IMPLICATIONS OF CLIMATE AND LAND USE/LAND COVER CHANGES ON PASTORAL RESOURCES AND PRACTICES WITHIN KOMPIENGA PROVINCE, BURKINA FASO

BY

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MTech/SPS/2015/6069

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THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL. FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGERIA, IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF TECHNOLOGY (M. TECH) IN CLIMATE CHANGE AND ADAPTED LAND USE

MARCH, 2018

DECLARATION

I hereby declare that this thesis, titled: **"Implications of Climate and Land Use/Land Cover Changes on Pastoral Resources and Practices within Kompienga Province, Burkina Faso"**, is a collection of my original research work and it has not been presented for any other qualification anywhere. Information from other sources (published or unpublished) has been duly acknowledged.

SANOU, Charles Lamoussa ----------------------------------

SIGNATURE & DATE

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CERTIFICATION

The thesis titled: **"Implications of Climate and Land Use/Land Cover Changes on Pastoral Resources and Practices within Kompienga Province, Burkina Faso"** by SANOU, Charles Lamoussa (MTech/SPS/2015/6069) meets the regulations governing the award of the degree of Master of Technology (MTech) of the Federal University of Technology, Minna and it is approved for its contribution to scientific knowledge and literary presentation.

Dr D. N. Tsado ……..………………………

Supervisor Signature & Date

Prof. A. A. Okhimamhe ……..………………………

Director, WASCAL CC & ALU Signature & Date

Prof. M.G.M. Kolo ……..………………………

Dean of Postgraduate School Signature & Date

DEDICATION

I wish to dedicate this research work to my late father (Mr SANOU, F. Louis Pierre) and my loving mother (Mrs SANOU, D. Angèle). This work is also dedicated to my beloved wife and children (Mrs SANOU, Y. Jacqueline, SANOU, Alex T. Parfait and SANOU, Aimé K. Christian).

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ABSTRACT

The aim of this research work was to assess implications of climate and land use/land cover changes on pastoral resources and practices of herders in Kompienga province. The climatic data (1981-2016), Landsat images (1989-2015) and survey data were retrieved and analysed. Trend analysis using Mann-Kendall test, and Standardized Anomalies Index (SAI) analysis were conducted on rainfall, temperature, relative humidity and potential evapotranspiration data. Furthermore, rain onset, cessation, Length of Rainy Season (LRS) and Number of Rainy Days (NRD) were computed from daily rainfall data. In addition, deviations from a reference (climatology: 1981-2010), of each climatic variable were determined. Images classification was performed using Random Forest Algorithm in R-Software R 3.3.2. Changes detection and land use/cover prediction were done using MOLUSCE (Modules for Land Use Change Evaluation). Survey data were collected from 271 respondents (pastoralists, agro-pastoralits). Since 2011, annual rainfall amount was found lower than that of the climatology (877.8 mm), while temperature (minimum and maximum), RH and EPT of the other year were greater. An upward trend of temperature and the NRD were depicted at 95 % confident level. The minimum temperature was found evolving faster (0.50 °C per decade) than the maximum temperature (0.20 °C per decade). The period studied was characterized by more wet year (17 %) than dry year (14 %) while the normal year were predominant (69 %). Rain onset, cessation, LRS were highly variable compared to the average onset (15^{th} June), cessation (15^{th} October) and LRS (110.9 days) of the climatology. Land use dynamics was characterized by an increase in croplands at an average rate of 46.7 % per year, between 1989 and 2015. On the contrary a decline of grazable areas was observed since 2001 at an average rate of 6.0 % per year. Generally, results of climatic and images analysis were corroborated by respondents' perceptions. Respondents similarly depicted an increase in cropping areas (98.5 % of respondents) to the detriment of pasture land (97.8 % of respondents). In addition, 93.4 % of respondent depicted an increase in temperature while 97.8 % depicted a decreasing rainfall pattern. Climate change and land use/land cover (LULC) dynamics are negatively affecting forage availability (in quality and quantity); livestock production and reproduction performance; herders' practices, their livelihoods and the cohabitation of herding and crop farming. To adapt to these impacts, respondents adopt local adaptations strategies such as the use of crop residue (93.7 %), fodder trees (77.1 %), Fattening/Destocking (88.2 %), Prayers and other rites (94.5 %), transhumance (97.0 %), feed supplement (99.3 %) and use of ground water (65.3 %). The LULC is likely to keep evolving to the detriment of pasture lands in the next 10 and 20 coming year (Kappa coefficient = 0.7). The vegetation is likely to decreased from 85.9 % in 1989 to 75.7 % and 74.7 % in 2025 and 2045. On the contrary cropland areas which accounted for 0.8 % of land area in 1989 might increase up to 22.1 % in 2025 and slightly decrease in 2045 (21.9 %). This is consistent with respondents' perceptions on the future of pastoral herding in the province with a high probability to abandon this activity. Beyond, strategies adopted by respondents, urgent actions at both national and international level, need to be undertake to tackle side effects of the coupled climate and lands use and cover dynamics. That might successfully reduce the vulnerability of pastoral communities in Kompienga province, Burkina Faso.

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LIST OF ABBREVIATIONS/GLOSSARIES

ANN	Artificial Neural Networks
ADB	Asian Development Bank
BMBF	German Federal Ministry of Education and Research
BNDT	Base National de Données Topographiques
DGESS	Direction Générale des Etudes et des Statistiques Sectorielles
ECOWAS	Economic Community of West African States
ETM+	Landsat-7 Enhanced Thematic Mapper Plus
ETP	Evapotranspiration
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Product
GIS	Geographic Information System
GPS	Global Positioning System
IGB	*Institut Géographique du Burkina Faso* (Geographic Institute of Burkina)
INSD	*Institut national des Statistiques et de la Démographie du Burkina Faso* (National Institute of Demographic and Statistic)
IPCC	Intergovernmental Panel on Climate Change
LFP	Livelihoods and Forestry Programme

LRS	Length of the Rainy Season
LULC	Land Use Land Cover
LULCC	Land Use Land Cover Changes
MAEH	*Ministère de l'Agriculture, de l'Elevage et de l'Hydraulique* (Ministry of Agriculture, Livestock and hydraulic)
MAEP	*Ministère de l'Agriculture, de l'Elevage et de la Pêche* (Ministry of Agriculture, Livestock and Fishery)
MLP-MCA	Multi-Layer Perceptron-Markov Chain Analysis
MRA	*Ministère des Ressources Animales* (Livestock Resources Ministry)
MRAH	*Ministère des Ressources Animales et Halieutiques* (Livestock and halieutic resources Ministry)
NDVI	Normalized Difference Vegetation Index
NGO	Non-Governmental Organization
NIR	Near InfraRed
NRD	Number of Rainy Days
OLI	Landsat-8 Operational Land Imager
PRAPS-BF	*Projet Régional d'Appui au Pastoralisme au sahel Burkina Faso*
REDD	Reducing Emission from Deforestation and Forest Degradation

RH	Relative Humidity
SPSS	Statistical Package for Social Sciences
TM	Landsat-5 Thematic Mapper
UICN	Union Internationale pour la Conservation de la Nature
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
USGS	United States Geological Survey
WASCAL	West African Science Centre on Climate Change and Adapted Land Use
WMO	World Meteorological Organization
ECOWAS	Economic Community of West African States
RECOPA	Réseau de Communication sur le Pastoralisme (Network communication on pastoralism)
PANA	Programme d'Action National d'Adaptation à la Variabilité et aux Changements Climatiques (NAPA : National Climate Change and Variability Adaptation Programme of Action)

CHAPTER ONE

1.0. INTRODUCTION

1.1. Background to the Study

Worldwide, climate change constitutes one of the biggest challenges of the development process over the last century. This phenomenon is increasingly threatening communities' livelihoods in West Africa and particularly in Burkina Faso. Indeed, recent climate deterioration makes its economy gradually vulnerable mainly through the decline in rainfall that negatively affect pasture biomass and crop yield. The future climate of Burkina Faso will experience a decrease in rainfall (-3.4 % by 2025 and -7.3 % by 2050) coupled with a very strong seasonal and inter-annual variability of climatic factors (World Bank, 2009). This situation is likely to further affect forage resources (Swallow, 1994; Martin *et al.*, 2014) and jeopardize the development of livestock production in Burkina Faso. Yet livestock occupies a prominent place within its national economy after gold and cotton. Indeed, livestock sector contributes about 18 % to Gross National Product (GNP), account for 26 % of exports and constitutes a source of incomes for nearly 80 % of the population (MRA, 2010). Besides the economic aspect, livestock farming in Burkina Faso constitutes also an important socio-cultural value within the pastoral society. It relies largely on pastoral system which is the most practiced herding mode of the country. It is an extensive animal rearing system that depends on the exploitation of natural forage whose productivity is underpinned by climatic conditions and soil quality. Furthermore, forage availability and accessibility are dependent on the size of grazing areas and the operation of livestock routes. Over the last decades, pastoral areas within the country are affected by the recent land use and land cover dynamics.

Climate change coupled with population growth constitutes drivers of these dynamics characterized by croplands and cities expansion to the detriment of grazing reserves, range lands and livestock routes. To better address the current issue of pastoral areas in Burkina Faso, it is necessary to assess the conversion rate of those areas into other land use units. For this purpose, land use land cover dynamics analysis appears to be a suitable approach. Indeed, analysing land-cover change is important because it impacts widely on ecological processes and ensures a thorough understanding on the past, present and future changes in land-cover (Sohl and Sleeter, 2012) and land-use. Therefore, this will allow a better management of potential effects of these changes on biodiversity, hydrology, carbon fluxes, climate change, and many other ecological processes (Sohl and Sleeter, 2012). Among these effects, the deterioration of pastoral areas/resources (decline in range land size and forage biomass) is one of the focuses of this work. That deterioration has several negative implications such as the decline in livestock production, the increase of competitions and conflicts between farmers and herders. This situation constitutes currently a major preoccupation within most localities of Burkina Faso, and mainly in its south-eastern region. Indeed, this region is characterized by a rapid conversion of pastoral areas into croplands (UICN, 2015). This contributes to reducing the accessibility of pastoralists to pastoral resources (pasture and water) which is influenced by an unfavourable land tenure system of the receptions or transit zones. Pastoral system could be a profitable system with good production performance if minimum standard of organisation was ensured to satisfy the needs of pastoral herds. Unfortunately, pastoralists are mostly kept aside in decision making relative to natural resources management.

It is therefore urgent to find adequate solutions in order to ensure the survival of the pastoral system in Burkina Faso and within Kompienga Province in particular. The determination of adequate solution needs a better understanding of the impacts of climate and LULC changes on the pastoral resources and herders' practices. For this purpose, the study intends to investigate within the Kompienga province, the changes of climate conditions from 1981 to 2016 and the dynamic of land use land cover pattern between 1989 and 2015. This will provide information on how forage, watering points, range lands, livestock routes and herders' practices are affected by both climate change and land use/land cover dynamics.

1.2. Statement of Research Problem

Pastoral system relies on the equilibrium of three major components which are: (i) a suitable environment (rich pasture, abundance of water, free from animals' diseases); (ii) herds with their needs for growth and reproduction and (iii) herdsmen with their socio-economic needs. In the context of arid and semi-arid regions, this equilibrium is usually disrupted through mainly the depletion of the environment. Under the increasing pressure, areas once used for pastoral activities are gradually converted mainly into farmlands. According to (UICN, 2015), within the eastern region of Burkina Faso, 215,763 hectares of pastoral land have been lost while farmland have increased to 214,503 hectares, between 1992 to 2012. Oksen (2000) and Reenberg *et al.* (2003), both argue that pastoral activities are really threatened through farmlands expansion within Boulgou province belonging to the same region as Kompienga. Similarly, Soungalo (2016) found that areas sown for cotton in the Kompienga have increased from 1,679 hectares in 2001 to 4,321 hectares in 2004, an increase of 157 %. This rate of conversion of pastoral lands into agricultural land is very worrying and is likely to continue if swift actions are not taken by policies makers to reverse this trend. In fact, the rapid expansion of farmland underpinned by rapid population growth, coupled to climate change constitute the main drivers of pastoral resources degradation and thereby the decrease in animal production. Indeed, beside LULC changes, climate change affects seriously pastoral resources and accordingly livestock production and reproduction performances (Sanfo, 2014; Zampaligré *et al.,* 2013; PANA, 2007). Moreover, increasing pressure and gradual degradation of natural resources fuel the emergence of conflicts between crop farmers and pastoralists.

With regards to the actual tendency in climate change and the increasing pressure on lands and natural resources, the future of pastoral system in Burkina Faso might be seriously compromised. However, there is limited information on the climatic changes in relation to pastoral resources and practices in Kompienga province. Similarly, information on LULC dynamics and its impacts on pastoral resources and practices is also scarce . It is therefore necessary to undertake studies on current and future threats to which the pastoral system might be exposed, particularly within Kompienga Province.

1.3. Aim and Objectives

The aim of this study is to assess the implications of climate and land use and cover changes on pastoral resources and practices of herders in Kompienga province, Burkina Faso.

The objectives of the study are to:

i. Analyse the characteristics of climate variables such as rainfall, temperature, potential evapotranspiration and relative humidity of the study area from 1981 to 2016,

ii. Assess the changes in land use and land cover within Kompienga province, Burkina Faso between 1989 and 2015,

iii. Assess the perceptions of pastoralists and agro-pastoralists on the implications of climate and land use/land cover changes on pastoral resources and practices within Kompienga province, Burkina Faso,

iv. Predict future changes in land use and land cover and its implications for pastoral resources within Kompienga province, Burkina Faso at 2025, 2045.

1.4. Justification for the Study

Livestock production which occupied an important place in Burkina Faso economy, relies strongly on pastoral system. This system is essentially an extensive exploitation of natural resources (water and pastures), vulnerable to climate change and land use and cover dyanmics. But limited knowledge exists on the vulnerability of pastoral resources and herders' practices in a context of climate change. Indeed, under the changing climate, some forage species might have disappeared or are in extinction. In the same way, the palatability of the main pasture might have declined with the deterioration of climate conditions. Moreover, few information exist on the current and future LULC dynamics and their impacts on pastoral resources and herders' practices. Therefore, the existing knowledge about the impacts of climate variability/change and land use/cover dynamics on pastoral resources, need to be researched on in Burkina Faso, particularly in Kompienga Province.

The results of such study will provide information on different constraints related to pastoral rearing system and give room for good policy decisions on resource management. Indeed, this study will further provide data on pastoral resources and practices (mobility, herds management) and the possible changes that might have occurred over the years in these practices and resources in Kompienga Province of Burkina Faso.

1.5. Scope and Limitation of the Study

The scope of the study covers the province of Kompienga in Burkina Faso. The land area of this province is about 2.6% of the country's total area (274 200 km^2). Twelve (12) of the thirty-eight (38) villages and two hamlets were selected in the province to conduct the study. Questionnaires were administered and training sample for satellite images classification were collected from the selected villages. Satellite data analysis were scaled up to the whole province. This study gives an overview on the existing herbaceous pastures and fodder trees and the threatened forage species or in extinction within the rangelands. It did not allow the assessment of forage biomass within the study area. Furthermore, determining the scientific names of forage species from their local names was not exhaustive because of limited expertise and insufficient data on endogenous knowledge of forage resources, particularly grass forage.

1.6. Description of the Study Area

1.6.1. Geographical location

The study will be carried out in Kompienga province (Figure 1.1), located in the eastern part of Burkina Faso and it is made up of three districts: Pama (capital of the province), Madjoari and Kompienga. It is bordered by Gourma province in the North, Topoa province in East, Koulpélogo province in West and in the South by Togo and Benin Republic. It is located between 0°30'4.96" and 1°22'22.25" longitude East and between 10°56'16.85" and 11°27'21.09" latitude North (Google earth). This province covers an area of 6998 km^2 (INSD, 2014) about 1/3 of which is occupied by forest reserves and about 1/3 (223,000 ha) by wildlife reserves (Gomgnimbou *et al*., 2010a). It represents 2.6% of the country's area (274 200 km^2). The province has about thirty-seven (37) villages divided between the three communes: Pama (12 villages), Kompienga (17 villages) and Madjoari (8 villages).

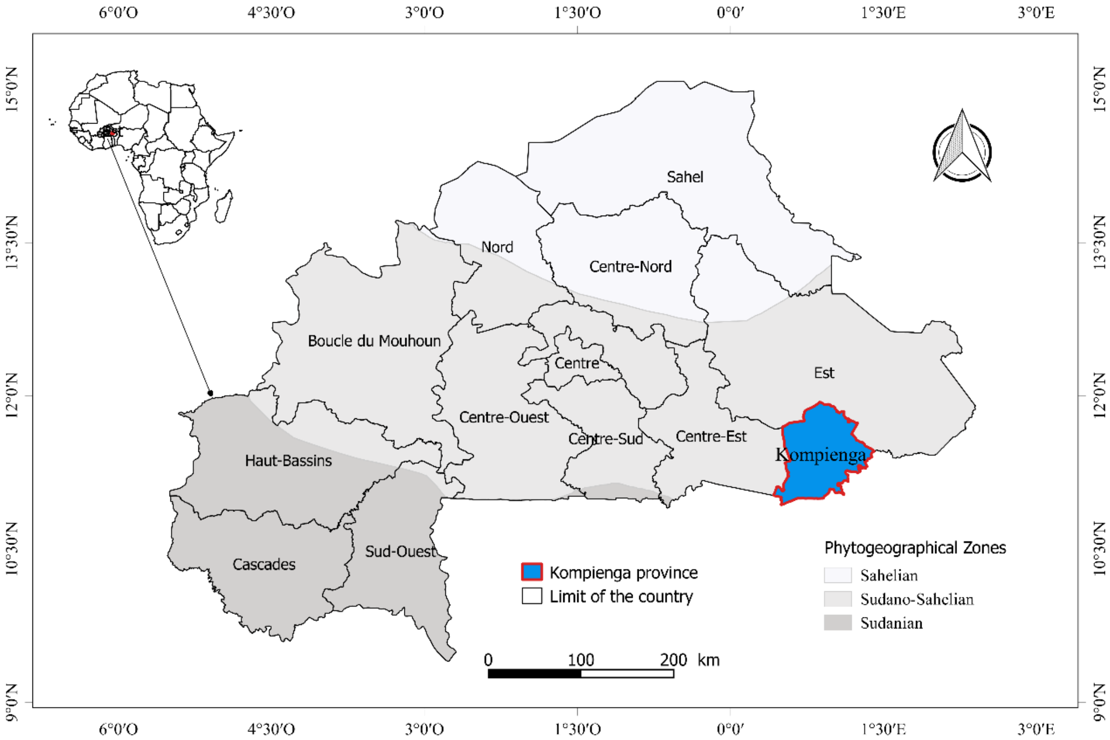


Figure 1.1: Burkina Faso showing Kompienga province

1.6.2. Biophysical characteristics

The province of Kompienga has climatic characteristics favourable to the development of agricultural and pastoral activities (Gomgnimbou *et al*., 2010b).

1.6.2.1. Climate

The climate of Kompienga province is sudanian, characterized by five rainy months (May to September) and a longer dry season (October to April). The dry period is dominated by a dry and warm wind known as harmattan (Dipama *et al*., 2011) While the rainy season is characterized by moist winds (monsoon) and the annual rainfall fluctuates between 700 and 1000 mm on average. The average annual temperatures range from 30.7 °C to 39.7 °C for the maximum and 17.5°C to 26.3°C for the minimum. The warmest months are March (38.9 ° C) and April (39.7 ° C) while low temperatures are recorded in December (17.6 ° C) and January (17.5 ° C). The minimum relative humidity is 33% on average with a low value in February (11%) due to harmattan. Relative humidity is highest in August-September (97%), but the average over the period (1983-2013) is 68% (Soungalo, 2016).

1.6.2.2. Soils and Vegetation

The whole of the eastern region, is characterized by a peneplain with some hills around Pama (Soungalo, 2016). The leached tropical ferruginous soils predominate, sometimes with hydromorphic soils found along rivers (Mbayngone *et al*., 2008).

There are essentially two types of plant formations in the eastern region : savannah and dry forests. Savannah is the most widespread, while dry forests exist only in the form of dense forest islets or narrow strips of light forest along rivers. This forestry formation, generally dominated by *Anogeissus leiocarpus*, also contains *Pterocarpus erinaceus,* *Stereospermum kunthianum, Tamarindus indica, Diospyros mespiliformis, Acacia polyacantha and Acacia sieberiana*. The savannas are generally shrubby, sometimes wooded or grassy in the alluvial plains. They are dominated by woody species such as *Combretum glutinosum*, *C. collinum*, *Vitellaria paradoxa*, *Terminalia avicennioides, Acacia dudgeoni, A. gourmaensis, A. hockii, Crossopteryx febrifuga, Piliostigma thonningii, Combretum nigricans and Lannea acida*. The dominant herbaceous species are *Andropogon pseudapricus, Andropogon gayanus, Aristida kerstingii, Andropogon chinensis* and *Hyparrhenia involucrata* (Mbayngone, 2008).

1.6.2.3. Wildlife

Kompienga province is characterized by the Partial Wildlife Reserve of Pama created by Order No. 6090 / SE / F of 03 August 1955, and then reclassified by Decree No. 70/175 of 13 April 1970. Its main objective was to promote the rational management of natural heritage and to ensure its preservation. To this end, some rights of use have been granted to the riparian population: the harvesting of leaves, roots and bark for the pharmacopoeia, the mowing of straw and the gathering of dead wood for domestic consumption. Pasture and traditional hunting are prohibited (MBayngone, 2008).

1.6.2.4. Hydrology and water resources

The study area has two important rivers: (i) the Pendjari River in the extreme south-east (as a natural border with Benin) which has a permanent flow; and (ii) the Singou river in the eastern boundary of the reserve, is a temporary watercourse. It contains numerous tributaries. There are also water bodies, the most important of which is Lake Kompienga in the southwest of the zone (Mbayngone, 2008).

1.6.2.5. Socio-economic characteristics

Demography

Three main ethnic groups exist in the province of Kompienga: Gourmantchés, Mossis and Fulanis. The Gourmantchés constitute the most important ethnic group, followed very far by the Mossis and the Fulanis (Balima, 2013). But the proportion of mossi is growing steadily due to immigration in search of arable land (MBayngone, 2008).

In the last population census of 2006, the population of Kompienga was estimated at 75 867 people including 38 357 men and 37 510 women with a density of 10.8 persons by square kilometre (INSD, 2009). The population dynamic in the study area is important and the population tripled in two decades after the construction of the Kompienga dam. Indeed, the annual growth rates of the Kompienga populations between 1985 and 2006 was 5.67%. The projected population based on estimated growth rate of 4.41% was 102 645 peoples in 2013 which was four time more than 1985 Figure (23, 818 peoples) (INSD, 2009; INSD, 2014).

Livelihoods and income

Within Kompienga province, the population practices a variety of activities including agriculture, livestock, fisheries, hunting and trading. The main activity is agriculture which is traditional, extensive and itinerant characterized by weak technologies and inadequate processing and market opportunities. Productions consist in the cultivation of cereals (sorghum, rice, millet) and cash crops (cotton, sesame, peanuts) with more emphasis on cereal cropping (Soungalo, 2016). Secondary activities are represented by fisheries and trade, partly because of the fisheries potential of the Kompienga and Pendjari reservoirs, and secondly because of the border position of the province. In addition, arboriculture, which represents a promising new sector, is valued by farmers in Pama. These are mainly orchards of *Mangifera indica* (mango), *Psidium guajava* (guava) and Western anacardium (cashew nut) (Balima, 2013).

CHAPTER TWO

2.0. LITERATURE REVIEW

2.1. Conceptual Framework

2.1.1. Climate and related concepts

2.1.1.1. Climate

Climate is commonly understood as the average weather for a particular location and period of time (WMO, 2011). It refers to a long-term weather pattern (Met Office, 2013). In a rigorous sense, climate is defined as the statistical description in terms of the mean and variability of relevant quantities (temperature, precipitation, wind…) over a period of more or less long time ranging from months to thousands or millions of years. However, a thirty-years period is defined by the World Meteorological Organization (WMO), as sufficient to describe climate. Finally, in a wider sense, climate is the state, including a statistical description, of the climate system (IPCC, 2014).

2.1.1.2. Climatological normal

Climatological standard normal is an average of climatological data computed for the following consecutive periods of 30 years: 1 January 1901 to 31 December 1930, 1 January 1931 to 31 December 1960, and so forth. As far as possible, the data used in the calculation of climate normal and averages should be homogeneous. It is recommended that, where possible, the calculation of anomalies be based on climatological standard normal periods, in order to allow a uniform basis for comparison (WMO, 2011). Climate anomalies give an idea on how a climatic parameter shift from the climatological normal.

2.1.1.3. Climate variability

The spatial and temporal variations of the mean state and other statistics (standard deviations or the occurrence of extremes events.) upon climate refer to the climate variability. That variability maybe driven either by internal variability (processes within the climate system) or by external variability relative to variations in natural or anthropogenic external forcing (IPCC, 2001; IPCC, 2014). Unlike weather variability that is more perceptible, climate variability is not so noticeable. It corresponds to the way climate fluctuates yearly above or below a long-term average value (Dinse, 2010).

2.1.1.4. Climate change

Climate change refers to a change in the state of the climate that can be perceived (using statistical test) through changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer (IPCC, 2014) . This change is due to changes in atmosphere composition through accumulation of greenhouse gasses in the lower atmosphere. Change drivers involves both natural processes (such as volcanic eruptions) and anthropogenic activities (fossil fuel burning) which release greenhouse gasses (namely carbon dioxide, methane, nitrous oxide and chlorofluorocarbons) (IPCC, 2014; LFP, 2010). On the contrary, climate change is defined according to the UNFCCC as a change which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability, observed over comparable time periods (IPCC, 2007; United Nations, 1992). Its appears then to the point of view of the UNFCCC that climate change is attributed to anthropogenic activities which alters the composition of atmosphere while climate variability is attributed to natural causes (IPCC, 2014). Furthermore, for Dinse (2010) climate change is a continuous change (increase or decrease) in the mean weather conditions or in the range of weather (more frequent and severe extreme storms), occurring over a long period of time.

2.1.1.5. Impacts of climate change and adaptations strategies

Impacts of climate change: the effects of extreme weather, climate events and climate change on a system, consist in impacts. The system affected can be natural or a human system. Impacts involve effects on people lives, their health and livelihoods, on ecosystems, socio-economic and cultural dimensions, on services and infrastructures. The impacts appear to be a resultant of the interactions of climate change and its associate risks with the vulnerability of an exposed society or system (IPCC, 2014). Taking to account the adaptation perspective climate change impacts can be distinguished in potential and residual impacts. The potential impact represents the possible impacts that may occur within a society or upon a system if any adaptation measures is adopted. On the contrary, the residual impact represents the impact that persists after the adoption of adaptation practices (IPCC, 2007).

Adaptation strategies: adaptation is a way of adjusting to disruptive phenomenon, situation or event. Adaptations modes may vary according to the nature of impacts and the adaptive capacities of the exposed or impacted society or system. Thus, (IPCC, 2001) defines adaptation as an: "*adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation*".

2.1.2. Concepts of land use and land cover

Very often a confusion exists between land use and land cover. Yet the two terms have two different concepts (Giri, 2012) even though they remain very interlinked. Indeed, a cover type of a piece of land can be unique while its use is multiple. For instance, a forest may have several uses such as religious, recreational, educational or conservational (Giri, 2012). Thus, it is important to have a sound understanding of these terms for the purpose of a successful and meaningful used in the present thesis.

Land cover (LC): refers to how features are displayed on the earth surface. Land cover consists in the observed physical and biological coverage of earth's surface (Di Gregorio and Jansen, 1998; Di Gregorio and Leonardi, 2016; Meyer and Turner II, 1992; Burley, 1961; Ouedraogo, 2010) that is easily observable such as water bodies, vegetation, farmlands and settlement. It is the resultant of several processes occurring on the land and the representation of the occupation/transformation pattern of land by natural or modified systems. Furthermore, land cover gives an idea on how these systems affect the land. Moreover, land cover pattern constitutes an easy way of detecting mankind interventions on land. Therefore, it appears to be a good proxy for dynamics of the earth surface as result of different drivers and factors (Di Gregorio and Leonardi, 2016). It refers to the vegetation and artificial constructions covering the land (Burley, 1961).

Land Use (LU): the way in which the land and its resources are used or occupied by different mankind activities, is defined as land use (Agarwal *et al.*, 2002; Di Gregorio and Jansen, 2005; Giri, 2012). Land use is "people or activity oriented" in the sense that its preoccupation refers to the utilisation pattern performed on a given land cover type. Its essence is underpinned by the socio-economic purpose for which a given land is being used (Comber *et al.*, 2008; Giri, 2012). Indeed, the use of land involves activities, inputs and arrangements that people perform upon a particular type of land cover for a purpose of production, modification or maintenance of its characteristics (Di Gregorio and Jansen, 1998). It appears in this point of view that land use set down an intimate connection between land cover and mankind interventions or actions within their environment.

2.1.2.1. Land use and cover changes

Land cover change: is the conversion and modification of the cover pattern of earth's surface coverage. The conversion refers to a complete shift from one land-cover type or cover unit to another (for example from forest to grassland) while the modification consists in a change within a land-cover category. This involves alterations in the attributes of a cover (for example from grassland to degraded grassland) (Turner *et al.*, 1994).

Land-use change: is a change in the use or management of land by humans. Changes in Land-use is not synonymous of changes in land-cover; however, land-use change is likely to cause land-cover change. On the contrary, land cover may change even if the land use remains unchanged (Giri, 2012).

2.1.2.2. Change detection

Change detection is the process of identifying differences in the state of an object, a surface, or a process by observing it at different times (Singh, 1989). Changes detection technique in remote sensing consists in analysing times series images over the same area and involves the detection and the display of changes within the image (Abuelgasim *et al.*, 1999). The success of change detection will be attributed to both the nature of the change involved and a good achievement of pre- processing and classification procedures (Shalaby and Tateishi, 2007).

