___/___/
	D.4 Social	
103	**Have you ever been the victim of a hazard? 1=**Yes 2=No	/___/
104	**If yes, what damage did you suffer? 1=**Animal loss 2=Habitat loss 3=both 4=Other	/___/___/___/
105	**To cope with the harmful effects of CC do you receive help from whom?** **1=**State 2=NGO 3=Projects 4= Mixed 5=Other 6= Not at all	/__/___/___/___/__/
106	**What is the nature of government assistance? 1**=Money 2=Free food 3=Living subsidies 4=Livestock feed subsidies 5=Others	/__/___/___/___/__/
107	**What is the nature of NGO aid? 1=**Money 2=Free food 3=Living subsidies 4=Cattle feed subsidies 5=Others	/__/___/___/___/__/
108	**What is the nature of the project aid? 1=**Money 2=Free food 3=Living subsidies 4=Cattle feed subsidies 5=Others	/__/___/___/___/__/

E. response strategies and practices

	E.1 Technical adjustment	
109	**What are your actions in the face of droughts? 1=**Practice of forage crop 2= collection and storage of crop residues 3= aerial grazing 4 =Other	/____/____/___ /

110	**What are your actions in the face of strong winds?** **1=**concerted reforestation 2= Others	/____/
111	**What are your actions in the face of high T°C? 1**= Driving herds in the early evening **2**=Modification of watering rhythms 3= Others	/___/___/__/
112	**What are your actions in the face of floods? 1**= Concerted demarcation of pastoral areas 2= stone barriers, 3= Modification of watering rhythms 4= Others	/___/___/___ /
113	**What are your actions to restore the pasture?** **1=**defence, 2=RNA 3= Others……………………………………	/___/___/___ /
	Institutional adaptation	
114	Do you get help from the state? 1=Yes 2=No	/____/
115	**what is the help-adaptive nature that you have the state?** **1**= Construction of warehouses for stocking animal feed, 2 = Drilling **3**= Construction of veterinary product stores and vaccination parks 4= Access to credits 5= Livestock market equipment 6 = Pasture preservation programs 7=Other	/__/___/___ /___ /___/
	Strategic adaptation	
116	**What strategic steps are you taking to adapt?** **1=**Improved breeds 2= Aerial grazing, 3= Collection and storage of agricultural residues 4= Purchase of complementary feed, 5= Hay 6= Others	/__/__/__/__/__/__/
117	**What is your mare on these strategies?**□ Low □ Medium □ High	
118	**If low or medium, what do you intend to do to improve it? …………………………**	

II. Focus group survey sheet (breeders, agropastoralists, users of livestock products) on community perception of climate variability and change and their adaptation strategies in Mali in the rural town of Tioribougou

Number…… Date of the survey....../…../ Cercle of Bougouni

Climatic zone: Sudano-Sahelian; Village of ………………………………………

Number of women:……………………. Number of men:……………………………

2.1. What are the major events that have marked the history of your area over the past thirty years? (specify the time frame of the event)

No.	Major historical events	Years	Vernacular names
1			
2			
3			
4			
5			
6			
7			
8			
9			

2.2. What are the major climate risks related hazard identified by your municipality? (order)

1……………………………………………… 4…………………………………………..

2……………………………………………… 5…………………………………………

3……………………………………………… 6…………………………………………

3. Seasonal calendar

What are your main key events and activities during the year?