- Images classification

Image classification is a process of grouping pixels of satellite images into identical classes on the basis of their reflectance. According to Eastman (2003), image classification refers to the computer-assisted interpretation of remotely sensed images. The main steps in image classification procedure may involves: (i) determination of a suitable classification system, (ii) training samples selection, (iii) image pre-processing, (iv) feature extraction, (v) selection of suitable classification approaches, (vi) post-classification processing, and (vii) accuracy assessment (Lu and Weng, 2007).

- Image enhancement

Image enhancement is the improvement of the visual interpretability of an image by increasing the apparent distinction between the features (Lillesand and Kiefer, 1994). In other words, image enhancement involves the modification of images to make them more adapted to the capabilities of human vision (Eastman, 2003).

- Accuracy assessment

Confusion matrix appears to be currently an obvious basis for accuracy assessment (Canters, 1997). It constitutes a simple cross-tabulation of the mapped land cover units against those existing on ground or reference data at specified locations. The error matrix gives information on covers that are being mistakenly included in a particular class (errors of commission) and those that are being mistakenly excluded (errors of omission) from that class. On the basis of that information, the classification methodology may be refined (Foody, 2002; Eastman, 2003).

2.1.2.3. Land use land cover changes modelling

Models are used in several domains, including land use land cover field, to better apprehend the dynamics of systems, to develop hypotheses, and to make predictions and/or evaluate scenarios for use in assessment activities (Brown *et al*., 2004) . Modelling land use change can address two different issues: where are land-use changes likely to take place (location of change) and at what rates are changes likely to progress (quantity of change). It consists in an important technique for the projection of alternative pathways into the future (Veldkamp and Lambin, 2001). In addition, it allows the forecast of the future land use and cover pattern to give an overview on the possible future dynamic of a particular land use or cover type within a given zone of interest. That might provide policy makers and other stakeholders with tools to examine future effects of land-cover change on ecological and socioeconomic processes Sohl and Sleeter (2012), such as expansion of agricultural land and decline in pastoral and forest areas.

2.1.3. Concepts on pastoralism

2.1.3.1. Pastoral resources

Pastoral resources consist of a set of inputs (pastures, water, post-harvest residues, natural salt lick) that underlie the production of animals in the pastoral system. In other words, pastoral resources constitute the foundation for the functioning and productivity of the pastoral system. It is precisely for this reason that in the system, livestocks frequently move from areas of scarcity towards zones rich in pastoral resources in order to ensure their access to livestock. For Alassane (2011), pastoral resources refer to resources (natural pastures, harvests residues, water) used by herders to ensure livestock production (milk, meat, leather, manure).

2.1.3.2. Pastoralists

A pastoralist is a person whose livelihoods is ensured directly or not through livestock grazing on native pasture. It is anybody who practices pastoral activity as his main occupation and who derives from it most of his income, whether he owns all or part of the herd (MRA, 2002).

2.1.3.3. Pastoral areas

A pastoral area is a territorial entity on which a mobile livestock farming or a pastoral breeding system is carried out. It includes all the land (natural or modified lands devoted to livestock, cropland accessible to herds after harvest, forage cropping land, plantations, forest rangelands, ...) accessible to livestock in search of their food (Botoni, 2003). Further definitions of some key concepts of pastoral areas was done by the *Law No. 034-2002 / AN of 14 November 2002* on the orientation of the pastoralism in Burkina Faso (MRA, 2002). These are presented on Appendix B.

2.1.3.4. Pastoral mobility

Pastoral mobility involves all movement of livestock from a departure point to a destination point on a small or large distance scale in search for pastoral resources. This mobility, refers to the time-space behaviour of herds and herders in response to the variations in pasture and its distribution. The mobility mode is either regular according to a grazing gradient of resources or opportunist guided by herders in concordance with indigenous management systems (Oba, 2011). Livestock mobility have been for pastoralists an essential mean of copping with uncertainty and risks within unpredictable and low-productivity environments (IPCC, 2014; Fernandez-Gimenez and Le Febre, 2006; Nkedianye *et al*., 2011; Bassett, 1986; Scoones, 1994). Furthermore, livestock mobility is a precious way that allows herders to improve pastoral system outputs (Niamir-Fuller, 2000), and reduce these outputs fluctuations as result of spatial and temporal rainfall variability (Swallow, 1994; Van den Brink *et al*., 1995; McCarthy *et al*., 2004).

2.1.3.5. Pastoral system and pastoralism

In the literature, pastoral system has been alternatively used for pastoralism (Dong, 2016). Thus, the two terms have nuances with pastoralism emphasising on the form or the functionality of different components (herds, herdsmen and resources) within the pastoral system.

- Pastoral system

Pastoral system or mobile livestock system consists in an ensemble of functional and interacting components: (i) herder or herders, (ii) animal or herds and (iii) resources: pasture/rangelands, water bodies, salt licks. Indeed, according to (Lhoste, 1984), a livestock system is a combination of resources, animal species, techniques and practices performed by a community or a breeder in order to satisfy its own needs through the valuation of available natural resources by animals. For Landais (1994), it is a set of elements in a dynamic interaction organized by man, with the aim of valuing resources through domestic animals to obtain various productions (milk, meat, hides and skins, labour, fertilizers...) or to meet other objectives.

- Pastoralism or mobile herding

Pastoralism is a mode of livestock farming associated with animals' mobility in search of resources (pasture, water, salt lick…) to meet their needs for maintenance, production and reproduction. It consists in a sustainable utilisation/management of rangelands (Rota and Sperandini, 2009) and natural resources (Dong, 2016, Blench, 2001, Alassane, 2011, Liao *et al*., 2014), namely in dryland areas (Sulieman and Elagib, 2012; Koocheki and Gliessman, 2005) requiring displacements of varying magnitude. IPCC (2014), defined it as a livelihood strategy underlined by livestock movement to seasonal pastures for the purpose to convert grasses, forbs, tree leaves, or crop residues into human food. Referring to the amplitude of displacements and their frequency, one can distinguish three kinds of pastoral breeding: (i) sedentary breeding (using local rangelands within village territories), (ii) the transhumant breeding (small and large transhumance) and (iii) the nomadic breeding (Sawadogo, 2011).

- Transhumance

The most important herding kind in the pastoral system, transhumance is characterized by herds seasonal and cyclical movements of varying amplitude between many agro-ecological zones (Gentle and Thwaites, 2016). It refers to a routine mobility (Brottem *et al*., 2014; Gautier *et al*., 2005) of livestock between well-defined pasture areas (Blench, 2001; Niamir-Fuller, 2000) or between two seasonal ranges (Koocheki and Gliessman, 2005) for the purpose to optimize livestock access to water and to grazing of good quality (Diop *et al*., 2012). Indeed, Sawadogo (2011), specified that seasonal movements are carried out between complementary ecological zones with the care of few people while the greatest part of the group remain sedentary.

2.1.3.6. Pastoral practices

Pastoral practices correspond to how herders manage forage resources by moving livestock throughout the year from one point to another (Alassane, 2011). In a comprehensive way, pastoral practices should involve all the skills and knowledge that are performed by herdsmen within the pastoral system in process of taking care of herds and managing pastoral resources. Landais (1994), has classified pastoral practices in three main categories: (i) breeding practices stricto sensu, which intervene directly on livestock; (ii) fodder practices which is about all agronomic operations performed on forage areas; and (iii) management practices of grazing and forage stocks, which connect, directly or indirectly herds to pasture lands subunits. In the case of herbivorous husbandry, breeding practices stricto sensu implemented by the breeders are subdivided into five sub-group: (i) aggregation or batching practices, (ii) husbandry practices or conduct of herds, (iii) operating practices, (iv) renewal practices, and (v) valorisation practices.

2.2. Climate and Pastoralism in West Africa

2.2.1. Climate change in West Africa

West Africa is characterized by a very particular climate patterns and unfortunately, by a limited availability of historical data over the region (Joiner *et al*., 2012). However, during last decades, evidences have shown that this region is undergoing great modification in its climate pattern due to global warming. Indeed, since 1950s, this region, as well as at global scale, is experiening an unequivocal warming causing increases in atmosphere and ocean temperatures. This global warming is induced by an excessive increase of atmospheric concentration of greenhouse gases since 1750 due to anthropogenic activities (IPCC, 2013). One major consequence of climate change is the decrease in rainfall pattern which is the most determinant factor of African and namely west African countries economy. Indeed, a decline in trend (nearly four percent per year) of rainfall have been detected in the region since years 1960s (Chappell and Agnew, 2004; Dai *et al*., 2004; Nicholson *et al*., 2000; IPCC, 2007), except Guinean coast where rainfall has increased at a rate of ten percent (Nicholson *et al*., 2000). This decrease in rainfall caused by a changing climate over West Africa have numerous negative repercussions on people and their livelihoods. Alongside this decline in rainfall, the region is confronted with several other constraints such as climatic extremes events and their recurrent disastrous impacts over the last thirty years. It is in this context that West Africa is described as one of the most vulnerable region in the world (Niasse *et al*., 2004). Furthermore, West African populations will become more vulnerable due to spatio-temporal variability of rainfall because of their reliance on climate-dependant activities namely herding and rain-fed cropping (Joiner *et al*., 2012).

Concerning the future climate pattern of the region of West Africa, the climatic models are quite divergent. However, the majority of these models agree on: (i) an overall global warming trend with an average temperature increase rate of 0.5 C per decade, (ii) an overall decrease of rainfall by 2050 of 0.5 - 40 per cent at an annual average rate of 10-20 per cent, and (iii) a projected sea-level rise of 0.5-1 m over the next century (USAID, 2008). Rainfall is likely to be more variable and unpredictable (Connolly-Boutin and Smit, 2016). In this regard, what is the current level of information about the impacts of climate change on pastoral herding, particularly in Burkina Faso and Kompienga province?

2.2.2. Pastoralism in West Africa

One of the most vulnerable sectors to the climate change and variability in West Africa is livestock farming recognized to be very rain dependant. Unpredictable weather condition will, therefore, increase the vulnerability of actors involved in this sector; namely pastoralists which are the main target actors of this study. Thus, herders and their livestock depend on a stable climatic condition to ensure an environment conducive to the growth of pasture for livestock (Joiner *et al*., 2012). With climate change such environments become increasingly rare with their corollaries of constraints.

Martin *et al.* (2014), asserts that in drylands, which cover more than 40% of the surface of the earth, climate change through the decrease in annual mean precipitation and its increasing variability affect severely rangelands productivity and thereby jeopardize pastoral livelihood security. Thus, the production supports of the pastoral system are gradually threatened by the changing climate. One fundamental support is land and its related resources such as pastures (herbaceous and fodder trees), rangelands, water, natural salt lick. Land and its resources are either directly affected through drought and excessive heat, either indirectly through reduction of pastoral areas to the profit of others LULC units. However, what is the current dynamics of this LULC in West Africa and Burkina Faso in particular?

2.2.3. Land use and land cover change in West Africa

In West-Africa, the most dominant lands dynamics is agricultural expansion (Judex *et al.*, 2003; Wood *et al*., 2004; Braimoh and Vlek, 2005). The expansion occurred to the detriment of forests and savannahs (Lambin *et al*., 2003). In the same way in Burkina Faso, since the 1970s, farmlands have been expanded to the detriment of forest. This expansion of cropland and the decline in forest cover are associated with population growth (Ouedraogo, 2010). Agricultural land expansion occurred mainly in the western and southern localities of the Burkina Faso, including Kompienga Province because these localities constitute reception zones of farmers and herders in search of arable lands and rich pasture. Thus, the pressure on lands and natural resources is gradually increasing leading to environment degradation. Indeed, according to Ouedraogo *et al.* (2009), the degradation is underpinned by immigration, which if not checked, will seriously degrade the environment.

2.3. Review of other Related Studies

Gonin and Gautier (2015), have conducted a study entitled "Shift in herders' territorialities from regional to local scale: the political ecology of pastoral herding in western Burkina Faso". This study addresses the issue of pastoral areas in context of changes in land use land cover within the western region of Burkina Faso. Methodology adopted consisted of individual interviews, focus groups discussion, workshop with different stakeholders (farmers, pastoralists, experts from NGOs and publics services). Otherwise, fields observations were done and satellite data were analysis for better understanding of land use pattern and change in pastoral areas. The authors found out a rapid regression of pastoral areas (rangelands, transhumance routes) to the benefice of croplands namely cotton cultivation which have been promoted by the state development policies. Indeed, mobile herders' territorialities have been compromised since independence and until now there is a lack of appropriate legislation on rangelands. Moreover, the law of hope (*Law No. 034-2002 / AN of 14 November 2002)* on pastoralism voted in 2002, failed in application. All this situation gave priority to agriculture ahead of pastoralism and showed how the state was unable to protect rangelands and regional stock routes from the extension of farmland. Furthermore, the authors found out that recently, transhumance herders are confronted to fields obstructing historically and or officially delimited livestock routes. Their movement are gradually causing conflicts when going back to their home territories in the northern part of the country. Thus, to avoid conflicts many pastoralists go back earlier than usual to their home territory. Therefore, they leave earlier, grassed lands of reception zones for Sahelian pastures where grass have not yet grown. Finally, satellite image analysis demonstrated a regression of rainy rangeland passing from 58% (54,400 km^2) of the total area of western Burkina Faso in 1992 to 48% (45,200 km^2) in 2002.

In sum, this study was able to give an understanding on how pastoral areas are evolving in the West of Burkina. However, the study did not give an idea on the implication of climate change on pastoralism. Also, the study was not able to predict the future land use pattern on how rangelands and livestock routes will evolve. The current research aims to fill these gaps by investigating how climate change in Burkina Faso affect pastoral breeding and how the present and future land use and cover change will impact pastoral resources and practices.

Zampaligré *et al*. (2013), conducted a study on the perception and adaptation strategies of pastoralists and agro-pastoralists to climate change and variability across different zones of Burkina Faso. The study aimed to assess the perception and coping strategies of these actors within three major agro-ecological zones of the country (Nobere, Sokouraba, Taffogo). To achieve this goal, data collection has been done based on a random choice of participant households to the study. The approach involved both individual and focus group survey. Through, chi-square test and the non-parametric Kruskal–Wallis test, the factors affecting the choice of farmers' coping strategies were determined. Then, a binary logistic regression was used to explore the key variables influencing farmers choice for future adaptive options. Furthermore, a simple multi-linear regression was performed to calculate the annual rainfall and maximum temperature over the period 1988 to 2008 and then time series analysis was done during this period. The authors found out that, farmers in majority recognized the increase in dry season duration and its temperatures. Likewise, all the respondents agreed on the high variability in rainfall and the unreliability in predicting the beginning and the duration of the rainy season. They also found out that, changes in climate patterns affect farmers livelihoods through the regression of soil fertility, land degradation leading to crop yields decline. Likewise, climate change affects herds mobility, pastoral resources, forage availability and therefore decreases livestock's production and reproduction performances. Adaptive strategies involve the use of improved seeds and new crop species, extension of cultivated areas, the implementation of water and soil conservation measures, diversification in cropping system. Moreover, adaptation encompasses destocking, splitting of herds, shifting from cattle to small ruminants, and transhumance found out as the most suitable coping strategy with big size of herd. Adaptive strategies were greatly affected by the agro-climatic zone, the size of herds and cultivated area, the size and the education level of household. The study was not able to give enough information on the declining trend/amount of grazing area and watering point. Furthermore, the study did not address the present and future impacts of land use /and cover change on pastoral areas. It is essential to have such information for a better design and planning of development strategies and policies in favour of a concerted, integrated and peaceful management of natural resources.

Sulieman and Elagib (2012) have investigated on the implications of climate, land-use and land-cover changes for pastoralism in eastern Sudan. The authors' objective was to examine climate and land use/land cover changes along the seasonal migration routes in El Gedaref region within the east Sudan. On the one hand, the study has focussed on changes in climate parameters looking at their deviation from climatology assessed through the determination of Standardized Anomaly Indices (SAIs) for each parameter. Using the non-parametric test of Kendall's tau, the long-term trends of the climate parameters were determined. Then the trend rate was obtained through linear regression. moreover, monthly and annual reference evapotranspiration were determined, through the method of Hargreaves and Samani (1985), which allowed the calculation of the aridity index as a ratio of rainfall to reference evapotranspiration. Changes occurred in Median rainfall, rainfall variability, concentration and distribution between (1941-1978) and recent (1979-2008) were examined. One the second hand, LULC analysis were performed on cloud-free satellite from Global Land-Cover Facility. LULC types were determined using field survey and interview with local population (6-8 person interviewed by study site). Image processing was done through supervised classification using the maximum likelihood method.

The authors found out that climate is warming but more in night than daytime. Moreover, they found out, over the period (1979-2008), an increase rate of 0.53°C, 0.22°C and 0.38°C per decade respectively for minimum, maximum and mean temperatures. The deviation of the temperature parameters from normal was 1.5 -1.6°C. The rainfall has slightly increase between the periods 1941-1978 and 1979-2008 by 18.8mm. LULC changes analysis have shown a global rapid increase of agricultural and bare land areas compared to vegetation areas which decrease in exception of the site 3 of study which experienced a rapid increase in vegetation cover during 1979-2008. These drastic changes in LULLC in El Gedaref region is affecting and reducing significantly grazing resources. It appeared that land-use policy is the major driver of the observed agricultural rapid expansion at the detriment of rangeland. This study could not highlight explicitly, the impacts of climate change on pastoral resources and herders' practices. Also, the study was not able to give a perspective on how LULC within the region, will look like in the future.

Gautier *et al*. (2005), have studied the relationship between herders and trees in space and time in northern Cameroon. The purpose of the study was to analyse how fodder trees intervene in the determination of herders' territorial strategies. It focussed on the role of trees in the definition of nutrition strategies of herds on a spatio-temporal dimension as well as in the land appropriation. The methodology has involved sociological survey, individual interviews, field observations and analysis of herders' practices. Daily pathways of herds as well feeding, resting and watering of herds were timed and geolocalized. Then systematic measures were performed on all fodder trees harvested by herdsmen. The results showed that ligneous fodder occupied a paramount place in the nutrition strategies of herds. They are essential in dry period for herds' production and health and represent 95% of grazing time. Pruning practices used by herders were globally suitable and found to be essential for herding activities. Unfortunetely these practices are gradually threatened by farmlands expansion through clearance and burning ligneous resources. In this perspective, the authors think that to preserve the mobile herding and their access to fodder resources, policies makers have to promote the integration of herding and crop farming. This study was able to show some herding practices in dry season without linking it to climate change context. It also deals with the issue of land use and its implication on herding activities but was not able to quantify the changes in land use and cover and its impacts on pastoral resources. It is essential to understand how herders' practices may evolve under a changing climate and to be determine the rate of conversion of rangelands to other LULC units and the related consequences. This will help for a good decision making accordingly.

Liao *et al*. (2014) worked on the topic *"Following the Green: Coupled pastoral migration and vegetation dynamics in the Altay and Tianshan Mountains of Xinjiang, China"*. Their objectives were to understand the mobility pattern and its relation with vegetation dynamics along livestock routes, in Altay and Tianshan Mountains of Xinjiang (China). Data were collected through semi-structured interviews, land use mapping, Geolocalisation processes and using Normalized Difference Vegetation Index (NDVI) imagery. Pastoralists communities were involved in land use mapping. This participatory method will be integrated in our research. The results of the study revealed that facing forage shortage, herds mobility amplitudes increase to ensure elsewhere fodder accessibility. Thus, herders' sedentarization as intended by the government will threaten the availability of forage for Altay pastoralists. Therefore, the authors think that the future sustainability and effectiveness of pastoral policies must underlie on local knowledge as guide to decisions making by national and local government institutions. The study was able to show the potential impacts of changes in land use on pastoralists' practices. That aspect is of interest for the current research which will investigate the impacts of the changing land use and cover on not only herds mobility but also on other pastoral practices. Furthermore, this research will quantify changes extent/rate in pasture land that was not addressed by the authors.

Mishra and Rai (2016), used the multi-layer perceptron-Markov chain analysis (MLP-MCA) integrated method to predict changes in land use and land cover within Patna district (Bihar), India. The purpose of these author was to monitor changes in LULC between 1988 and 2013 and predict the future LULC pattern by 2038 and 2050 within the study area. The study relied on the integrated method (multi-layer perceptron-Markov chain analysis (MLP-MCA)). The findings of the study showed that the build-up area have increased (5.08 %) from 1988 to 2013 while a decreased rate was noticed in agriculture land (2.18%), in fallow land (13.23%), in shrubs (1.20%) and water bodies (5.68%). The prediction results showed an increase rate in agricultural land by 2038 and in built-up while the vegetation will decrease. By 2050 agricultural land will decreased as well as vegetation-covered area while built-up will keep on increasing. This study is a perfect illustration of the research activities that we want to carry out under the fourth objective of our research. Therefore, the study did not address the impacts/implications of the observed and future LULC changes patterns on pastoral resources and herders' practices.

Martin *et al*. (2014) , carried out a study on "*How much climate change can pastoral livelihoods tolerate? Modelling rangeland use and evaluating risk*". They aimed to investigate how projected climate change could affect pastoralism within drylands areas. The methodology used was based on an ecological-economic modelling approach taking to an account household type, vegetation growth and herds mobility. The results obtained found out that changes in precipitation and mismanagement practices may threaten pastoral livelihoods. This study focussed on the impacts of changing precipitation on pastoralism without taking to account the temperature that appears, however, to be one important factor likely to threaten pastoral resources within drylands areas. The mobility of herds was also addressed ignoring other pastoral practices that might be suitable adaptive strategies to climate change.

Gentle and Thwaites (2016), conducted a study on "*Transhumant Pastoralism in the Context of socioeconomic and Climate Change in the Mountains of Nepal*". This study sought to understand how transhumant pastoralism was able to survive in a context of climate and socio-economic changes within the study area. The methodology used was based on individual interviews and focus group discussions. From the survey, it appeared that climate change over the study area was evident and have occasioned a real impact on pastoral resources (decreases in water and pasture, replacement of palatable grasses by invasive weeds) and on herds through emergence of new livestock's diseases associated with high mortality rate. Otherwise the socio-economic changes characterized by unsuitable policies, conflicts between herders and non-herders, market influence, increasing youth migration and their disinterestedness for livestock farming are threatening pastoralism. This study addressed one aspect of our objective 3 looking at climate change impact on pastoral resources and practices. However, the authors were not able to give an idea on pasture species which disappeared or are in extinction within the study area. The above-mentioned objective intends also to investigate and give an overview on valuable fodder species lost within Kompienga province due to climate change. Furthermore, the study could not establish a relationship between herders' practices and climate change; what will be investigate as well under the current research.

Soulama *et al*. (2015), investigated the impacts of anthropogenic activities on vegetation within Pama partial wildlife reserve and its surroundings under climate change. The aim pursued by the study was to assess vegetation dynamic under climate variability and human disturbances. The methodology adopted involved analysis of satellite imageries, of climatic data and the assessment of vegetation. A stratified and random sampling method were used to install experimentation plots. An overlay of derived maps of 2001 and 2013 allowed to show the land cover dynamics. The findings showed an overall degradation pattern and namely, forest cover units were converted into shrub or tree savannahs due to the combined effects on climate and anthropic factors. This paper addressed some aspects of the objective 2 of our research topic. But LULC changes analysis are performed over a shorter period (2001-2013) than what is intended by the current research (1987-2015) that will give a recent overview of study area (three years later after the work of the authors). Furthermore, the paper did not deal with the likely future LULC pattern within the study area. This gap will be fulfilled under the objective 4 of the current research.

Kima (2014) conducted a study on " *Assessment of the impact of climate and land use changes on pastoral livestock farming in boulgou province, South-Eastern Burkina Faso*". The aim of the study was to assess climate variability/change and land use/cover dynamics and their related impacts in Boulgou province between 1980 and 2013. To achieve this aim, survey data, climatic data (1980-2012) and landsat images (1989-2013) were retrieved and analysis. Mann-Kendall test, Standard anomalies Index analysis were conducted on temperature and rainfall. Images classification was done usimg maximum likelihood algorithm and survey data were analysed in SPSS Statistics version 22. The results showed a significant upward trend in temperature while rainfall trend was not significant but substantially variable. This have a negative implication for livestock farming. Moreover, the results indicate a decrease in vegetated areas while croplands increased in size. Likewise, farmers depicted an increase in farmland and a decrease in pasture land. The author's study did not account for cross borders transhumance which is gradually facing news challenges due to climate deterioration and land use and cover changes. In addition the author did not look at the forage species that are threatened or disappeared from grazing lands. Moreover, the study was not able to capture the future land use and cover changes as well as their impacts on pastoral herding. These gaps will be fulfilled in the current research under objectives 3 and 4. It will provide information on how climate deterioration and current and future land use/land cover dynamics would affect pastoralism in south-eastern Burkina Faso.

This section allows to give an overview on different concepts related to climate, land use land cover and pastoralism over West Africa. In addition, a review of selected scientific papers dealing with the present research topic was carried out. The analysis of these articles was able to point out some research gaps such as a : (i) lack of findings on climate change impacts on pastoral resources namely rangelands, pastures species and watering points, (ii) insufficient information on impacts of climate change on herders practices; (iii) scarce information on land use and cover changes on rangelands and pastoral practices and finally (iv) a lack of information on prediction of future land use land cover pattern and its impacts on rangeland and accordingly on pastoralism.

These gaps therefore have served as a springboard for achieving the objectives assigned to current research. For this purpose, a series of methods has been adopted as described in the following section.

CAHPTER THREE

3.0. MATERIALS AND METHODS

3.1. Methodological Flow Chart Framework

The flow chart (Figure 3.1) summarizes the main steps followed to achieve the aim of the research work. These steps give an overview on data type analysed and techniques used to carry out impacts assessment throuth the following three main axes:

(i) The first axis evaluated the climatic change impacts on pastoral resources and practices in Kompienga province. For this purpose, climate data over 36 years (1981-2016) were collected and analysed using R software 3.3.2 and XLSTAT 2014.5.03.

(ii) The second axis studied the perceptions of pastoralists and agro-pastoralists on changes in climate and LULC and their implications on pastoral resources and practices. It was conducted through both individual survey and focused group discussions.

(iii) The third axis was related to land use and cover dynamics. This was done by retrieving and analysing Landsat images using R software 3.3.2 and QGIS 2.18.3.

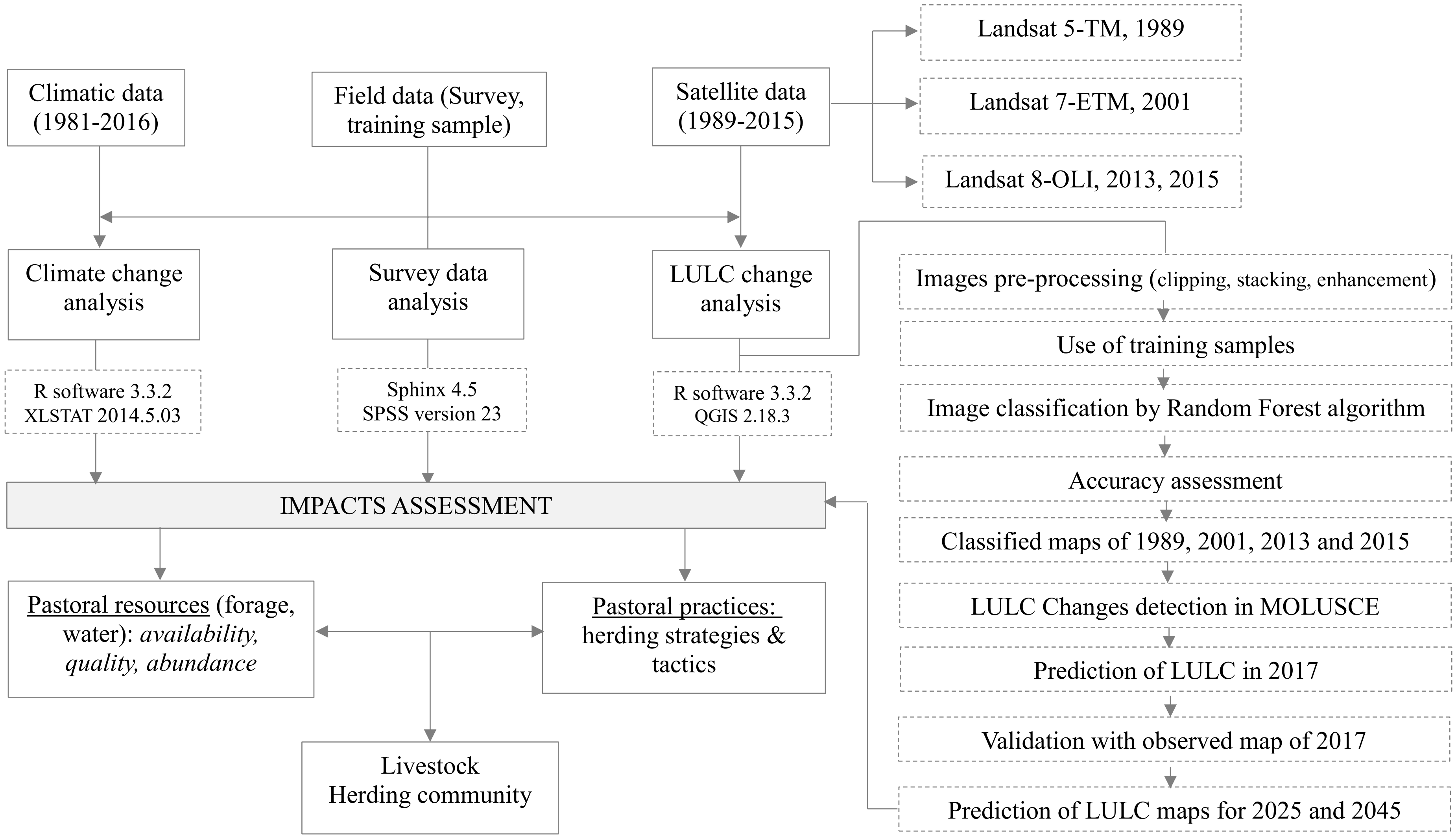


Figure 3.1: Methodological flow chart

3.2. Data Collection Methodology

3.2.1. Climatic data collection

Climatic data over a thirty-six years period (1981-2016), were collected from National Office of Meteorology (*Direction Générale de la Météorologie du Burkina Faso*). The parameters studied are maximum and minimum temperatures, rainfall, relative humidity and potential evapotranspiration of the study area. Two periods, the climatology (1981-2010) and the period (2011-2016) were investigated and the mean of climate parameters compared over the two periods.

3.2.2. Satellite data collection

Satellite images of the study area were acquired from United States Geological Survey (USGS) website. These images were acquired following the path 193 and row 52, from Landsat-5 Thematic Mapper (TM), Landsat-7 Enhanced Thematic Mapper Plus (ETM+) and Landsat-8 Operational Land Imager (OLI). The respective characteristics of these Landsat Satellite are shown on appendix C. The periods of interest for images analysis covers three sets of periods (1989, 2001, 2013) with twelve years intervals. However, the image of year 2015 was also analysed because major changes in land use were noticed after 2013. 350 training sample were collected from field, over the study area for both the purpose of supervised classification and accuracy assessment. The collection was performed within chosen training areas representing the identified land use land cover classes. Training sample were also, as much as possible, generated directely from each satellite image based on the visual interpretation after image enhancement in QGIS 2.18.3 software.

For the purpose of a better accuracy, ground truth data were collected avoiding pixels over a transition area between two or more classes. Each sample unit was geo-localised by taking GPS points as much as possible at it centre. These points were collected between June and July and land use and cover units were photographed.

3.2.3. Survey data collection

3.2.3.1. Sampling

Survey data was collected in twelve (12) out of thirty-eight (38) villages in the province to conduct the study. The selection of these villages was based on some criteria such as: (i) importance of herding (ii) recurrence of conflicts among land users; (iii) constraints in range lands and other pastoral resources conditions.

The targeted respondents of the study were pastoralists and agro-pastoralists household heads and respectively classified as owner of 10-25 cattle for agro-pastoralists then more than 25 cattle for pastoralists. A total of 271 respondents were involved in the study (Table 3.1). Besides these respondents following stakeholders were also interviewed: (i) representatives of livestock's public services, (ii) representatives of environment service, (iii) prefects of the three districts, (iv) representatives of Non-Governmental Organization (RECOPA, Andal and Pinal), (v) representatives of Regional Support Project to Pastoralism in Sahel - Burkina Faso ('*Projet Régional d'Appui au Pastoralisme au sahel Burkina Faso (PRAPS-BF)*'). Furthermore, group discussions were conducted within each targeted village. Each group was composed of at least three persons of age not less than 45 years. This is essential for observations or analysis of changes in climate and land use and cover dynamics.

Table 3.1: Respondents involved in the study

Villages	Main activities		
	Pastoralism	Agro-pastoralism	Total
Nadiagou	16	11	27
Oumpougoudeni	7	20	27
Mamanga	13	4	17
Kaboanga II	11	17	28
Kalmama	6	12	18
Bombantangou	2	7	9
Folpodi	14	7	21
Madjoari	3	2	5
Bounou	14	4	18
Diabiga	3	17	20
Kpankpaga	41	19	60
Kompienga	18	3	21
Total	148	123	271

Source : Author's field work, 2017

3.2.3.2. Data collection on farmers' perceptions

Data collection was conducted both through individual survey and focused group discussions following these steps:

(i) A questionnaire was first designed around the key points, namely the perception of farmers on climate change and its impact on pastoral resources and herder's practices. This questionnaire first written in English was then translated in French to facilitate understanding by the translator to ensure a better translation of the questions in local languages.

(ii) Conduct of survey: this was carried out both through an individual interview of household' heads and groups discussions. Groups discussions were done as complementary to individual interviews. Discussions were conducted following a Semi-Structured Interview Methodology.

During these discussions, participants' perceptions were collected on the past and present climate conditions as well as on land use and cover dynamics. On the one hand, they were asked to make a comparison of the key climatic parameters according to their own understandings. This was about the amount and intensity of rainfall, occurrences and intensities of drought, floods, strong winds over two sets of periods: Past (1987) and Present (2017). On the other hand, they were asked to illustrate changes in LULC between 1987 and 2017. For this purpose, the following steps were followed: (i) the representation on a "*kraft paper*" of the village territory with the current major existing resources (houses, roads, water bodies, bore hole, wells, forests, farms lands, livestock's routes, grazing lands…); (ii) the representation of a past picture of the village territory with the majors existing resources; (iii) a participatory analysis was done to give an idea on how the main LULC units have changed over the last three decades and their implications in herders' access to pastoral resources. An investigation was done from transhumant pastoralists over their constraints on their way to transhumance. They were also invited to design on a "*kraft paper*" the villages territories crossed during their movement. They were then asked to focus on zones characterised by recurrent conflicts most often resulting in casualties of both men and livestock.

Furthermore, a survey on threatened forage species, was carried out both through individual survey with 271 respondents (pastoralists, agro-pastoralists) and group discussions. The name of different forage species investigated was given in local languages: *Fulani, mooré and gourmatcheman*. Their scientific names were determined with the help of experts from the National School of Water and Forests (*Ecole Nationale des Eaux et For*êts) and the National Center of Forestry Seeds (*Centre National de Semences Forestières (CNSF)*).

3.3. Data Preparation

3.3.1. Preparation of climate data

Climate data were arranged in Excel sheets in a suitable format to allow subsequent computation analysis of targeted climatic parameters (rainfall, temperature, relative humidity, potential evapotranspiration (ETP)).

3.3.2. Preparation of satellites data

Satellite images were pre-processed before proper analysis. Pre-processing of satellite data consisted in images enhancement through bands combinations to provide false colour composite for better images observations and better classification or interpretation of land use land cover units. Image enhancement was done through Red-Green-Blue (RGB) composite using the bands NIR, Red and Green. This corresponds to the combination of bands 4. 3. 2 for TM/ETM+ while its corresponds with the combination of bands 5.4.3 of OLI because Landsat 8 data includes additional bands (band 1 and 9) responsible to a spectral shift in Landsat 8 bands (USGS, 2013). According to (Soungalo, 2016), the RGB composite of NIR, Red and Green is a suitable bands combination for vegetation characterization. In this combination, vegetation appears red, water appears navy blue or black and they are especially responsive to the amount of vegetation biomass present in the images (Kima, 2014). QGIS 2.18.3 software was used for bands combination and images enhancement process using the Semi-Automatic Classification Plugin (SCP). Image enhancement ensures the improvement of images interpretability.

3.3.3. Preparation of data collected from the respondents

Data entry for individual survey was carried out using an input mask designed with the software Sphinx version 4.5. For the focus group discussion data collected were compiled using Excel software following headings established according to the key information derived from group discussion.

3.4. Data Analysis

3.4.1. Statistical analysis of climate data

3.4.1.1. Rainfall data analysis

For rainfall data analysis, the following characteristics were considered in the analysis:

i. The annual rainfall for each year between 2011 and 2016; and the annual average rainfall of the climatology (1981-2010) were computed to investigate the inter-annual variation and the anomaly in the rainfall pattern over the last decade.

ii. The Standardized Anomaly Index (SAI) of rainfall which determines the precipitation deficit for multiple time scales (WMO, 2012) was also determined as followed:

$$\text{SAI} = \frac{(x-\mu)}{\delta} \quad (3.1)$$

where χ is the total annual rainfall, μ is the mean of all the series and δ the standard deviation from the mean of the series. The analysis of this index allows to characterize a year as dry or rainy year on the basis of the Standardized Anomaly Index value (Table 3.2).

Table 3.2: Characterisation of years according to the anomalies index values

Index Values	Interpretations
2.0 and over	Extremely wet
1.5 to 1.99	Very wet
1.0 to 1.49	Moderately wet
-0.99 to +0.99	Near normal
-1.0 to -1.49	Moderately dry
-1.5 to -1.99	Severely dry
-2 and less	Extremely dry

Source : McKee *et al.* (1993) ; WMO (2012)

iii. Monthly rainfall values for each year of the period 2011-2016 and for the climatology (1981-2010) were computed and plotted using R software version 3.3.2.

iv. Rains onset (X) was determined as the cumulative amount of at least 20mm of rainfall during three successive rainy days after 1st April with no dry spell beyond 7 days within the following 30 days (Somé and Sivakumar, 1994; Kiema, 2013; Kima, 2014).

v. Rains cessation (Y) occurs when there is no rainfall beyond or equal to 5 millimetres obtained by unit or cumulative rainfalls event over at least 20 successive days after the 1st September. The duration of the rainy season (Z) is the difference in days between the cessation and the onset of the rainy season (Y – X) (Somé and Sivakumar, 1994).

vi. The number of rainy days was also computed and its trend determined over the study period.

vii. A trend analysis was performed on the onset, the cessation, the length of rainy season, the number of rainy days. For this purpose, Mann-Kendall test was done. This test is a non-parametric test used to identify trends in time series data. The essence of the test is to compare each data value with all subsequent data value within the time series. It is assumed that initial value of the Mann-Kendall statistic, S equals 0 (meaning no trend). The value of S is incremented or decremented by 1 depending on whether the subsequent value of the data is greater or less than the data value from an earlier time period. The final value of S is obtained by computing all the increments and decrements values of S (Khambhammettu, 2005).

The formula of Mann-Kendall statistic (S) is as followed:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sign(x_j - x_k) \qquad (3.2)$$

where:

sign (x j − xk) = 1 if xj − *xk*> 0

sign (x j − xk) = 0 if xj − *xk* = 0

sign (x j − xk) = -1 if xj − *xk* <0

x1, x2, … xn represent n data points with x j the data point at time j.

When S has a high and positive value that means an increasing trend in the time series; while a low negative value shows a decreasing trend. The probability associated with S value need to be compute in order to analyse the statistical significance of the observed trend in the time series. This probability is given by the following formula:

$$f(z) = \frac{1}{\sqrt{2\pi}} \frac{e^{-z^2}}{2} \qquad (3.3)$$

where Z value can be respectively negative, null or positive:

$$Z = \frac{S-1}{[VAR(S)]^{1/2}} \quad \text{if } S > 0 \qquad (3.4)$$

$$Z = 0 \quad \text{if } S = 0 \qquad (3.5)$$

$$Z = \frac{S+1}{[VAR(S)]^{1/2}} \quad \text{if } S < 0 \qquad (3.6)$$

Data analysis have been done using the software XLSTAT 2014.5.03. In the process of trend analysis two hypothesis were defined: a null hypothesis (H0): There is no trend in the time series and an alternative hypothesis (Ha): There is a trend in the time series. H0 is accepted when the p-value computed is lower than alpha (0.05) and H0 is rejected when the p-value computed is greater than alpha (0.05).

3.4.1.2. Temperature data analysis

As for rainfall data analysis, the standardized anomalies were computed for both minimum and maximum temperature. Furthermore, the trend analysis of the temperature was carried out over the last three decades to assess any change in the climate pattern using XLSTAT 2014.5.03. A comparison between annual and monthly mean temperature of the climatology (1981-2010) and that of each year of the period 2011-2016 was carried out. Deviations of average values of each year from the climatology average values were also computed to assess changes in temperature. R software version 3.3.2 was used to plot monthly evolution of mean temperature of the climatology and that of each year of the period 2011-2016.

3.4.1.3. Analysis of Relative Humidity and Evapotranspiration

A trend analysis was done on other climatic parameters such as Relative Humidity, Potential Evapotranspiration. Deviations of average values of each year from the climatology average values were computed to assess changes in Relative Humidity and Potential Evapotranspiration.

3.4.2. Land use and land cover changes analysis

3.4.2.1. Images classification

Classification method adopted used the Random Forest Algorithm run (RFA) in R-Software (version 3.3.2). This classification technique is one of newest proposed by Breiman (2001) for classification and clustering. It was chosen because of its good level of correctness. Indeed, Random Forest has an unexcelled accuracy among current algorithms (Lowe and Kulkarni, 2015 and Kulkarni and Lowe, 2016). Thus, in a comparative study, Lowe and Kulkarni (2015) found for the RFA an overall accuracy (96.25%) and Kappa coefficient (0.95) greater than those obtained respectively by Neural Network algorithm (76.87% and 0.69), Support Vector Machine algorithm (86.88% and 0.83) and Maximum Likelihood algorithm (83.13% and 0.78).

In order to determine the number of land use land cover classes a field observation was done as complement to the visual interpretation of satellite images. The choice of land use and land cover classes was inspired from the National Topographic Data Base of Burkina Faso: "*Base Nationale de Données Topographiques du Burkina Faso (BNDT) 2015)*" (IGB and IGN/IGN-FI, 2015). These classes consist in: 1: gallery forest/wet area, 2: woody savannah/shrubs/grassland, 3: croplands, 4: water body; 5: settlement/urban 6: bare land. The description of these land use land cover is as followed (Plate I to V):

Plate I: Field photograph of Gallery forest

Plate II: Field photograph of Woody Savannah

Plate III: Field photograph of Shrub and grassland

Plate IV: Field photograph of cropland

Small reservoir of rainy season Kompienga dam

Plate V: Field photograph of water body

Urban/settlement: This class encompasses villages settlements and towns within the province of Kompienga involving buildings, houses and roads.

3.4.2.2. Land use land cover changes detection

Satellite images time series were used to investigate changes detection in the landscape particularly in the pastoral resources (pasture lands, water) distribution pattern. It has helped to observe how range lands have been affected or depleted over the last decades. QGIS software version 2.18.2 was used for land use land cover change detection using the plugin MOLUSCE (Modules for Land Use Change Evaluation). This plugin provides a set of algorithms for land use change simulations among which Artificial Neural Networks (ANN) was used. It allows the generation of statistics table showing land use/cover change (LUC) areas and the transition matrix depicting the proportions of pixels that changed from one land use/cover to another. QGIS software version 2.18.2 was also used for vectorization, images clipping and land use land cover maps production for years 1989, 2001, 2013 and 2015. The increase or decrease rate of croplands areas and grazing lands areas was estimated using the formula :

$$APCR = \frac{\frac{(lulc_{present} - lulc_{past})}{lulc_{past}} \times 100}{N} \qquad (3.7)$$

where :

APCR = annual percentage change rate in land use and cover

$lulc_{present}$ = present or recent area (ha) of land use and cover

$lulc_{past}$ = past area (ha) of land use and cover

N = number of years between the two land use and cover

3.4.2.3. Accuracy assessment of image classification

In the process of classification accuracy assessment, training samples were used to verify the correctness of the classification. For this purpose, these samples were divided in to two subgroups: 70% used to perform images classification and the remaining 30% used for validation. The result gives a confusion matrix that compare the cartographic results and the data collected in the field. From the confusion matrix, common measures of accuracy assessment were derived such as user' accuracy, producer' accuracy, overall accuracy and Kappa coefficient. These measures were computed using the Table 3.3 to derived required formulas (Foody, 2002). R software 3.3.2 was used in this accuracy assessment.

Table 3.3: Principle of accuracy computation

		Actual LULC Units				
		A	**B**	**C**	**D**	**Sum**
Predicted LULC units	**A**	**n AA**	n AB	n AC	n AD	n A +
	B	n BA	**n BB**	n BC	n BD	n B +
	C	n BC	n CB	**n CC**	n CD	n C +
	D	n DA	n DB	n DC	**n DD**	n D +
	Sum	n +A	n+B	n +C	n +D	n

Source : Foody (2002)

$$\text{Percentage correct} = \frac{\sum_{k=1}^{q} n_{kk}}{n} \times 100 \tag{3.8}$$

$$Kappa\ coefficient = \frac{n\sum_{k=1}^{q} n_{kk} - \sum_{k=1}^{q} n_{k+}\, n_{+k}}{n^2 - \sum_{k=1}^{q} n_{k+}\, n_{+k}} \tag{3.9}$$

$$User's\ accuracy = \frac{n_{ii}}{n_{\mathrm{i}+}} \tag{3.10}$$

$$Producer's\ accuracy = \frac{n_{ii}}{n_{+\mathrm{i}}} \tag{3.11}$$

3.4.2.4. Analysis of survey data

Statistical analysis was carried out on data collected from respondents. The Statistical Package for Social Science (SPSS) software, version 23 was used to code and analyse these data exported from Sphinx 4.5. Results obtained were presented through charts and tables.

Frequency analyses and Pearson's chi-squared test were done for question statements relating herding experiences, ethnic group and respondents' ages and statistical tests significance was set at 5%. Participatory maps produced during groups discussions were analysed together with respondents putting a light on land use and cover dynamics and their drivers within each village.

3.4.3. LULC changes prediction

Changes prediction analysis of LULC within the study area was perfomed using the plugin MOLUSCE (Modules for Land Use Change Evaluation) of QGIS software version 2.18.2. The process of land use land cover modelling involved the following major steps:

i. Variables selection : in order to enhance the accuracy of land use and cover change prediction some factors have been considered. These factors are variables such as the slope, the elevation, the aspects and distances to major roads. Distance to road is an important factor because it consists of one of the most importance drivers of land use and cover changes. Indeed, roads networks development underpins built-up development and anthropogenic activities expansions (farming and other pressure on land and its resources).

ii. Land use and cover transition. This step involved giving an overview of the major transitions between land use-cover units. It allows to create transition matrix between $LULC_{t1\ (at\ time\ t1)}$ and $LULC_{t2\ (at\ time\ t2)}$, and change maps that gives room to the construction of prediction model.

iii. Transition potential modelling : at this step, Artificial Neural Network (ANN) algorithm was used to model transition potentials. A Probability matrix was generated from the transition matrix ($LULC_{t1}$ – $LULC_{t2}$) and subsequently used for land use and cover prediction.

iv. Validation of the model and land use and cover predictions: the validation of the model was carried out by comparing the predicted map of 2017 with the observed map of the same year. In the process of validation, the accuracy of the prediction model was tested in term of location ($K_{location}$) and quantity (K_{histo}) using Kappa statistics as suggested by Pontius (2002). Therefore, the overall Kappa is defined as the product of two factors ($K = K_{location}\ x\ K_{histo}$). The first factor is $K_{location}$, which is a measure for the similarity of spatial allocation of categories of the two compared maps. The second factor is K_{histo}, which is a measure for the quantitative similarity of the two compared maps (Gómez and Montero, 2011). After validation of the model, land use and cover in the study area was predicted over next decades (2025 and 2045). The cellular automata simulation tab in MOLUSE allowed to run the prediction model based on the transition potential statistics used as input in the process.

CHAPTER FOUR

4.0. RESULTS AND DISCUSSION

4.1. Statistical Analysis of Climate Data of Kompienga Province

4.1.1. Rainfall

4.1.1.1. Annual rainfall amount

Figure 4.1 Shows the results of the statistical analysis of rainfall data of Kompienga province over the period 1981-2016. During this period, the year 1998 was the wettest year (1 266.7 mm) with 65 rainy days and the year 1983 was the driest year (586 mm) with also the lowest number of rainy days (33 days). Kima (2014) obtained different results (1 136.7 mm and 591 mm) for maximum and minimum rainfall amount respectively. The highest number of rainy days occurred in 1994 (78 days). Globally, between 1995 and 2010 the number of rainy days decreased while the rainfall concentration increased. After 2010, both the number of rainy days and rainfall concentration globally decreased compare to the period 1995-2010. This can be attributed to climate changes effects. The recent reduction in rainfall would be affecting rain related activities such as crop and livestock farming in the province.

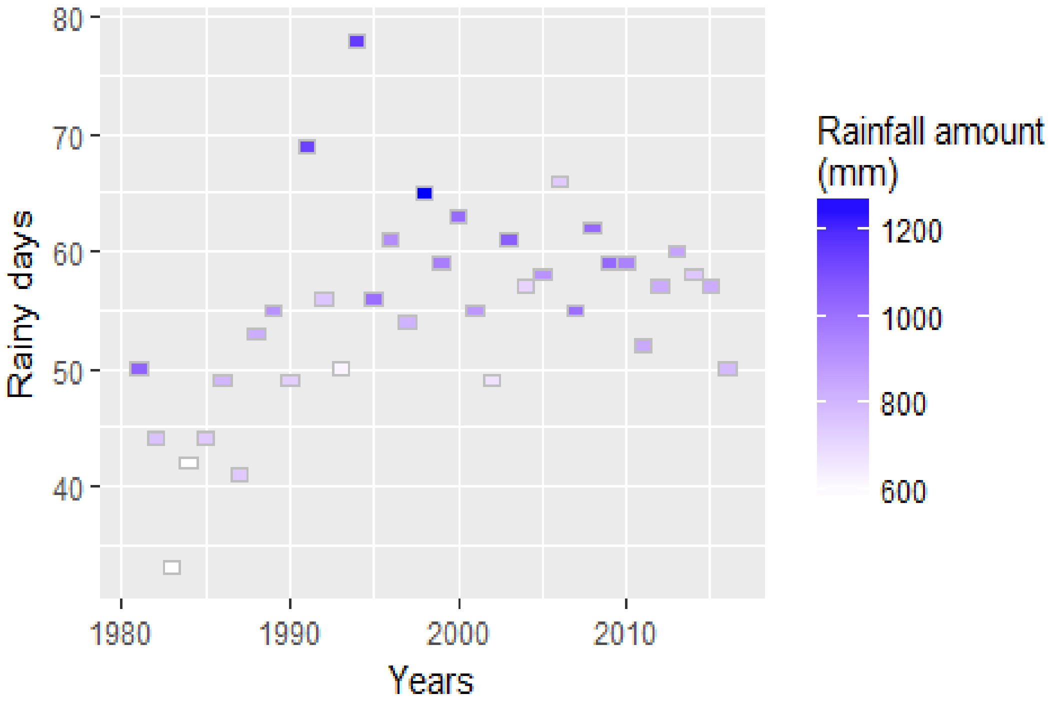


Figure 4.1: Compared evolution of annual rainfall and rainy days in Kompienga Province

4.1.1.2. Rainfall categories

Figure 4.2 presents five rainfall categories of the climatology compared to that of the last six years (2011 to 2016). It appears that the rainfall category [0-10mm] is predominant for all the periods. The climatology (1981-2010) constitutes the standard for which the rainfall categories will be compared with those of the last six years (2011, 2012, 2013, 2014, 2015 and 2016). The percentages of rainfall category [0-10mm] over the last six years (59.6%, 61.4%, 56.7% 62.1%, 56.1% and 56.0% respectively) are all greater than that of the climatology (52.6%). For the category [10-20mm], the percentage is lower over the year 2013 (18.3%) and 2014 (19.0%) than that of the climatology (20.7%). With the exception of the year 2013, the percentage of the rain category [20-40mm] over 2011 (15.4%), 2012 (15.4%), 2014 (13.8%), 2015 (12.3%) and 2016 (14.0%) are lower than that of the climatology (19.1%). The percentage of the category [40 - 60mm] over the years 2011 (1.9%), 2012 (3.5%), 2013 (3.3%), 2014 (3.3%), and 2015 (5.2%) is lower than that of the climatology (6.0%) which is equal to the percentage in 2016 (6.0%). For the rainfall category (>60mm), the percentages are greater over years 2011 (1.9%), 2012 (1.8%), 2013 (1.7%), 2015 (3.5%), 2016 (2.0%) than that of the climatology (1.6%) except the year 2014 (0.0%).

The analysis of these results suggests a negative change in rainfall patterns in recent years with global predominance of the lowest ([0-10mm]) and the highest (>60mm) rainfall categories. This may have negative implications for crop and livestock farming. Either the amount of rainfall will be insufficient for crop production and pasture growth in grazing lands, or the rainfall could be excessive with risk of flooding. Kiema *et al.*, (2013), indicated similarly the predominance of ([0-10mm]) in Diapaga and Kantchari (south eastern Burkina Faso) over two normal periods 1941-1970 and 1971-2000. But unlike this study, the frequencies of rainfall categories were gradually decreasing while the categories increase.

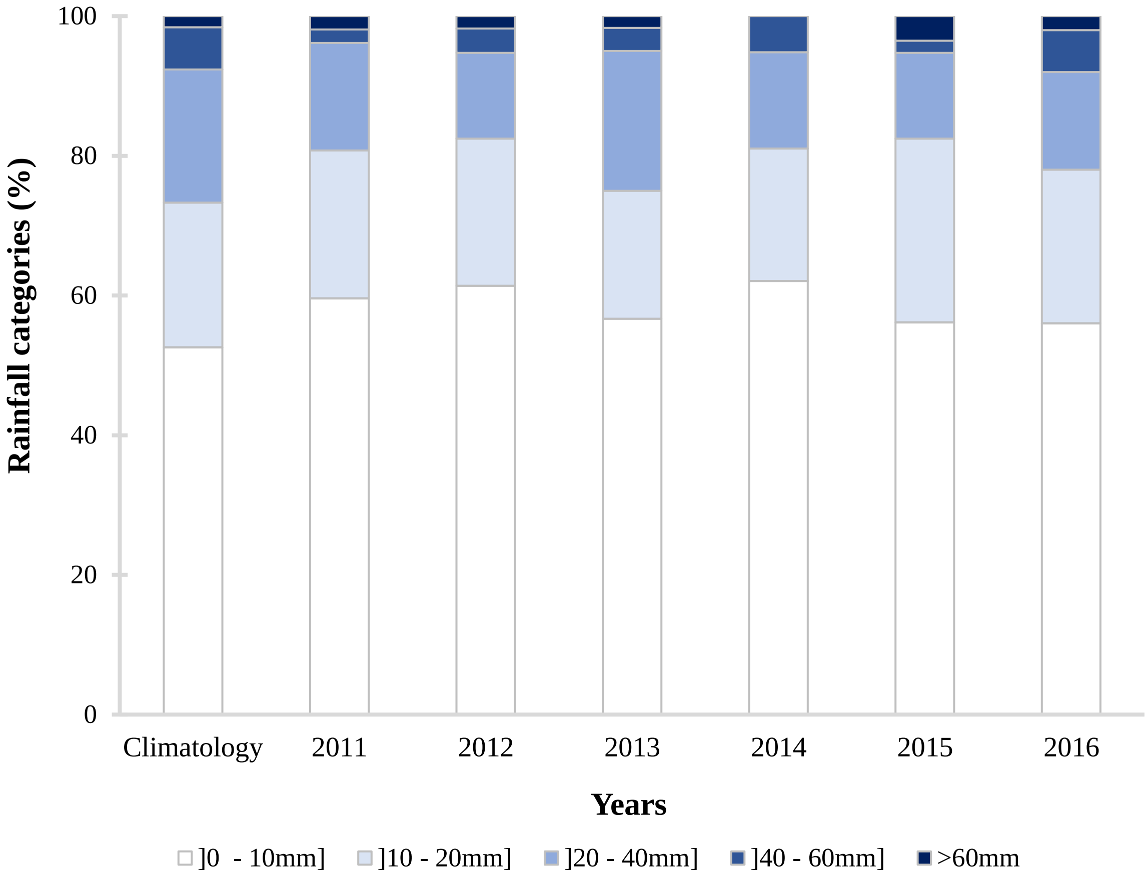


Figure 4.2: Comparison of rainfall categories between climatology (1981-2010) and years of the period 2011-2016

4.1.1.3. Rainfall characteristics in Kompienga

The onset, cessation, length of the rainy season, number of rainy days, and annual rainfall amount in Kompienga Province from 1981 to 2016 is presented in Table 4.1. Among these parameters rainy season length, onset and cessation appears to be paramount for both crop production and pasture growth and availability for herds. The averages onset and cessation are 16th June and 15th October respectively with a standard deviation of 9 days each. The rainy season length is 111±27 days with 55±8 rainy days and 867,0±164,3 mm of annual rainfall on average.

Kiema *et al*. (2013) conducted similar study on onset, cessation, rainy days and rainy season length in two districts (Kantchari and Diapaga) over two normal periods 1941-1970 and 1971-2000. For the normal period (1941-1970), the authors found in Kantchari district (17^{th} June ±27 days) a similar value of onset to that of Kompienga (16^{th} June±9 days); but in Diapaga district the onset (9 June ±29 days) is observed to be earlier. Similarly in Fada, Sarr and Kafando (2011) observed that the onset (10 June±18) is earlier. These authors also found out different values of rain cessations: 30 September±11 days, 5 October ±8 days and between 16-21 October respectively for Kantchari, Diapaga and Fada. The cessation is earlier in Kantchari and Diapaga districts while later in Fada than in Kompienga. Kima (2014), found out an earlier onset (9^{th} June±18 days) and cessation (7^{th} October±9days) in Boulgou Province. Longer rainy season length was also found by Kima (2014), Sarr and Kafando (2011) and Kiema *et al*. (2013) respectively in Boulgou (119±21days), Fada (120±23) and Diapaga (117±30 days) than in Kompienga (111±27 days). However, in Kantchari, the rainy season length was a bit shorter (105±34 days) than in Kompienga (Kiema *et al*., 2013). Except in Boulgou with 50 rainy days, the number of rainy days was quite similar for Kompienga (55 rainy days), Kantchari (54 rainy days) and Diapaga (56 rainy days).

For the normal period (1971-2000), the onset date in Kompienga was similar to that found by the authors in Kantchari (20^{th} June ±22 days) and Diapaga (and 18 June ±29 days). However, rain cessation dates were earlier in Kantchari (23 September±12 days) and Diapaga (22 September ±13 days) than in Kompienga. The length of the rainy season was observed to be longer in Kompienga than in Kantchari (95±26days) and Diapaga (97±35 days). The rainy days in Kompienga is quite different from that found by the authors in Kantchari (52 rainy days) and Diapaga (50 rainy days). The earliest onset (28^{th} April) in

Kompienga over the last 36 years occurred in 2012 while the most delayed onset (5th August) was noticed in 2003. In addition, the earliest cessation (12th September) and the most delayed cessation (31th October) occurred respectively in 1991 and 1982. There are three months between the earliest onset and the most delayed onset and more than one month between the earliest cessation date and the most delayed one. This situation indicates a very great variability in the onset and the cessation of the rainfall. As a result, there is great inter-annual variability of the LRS and the growth of annual forage species accordingly.

Space-time variability of rainfall amounts and the onset and cessation of the rains affects negatively agriculture production (Camberlin and Diop, 2003) and certainly pasture. The lack of pasture due to the delayed onset of rainfall results in an early departure of herds in cross-border transhumance, with all the risks that this may represents for pastoralists. Indeed, the major host countries (Togo, Benin), have set official dates of entry and departure of transhumant herds from their territories. For example, for the transhumance campaign 2016-2017, the official dates for Benin republic depending on the departments visited by transhumant herds, were 15 to 31 December 2016 and 31 March to 30 April 2017 respectively for the entry and departure dates.