2.4. Impact matrix

2.4.1. Pastoral resources

Impact Matrix	Exposure Units (Animal Resources)				
	Resource 1	Resource 2	Resource 3	Resource 4	Resource 5
Risk 1					
Risk 2					
Risk 3					
Risk 4					

2.4.2. Fodder resources

Impact Matrix	Exposure units (Forage resources)			
	Resource 1	Resource 2	Resource 3	Resource 4
Risk 1				
Risk 2				
Risk 3				
Risk 4				

2.4.3. Human ressources

Impact Matrix	Exposure Units (Human Resources)			
	Resource 1	Resource 2	Resource 3	Resource 4
Risk 1				
Risk 2				

Risk 3				
Risk 4				

2.5. Adaptation Measures

2.5.1. Animal resources

Adaptation options	Exposure Units (Animal Resources)				
	Resource 1	Resource 2	Resource 3	Resource 4	Resource 5
Risk 1					
Risk 2					
Risk3					
Risk 4					

2.5.2. Fodder resources

Adaptation options	Exposure units (Forage resources)			
	Resource 1	Resource 2	Resource 3	Resource 4
Risk 1				
Risk 2				
Risk 3				
Risk 4				

2.5.3. Human ressources

Adaptation options	Exposure Units (Human Resources)			
	Resource 1	Resource 2	Resource 3	Resource 4
Risk 1				
Risk 2				
Risk 3				
Risk 4				

2.6. Limit of coping strategies

Strategies	Limits	New needs

2.7. Sensitivity matrices of elements of the livestock system exposed to climate risks.

			Size scales	Risk sensitivities					
			1. 2. 3.	Weak. Medium. strong.					
				R1	R2	R3	R4	Exposure index	rankings
Animal resources	Number	Resources							
	1								
	2								
	3								
	4								
	5								
	6								
Food resources	1								
	2								
	3								
	4								
	5								
Human resources	1								
	2								
	3								
	4								
	5								
	Impact index								

2.8. What species are eaten by the animals in the area (prioritize)?

……………………………………………………………………………………………… ………………………… ……………

……………………………………………………………………………………………… ………………………… ……………

and unpalatable (prioritize)?

……………………………………………………………………………………………… ………………………… ……………..

and also extinct or endangered species? ....

……………………………………………………………………………………….

2.9. What coping strategies are currently applied during difficult times?

……………………………………………………………………………………………… …………………………

……………………………………………………………………………………………… ………………………… …………………………….

Do they work?... ....

2.10. Are these adaptation strategies modified by climate variability and change??... ....

If so why?.. ....……………………………

Do you have access to climate information?.. ....

If not why ?…………………………………………………………………………..

If yes, through which channel?? …………………………………………………………………

………………………………………………………………………………………..

2.11. How are your decisions about coping strategies made based on this information? ....

……………………………………………………………………………………….

2.12. What are the different interventions that you have carried out to increase the resilience of your population in the face of climate change?

…………………………………………………………………………………………………… …………

2.13. What are your future prospects for further increasing the resilience of your populations? ....

III. Maintenance guide for technical services

Identification of local structures on adaptation measures to climate variability and change in the livestock sector

3.1. Identification

Region…………………………………….. Circle ……………………………… Municipality of …………………… Village of ……………………………

3.2.ID

Questionnaire number ______ / Date taken ______/_____ /_____/__________/
Name of the organization …………………………Acronym ……………………………
Type of organization: State/____/ NGO/____/ Association/____/project/programme/___/
Contact person **Last Names :** **Age: Sex: 1=M 2=F** **Training**: Function within the organization:………………………………………………….

3.3. How long has your organization existed? (for NGOs and projects)……………………………………………………………………………. …………………………………………………………………………………

3.4. What are the organization's main areas of intervention in the livestock sector? ....

…………………………………………………………………………………

3.5. What are your areas of intervention and the reasons that motivated this choice? ....

………………………………………………………………………………

……………………………………………………………………………….

3.6. Is your organization interested in climate change issues?... ....

……………………………………………………………………………...

3.7. What do you think are the main climate risks facing your municipality?…………………………………………………………………………
...

………………………………………………………………………………………...

3.8. What are the impacts of these climatic risks on the livestock sector?

………………………………………………………………………………………...
....
....