Table 4.1: Rain onset, cessation, length of the rainy season, number of rainy days, and annual rainfall amount in Kompienga Province from 1981 to 2016

Parameters	Mean	Standard deviation	Minimum	Maximum
Onset	16th June	9	28 th April	5th August
Cessation	15 th Oct.	9	12 th Sept.	31 th Oct.
Length of rainy season (days)	111	27	63	181
Number of rainy days	55	8	33	78
Rainfall amount (mm/year)	867.0	164.3	582.5	1266.7

Source : Author's computation, 2017

4.1.1.4. Comparison of rainfall parameters between the normal period (1981-2010) and the period 2011-2016

- Monthly precipitation

Figure 4.3 shows the situation of rainfall on monthly basis of the climatology (1981-2010) and the six last years. The climatology period had less dry months than the last six years. Indeed, the climatology shows five dry months with traces of rain of the order of 0.4; 0.6; 8.8, 0.7 and 0.3 mm respectively for January, February, March, November and December. While these months are totally dry for the last six years in exception of 2013 and 2014 which recorded each rainfall in the order of 16.5 mm in March. The months of June in 2011 and 2012 registered far lower rainfall amount (47.7 and 13.3 mm respectively) than that of June of the climatology (125.5 mm). During the months of July 2011 to 2016, there were fewer rainfall (134.5, 137.2, 119.9, 147.7, 160.5, 136 mm respectively) compared with July of climatology (162.3 mm). In exception of 2011 (44.6 mm) and 2012 (59.6 mm), October of 2013 (24.7 mm), 2014 (7.7mm), 2015 (30mm) and 2016 (13.5mm) is drier than October of the climatology (44.2 mm). The months of May, August and September present a great variability between the climatology and the six last years. The months of May of the years 2012 (243 mm), 2016 (142.7 mm) recorded more rains than May of climatology (93.4 mm) and that of the other years. In addition, August 2011 (391.8 mm) and 2015 (297.2 mm) proved to be wetter than the month of August of climatology (243.9 mm) and that of the other years. Finally, the month of September 2012 (189.1mm), 2013 (166.4mm), 2014 (212.4mm) and 2016 (185.3mm) appears to be wetter than the September of climatology (160.4mm) and that of the other years. It appears a great variabilities of monthly rainfall amount and dry months. This affects annual biomass and water availability for livestock grazing and watering. Indeed, it may result to high variabilities of forage species growth cycle (germination, establishment, senescence) within grazing lands. In a similar way, it may result, a variability of the availability of watering point mainly based on annual water bodies. Consequently, livestock production performance and herders' practices might be deeply disturbed.

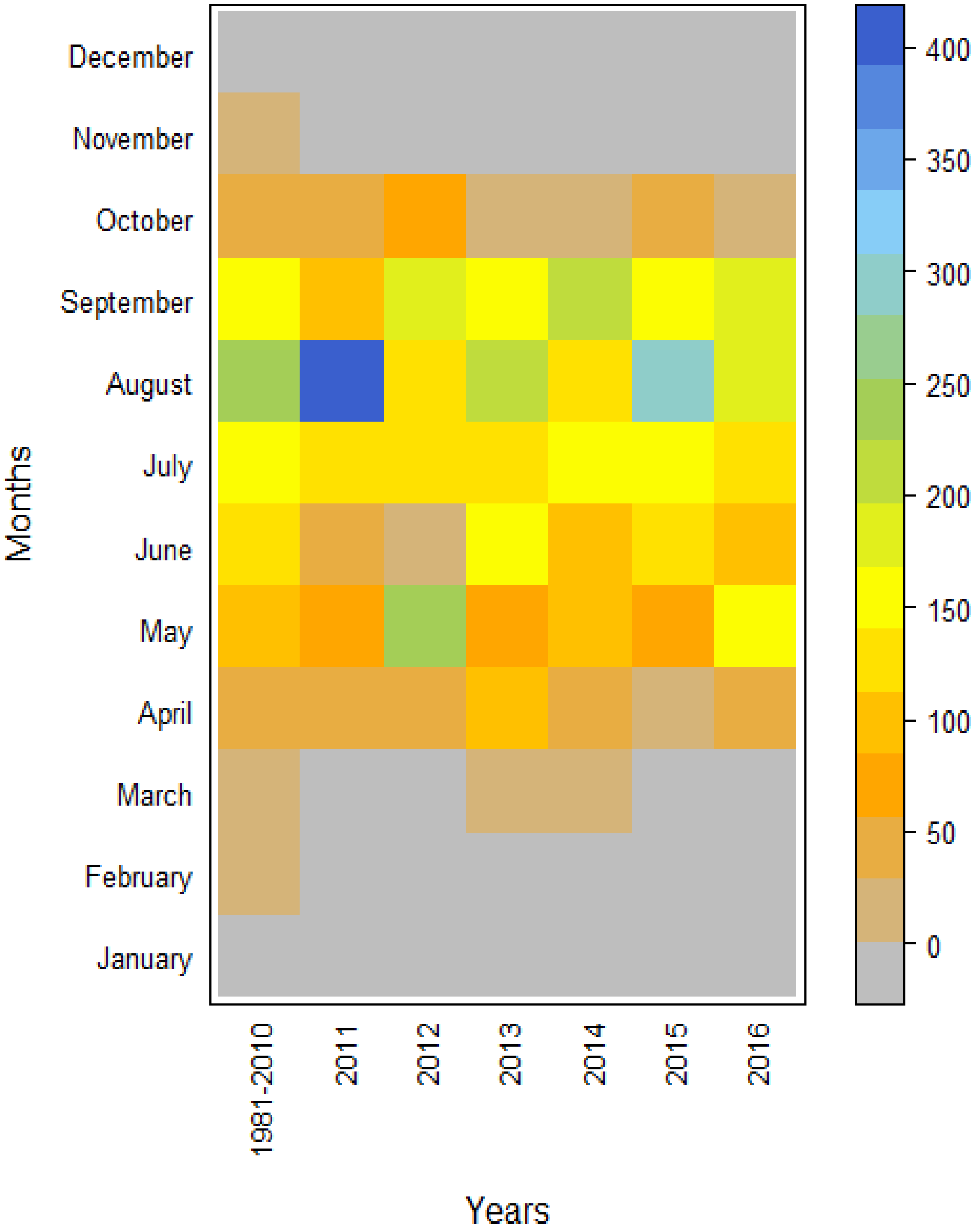


Figure 4.3: Dry and wet months of the period 2011-2016 and that of the climatology

➤ Annual mean rainfall

Figure 4.4 describes the comparison of the mean annual rainfall amount of the Climatology with that of each year between 2011 and 2016. The results reveal that the amount of annual rainfall registered between 2011-2016 were lower than that of the climatology. This may be attributed to negative effects of climate change. The implications might be negative both for crop production and livestock farming. Indeed, with the decreasing rainfall amount, the majors crop species produced in the province (maize, cotton, sorghum. …) may have difficulties to attain their maturity and may also affect negatively pasture growth in the province. Consequently, there is an early shortage of pasture which underpin the increasing mobilities of herders in search of forage.

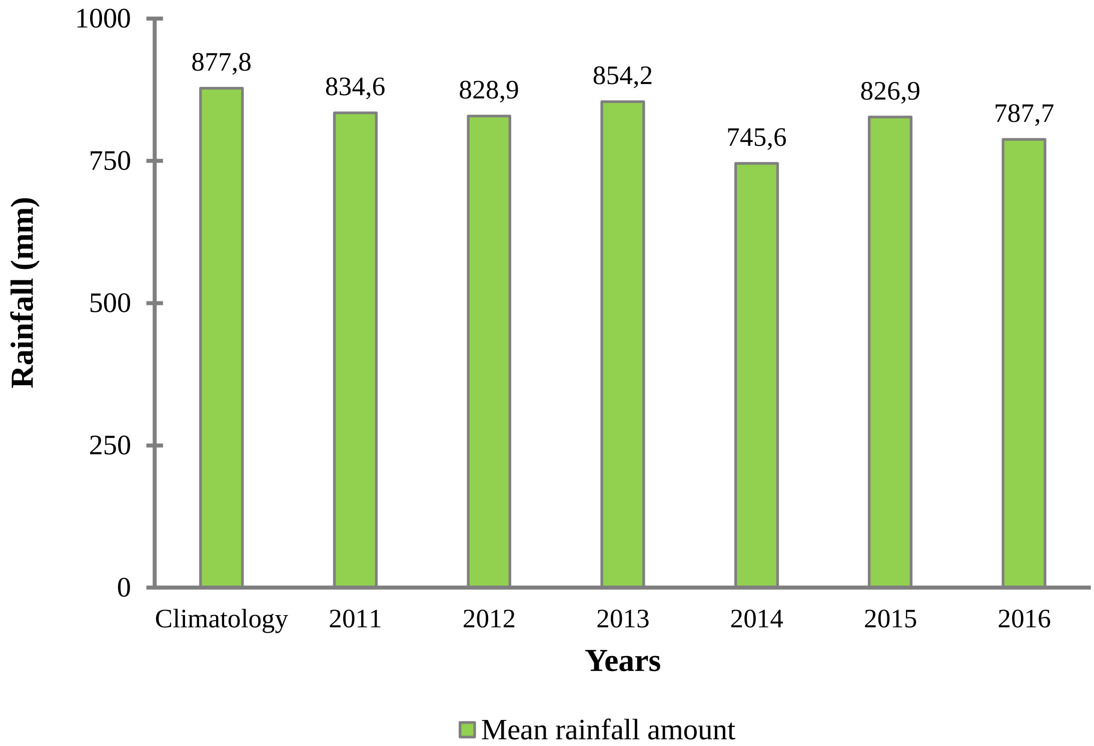


Figure 4.4: Compared annual rainfall between climatology and the period 2011-2016

➢ Onset, cessation, rainy days and rainy season length

Table 4.2 depicts how the onset, cessation, rainy days and rainy season length over the period 2011 to 2016 differ from the climatology. The results show that all the parameters studied over the last six years, differ from the climatology values. In rain onset it is observed to be earlier in 2012 and 2015 but later in 2011, 2013, 2014 and 2016. Rain cessation results shows that it is earlier in 2011, 2013 and 2014 but later in 2012, 2015 and 2016. A similar trend is observed in the Length of Rainy Season where it is shorter in 2011, 2013, 2014 and 2016 but longer in 2012 and 2015. The Number of Rainy days is lesser in 2011 and 2016 but higher in 2012, 2013, 2014 and 2015. This differencies can be accounted for as a result of climate variabilities. At the difference of 2011, 2013, 2014 and 2016, 2012 and 2015 had the best performance in terms of rain onset, rain cessation, Length of Rainy Seasson and number of Rainy Days. This is a confirmation of climate variability in the study area.

Table 4.2: Comparison of rainfall parameters between climatology and last six years

Climate parameters	1981-2010	2011	2012	2013	2014	2015	2016
Rain onset	15 June	9 July	28 April	19 June	28 July	10 June	25 June
Rain cessation	15 Oct.	10 Oct.	27 Oct.	4 Oct.	2 Oct.	20 Oct.	22 Sept.
LRS (days)	110.9	92.0	181.0	106.0	65.0	131.0	88.0
NRD	55.1	52.0	57.0	60.0	58.0	57.0	50.0

LRS: Length of rainy season; NRD: Number of rainy days

Source : Author’s computation, 2017

4.1.1.5. Trend analysis

Trend analysis of rainfall parameters over 36 years (1981-2016) in Kompienga province is presented on the Table 4.3. The rainy days show a significant positive trend at 95% confidence level (p-value=0.006) (Figure 4.5). The figure gives an overview on the trend of rainy days with a trend curve whose slope is 0.357 reflecting a rather low growth of the number of rainy days per year since 1981. With the exception of the number of rainy days, all the other parameters (onset, cessation, length of rainy season, annual rainfall amount, and wettest month of the years) did not show any significant trend at 95% confidence level over the last decades. This may indicates more variability in rainfall characteristics rather than a change.

Table 4.3: Summary of Mann Kendall test on rainfall parameters

Variable	Kendall' s tau	S	Var (S)	p-value (Two-tailed)	alpha	Test interpretations
Onset day	0.105	65.000	5,360.333	0.382	0.05	H0 is accepted
Onset month	0.074	40.000	4,863.333	0.576	0.05	H0 is accepted
Cessation day	-0.124	-77.000	5,374.333	0.300	0.05	H0 is accepted
Cessation month	0.215	77.000	2,503.667	0.129	0.05	H0 is accepted
ARA	0.105	66	5390	0.376	0.05	H0 is accepted
Rainy days	0.324	201	5,367.667	0.006*	0.05	H0 is rejected
LRS	-0.056	-35	5,380.333	0.643	0.05	H0 is accepted
Wettest month	0.031	14.000	7,652.839	0.882	0.05	H0 is accepted

LRS: Length of Rainy Season;
ARA: Annual Rainfall Amount

Source : Author's computation, 2017

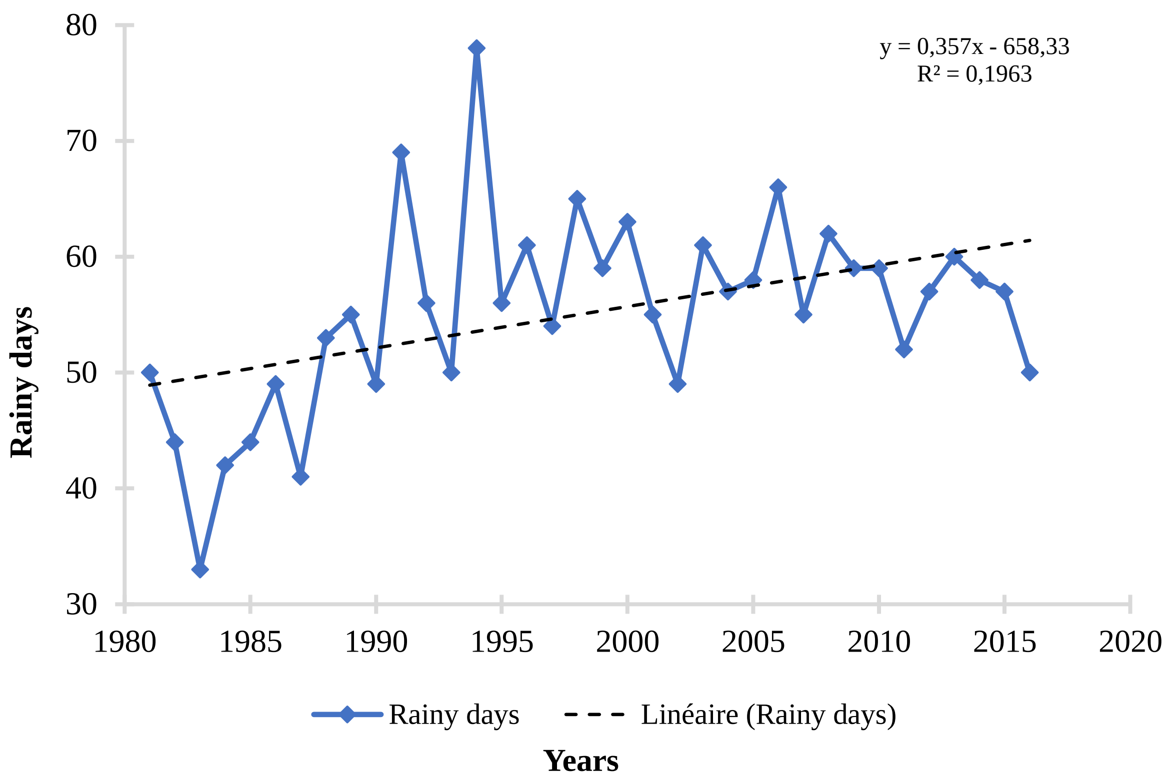


Figure 4.5 : Rainy days trend in Kompienga Province (1981-2016)

4.1.1.6. Anomalies analysis

Figure 4.6 describes the analysis of rainfall Standardised Anomaly Index (SAI) in Kompienga Province over the period 1981-2016. For the SAI closed to zero value, the corresponding years are said to be normal, while the indices far above or below the value zero are qualified to be either wet or dry years. Thus, for indices between -0.99 to +0.99, the corresponding years are near normal; for indices of ±1.0 to ±1.49 the corresponding years are moderately wet/dry; for indices of ±1.5 to ±1.99, the corresponding years are said to be very wet/severely dry. Finally, for SAI value of ±2 the corresponding years are qualified of extremely wet/dry. On this basis, 25 out of the 36 years were normal years. The years 2002 (SAI=-1.2) and 2004 (SAI=-1) were moderately dry while 1983 (SAI=-1.7), 1984 (SAI=-1.7) and 1993 (SAI=-1.5) were severely dry years. On the contrary, 2003 (SAI=+1.2), 2008 (SAI=+1.0), 2009 (SAI=+1.0) were moderately wet; 1991 (SAI=+1.7), 1994 (SAI=+1.8) were very wet and 1998 (SAI=+2.4) was extremely wet.

Rainfall variabilities as indicated in Figure 4.11 might affect livestock farming and may likely get worse in future within Kompienga province. This agree with Cooper et *al.* (2008); Sirohi and Michaelowa (2007); Galvin *et al.* (2004); Thornton *et al.* (2007) who reported that rainfall variabilities affects pastoral resources.

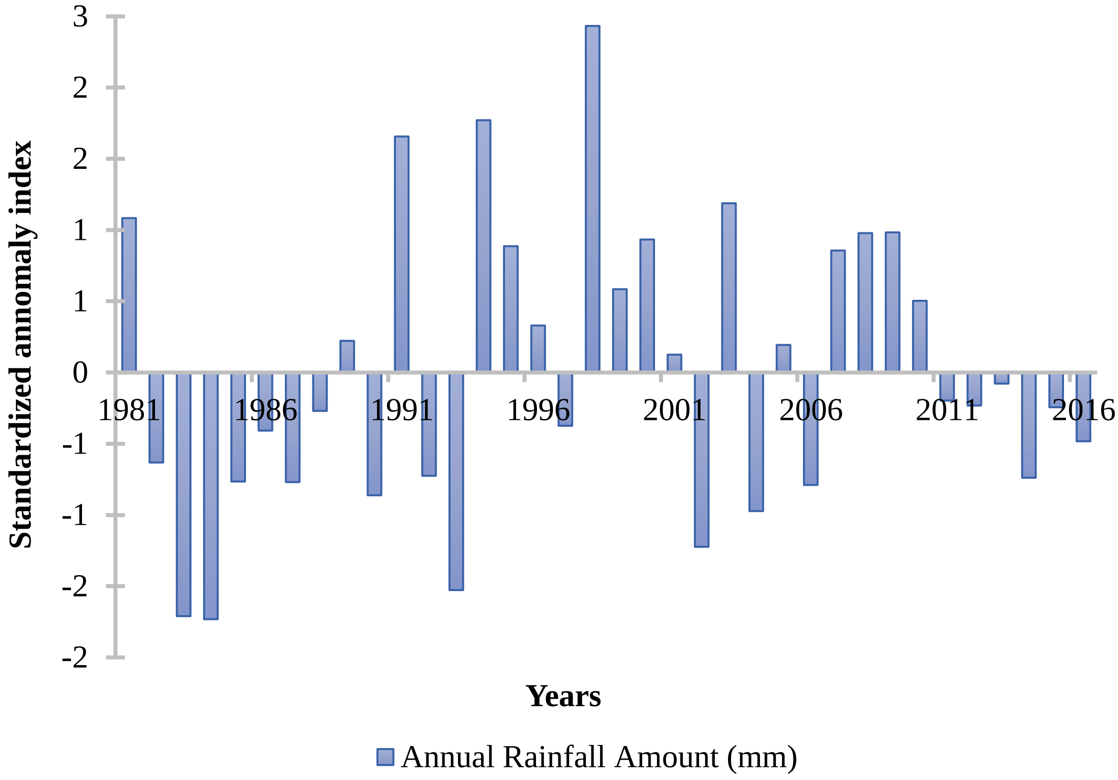


Figure 4.6: Annual rainfall anomalies in Kompienga Province (1981-2016)

4.1.2. Temperature

4.1.2.1. Temperature

Table 4.4 gives the situation of mean, minimum and maximum temperature within Kompienga province over 36 years. The values of 28.8±2.6°C, 22.3±3.0°C and 35.3±3.1°C were registered respectively as average values of mean, minimum and maximum temperature. The mean annual minimum temperature (22.3±3.0°C) recorded is similar to that of 22.2 °C and 22.1 °C reported respectively by Allakonon (2015) in Niger State (Nigeria) and Kima (2014) in Boulgou province (Burkina Faso). Contrary, the mean annual maximum temperature (35.3±3.1 °C) is greater than that of 33.4 °C and 34.4 °C reported by these authors in Niger State and Boulgou province respectively.

Table 4.4: Temperature characteristics within Kompienga Province (1981-2016)

Temperature	Mean	SD	Maximum	Minimum
Minimum temperature	22.3	3.0	23.4	21.2
Mean temperature	28.8	2.6	23.9	28.2
Maximum temperature	35.3	3.1	35.9	34.5

Source : Author’s computation, 2017

4.1.2.2. Comparison of temperature parameters with the normal 1981-2010

Figure 4.7 shows an overview on the comparison of monthly mean temperature between climatology and years between 2011 and 2016. Globally, it appears that in Kompienga province, the monthly mean temperature increases as the years advances. During the last six years, an increase in temperature was noticed in February, June, October and November with respectively amplitudes of [+0.2°C to +1.7°C]; [0.3°C to +2.0°C]; [+0.5°C to +1.4°C] and [+0.3°C to +1.9°C]. For the other months, there is variability in the evolution of the temperature in the province. The increased temperature in the province had negative impacts on water bodies within the province. This might be responsible for the earlier dry out of livestock watering points through heavy evaporations. This will affect livestock performance (milk, body weight gain and meat).

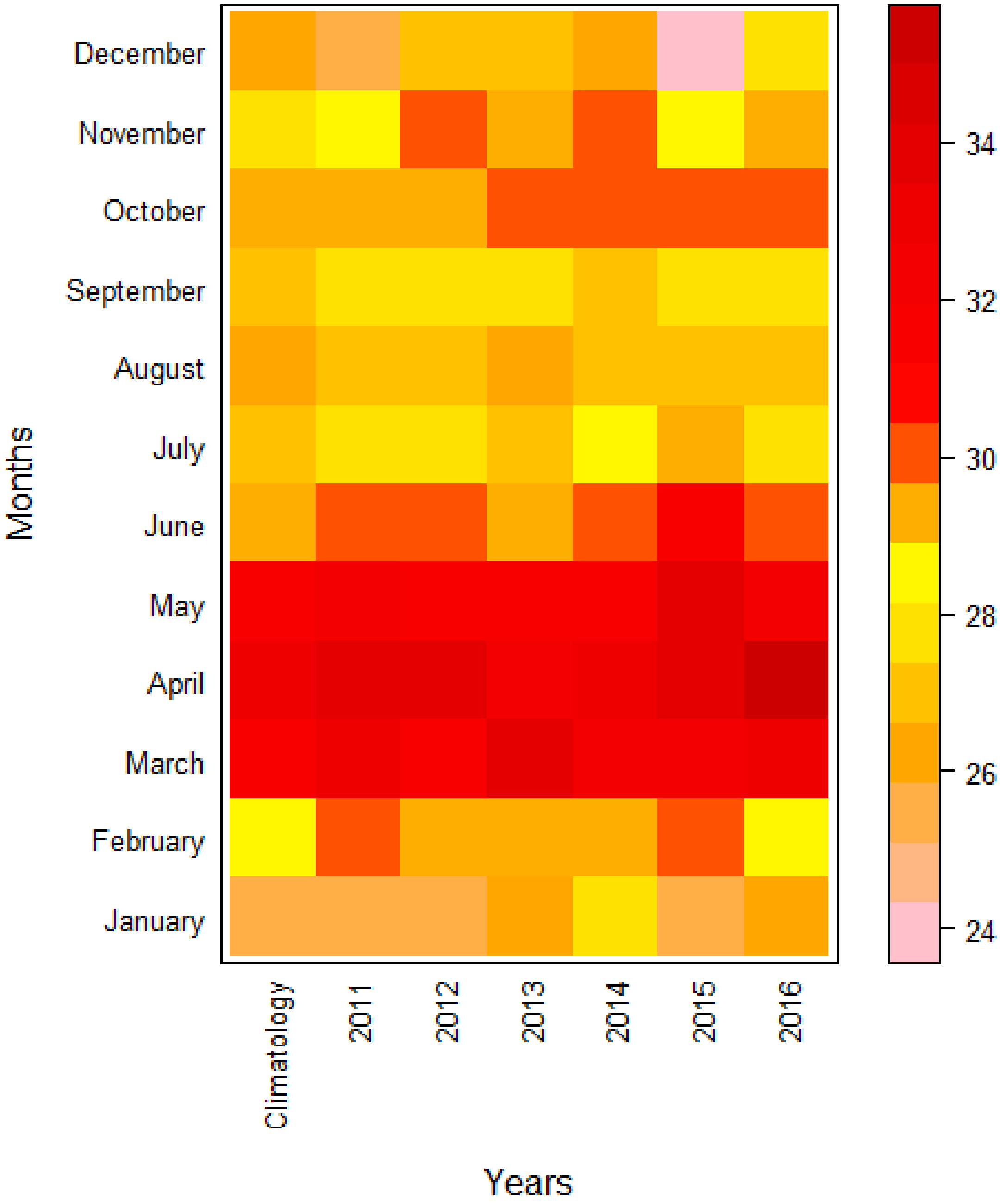


Figure 4.7: Mean temperature of the period 2011-2016 and the climatology (1981-2010)

Table 4.5 shows a comparison of annual temperature of the climatology (1981-2010) to that of the six last years (2011 to 2016). The averages of minimum, maximum and mean annual temperature increased compared to the climatology.

The deviation amplitudes of the last six years of annual temperature values from that of the climatology are [0.6°C to +0.9°C]; [+0.6°C to +1.3°C]; [+0.2°C to +0.6°C] respectively for minimum, mean and maximum temperature. This increase rate in temperature would be the manifestation of climate change in the province.

Thus, annual temperature increased in the province with its negative implications on livestock production. Moreover, it is observed that 2016 recorded the higest deviation in mean temperature (+0.9°C) from the climatology.

Table 4.5: Compared temperature between climatology and the period 2011-2016

Temperature	Climatology	2011	2012	2013	2014	2015	2016
Mean temperature (°C)	28.7	29.3 (+0.6)	29.3 (+0.9)	29.3 (+0.8)	29.3 (+1.1)	29.4 (+0.8)	29.6 (+1.3)
Minimum temperature (°C)	22.1	22.7 (+0.6)	23.0 (+0.6)	22.9 (+0.6)	23.2 (+0.7)	23.2 (+0.8)	23.4 (+0.9)
Maximum temperature (°C)	35.2	35.8 (+0.6)	35.5 (+0.3)	35.6 (+0.4)	35.4 (+0.2)	35.7 (+0.5)	35.7 (+0.5)

Source : Author’s computation, 2017

4.1.2.3. Trend analysis of maximum and minimum temperature

Table 4.6, figures 4.13 and 4.14 show the evolution of temperature within Kompienga province from 1981 to 2016. A significant upward trend at 95% confidence level was experienced within Kompienga province since 1981 for minimum temperature (p-value< 0.0001), mean temperature (p-value< 0.0001) and maximum temperature (p-value=0.0002).

Table 4.6: Summary of Mann Kendall test on temperature parameters

Variables	Kendall's tau	S	Var(S)	p-value (Two-tailed)	alpha	Test interpretations
Max. temp.	0.429	270.000	5,390.000	0.0002	0.05	H0 is rejected
Min. temp.	0.724	456.000	1,1343.680	< 0.0001	0.05	H0 is rejected
Mean temp.	0.670	422.000	1,1307.144	< 0.0001	0.05	H0 is rejected

Source : Author's computation, 2017

The lowest and highest maximum temperature are 34.5°C and 35.9°C registered respectively in 1994 and 1987 (Figure 4.8). While the lowest and highest mean temperature are 27.9°C and 29.6°C obtained in 1989 and 2016 respectively. The change rate in the maximum temperature is equal to 0.20°C per decade while for the mean temperature the rate is 0.35°C per decade. The increase rate of maximum and mean temperature is quite similar to that of 0.22°C and 0.38°C per decade found in eastern Sudan by Sulieman and Elagib (2012) respectively for maximum and mean temperatures. However, the increase rate of maximum temperature in Kompienga was higher than that of 0.16 °C per decade reported at a global scale by Vose *et al.* (2005) during the period 1950-2004 and that of 0.09 °C per decade recorded by Easterling *et al.* (1997) during the period 1950-1993. On the contrary the increase rate was lower than that of 0.24°C and

0.28°C obtained respectively by Kima (2014) and Allakonon (2015) in Boulgou province of Burkina Faso and Niger State of Nigeria. In addition, the mean temperature experienced at Kompienga province is higher than the value (0.29°C) reported by Boko *et al.,* (2007) and Conway (2008) over African Tropical forests. These differences with our results could be due mainly to the differences between the periods and the study areas. From 1981 to 2016 the maximum temperature has increased about +1.14°C and about +1.64°C for the mean temperature.

The lowest (21.2°C) and highest (23.4°C) minimum temperature were recorded in 1981 and 2016 respectively (Figure 4.9). The increase rate of the minimum temperature in Kompienga is 0.50°C per decade, quite similar to that found in eastern Sudan (0.53°C) by Sulieman and Elagib (2012) and much higher than that found in Boulgou province (0.25°C) (Kima, 2014). Moreover, Vose *et al*. (2005) and Easterling *et al.* (1997) recorded lower increase rates per decade of 0.23°C and 0.19 °C in the Northern Hemisphere between the period of 1950-2004 and 1950-1993 respectively. The total increase in minimum temperature within the province from 1981 to 2016 accounts for +2.13°C.

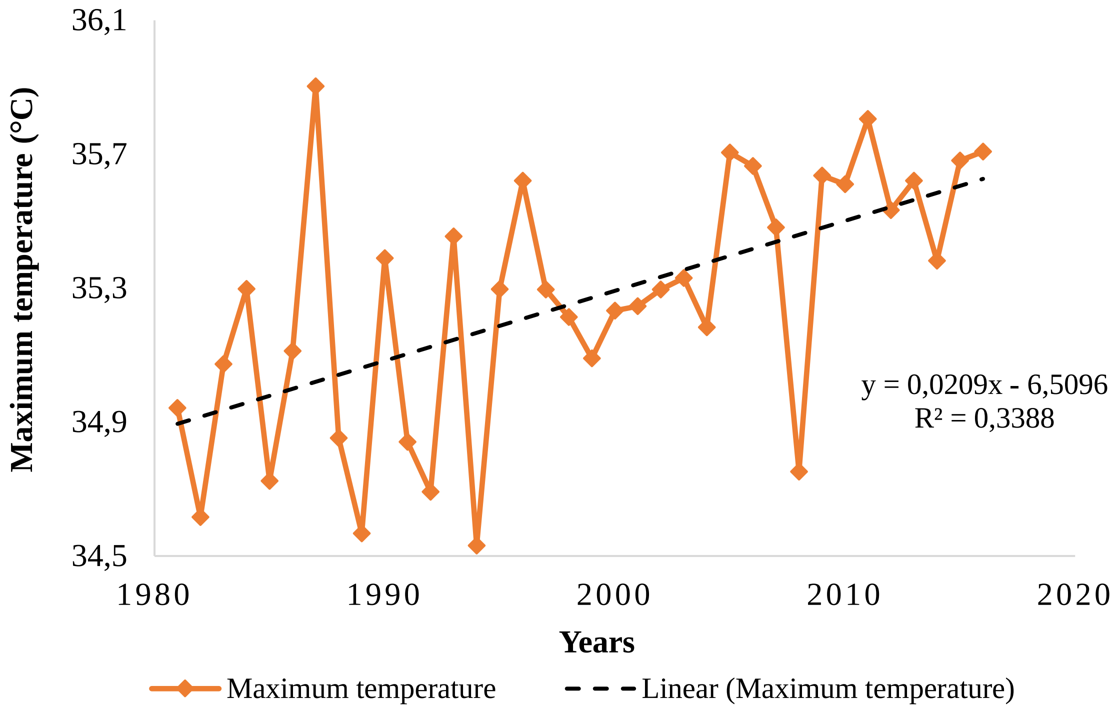


Figure 4.8: Maximum temperature trend in Kompienga Province (1981-2016)

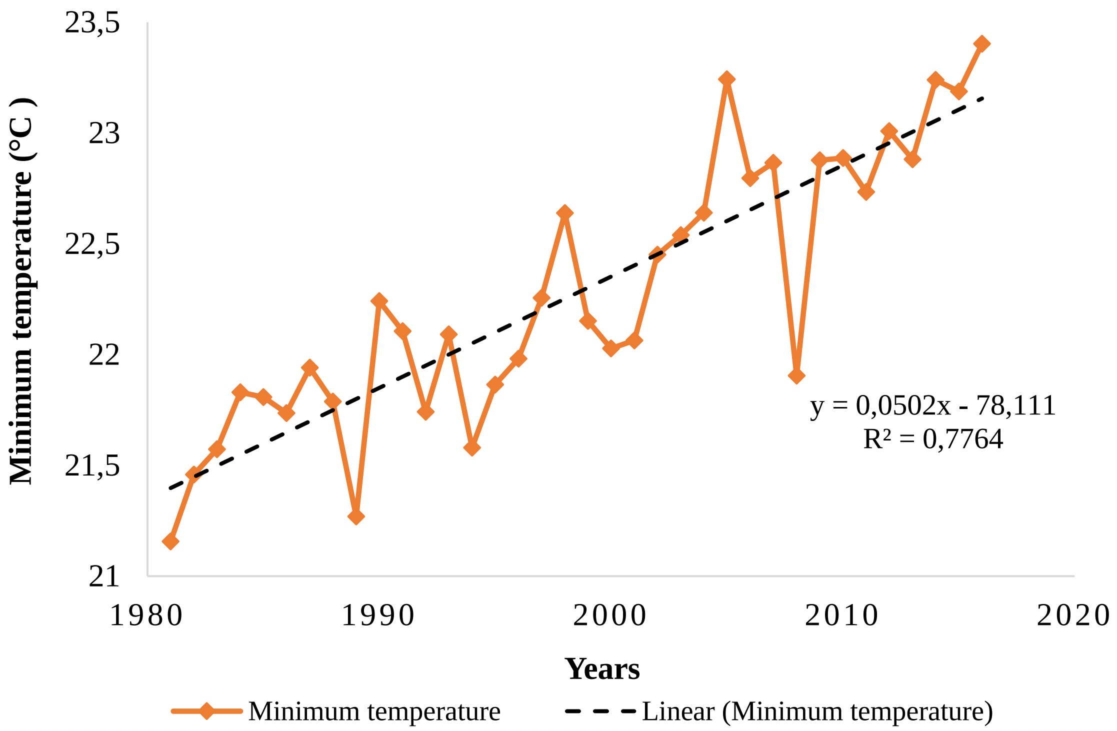


Figure 4.9: Minimum temperature trend in Kompienga Province (1981-2016)

4.1.2.4. Temperature Anomalies from the annual mean of normal period 1981-2010

Maximum temperature anomalies in Kompienga Province over 36 years (1981-2016) is hereby presented in Figure 4.10. The lowest (-1.93 °C) and the highest (1.7°C) anomalies were obtained in 1994 and 1987. Between 1981 and 2004, the majority of the anomalies over 16 years out of 24 years, shows negative values with a variation amplitude of [-0.04°C and -1.93°C]. This period was then less hot than the average temperature of the 36 years under study (1981-2016). From 2005 to 2016, the anomalies are positive (except in 2008 with -1.34 anomaly index), depicting a global hotter period (2005-2016) than the average maximum temperature of the period 1981-2016. The values of maximum temperature of the period between 2000 and 2004 and in years 1984, 1995, 1997 and 1998 were closer to the long-term average temperature with anomalies values fluctuating between -0.2°C to 0.18°C. The 5-year moving average curve depict a gradual increase of the maximum temperature anomalies from 1992 preceded by a short period of decrease over the period 1987-1992.

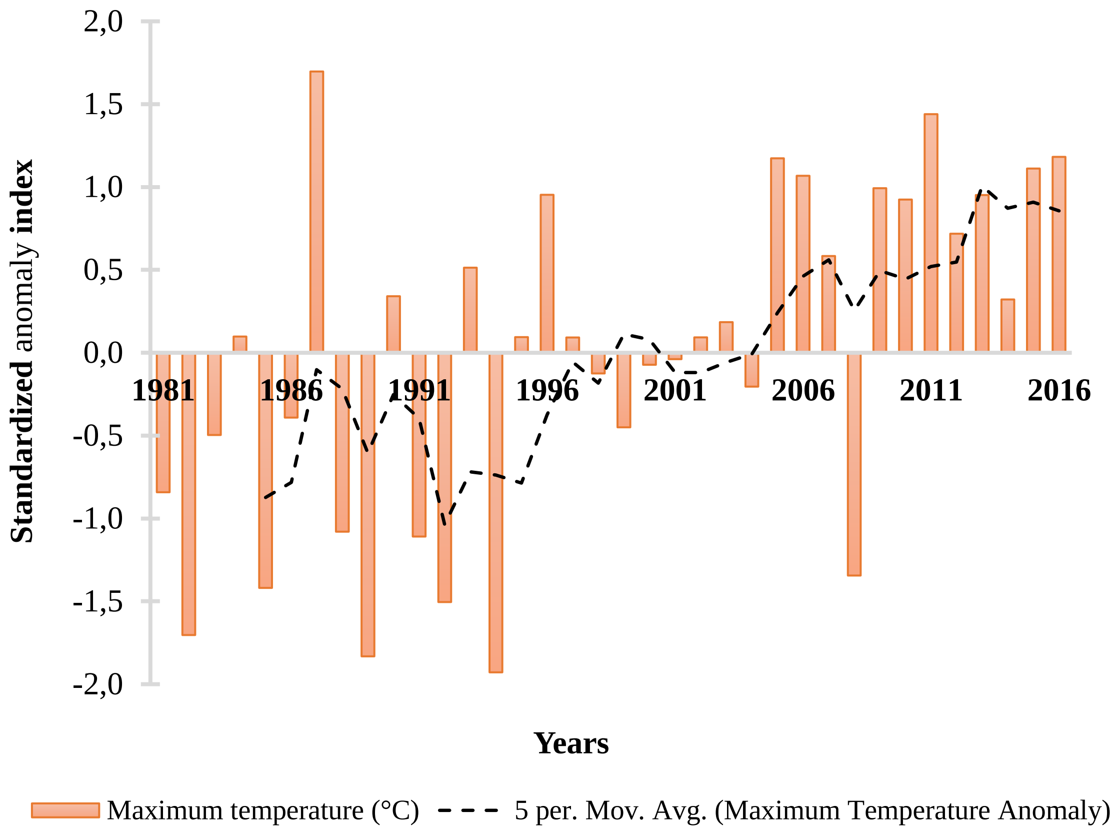


Figure 4.10 : Maximum temperature anomalies in Kompienga Province (1981-2016)

Figure 4.11 presents anomalies of minimum temperature over 36 years (1981-2016). The figure shows two major periods of negative anomalies (1981 to 2001) and positive anomalies (2002 to 2016) with anomalies values varying between [-0.03°C; -1.86°C] for the first period and [+0.29°C; +1.87°C] for the second period. The 5-year moving average curve depict a gradual increase of the minimum temperature. The minimum temperature values of 1990 (-0.06 °C) and 1997 (-0.03°C) were the closest to the long-term average over 1981-2016.

The increase in temperature will affect negatively pastoral resources and livestock production. This agrees with the report of NRC (1981) who said water demand by livestock drastically increase up to 10 kg per kilogramme of Dry Mater (DM) at 35°C. Given an average of 35.3 °C of maximum temperature within Kompienga between 1981-2016, water demand might have increased accordingly while the rainfall is highly variable and globally decreasing.

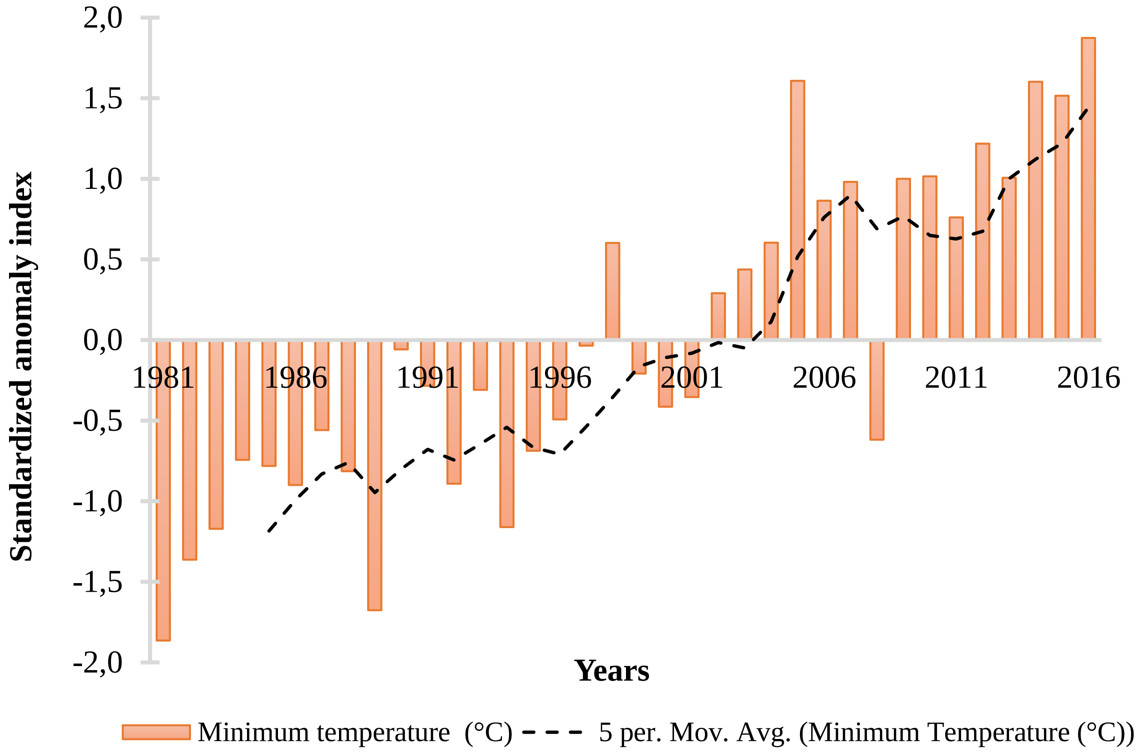


Figure 4.11: Minimum temperature anomalies in Kompienga Province (1981-2016)

4.1.3. Analysis of Relative Humidity and Evapotranspiration

4.1.3.1. Overview on Relative Humidity and Evapotranspiration

Table 4.7 gives minimum, maximum and mean values of Relative Humidity (RH) and Evapotranspiration (Potential Evaporation) within the Kompienga province over the period 1981 to 2016. The following values were obtained for maximum RH (67.5%±24.9), minimum RH (33.3%±20.3), maximum ETP (6.7mm±1.0), and minimum ETP (3.2mm±0.7).

Table 4.7: Relative humidity and Evapotranspiration in Kompienga Province from 1981-2016

Parameters	Mean	Standard Deviation	Maximum	Minimum
Maximum RH	67.5	24.9	63.4	71.4
Minimum RH	33.3	20.3	36.8	29.2
Maximum ETP	6.7	1.0	7.5	6.2
Minimum ETP	3.2	0.7	3.7	2.9

RH : Relative Humidity ETP : Potential Evapotranspiration

Source : Author's computation, 2017

4.1.3.2. Comparison of Relative humidity and Evapotranspiration with the normal period 1981-2010

Table 4.8 compared evolution of Relative Humidity and Potential Evapotranspiration between climatology and the period 2011-2016 within Kompienga province. The province appears to have experienced an increase of both RH and ETP after the period of climatology. The deviation amplitude of maximum ETP is +0.4 mm for each year between 2011-2014. The deviation amplitudes of mean and minimum ETP are [+0.3mm to +0.4mm] and [+0.1mm to +0.4mm] respectively. The increase in ETP could be due to the increase in temperature over the same period in the province. The increase in temperature, directely increase water evaporation and crops transpiration. As result of both transpiration and water bodies evaporation, there is a global augmentation of Relative Humidity within the province. Thus, in comparison with climatology, the province has experienced a rise of RH in 2011 (+0.1%), 2012(+2.0%), 2013(+3.1%), 2014 (+1.2%) and 2016 (+0.3%) while 2015 was characterized by and decrease in RH (-4.0%). Temperature, ETP and RH are all related and are positively correlated. Their upward trend has a negative implications on both crop production and livestock farming. In fact, the excessive rise of ETP and RH provoke the shortage of available water for livestock and the increase of crops water stress.

Table 4.8: Compared evolution of Relative Humidity and Potential Evapotranspiration between climatology and the period 2011-2016 within Kompienga province

Years	Climatology	2011	2012	2013	2014	2015	2016
Maximum RH (%)	67.5	67.6 (+0.1)	69.5 (+2.0)	70.5 (+3.1)	68.7 (+1.2)	63.4 (-4.0)	67.7 (+0.3)
Minimum RH (%)	33.0	33.3 (+0.2)	35.2 (+2.2)	35.9 (+2.8)	35.8 (+2.7)	32.3 (-0.7)	34.3 (+1.3)
Mean RH (%)	50.3	50.4 (+0.2)	52.3 (+2.1)	53.2 (+2.9)	52.2 (+2.0)	47.9 (-2.4)	51.0 (+0.8)
Maximum ETP (mm)	6.7	7.1 (+0.4)	7.1 (+0.4)	7.1 (+0.4)	7.1 (+0.4)	-	-
Minimum ETP (mm)	3.2	3.6 (+0.4)	3.6 (+0.4)	3.3 (+0.1)	3.4 (+0.2)	-	-
Mean ETP (mm)	4.9	5.3 (+0.4)	5.3 (+0.4)	5.2 (+0.3)	5.2 (+0.3)	-	-

Source : Author’s computation, 2017

4.1.3.3. Trend analysis of Relative Humidity and Evapotranspiration

Figure 4.12 and Table 4.9 show the evolution of minimum, mean and maximum ETP and RH over the period 1981-2016. Among all these parameters, only the minimum Relative Humidity is showing a significant upward trend at 95% confidence level (p-value=0.001). The lower (29.2%) and higher (36.8%) minimum relative humidity were obtained in 1990 and 2010.

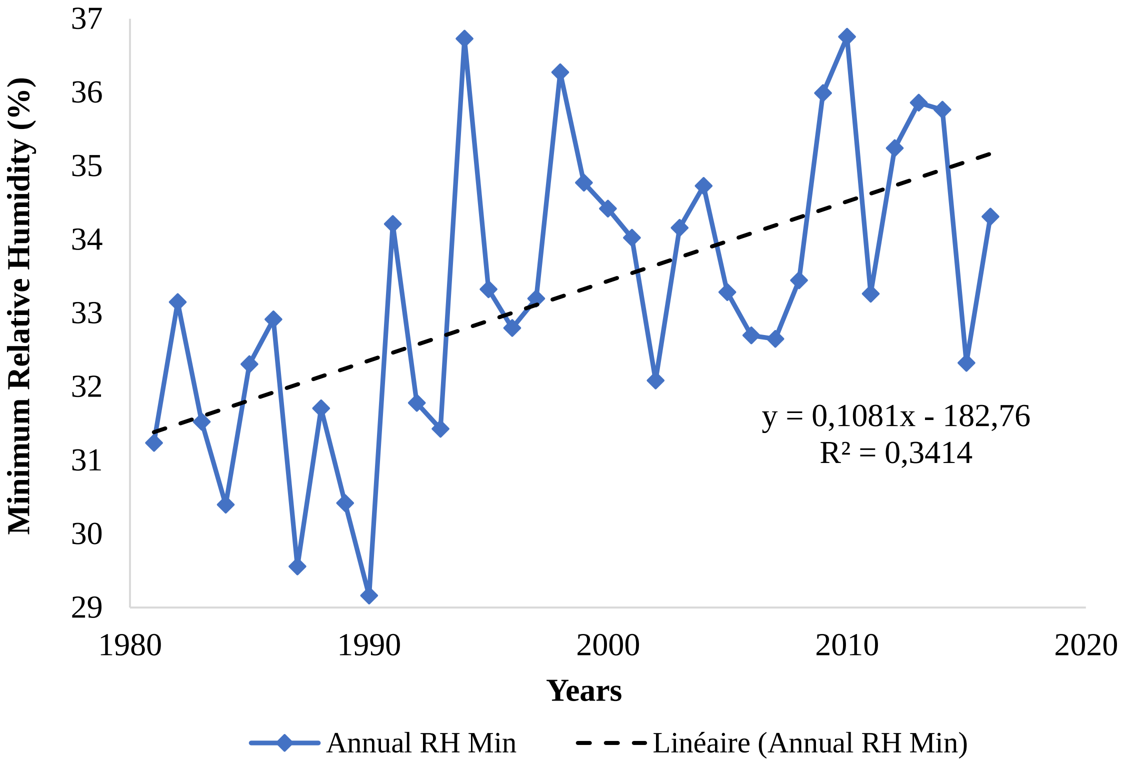


Figure 4.12: Maximum Relative Humidity trend in Kompienga Province (1981-2016)

Table 4.9: Summary of Mann Kendall Test of Relative Humidity and Evapotranspiration

Variables	Kendall's tau	S	Var (S)	P-value (Two-tailed)	alpha	Test interpretations
Maximum RH (%)	0.01	4.00	5.390.00	0.97	0.05	H0 is accepted
Minimum RH (%)	0.40	252.00	5.390.00	0.001*	0.05	H0 is rejected
Mean RH (%)	0.18	116.00	5.390.00	0.12	0.05	H0 is accepted
Maximum ETP (mm)	0.14	76.00	4.549.33	0.27	0.05	H0 is accepted
Minimum ETP (mm)	-0.11	-62.00	4.542.67	0.37	0.05	H0 is accepted
Mean ETP (mm)	0.07	38.00	4.547.33	0.58	0.05	H0 is accepted

Source : Author's computation, 2017

In Kompienga province, the climate parameters (rainfall, temperature, RH and ETP) are experiencing important variabilities and changes. These changes and variabilities affect negatively crops production and pasture growth within rangelands (later establishment and earlier dry of forage species). This is in line with the viewpoint of Thornton *et al.* (2007) who think that the most visible impacts of climate changes on pastoral system, is changes in primary productivity of crops, forages and rangelands. In addition, climate deterioration will affect forage quality. Minson (1990) indicated an increased lignification of plant tissues with a rise in temperature. Consequently, forage digestibility decreases, resulting in lower animal production. This may affect negatively food security and incomes of pastoral households through the reduction of milk and meat production. Shortage of pasture exacerbates internal and cross-border mobilities of herders in search elsewhere of complementary feed (rich herbage and water).

Beside the climate parameters variabilities, changes and their related impacts, LULC in the Kompienga is also susceptible to important changes. However, what are the changes occurred in the Kompienga province over these last decades? What are the related impacts of LULC dynamics in the province?

4.2. Land Use and Land cover Change Assessment

4.2.1. Land use land cover dynamics within Kompienga province between 1989 and 2015

Land use and cover of Kompienga province in 1989, 2001, 2013 and 2015 is presented in Table 4.10 while Table 4.11 shows the dynamics of land use and cover within Kompienga province from 1989 to 2015.

The result shows that Gallery Forest/wet area and the group constituated by Woody Savannah/Shrub/Grassland were the most dominant land cover unit over years 1989

(45.5 % and 40.4 %) and 2001 (41.6 % and 47.0 %). This group remained predominant in 2013 (79.1 %) and 2015 (75.8 %). Similarly, Soulama *et al*. (2015), reported that Woody Savannah and Shrub/Grassland was the most predominant LULC category over the province between 2001 and 2013.

It was noticed that croplands that occupied one of the smallest area (0.8 %) in 1989 have increased their proportion and became the second largest LULC unit (10.6 %) after the unit constituted by Woody Savannah/ Shrub/Grassland (75.8 %). The increased rate of croplands areas is estimated at 46.7 % on average per year.

The proportion of Forest Gallery/Wet area has experienced a continuous regression of their area since 1989. Urban/Settlement and water were the smallest unit over all the years under study with respectively amplitudes of 0.2 % - 0.3 % and 1.5 % - 1.9 % of the province land areas.

Table 4.10: Land use and cover of Kompienga province in 1989, 2001, 2013 and 2015

Years	**1989**		**2001**		**2013**		**2015**	
LULC	Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)
Bare land	80,115.6	11.5	34,354.3	4.92	43,655.5	6.2	41,194.8	5.9
Cropland	5,646.2	0.8	34,838.7	4.99	41,788.7	6.0	74,220.4	10.6
G F/ Wet area	317,974.6	45.5	290,669.0	41.61	45,255.7	6.5	40,779.2	5.8
Urban/Settelment	1,397.5	0.2	1,808.9	0.26	2,118.2	0.3	2,341.6	0.3
Water	11,392.8	1.6	8,487.1	1.21	13,360.2	1.9	10,692.8	1.5
WS/Shrub/GL	28,2578.7	40.4	328,402.7	47.01	552,906.9	79.1	529,856.3	75.8

GF: Gallery Forest; WS: Woody Savannah; GL: Grassland, LULC: Land Use and Cover Change
Source : Author's computation, 2017

Table 4.11: Land use and cover dynamics within Kompienga province from 1989 to 2015

Years	**Change 1989 - 2001**		**Change 2001- 2013**		**Change 2013- 2015**		**Change 1989- 2015**	
LULC	Δ	Δ %	Δ	Δ %	Δ	Δ %	Δ	Δ %
Bare land	-45,724.8	-6.5	9,260.6	1.3	-2,460.7	-0.4	-38,875.1	-5.6
Cropland	29,230.7	4.2	6,913.5	1.0	32,431.7	4.6	68,489.7	9.8
G F/ Wet area	-26,998.3	-3.9	-245,431.9	-35.1	-4,476.5	-0.6	-276,980.8	-39.7
Urban / Settlement	418.7	0.1	304.7	0.04	223.3	0.0	940.6	0.1
Water	-2,891.5	-0.4	4,615.0	0.7	-2,667.3	-0.4	-619.2	-0.1
WS/Shrub/GL	45,965.3	6.6	224,338.1	32.1	-23,050.5	-3.3	247,044.8	35.4

GF: Gallery Forest; WS: Woody Savannah; GL: Grassland, LULC: Land Use and Cover Change
Source : Author's computation, 2017

Between 1989-2001, 2013-2015 and 1989-2015 bare land unit decreased globally while there is slight increased between 2001-2013. On the contrary, croplands have gradually increased their areas over the above periods partly to the detriment of pasture land. Similarly, number of studies depicted an increase in croplands to the detriment of grazing lands affecting pastoral herding (Larsson, 1995; Reenberg *et al.*, 2003; Lambin *et al.*, 2003; Sulieman, 2010; Sulieman and Elagib, 2012; Byenkya *et al.*, 2014; Gonin, 2014; Gonin and Gautier, 2015; Kima *et al.,* 2016). The increasing pressure on pastoral areas due to agricultural activities definitively results in a shortage of forage resources (Amanor, 1995).

Comparing the periods between 1989 and 2001 (12 years), 2001-2013 (12 years) and 2013-2015 (2 years) the highest increase in cropland was noticed over 2013-2015 (9.8%). These results mean there is a recent increase in anthropic pressures (human activities) on land over the last five years. This might be due to the decline in climate conditions. Under worse climatic conditions, soils fertility is often affected and farmers are prone to increase cropland to maintain the level of production. The second reason for rapid increase in cropping areas over the five last years, may also be due to cash crop development and cultivation facility using herbicides.

Gallery Forest/Wet area unit have decreased over each period at a rate of -3.9%, -35.1%, -0.6% and -39.7% respectively over 1989-2001, 2001-2013, 2013-2015 and 1989-2015. It appears therefore, that the degradation of these land use units was more visible after 2001. That maybe due to a visible decline in climate condition from 2001. Indeed, 2001 was the second drier year (SAI=-1.2mm) of the period 1989-2015 after year 1993 (SAI=-1.5mm). Furthermore, a global increase of temperature from 2001 was also noticed which could have caused an increased rate of evaporation and a degradation of wet area. Urban/Settlement unit experienced a slight increase between 1989 and 2001 (+0.1%) and over the period 2001-2013 (+0.04%) and was constant between 2013-2015.

The decrease in water over periods between 1989 and 2001, 2013 and 2015, 1989 and 2015 and the increase in water over the period 2001-2013 maybe due to the variability of rainfall over these periods. Indeed year 1989 (SAI=+0.2mm) was wetter than year 2001 (SAI=-1.2mm) which was drier than 2013 (SAI=-0.1mm). This may be the cause of the decrease of water areas between 1989 and 2001 followed by an increase between 2001 and 2013. Year 2015 (SAI=-0.2mm) was far drier than year 1989 (SAI=+0.2mm). This may explain the decrease of water between the two dates.

Finally, the ensemble Woody Savannah/Shrub/Grassland has increased over periods between 1989 and 2001 (+6.6%) and 2001 to 2013 (+32.1%) and has decreased over the period 2013-2015 (-3.3%). The increase in these units might be essentially due to the degradation of Gallery Forest/Wet areas while the decrease rate noticed maybe due to the increase in cropland areas over the last five years.

Kompienga province is one of the biodiversity conservation areas of Burkina Faso. This situation explains the predominance of vegetation compared to other land cover units due to the existence of large protected areas in the province. The protected forests which is a total of about 555,967.4 hectares constituted: (i) parts of total wildlife reserve of Singou, Madjoari, Konkombouri; and (ii) Partial Wildlife Reserve of Pama. Besides these forests a second kind of protected areas were created after year 2010 in the province which constituted the village areas of Hunting interest measuring 4,577.91 hectares. Therefore, out of the total areas of 600,553.3 hectares of vegetation in 1989, 555,967.4 hectares (92.6%) were protected and about 44,585.84 hectares (7.4%) were accessible to livestock. In 2001, 10.2% (63,104.2 hectares) of the total vegetated areas (619,071.7 hectares) were grazable while about 555,967.4 hectares (89.8%) were still protected. In 2013 and 2015, protected areas increased up to 560,545.3 hectares and grazing lands amounted respectively 6.3% (37,617.2 hectares) and 1.8% (10,090.2 hectares) of the vegetation areas (Figure 4.13). As a result, a gradual decline in area available for grazing has been observed since 2001 at an average rate of 6.0% per year. This is far higher than the reduction rate of the vegetation (0.96% per year) found by Ouedraogo *et al.* (2010) within Sissili Province of Burkina Faso between 1986 and 2006.

This situation coupled with the decline in climate conditions underpinned the increasing pressure and competitions for the residual lands between crop farmers and herders.