3.9. What provisions do you take as measures to adapt to climate risks?

strategies	Costs	Implementation challenges

3.9.1. Have these strategies contributed to strengthening the resilience of livestock keepers to the effects of climate change?1. Yes_______; 2.No______

If yes, which ones ?

…………………………………………………………………………………………
……………………………… ……………………………………………………

3.9.2 If not, what are the effective strategies to be developed to deal with the major climate risks identified in your area of intervention? (specifically in the area of animal husbandry)?

…………………………………………………………………………………………
……………………………… ………………………………………………………….

3.10. Are there opportunities to support these strategies in your area of intervention? a) yes /………/ b) no/………/

If so why ?

…………………………………………………………………………………………
……………………………… …………………………………………………

3.11. Are there barriers to implementing these strategies?

1. Yes_____ 2. No_____.

If yes, which ones ?

Appendix 6: Phyto-Ecological Survey November 2022

Date :… ……………………………………………Geographic Coordonates……………………………………………………………..

Site name :……………………………………………

Type of soil :…… ………………………………………………….

A. GRASS STAND SURVEY FORM – METHODE DES POINTS QUADRATS

SHEET OF QUADRATS POINTS SURVEY

N° of Line of 20 m (suite) :
District……………………
Commune………………...
Site.. ..……………………
Village…………………….
Date………………………………
Vegetation Formation.………………………………………………………………..
GPS Points…….

Points of contact (cm)	20	40	60	80	**6m**	20	40	60	80	**7m**	20	40	60	80	**8m**	20	40	60	80	**9m**	20	40	60	80	**10m**

B. SHEET OF WOODY INVENTORY BY DIRECT COUNTING METHOD

Code du site :

Site Name : Date :

Village :

N°	Especies	Number of species	Average height (m)	Average Circunference (cm)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
29				
30				
31				
32				
33				
34				
35				
Totaux				

C. BIOMASS ESTMATES FORM

Region :

District :

Commune :

Site :

Village de Benguéné

Date : /___/___/________/

Vegetation Formation : /_______________________________________/

Code of GPS : /____________________/

Plot code	GW (g)	GW Mix (500g)	DW Mix (g)	Dry Mater* (g)
L1				
L2				
L3				
M1				
M2				
M3				
M4				
M5				
M6				
H1				
H2				
H3				

L : low ; M : Medium ; H : High ; GW : Green Weight; Dry Weight : DW Dry Mater : GW*DW-mix/GW-mix*

D. TOOLS USED FOR PHYTO-ECOLOGICAL DATA COLLECTION

Appendix 7: Major Components and Sub-Components Comprising the Livelihood Vulnerability Index (LVI) Developed for two Districts of Mali

Composantes Majeures	Sous-Composantes Majeures	Explanation Of Sub Componeny	Questions	Source	Potential Limitation
Sociodemographic	Percent of person in charge	Percentage of household head who have more than 20 person in charge	How many person do you have in charge?	Individuel survey(December, 2022)	Mistrust for the real answer
	Percent of workforce population	Percentage of people who have only 5 person as workforce	How many workforce do you have?	Individuel survey(December, 2022)	Most of workforce population is not living at the same area
	Percent of person on education status	Percentage of people who have not educated	Are you educated or not ?	Individuel survey(December, 2022)	Confusing when the surveyed people has done any training
	Percent of person having training on livestock field	Percentage of people who been trained on livestock field	Have you been trained on livestock field?	Individuel survey(December, 2022)	Confusing when the surveyed people has participated to any meeting
Social network	Percent of people using social assistance	Percentage of people who have used social assistance	Have you used social assistance?	Individuel survey(December, 2022)	Mistrust for the real answer
	Percent of people belong to socioprofessional organisation	Percentage of people belong to socioprofessional organisation	Are you belong to any socioprofessional organisation?	Individuel survey(December, 2022)	Lack of information about sociopeofessional organisation management
	Percent of amicable conflict management cases	Percentage of people who have mentioned amicable conflict management cases	Do most of conflits between agropasteurs are managed in th way of amicable?	Individuel survey(December, 2022)	Conflict with a high scale
Livestock	Percent of people practicing livestock transhumance	Percentage of people who are pratcting livestock transhumance	Do you practice livestock transhumance ?	Individuel survey(December, 2022)	Based only transhumance between one country and other
	Percent of people on decrease of livestock weight	Percentage of people who have reported a decrease in the livestock weight	Have you noticed a decrease of livestock weight	Individuel survey(December, 2022)	Idea focused mainly on the large ruminant
	Percent of people on decrease of livestock weight	Percentage of people who have reported a frequency of livestock diseases	Have you noticed a frequency of livestock diseases ?	Individuel survey(December, 2022)	Idea focused mainly on the large ruminant
	Percent of people on frequency of livestock mortality	Percentage of people who have reported a frequency of livestock mortality	Have you noticed a frequency of livestock mortality?	Individuel survey(December, 2022)	Based on the large and small ruminant
	Percent of people without an animal feed storage facility	Percentage of people who have not an animal feed storage facility	Do you have an animal feed storage facility ?	Individuel survey(December, 2022)	Based on the rainy season