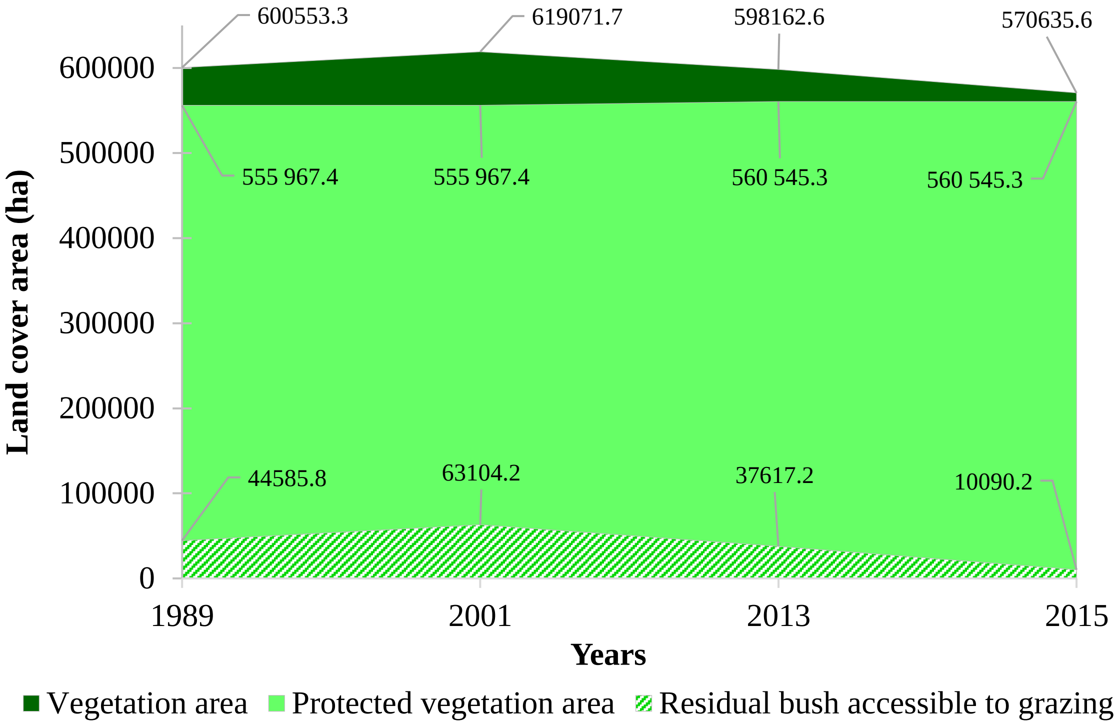


Figure 4.13: Evolution of grazing lands, total vegetated and protected areas within Kompienga Province from 1989 to 2015

The consequences of competitions over residual lands are the increasing occurrence of conflicts, the increase in cross-borders mobility of herds with also their corollary of conflicts within reception zones of transhumant herders. The Figures 4.14 and 4.15 give an overview on the spatial representations of the above land use and cover statistics.

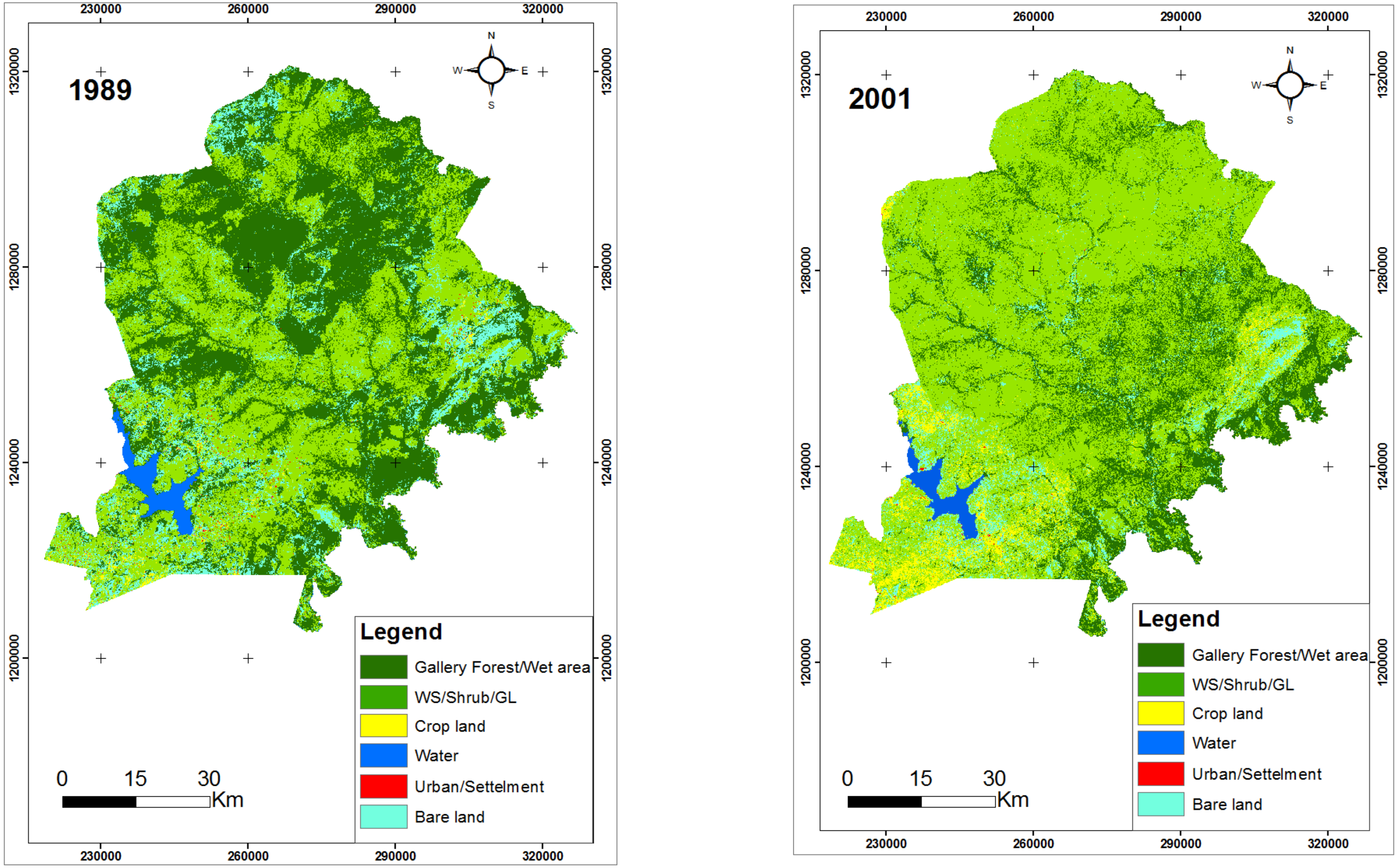


Figure 4.14: Land use and cover of Kompienga Province in 1989 and 2001

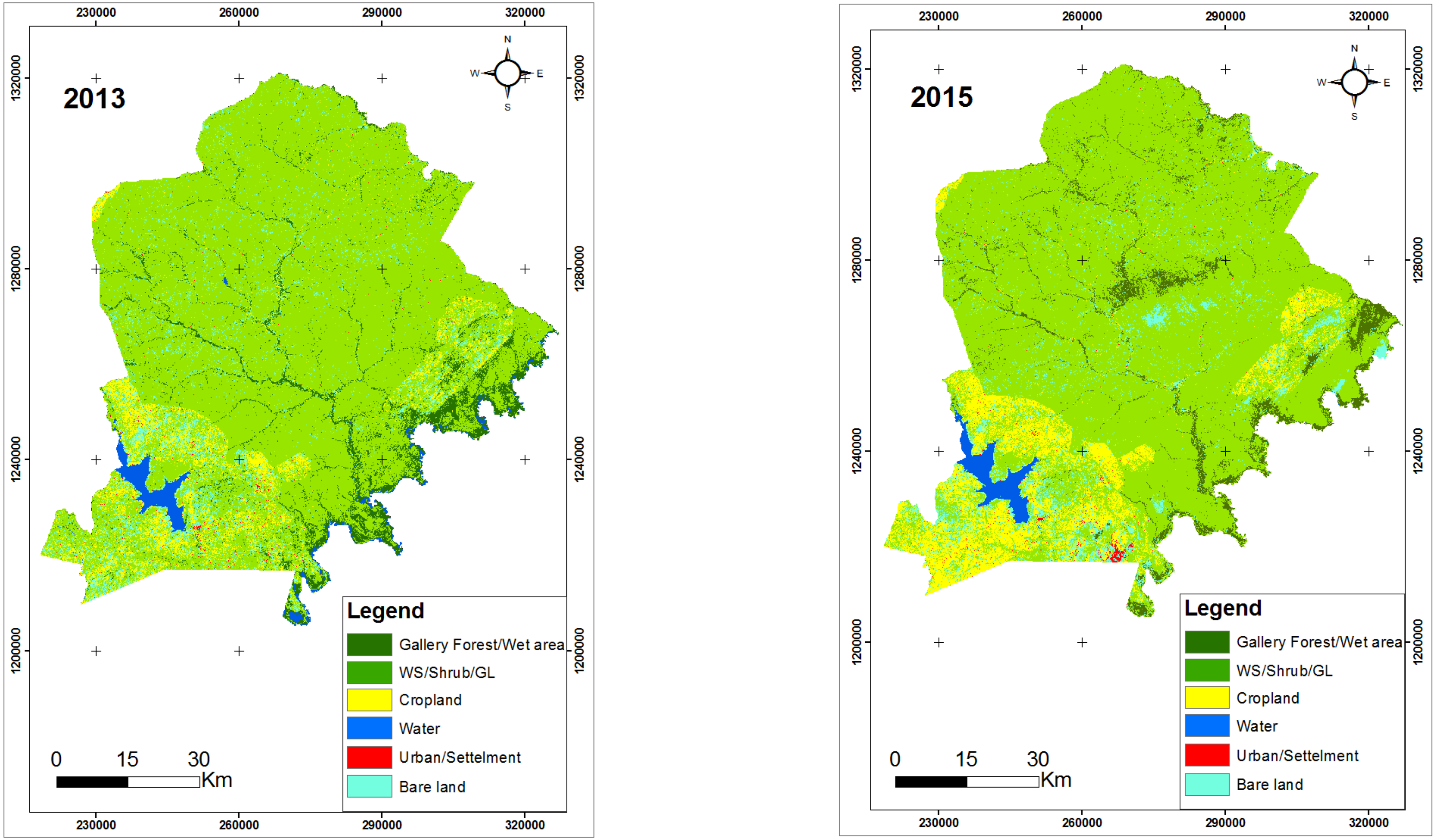


Figure 4.15: Land use and cover of Kompienga province in 2013 and 2015

4.2.2. Accuracy assessment of images classification

For each classified map, good accuracies were obtained. Indeed, the overall accuracies were 91.0%, 84.7%, 90.7% and 90.9% respectively for years 1989, 2001, 2013 and 2015 (Table 4.12). These accuracies values were within the range of [79.78% - 94.59%] reported by Sulieman and Elagib (2012) during LULC classification along livestock seasonal migration routes within eastern Sudan.

For Kappa coefficient, values of 0.88, 0.79, 0.87 and 0.88 were obtained respectively for classified maps of 1989, 2001, 2013 and 2015. Based on these Kappa values and according the categorisation of Landis and Koch (1977), a strong agreement was concluded between ground truth data and land use and cover units depicted on thematic maps of 1989, 2013 and 2015 (Kappa>0.81) while a substantial agreement was indicated for the thematic map of 2001 (0.61<Kappa<0.8). It appears therefore, that globally a good classification accuracy was achieved for each thematic map.

Table 4.12: Accuracy assessment of classified LULC maps of years 1989, 2001, 2013 and 2015

Years	**1989**		**2001**		**2013**		**2015**	
LULC class	**Producer's accuracy (%)**	**User's accuracy (%)**	**Producer's accuracy (%)**	**User's accuracy (%)**	**Producer's accuracy (%)**	**User's accuracy (%)**	**Producer's accuracy (%)**	**User's accuracy (%)**
Bare land	90.0	75.0	45.5	83.3	83.9	74.3	85.2	67.6
Cropland	96.9	98.4	88.0	95.7	93.3	86.2	84.3	89.7
G F/Wet area	93.4	87.7	84.8	86.7	80.0	80.0	40.0	100.0
Urban/Settelment	66.7	100.0	100.0	80.0	41.7	71.4	90.8	96.7
Water	95.7	100.0	100.0	100.0	98.2	100.0	100.0	100.0
WS/Shrub/GL	50.0	66.7	87.0	72.7	87.5	91.3	91.1	82.0
Overall accuracy (%)	91.0		84.7		90.7		90.9	
Kappa coefficient	0.88		0.79		0.87		0.88	

GF: Gallery Forest; WS: Woody Savannah; GL: Grassland

Source : Author's computation, 2017

4.3. Implications of Climate and Land Use/Land cover Changes on Pastoral Resources and Practices

4.3.1. Characteristics and perceptions of respondents

4.3.1.1. Socio-economic characteristics of respondents

Two hundred and seventy-one (271) respondents (pastoralists and agro-pastoralists) were involved in the current research. The Table 4.13 shows that the majority (98.2%) of them were male and 90.8% were over 30 years of age. They consisted of pastoralists (58.3%) and agro-pastoralists (41.1%). The *Fulani* were the major ethnic group involved in the study (62.0%) followed by the *Gourmatché* (21.0%) and the *Mossi* (17.0%). 65.3% of respondents were migrant, 30.6% native of the survey villages and 4.1% transhumant transiting. Majority of interviewees were illiterate (88.2%), 6.3% were literate against 4.8% and 0.7% which are respectively primary school and secondary school level. The low educational level of respondents could negatively impact the performance of skills transfers for a better improvement of livestock farming. 79.3% of interviewees asserted to have agriculture as secondary activities against 9.4%, 7.6%, 2.8% and 0.9% respectively for fishing, trade, artisan and worker. It appears that livestock farmers are more and more interested in agriculture within the province. That may be due to the degradation of pasture species and regression of pastoral areas. The changes in climate conditions may also explain that situation.

Table 4.13: Socio-economic characteristics of the respondents

Variable	Frequency (%)	Variable	Frequency (%)
Gender		**Age range**	
Male	98.2	20 to 30 years	9.2
Female	1.8	More than 30 years	90.8
Ethnic group		**Respondents' origin**	
Fulani	62.0	Native	30.6
Gourmantché	21.0	Migrant	65.3
Mossi	17.0	Transhumant transiting	4.1
Household size		**Main activity**	
Less than 10	50.6	Pastoralists	58.3
More than 10	49.4	Agro-pastoralists	41.1
Level of education		**Second activity**	
Illiterate	88.2	Agriculture	79.3
Literate	6.3	Fishing	9.4
Primary school	4.8	Trade	7.6
Secondary school	0.7	Worker	0.9
		Artisan	2.8

Source : Author's field work, 2017

98%, 79% and 51% of the interviewees are owning less than 90 heads of sheep, cattle and goat respectively (Table 4.14). The mean herds sizes are 65 heads for cattle, 12 for both sheep and goat. The maximum and minimum size of herds are 10 and 575 heads, 1 and 300, 1 and 100 heads respectively for cattle, sheep and goat.

Kiema *et al.* (2016) found lower cattle herds size (36 ±3) and quite similar herds sizes of sheep (14±14) and goat (14±17) for transhumant herds from Sahelian Region of Burkina Faso. This may be due to the fact that most Sahelian pastoralists shift from large ruminants rearing to small ruminants in response to reduced rainy season grazing. Indeed, these last years the Sahel region is gradually experiencing a reduction of rainfall and forage biomass (Kiema *et al*., 2014).

Table 4.14: Livestock ownership and herds sizes

Herd sizes	Cattle	Sheep	Goat
Less than 90 heads	214 (79) *	265(98) *	138(51) *
More than 90 heads	57 (21) *	6(2) *	133(49) *
Mean size of herd	65(80)	12(22)	12(15)
Minimum size of herd	10	1	1
Maximum of herd size	575	300	100

*Number and frequencies of respondents

Source : Author’s field work, 2017

4.3.1.2. Perceptions of respondents on climate changes

Figure 4.16 gives an overview on the perceptions of pastoralists and agro -pastoralists on climate change. 93.4% of respondents asserted that temperature is increasing, while the rainfall amount, intensity and the length of rainy season was said decreasing by respectively 97.8%, 97.4% and 94.5% of respondents. 90%, 58.3% and 92.6% of respondents reported an increase in the occurrence of strong winds, floods and animals' diseases; 92.6% stipulated a late onset of the rainy season, while its cessation is early (96.7% of respondents). Similar results were obtained in the eastern regions of Burkina Faso (Kiema *et al.*, 2013 ; Kima *et al.*, 2015). These authors found out from respondents' perceptions a decrease in rainfall, an increase in temperature and strong winds, a shift in rainfall onset and cessation. Similarly, Akponikpè *et al.* (2010) found from 98% of respondents, change in the overall climate pattern within Sub-Saharan West-Africa. Furthermore, Ouédraogo *et al.* (2010) and Dipama *et al.* (2011) indicated from respondents perceptions a pejoration in rainfall conditions. However, changes perceived by respondents were not always in agreement with the observed climate data as indicated by Ouédraogo *et al.* (2010); Allé *et al.* (2013) and Zampaligré *et al.* (2013). Indeed, respondents indicated that Kompienga have experienced over the last three decades : a shift in wettest month of the year, a modification of rain onset and cessation, and a decrease of the number of rainy days. On the contrary, climate data analysis over the same period disagreed with respondents' perceptions and rather agreed with high variabilities in of rainfall characteristics. Such high variabilities and their related impacts on respondents' livelihoods might be easily seen by them as climate change.

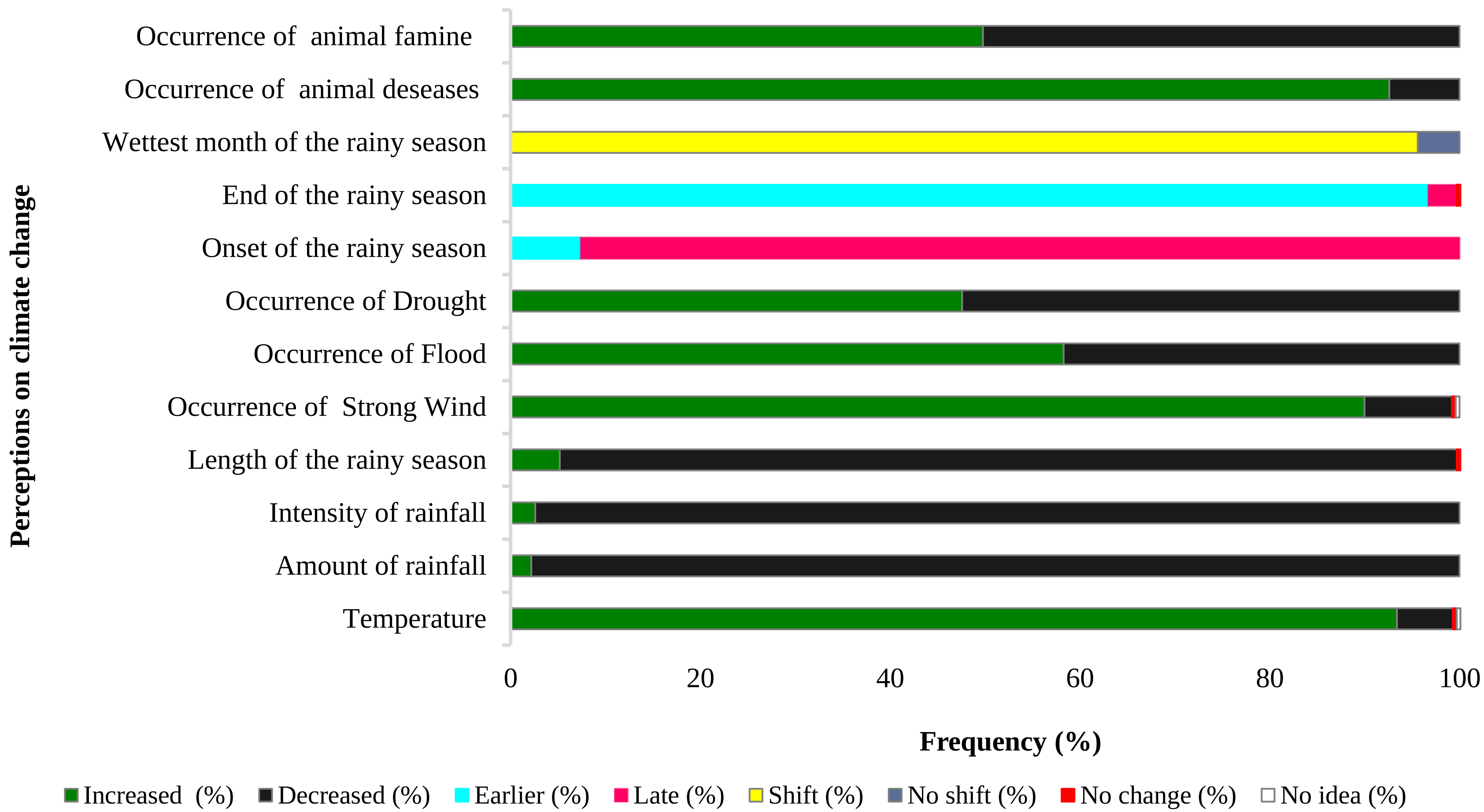


Figure 4.16 : Respondents’ perceptions of climate change and climatic hazards

Tables 4.15, 4.16 and 4.17 describe respondents' perceptions on climate variables in Kompienga province. Their perceptions on climate vary significantly according to the herding experiences, the ethnic and age groups.

Firstly, herding experience influences significantly ($p<0.05$) respondents' perceptions on temperature, rain cessation, floods and diseases occurrence (Table 4.15). Thus, more experienced pastoralists and agro-pastoralists were able to notice changes in climate parameters and their related undesirable impacts.

Secondly, Ethnic group influences significantly ($p<0.05$) respondents' perceptions on temperature, length of the rainy season and floods occurrence (Table 4.16). That situation may be due to socio-cultural realities of each ethnic group. Thus, ahead of *Gourmatché* and *Mossi* groups, Fulani were able to depict an increase in temperature, in flooding and a shortening of rainy season length than *Gourmatché* and *Mossi* group shortening.

Finally, the age influences significantly ($p<0.05$) respondents' perceptions on rain cessation, floods and drought occurrence (Table 4.17). Elder respondents (>30 years) were more able to appreciate climate variabilities and climatic hazards. Thus, they think a head of that [20:30 years] age group, that flooding is more and more frequent while drought is less recurrent in Kompienga province, and the cessation of rainy season is gradually earlier in the province.

Table 4.15: Respondents' perceptions on climate variables and climatic hazards according to herding experience

Climate parameters and climatic hazards		Herding experiences (years) > 20 (%)	[15:20] (%)	[10:15[(%)	[5:10[(%)	<5 (%)	Total	χ^2 (df)	P-value
Temperature	Increase	74.9	8.5	5.5	4.1	0.4	100	27.8(12)	0.006
	Decrease	5.5	0.0	0.4	0.0	0.0			
	Unchanged	0.0	0.0	0.4	0.0	0.0			
	No idea	0.0	0.4	0.0	0.0	0.0			
Floods occurrence	Increase	46.9	7.4	1.8	1.8	0.4	100	13.5(4)	0.009
	Decrease	33.6	1.5	4.4	2.2	0.0			
Diseases occurrence	Increase	76.0	8.1	4.1	4.1	0.4	100	21.5(4)	0.003
	Decrease	4.4	0.7	2.2	0.0	0.0			
Rain cessation	Late	2.2	0.4	0.0	0.4	0.0	100	17.1(8)	0.029
	Earlier	78.2	8.5	5.9	3.7	0.4			
	Unchanged	0.0	0.0	0.4	0.0	0.0			

Note: climatic variables for which the differences are insignificant are not represented

Source : Author's field work, 2017

Table 4.16: Respondents' perceptions on climate variables and climatic hazards according to ethnic group

Climate parameters and climatic hazards		Ethnic groups					
		Fulani (%)	Gourmantché (%)	Mossi (%)	Total	χ^2(df)	P-value
Length of Rainy Season	Decrease	59.8	18.5	16.2	100	16.1(4)	0.003
	Increase	1.8	3.0	0.4			
	No idea	0.0	0.0	0.4			
Temperature	Decrease	2.6	3.0	0.4	100	17.2 (6)	0.009
	Increase	59.0	18.1	16.2			
	No idea	0.0	0.0	0.4			
	Unchanged	0.0	0.4	0.0			
Flood occurrence	Decrease	27.3	10.3	4.1	100	7.5(5)	0.024
	Increase	34.3	11.1	12.9			

Note: climatic variables for which the differences are insignificant are not represented

Source : Author's field work, 2017

Table 4.17: Respondents' perceptions on climate variables and climatic hazards according to the age group

Climate parameters and climatic hazards		Respondents' Age (years)				
		>30 (%)	[20 :30] (%)	Total	χ^2(df)	P-value
Flood occurrence	Decrease	34.7	7.0	100	13.3(1)	0.0003
	Increase	56.1	2.2			
Drought occurrence	Decrease	49.8	2.6	100	6.6 (1)	0.010
	Increase	41.0	6.6			
Rain cessation	Earlier	88.6	8.1	100	8.0(2)	0.019
	Late	1.8	1.1			
	Unchanged	0.4	0.0			

Note: climatic variables for which the differences are insignificant are not represented

Source : Author's field work, 2017

4.3.1.3. Perceptions of respondents on land use and cover dynamics over 30 years

Respondents asserted changes in land use and cover over the last 30 years (10 years ago, 10-20 years ago and 20-30 years ago) within Kompienga province. Globally, croplands, settlement and water bodies were found out increasing while pasture lands, fallow, forest and bare lands are decreasing over the last 30 years. Thus, over (10, 10-20 and 20-30 years ago) croplands was found increasing by respectively 97.4%, 97% and 60.5% of respondents. Settlement was found increasing respectively by 98.9%, 98.2% and 62.7% of respondents. Water bodies was depicted increasing by 65.7%, 65.3% and 56.8% of respondents (Figure 4.17). 98.2%, 98.2% and 59.4% of respondents indicated a reduction of Forest over 10, 10-20 and 20-30 years ago. 72.7%, 74.2% and 55.4% of respondents depicted a decrease in fallow land over the same period while pasture lands (96.7%, 95.6% and 61.3% of respondent) and bare lands (68.6%, 70.5% and 62.4% of respondents) were found reducing. Similar results were reported by Kimiti *et al.* (2016), Kioko and Okello (2010) for grazing areas and croplands that were found respectively decreasing and increasing.

The most significant dynamics in land use and cover within Kompienga province during the last decades are the increase in croplands areas (98.5% of respondents) to the detriment of grazing areas (97.8% of respondents) (Table 4.18). Similarly Kimiti *et al.* (2016) indicated from respondents perspective that main change in pastoral resources over the last 40 years was the reduction of grazing lands due to the expansion of croplands and settlements.

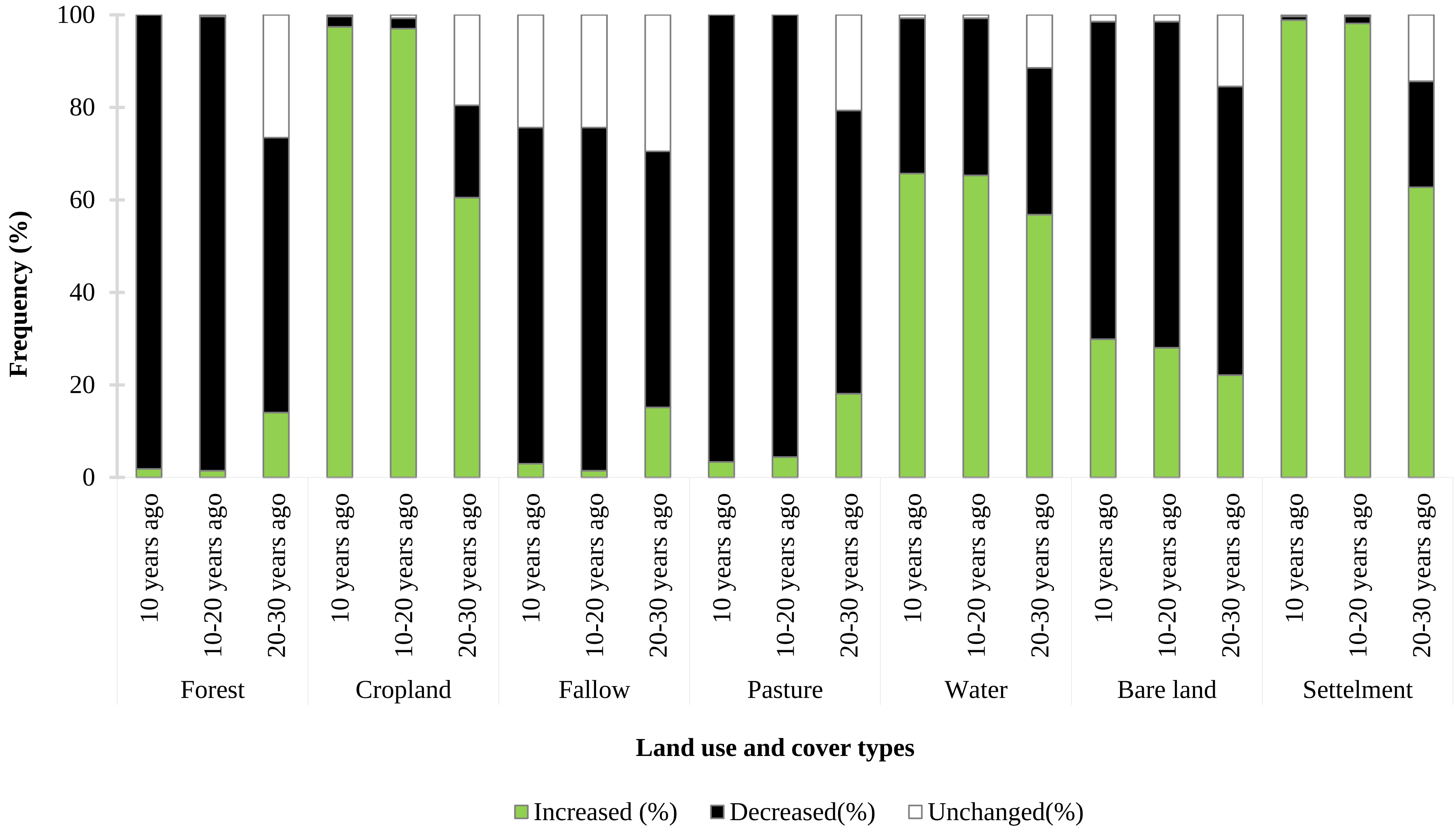


Figure 4.17: Perception of respondents on land use and cover dynamics

Table 4.18: Most significant changes in LULC over the last 30 years within Kompienga province

Land use and cover dynamics	Copland		Pasture	
	Agree (%)	Desagree (%)	Agree (%)	Desagree (%)
Most decreased	-	-	97.8	2.2
Most increased	98.5	1.5	-	-

Source : Author's field work, 2017

4.3.1.4. Drivers of the most significant changes in LULC within Kompienga province

The main drivers of the most significant changes in land use and cover types within Kompienga province are: population growth (99.1% respondents), cash crop development (33.6% respondents) and decline in rainfall (6.5% respondents) (Figure 4.18). Likewise, Ouedraogo *et al*. (2010), Maina and Mundia (2016) and Kima *et al.* (2016) revealed a strong relationship between population growth and land cover dynamics. In addition, respondents perceptions are corroborated by Ouedraogo (2010) who found that croplands expansion constitutes one of the most important drivers of land use change of developing countries.

On the contrary of Kima *et al.* (2016), collection of fire wood and increase in herd size did not constitute from respondents perspective, drivers of land use and cover dynamics within Kompienga Province.

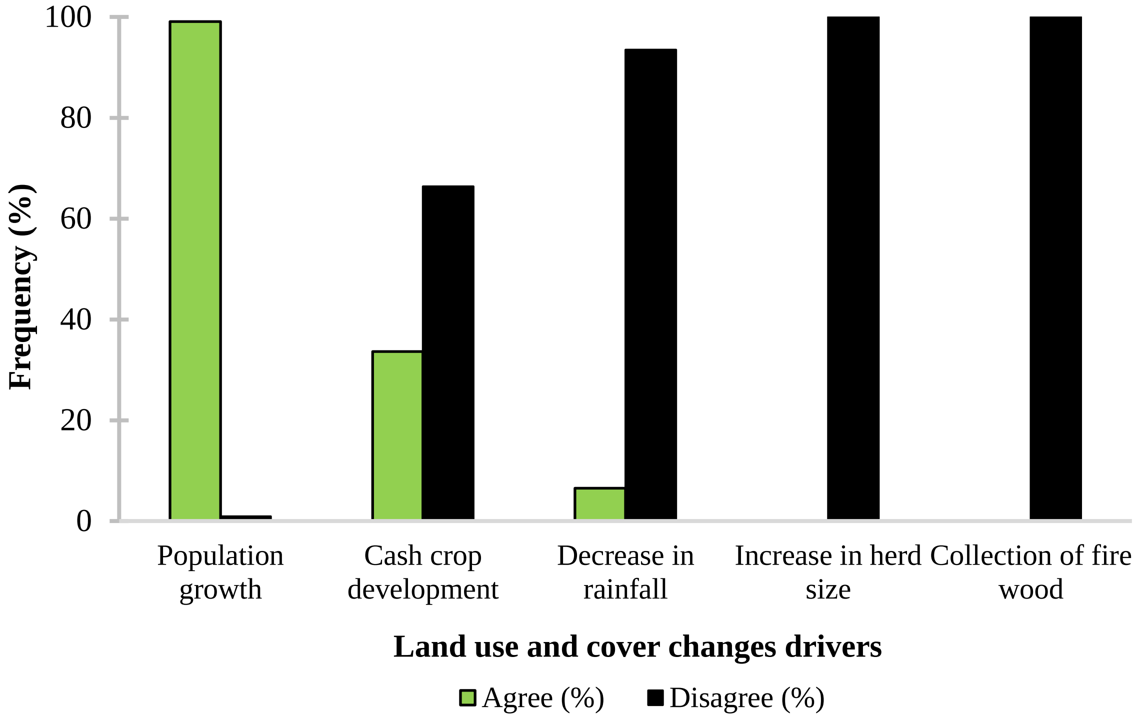


Figure 4.18: Drivers of the most significant land use and cover dynamics

Tables 4.19, 4.20 and 4.21 describe respondents' perceptions on land use and cover dynamics in Kompienga province over three-time periods (10, 10-20 and 20-30 years ago). These perceptions vary significantly ($p<0.05$) according to the herding experiences, the ethnic and age groups.

Thus, on the one hand, most experimented respondents depicted that cropland (10 years ago) and water bodies (10 years and 10-20 years ago) are decreased while bare lands are decreased over periods of 10, 10-20 and 20-30 years ago (Table 4.19).

On the other hand, unlike *Mossi* and *Gourmatché*, Fulani were better able to characterize the dynamics of land use and cover. They found that water bodies were reducing over 10 years and 10-20 years ago, while 20-30 years ago they were reducing. Pasture and fallow are indicated decreasing over 20-30 years ago while settlement was found increasing over the same period (Table 4.20).

Finally, older respondents were more able to describe land use and cover dynamics within the province. Thus, they indicated that water bodies increased in the province over 10, 10-20 and 20-30 years ago. Then croplands and settlement were found increasing over 20-30 years ago while forests were found decreasing over the same period (Table 4.21).

Table 4.19: Respondents' perceptions on land use and cover dynamics according to herding experience

Land use and cover Dynamics		Herding experiences (years)							
		> 20 (%)	[15 :20] (%)	[10 : 15] (%)	[5 : 10] (%)	<5 (%)	Total	χ^2(df)	P-value
Cropland 10 years ago	+	79.0	8.9	5.2	4.1	0.4	100	16.7(4)	0.002
	-	0.0	1.1	0.0	0.0	0.0			
Water 10 years ago	+	1.5	0.0	1.1	0.0	0.0	100	10.2(4)	0.037
	-	52.8	7.7	3.0	1.8	0.4			
Water 10-20 years ago	+	27.7	1.1	3.3	2.2	0.0	100	12.0(4)	0.017
	-	52.8	7.7	2.6	1.8	0.4			
Bare lands 10 years ago	+	27.7	1.1	3.7	2.2	0.0	100	10.8(4)	0.029
	-	26.9	0.4	1.1	1.5	0.0			
Bare lands 10-20 years ago	+	53.5	8.5	5.2	2.6	0.4	100	11.1(4)	0.025
	-	25.5	0.4	0.7	1.5	0.0			
Bare lands 20- 30 years ago	+	55.0	8.5	5.5	2.6	0.4	100	12.8(4)	0.012
	-	1.5	0.0	1.1	0.0	0.0			

Note: (+): increase; (-): decrease; LULC units for which the differences are insignificant are not represented

Source : Author's field work, 2017

Table 4.20: Respondents' perceptions on land use and cover dynamics according to ethnic group

Land use and cover Dynamics		Ethnic group			Total	χ^2(df)	P-value
		Fulani (%)	Gourmantché (%)	Mossi (%)			
Water 10 years ago	+	37.3	14.4	14.0	100	7.9(2)	0.019
	-	24.4	7.0	3.0			
Water 10-20 years ago	+	36.5	14.4	14.4	100	10.5(2)	0.005
	-	25.1	7.0	2.6			
Water 20 to 30 years ago	+	28.4	13.7	14.8	100	25.6(2)	0.000
	-	33.2	7.7	2.2			
Fallow 20 to 30 years ago	+	12.2	1.1	1.8	100	7.9(2)	0.019
	-	49.4	20.3	15.1			
Pasture 20 to 30 years ago	+	16.2	0.7	1.1	100	20.2(2)	0.000
	-	45.4	20.7	15.9			
Settlement 20 to 30 years ago	+	31.0	17.0	14.8	100	29.4(2)	0.000
	-	30.6	4.4	2.2			

Note: (+): increase; (-): decrease; LULC units for which the differences are insignificant are not represented

Source : Author's field work, 2017

Table 4.21: Respondents' perceptions on land use and cover dynamics according to age group

Land use and cover Dynamics		Respondents' age (years) >30 (%)	[20 :30] (%)	Total	χ^2(df)	P-value
Water 10 years ago	+	64.2	1.5	100	30.2(1)	0.000
	-	26.6	7.7			
Water 10-20 years ago	+	64.2	1.1	100	34.6 (1)	0.000
	-	26.6	8.1			
Water 20-30 years ago	+	55.4	1.5	100	18.7(1)	0.000
	-	35.4	7.7			
Forest 20 to 30 years ago	+	14.0	0.0	100	4.5(1)	0.034
	-	76.8	9.2			
Cropland 20 to 30 years ago	+	58.3	2.2	100	15.4(1)	0.000
	-	32.5	7.0			
Settelment 20 to 30 years ago	+	60.5	2.2	100	17.7(1)	0.000
	-	30.3	7.0			

Note: (+): increase; (-): decrease; LULC units for which the differences are insignificant are not represented

Source : Author's field work, 2017

Group discussion results from ten group of pastoralists allowed to give an overview on their viewpoints on climate change and land use/land cover dynamics (Appendix D) within Kompienga province over the last three decades. All group asserted an obvious increase in the occurrence of temperature, strong winds, droughts and a decrease in rainfall and shifts its onset and cessation. About land use and cover dynamics, within all villages great changes were depicted between 1987 and 2017. The major changes concern a rapid conversion of pastoral areas into croplands. The consequence is unprecedented on herders' activities. That situation is reflected in the declarations of Diao Hamadi, a herder of 40 years old, living in the village of Mamanga :*"Herding is now stifled by the fields that proliferate, there is no longer free grazing of animals; trapped between farmers and foresters. There are too many problems and sufferings, often with the desire to abandon this activity."*

In the same way, Diande Boureima, 67 years old, living in the Pastoral Zone Kaboanga; asserted that: *"Before, there were enough spaces for our animals that circulated and grazed freely unlike nowadays, due to a continual conversion of pastoral spaces into croplands*."

It is thus, obvious that land use and cover dynamics are affecting negatively pastoral activities in the province. Moreover, some important changes, such as within Nadiagou village (Figures 4.19 and 4.20) have concerned the conversion of forest or bush into settlement. Besides these changes, there is also conversion of pastoral areas and croplands into forest. Indeed, for instance, within Tambarga (Figures 4.21 and 4.22) the extension of Konkombouri National Park has been done to the detriment of pasture, cropland and settlement. Such dynamics might affect negatively both pastoral resources and practices respectively through the decline of available forage biomass amount and the pressure on fodder trees, changes in mobilities calendar and paths. Moreover, changes in land use and cover in the province have fueled the occurrence of violent conflicts between land users namely crop farmers and herders. Finally, majority of the herds have definitely migrated within Togo or Ghana due to a drastic reduction of pastoral areas.

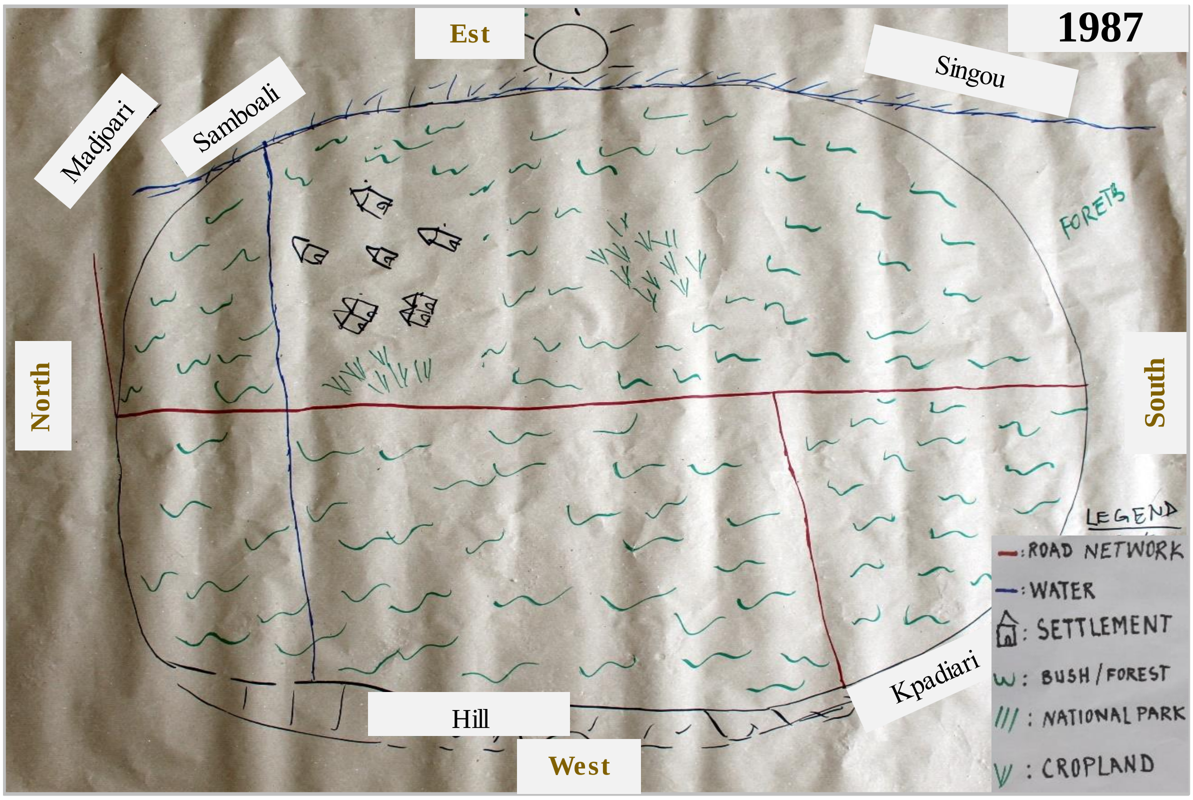


Figure 4.19: Participatory map of Land use and cover of Nadiagou 1987

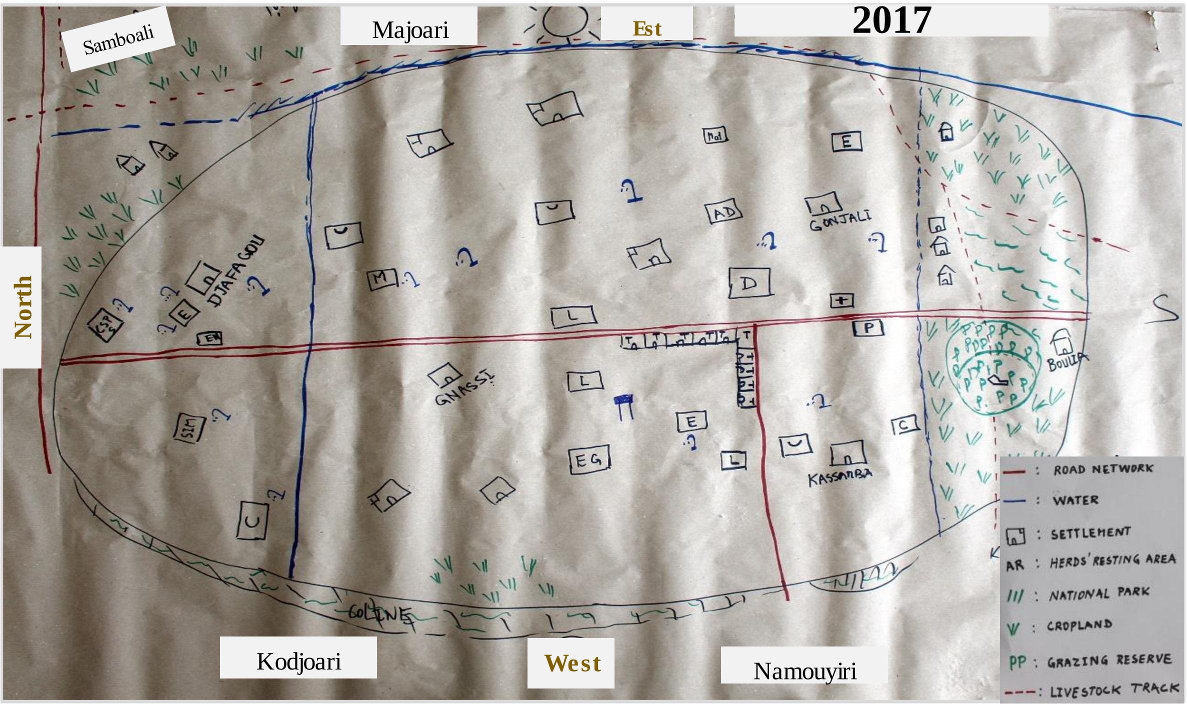


Figure 4.20: Participatory map of Land use and cover of Nadiagou 2017

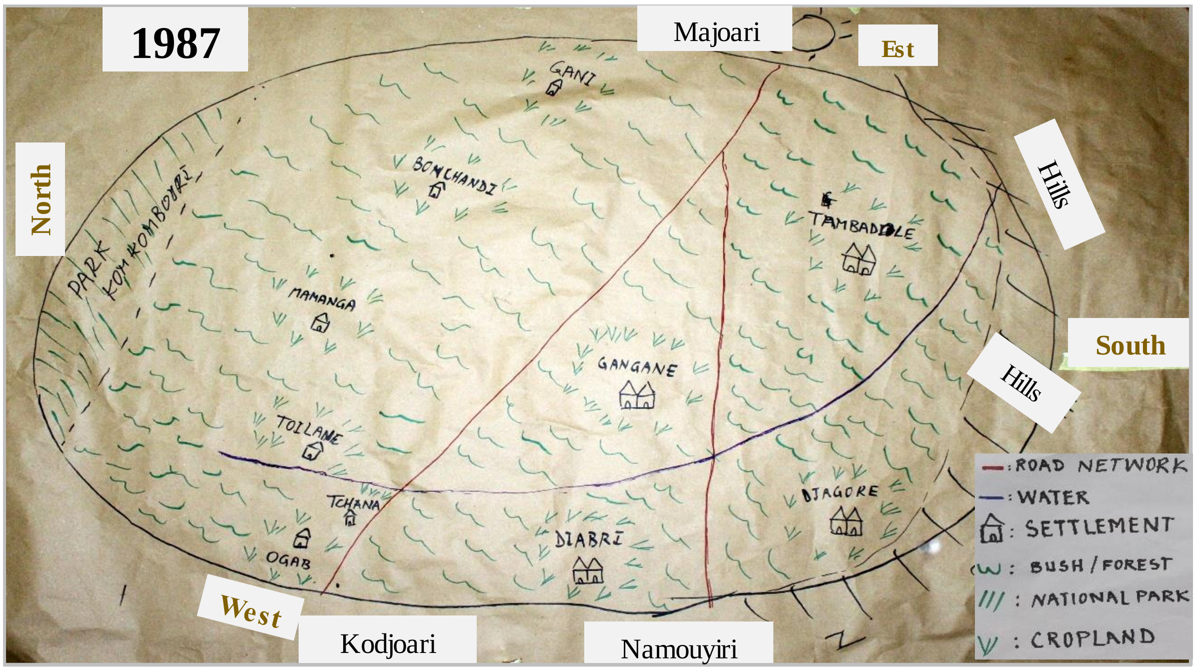


Figure 4.21: Participatory map of Land use and cover of Tambarga 1987

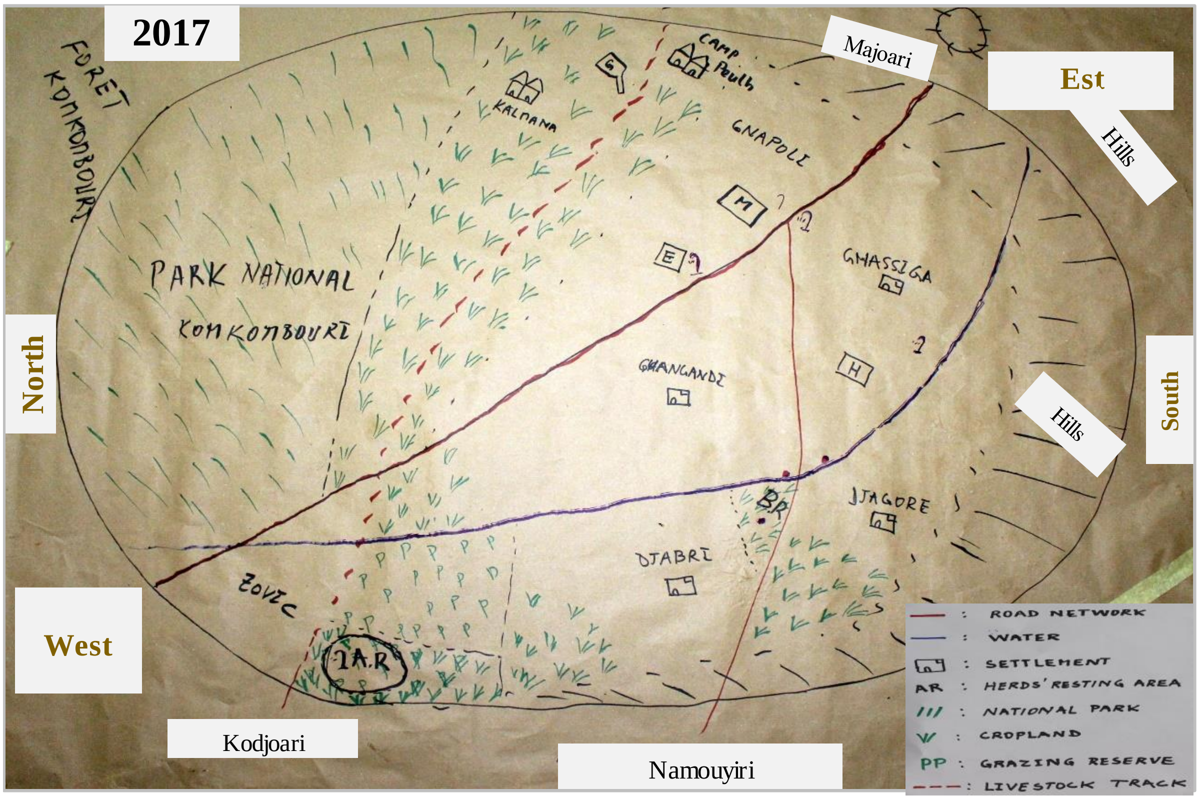


Figure 4.22: Participatory map of Land use and cover of Tambarga 2017

4.3.2. Respondents' perceptions of climate change impacts on pastoral system

4.3.2.1. Impacts of climate change on pastoral resources

Changes in climate condition of Kompienga province is affecting pastoral resources negatively during the last 30 years. Indeed, pastoralists and agro-pastoralists asserted that the changing climate have induced: (i) disappearance of herbaceous and woody forages species (100% of respondents); (ii) decline of herbaceous and woody forages nutritive quality (97.8% of respondents); (iii) shortage of pasture biomass over the last 5, 10 and 20 years (respectively by 99.6%, 93.3% and 73.8% of respondents) (Figure 4.23). This situation affects negatively the production performance of pastoral system which directly relies on the productivity of natural grassland. These results are corroborated by Zampaligré et *al.* (2013) in their findings across different zones of Burkina Faso. These authors found from pastoralists and agro-pastoralists a shrinkage of grazing areas and the decline of forage resources over the past 20 years. Furthermore, similar results were found by Breusers (2001), Sawadogo (2011) and Kiema *et al*. (2013). They attest that a decreased rainfall affects negatively the quality of pasture biomass and their productivity, inducing ultimately, the disappearance of most palatable species within grazing lands. Moreover, it was reported that climate change is affecting pastoral resources (Joshi *et al.*, 2013) through decreases in water and pasture, the replacement of palatable grasses by invasive weeds (Gentle and Thwaites, 2016). Similarly, Han and Hou (2011) and Maina and Mundia (2016), respectively, in Suniteyou District of China and Kajiado Region of Kenya, found that pastoral resources were negatively affected by climate change.

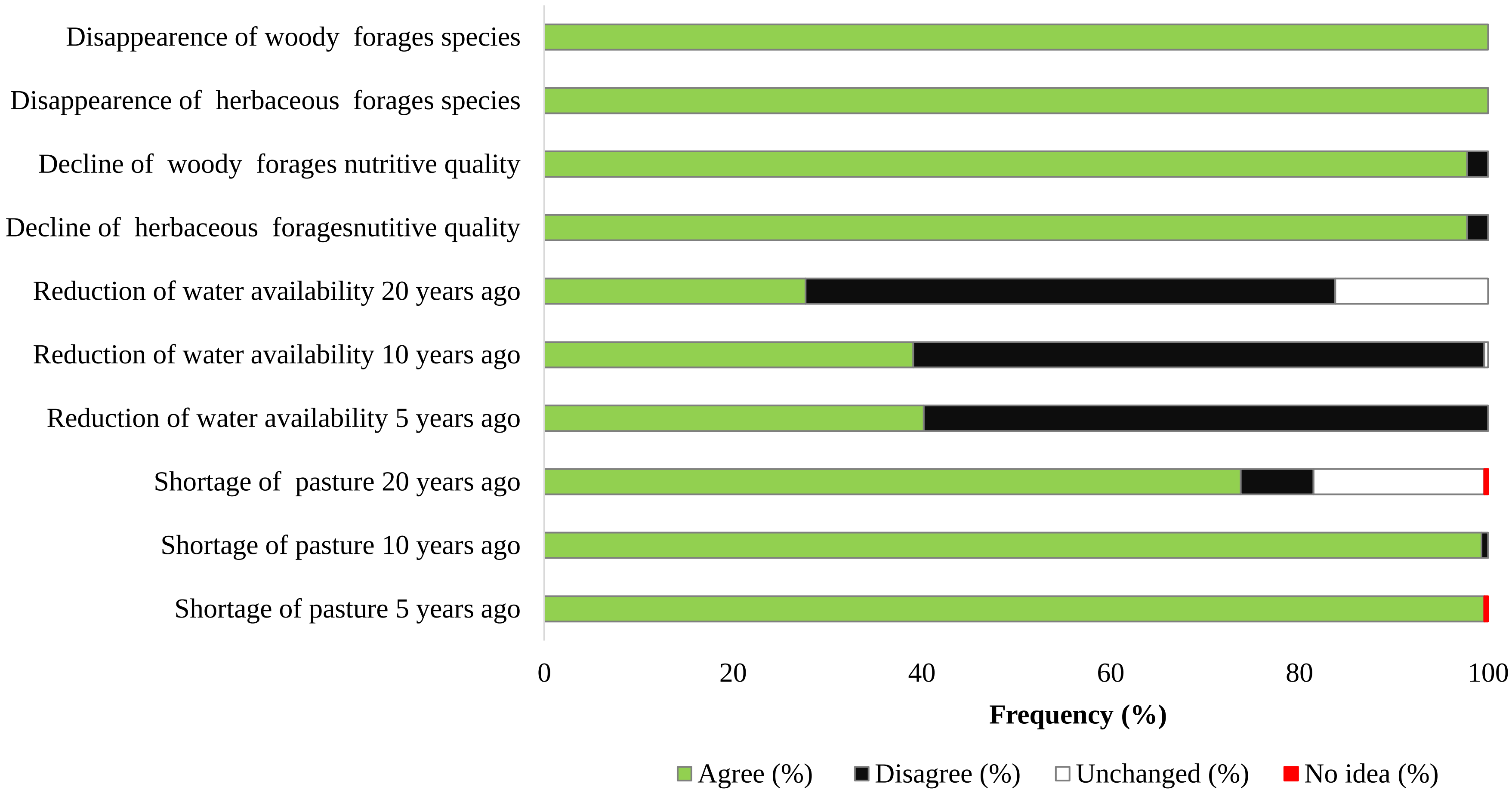


Figure 4.23: Impacts of climate change on pastoral resource

➢ Threatened forages species

Both individual survey and group discussion depicted that numerous forages are threatened or already disappeared from grazing lands.

These forages name were given in three local languages: *Fulani, Gourmatche and Mossi*. Most of forages species reported in local languages could not be identified by their scientific names. Indeed, from individual survey, only 5 (11.6%), 10 (47.6%) and 11 (15.1%) forages species were identified out of 43, 21 and 73 species respectively indicated *in Gourmatche, Moore* and *Fulani* (Figure 4.24 and Table 4.22).

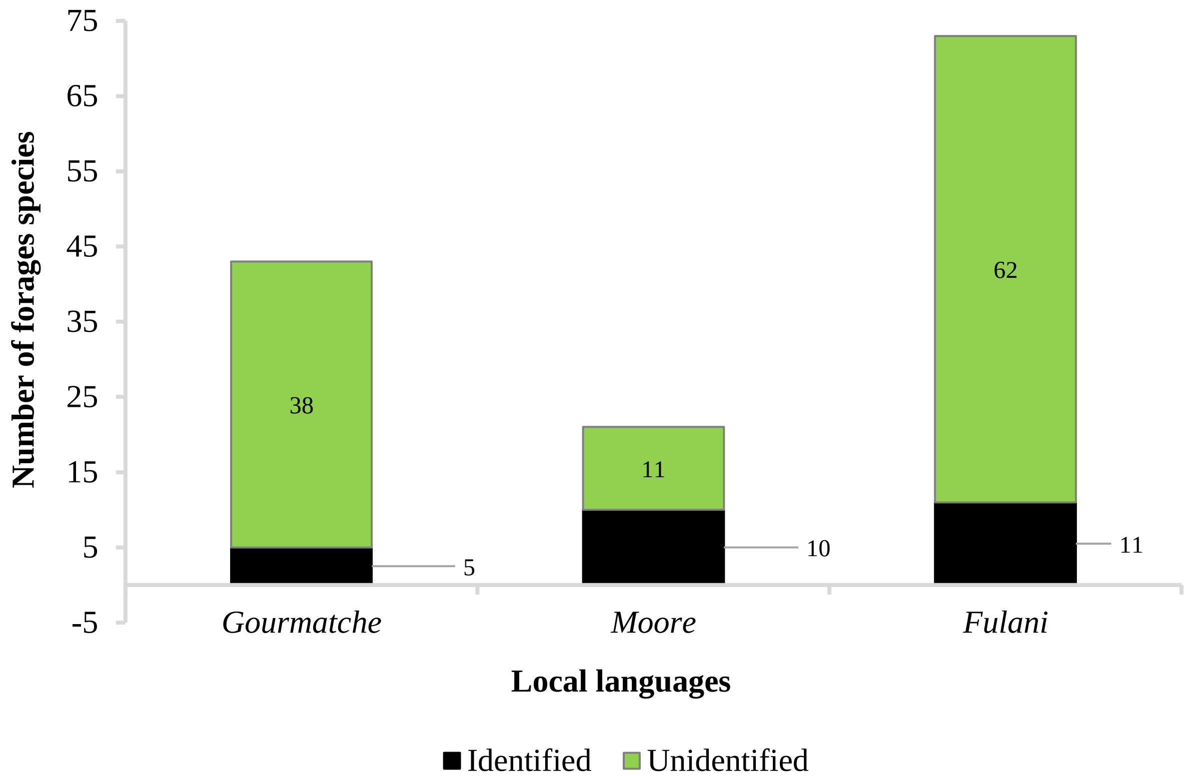


Figure 4.24: Number of forages species threatened or disappeared according to ethnic group

Table 4.22: Respondents' perceptions on forage species threatened or disappeared within Kompienga province

Scientific name of forage species	Local Name			Forage type
	Fulani	Gourmatche	Mossi	
Acacia gourmaensis	-	*Liguanguabli*	-	Ligneous, legume
Acacia senegal, Acacia seyal	-	*Ikonmonde*	-	Ligneous, legume
Andropogon ascinodis	*Soobo*	-	-	Herbaceous, grass
Andropogon gayanus	*Ɗayƴe*	-	*Moopaka*	Herbaceous, grass
Combretum nigricans	*Louiki, duyki, duyɗe*	-	-	Ligneous
Cymbopogon caesius	-	-	*Kouwessé*	Herbaceous, grass
Cymbopogon giganteus	-	-	*Mookanga*	Herbaceous, grass
Cymbopogon schoenanthus	*Buluuje, wuluunnde*	-	*Sompiiga*	Herbaceous, grass
Daniellia oliveri	-	*Onatonbou*	-	Ligneous, legume
Diheteropogon hagerupii	*Garaabal Garaabe*	-	-	Herbaceous, grass
Ficus S. Gnaphalocarpa	-	-	*Kankanga*	Ligneous
Hyparrhenia subplumosa	*Bukaare*	-	-	Herbaceous, grass
Lanea microcarpum	-	-	*Sabga*	Ligneous

Scientific name of forage species	Local Name			Forage type
	Fulani	**Gourmatche**	**Mossi**	
Monocymbium ceresiiforme, Schizachyrium sanguineum	*Yantaare, jantaaje*	-	-	Herbaceous, grass
Panicum laetum, Brachiaria xantholeuca, Brachiaria spp.	*Paguuri*	-	-	Herbaceous, grass
Pennisetum pedicellatum	*Bogodollo, bogodolloji*	-	*Garanga*	Herbaceous, grass
Pterocarpus sp.	-	*Inatondi*	-	Ligneous, legume
Rottboellia cochinchinensis, chasmopodium caudatum	-	-	*Kalgnaga*	Herbaceous, grass
Schizachryrium rupestre	-	-	*Gnantmiga*	Herbaceous, grass
Schizachyrium sp	*Houdo*	-	-	Herbaceous ; grass
Sterospermum kuntianum	-	*Inalinlinli*	-	Ligneous
Vitex doniana	-	-	*Gnandga*	Ligneous
Zornia glochidiata, Melliniella micrantha	*Dengeere, dengeeje*	-	-	Herbaceous, grass

Source : Author’s field work, 2017

Table 4.23 presents forage species described during group discussions with pastoralists. From group discussions, only 15 species (31.3%) out of 33 forage species described in *Fulani* were able to be identified. It appears today to be a real gap regarding the documentation of the equivalences between local appellation and scientific names of forages species in Burkina Faso. Filling this gap is essential to help a successful inventory of threatened and disappeared forages species of the country. That could help for a good decision making by policies makers; particularly through the reintroduction of certain species that disappeared from grazing lands.