Pastures	Percent of people on the pastures currently bad condition	Percentage of people who have reported the the pastures currently bad condition	What is your appreciation about the actual condition of pastures ?	Individuel survey(December, 2022)	Based on the rainy season
	Percent of people on disappearance of woody appetezing species by livestock	Percentage of people who have noticed a disappearance of woody appetezing species by livestock	Have you noticed a disappearance of woody appetezing species by livestock ?	Individuel survey(December, 2022)	Based on the rainy season
	Percent of people on disappearance of herbaceous appetezing species by livestock	Percentage of people who have noticed a disappearance of herbaceous appetezing species by livestock	Have you noticed a disappearance of herbaceous appetezing species by livestock ?	Individuel survey(December, 2022)	Based on the rainy season
	Percent of people on herbaceous species appeared non-appetized	Percentage of people who have reported herbaceous species appeared non-appetized	Have you noticed herbaceous species appeared non-appetized?	Individuel survey(December, 2022)	Based on the rainy season
	Percent of people on pastoral resource management training	Percentage of people who have got a training on pastoral resource management	Have you got a training on pastoral resource management?	Individuel survey(December, 2022)	Based on pastures
	Percent of people on frequency of bushfires	Percentage of people who have reported a frequency of bushfires	Have you noted a frequency of bushfires?	Individuel survey(December, 2022)	Reliance on last thirty years
	Livestock density per square kilometer in 2021	Livestock density of the district of Bougouni per square kilometer in 2021	What is the livestock density of the district of Bougouni per square kilometer in 2021?	DRPIA-Bougouni (2021), MDRI (1998)	Based on one year Livestock population
Water points	Percent of people on drought as a factor in the degradation of water points	Percentage of people who have mentioned drought as a factor of the degradation of water points	Is the drought as a factor of the degradation of water points ?	Individuel survey(December, 2022)	Reliance on last thirty years
	Percent of people on the length of water crisis period	Percentage of people who have indicated the length of water crisis period	How do you thank about the duartion of water crisis period ?	Individuel survey(December, 2022)	Reliance on last thirty years
	Percent of people on the watering points currently bad condition	Percentage of people who have reported the the watering points currently bad condition	How do you thank about the actual conditions of watering points ?	Individuel survey(December, 2022)	Reliance on last thirty years
Climatic hazards	Rainfall average of research sites from 2010-2021	Rainfall average of each research sites from 2010-2021	What is average of the research sites rainfall from 2010 to 2021?	DRA-Bougouni	Reliance on average data; short time period
	Temperature average of research sites from 2010 to 2021	Temperature average of research research sites from 2010 to 2021	Wath is average of the research sites temperature from 2010 to 2021?	DRA-Bougouni	Reliance on average data; short time period