Table 4.23: Forage species described during focus group discussion

Scientific Name	Fulani name	Forage type	Current state	Palatability
Acacia sieberana	*Alluki*	Ligneous, legume	Threatened	High
Pterocarpus erinaceus	*Banuuhi*	Ligneous, legume	Threatened	High
Sterculia setigera	*Mboɓoli, boɓole*	Ligneous, legume	Threatened	High
Pennisetum pedicellatum	*Bogodollo, bogodolloji*	Herbaceous, grass	Threatened	High
Hyparrhenia subplumosa	*Bukaare*	Herbaceous, grass	Threatened	High
Aristida spp., Schoenefeldia gracilis, Loudetia togoensis, Heteropogon contortus	*Celɓi, selɓo*	Herbaceous, grass	Threatened	High
Andropogon gayanus	*Ɗayƴe*	Herbaceous, grass	Threatened	High
Cymbopogon giganteus	*Fasuure, fassuuje*	Herbaceous, grass	Threatened	High
Andropogon ascinodis, Monocymbium ceresiiforme, Schizachyrium sanguineum	*Yantaare, jantaaje*	Herbaceous, grass	Disappeared	High
Rottboellia exaltata	*Ɗeloori*	Herbaceous, grass	Threatened	High
Khaya senegalensis	*Kahi*	Ligneous, legume	Threatened	Moderate
Afzelia Africana	*Kankalgahi, Kalkalgahi*	Ligneous, legume	Threatened	High

Scientific Name	Fulani name	Forage type	Current state	Palatability
Grewia bicolor	*Kieli*	Ligneous	Threatened	High
Combretum aculeatum	*Lawougni*	Ligneous	Disappeared	High
Panicum laetum, Brachiaria xantholeuca, Brachiaria spp.	*Paguuri*	Herbaceous, grass	Disappeared	High

Source : Author's field work, 2017

Forage specie that is more threatened or that are completely disappeared in some grazing lands is *Andropogon gayanus (dayŷe)***.** From the individual interview with the 271 pastoralists and agro-pastoralists 124 respondents (45.7%) indicted that this forage specie is about to completely disappeared from the grazing areas, while they indicated is presence within the protected area (Figure 4.25). In total, both for individual and group discussion, thirty (30) identified forages species were depicted to be threatened or already disappeared from the pastoral areas.

This situation is affecting negatively livestock productivity and the practices of herders which have to find forages for their herds.

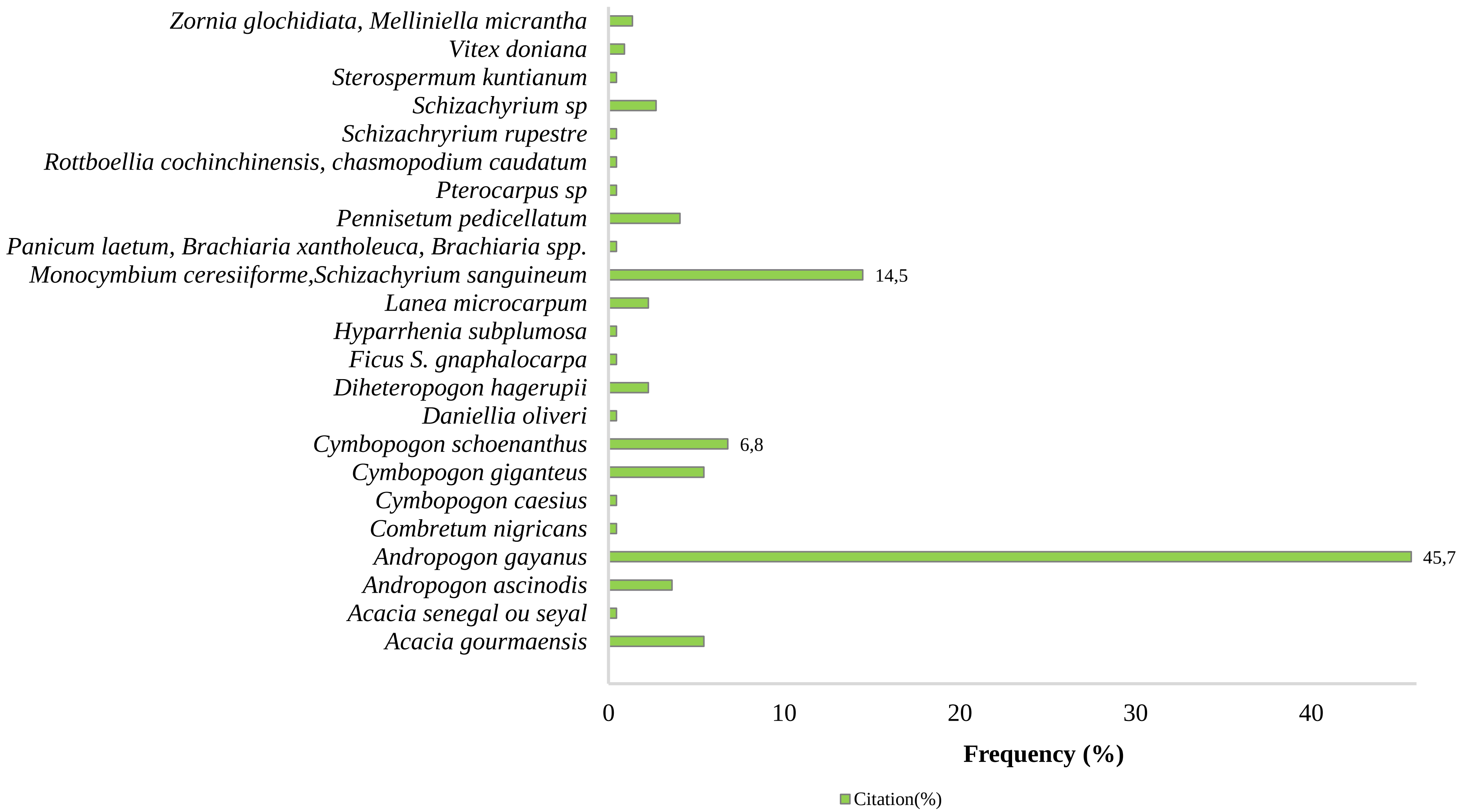


Figure 4.25: Percentage of citation of forage species threatened by respondents

- Causes of pasture degradation

Figure 4.26 describes the causes of pasture degradation within Kompienga province. Population growth (41%), and cash crop development (38.5%), are far the most important drivers of pasture degradation. Therefore, these drivers fuel land uses and cover dynamics as an immediate cause of this pasture degradation ahead of rainfall reduction (9.1%), increase in livestock size (6.3%), use of herbicide (3.8%) and Bush fire (1.3%). However, the gradual herbicide utilization by farmers appears today, one of the most preoccupant issues threatening biodiversity and a sustainable development of the province (Plate VIa,b). Otherwise, the use of herbicide plays also a paramount role in croplands expansion, because a farmer is able to burn out at least 2 hectares a day using an herbicide called Kalach (Plate VIb). In this process three immediate consequences are :(i) a rapid change in land use and cover, (ii) a progressive extinction of soils micro-organism essential for soil fertility; (iii) an interruption of the development cycle of annual grasses. Indeed, herbicide misuse could block the reproduction of some species due to a discontinued production of seeds burnt out during herbicide application. This certainly explains the extinction of fodder species reported by pastoralists and agro - pastoralists within Kompienga province. The declaration of Diallo Idrissa, 47 years old, living in the Kaboanga pastoral zone, is a perfect illustration: *"Following the proliferation of croplands, two very popular herbaceous species have completely disappeared from the rangelands: daŷŷe (A. gayanus) which stimulates dairy production and kankalgahi (A. africana) which is very nutritious for livestock. Misuse of pesticides is one of the causes."*

Besides, the decline in forage biomass, there is also a high risk of animal poisoning due to water contamination, the persistence of pesticides in soil and on grass. Indeed, as soon as the first rains start, farmers spray croplands using herbicides that are often unregistered. Grass so early pulverized intoxicates herds that graze there with heavy mortalities.

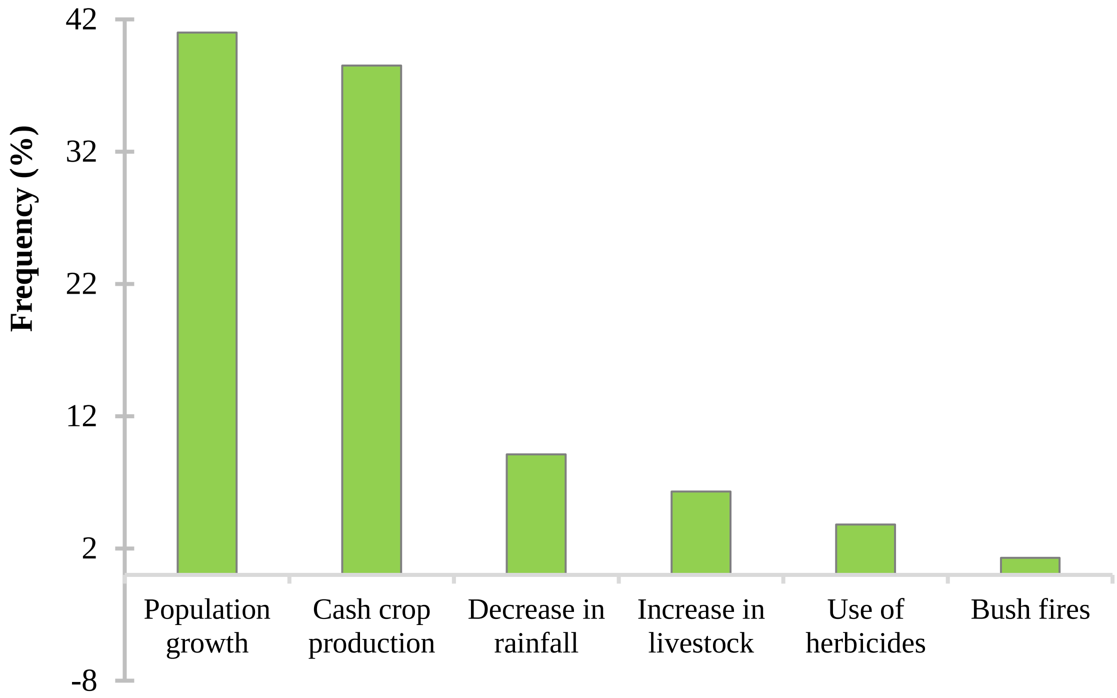
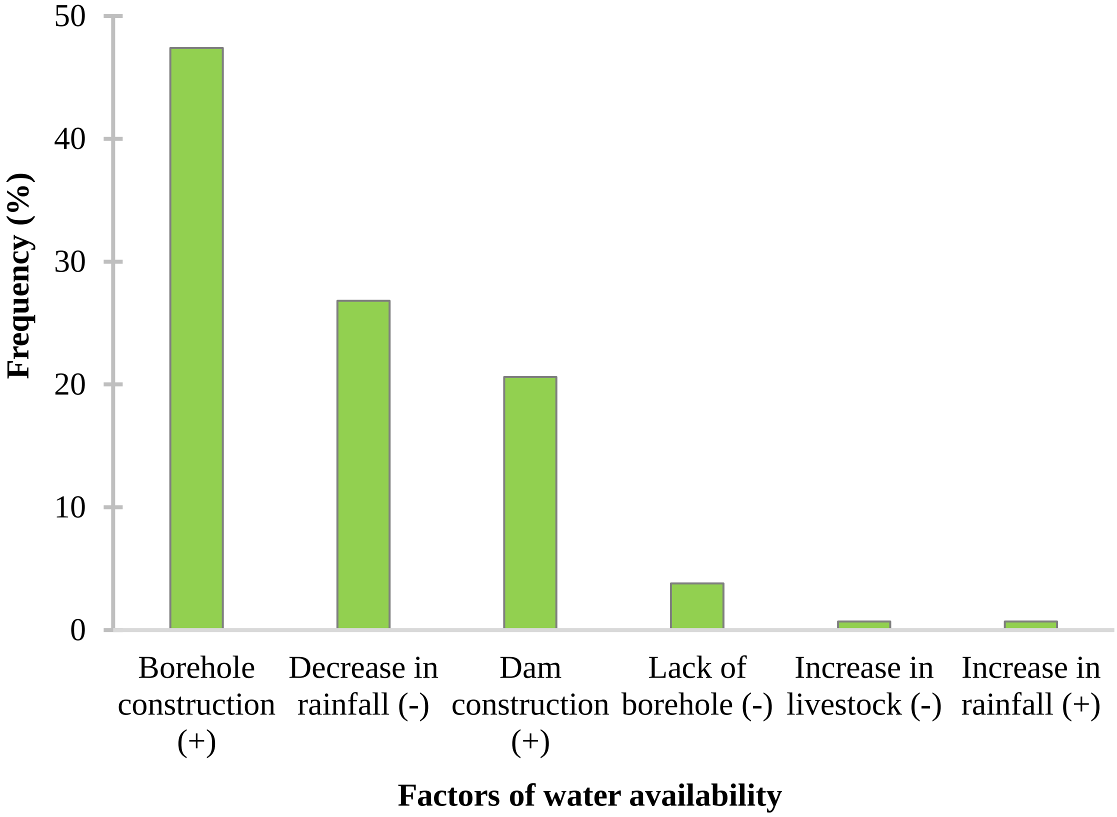


Figure 4.26: Causes of pasture degradation

(a) Spraying of herbicide in a field after sowing (b) effect of herbicide on fresh grasses
Plate VI: Increase use of herbicide in Kompienga province

➢ Factors of water availability for livestock

Within Kompienga province, numerous factors dictate the availability of water (Figure 4.27). According to the respondents, water availability in the province is increasing due mainly (47.4%) to the construction of borehole, then respectively by the construction of Kompienga dam (20.6%) and the increase in rainfall (0.7%). Otherwise, according to some respondent, factors responsible of water scarcity in the province are respectively the decrease in rainfall (26.8%), the lack of bore hole (3.8%) and the increase in herd size (0.7%). Generally, despite a gradual climatic variability over the province, water availability for livestock seem to be improved over the last decades due to government intervention.



(-) Factor contributing to decrease water availability; (+) Factor contributing to Increase water availability

Figure 4.27: Factors of water availability for livestock

4.3.2.2. Impacts of climate change on livestock

Table 4.24 gives an overview on respondents' perceptions on how climate change is affecting livestock during the last decades. 98.9%, 99.6% and 49.4% respectively reported a drop-in milk production, an excessive loss of body weight by livestock and a decline in yearly parturition of kids by cow. Otherwise 98.2 % reported an increase of infectious and parasitic diseases and an appearance of new animals' diseases. These results corroborate findings of Breusers (2001), Zampaligré *et al.* (2013), Sanfo (2014), and Gentle and Thwaites (2016). These authors asserted that climate changes affect livestock production performance (offspring numbers, milk and meat yields) and also causes the emergence of new livestock's diseases associated with high mortality. In addition, the combined effects of high temperatures, low rainfall, high evapotranspiration and high incidence of drought will have a negative impact on livestock (Sirohi and Michaelowa, 2007).

Table 4.24: Respondent's perceptions on climate change impacts on livestock over last 10 years

Climate change impacts	Agree (%)	Disagree (%)	No idea (%)
Animals travel longer distances to feed and drink	97.8	1.8	0.4
Decrease in the number of births per year	49.4	50.6	0.0
Drop in Milk production	98.9	1.1	0.0
Excessive loss of weight	99.6	0.4	0.0
Increase of infectious and parasitic diseases	98.2	1.8	0.0
Appearance of new animals' diseases	98.2	1.8	0.0

Source : Author's field work, 2017

4.3.2.3. Impacts of climate change on herder's livelihoods

Respondents reported that climate change negatively affect herders' livelihoods (Table 4.25). A decrease in incomes, a regression of animal heritage, food insecurity, increase in physical effort in herding and loss of prestige were noticed respectively by 95.9%, 98.5%, 78.2%, 100% and 87.5% of respondents. This is consistent with the results of Thornton *et al.* (2007) and Asian Development Bank (2013). These authors attest that climate change effects could affect severely pastoralists' livelihoods and food security. Dependent on rangelands conditions, this could happen through the numbers of animals that they can keep, livestock productivity, potential loss of animals during the dry season, and longer transhumance routes in search of feed for animals.

Table 4.25: Respondent's perceptions on climate change impacts on herder's livelihoods over last 10 years

Climate change impacts on herders' livelihoods	Agree (%)	Disagree (%)	No idea (%)
Decrease in incomes	95.9	3.7	0.4
Regression of animal heritage	98.5	1.5	0.0
Food insecurity	78.2	21.8	0.0
Increase in physical effort in herding	100.0	0.0	0.0
Loss of prestige	87.5	11.8	0.7

Source : Author's field work, 2017

4.3.2.3. Impacts of climate change on pastoral practices

Pastoral practices do not escape from the negative impacts of climate change. Figure 4.28 depicts how climate change is impacting pastoralists' practices. According to these respondents changes are observed over the last decade in the destination zone visited and transhumance route followed. About 46.6% of respondents reported changes in destination zone respectively 5 years and 10 years ago while 39.7% and 40.4% reported changes in paths followed by transhumant herds respectively over 5 years and 10 years ago. For the departure period in transhumance, it is reported to be earlier over the last ten years. Almost 92.5% and 91.8% of the respondents indicated earlier departure respectively over 5 years and 10 years ago. However, at least half of the respondents reported an increased duration within and to reach destination zones. Thus, 5, 10 and 20 years ago durations to reach receptions zones have increased respectively for 97.9%, 98.6% and 52.7% of respondents while 95.9%, 95.6% and 50.7% reported an increased duration within these zones.

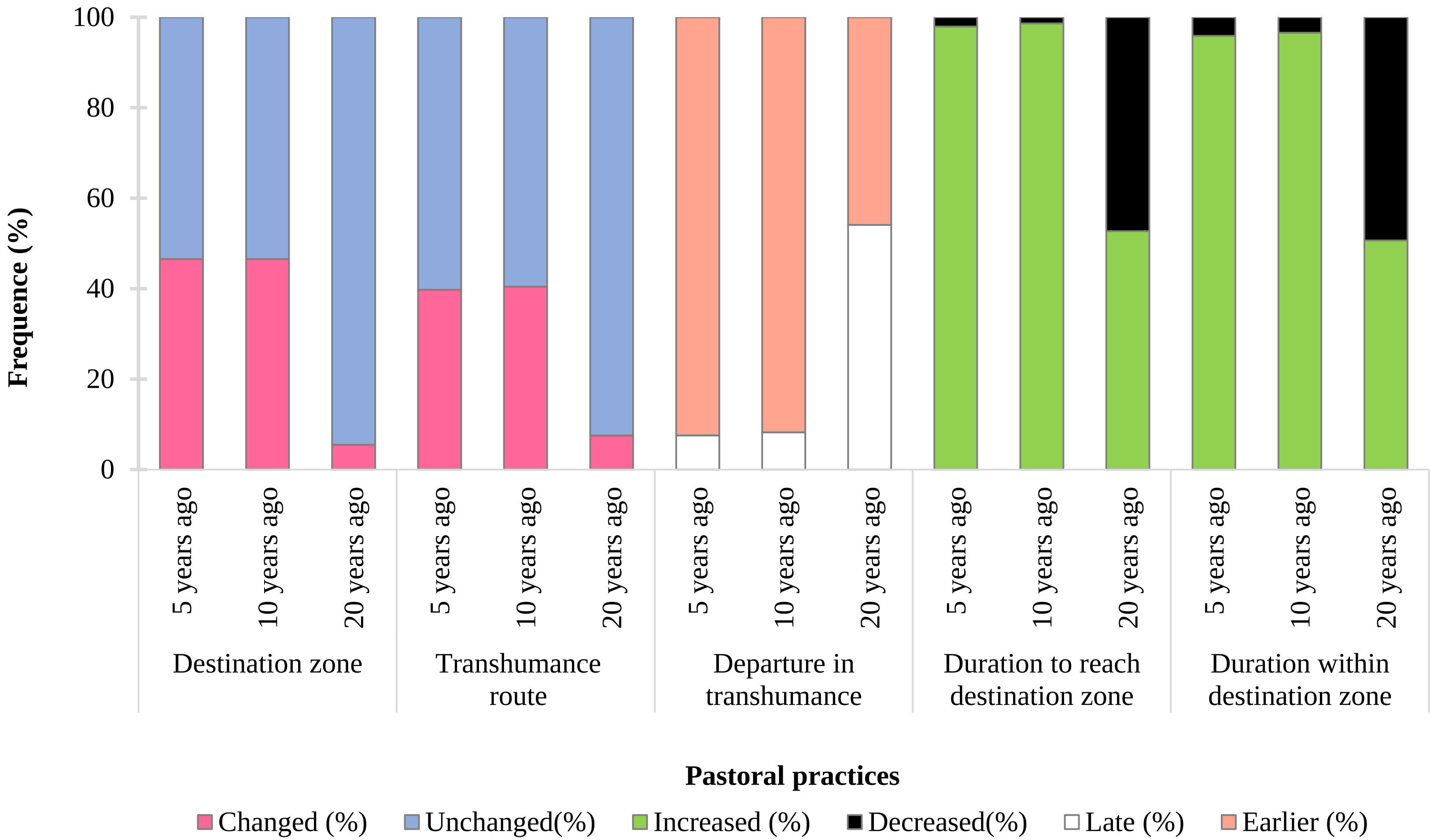


Figure 4.28: Impacts of climate change impacts on pastoral practices

4.3.3. Perception of respondents on LULC changes impacts on pastoral resources and practices

4.3.3.1. Impacts of land use and land cover changes on pastoral resources

In the respondents' perspective, Land use and cover dynamics is seriously affecting pastoral resources (Figure 4.29). As a result of changes in LULC, 82.3% of the respondents are of the view that LULCC (Land Use and Land Use Cover Changes) reduce access to pasture lands; 82.3 % opined that LULCC results to reduction in grazing areas sizes and some respondents (55 %) said an obstruction of transhumance routes. These results were similar to that of Kimiti *et al.* (2016), who reported significant changes ($p < 0.001$) in the range resources. The changes included a significant reduction in pasture ($\chi2 = 75.89$, df = 3, $p <0.001$) and livestock's routes ($\chi2 = 66.77$, df = 3, $p <0.001$) while croplands increased significantly ($\chi2 = 124.55$, df = 3, $p <0.001$). Furthermore, respondents' perceptions corroborate the findings of different authors (Niamir-Fuller, 2000; Western and Nightingale, 2003; Western and Maitumo, 2004; Western, 2006; Kioko and Okello, 2010; Msoffe *et al.*, 2011; Kioko *et al.*, 2012) who reported a decline in forage biomass and a reduction of pastoral areas to the benefit of settlement and croplands. Finally, there were 36.5 % and 17.5 % who mentioned reduced access to watering points and lands degradation respectively.

Land use and cover dynamics consequences are really worrying over the last decades. Within some villages during rainy season, livestock are confined in rocky areas unsuitable for agriculture (Plate VII a). Otherwise, the increasing search of arable land for cash crop development is aggravating the competition for land between herders and crop farmers. Pastoral areas are indeed, gradually coveted by crop farmers in Kompienga province with their corollary of conflicts. For example, Mamanga grazing area is gradually occupied by croplands (Plate VIIIa and VIIIb) despite the implication of local authorities to solve disagreement between crop farmers and herders. Despite boundaries between crop and pasture areas were delineated, crop farmers are still encroaching into the pasture lands. According to herders, crop farmers destroy trees that have been painted or simply removing the barks with the paint (Plate VIIIc); consequently, the consensually defined limits disappear gradually. Thus, cultivated land continues to expand beyond the defined limits and sustain conflict between the two groups. Furthermore, opposition was made to the delimitation of the Diabiga pasture area. The delimitation company abandoned the process of beaconing because of the misunderstandings between village actors who narrowly missed the clash (Plate VIIc).

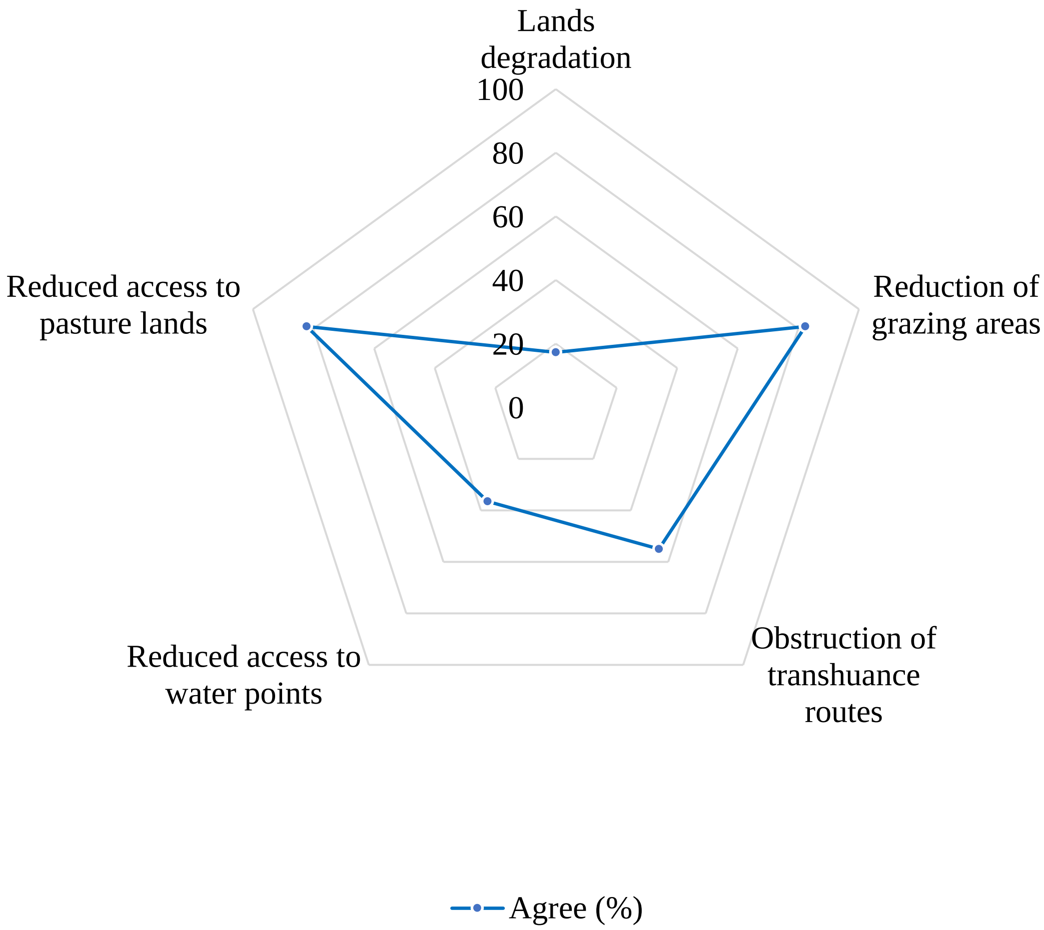


Figure 4.29: Impacts of LULC dynamics on pastoral resources

(a) Rainy season pasture in Kompienga districts

(b) Destruction of beacon in Diabiga

(c) Boundary marking challenges in Diabiga

Plate VII : Overview on grazing issue within Kompienga district

(a) View of an old field

(b) Clearing of a niew field

(c) Removal demarcation mark

Plate VIII: Contraints of Mamanga' grazing area withing Pama district

4.3.3.2. Impacts of land use and land cover changes on pastoral practices

The dynamics observed in land use and cover over the last decades within Kompienga province affected pastoral practices (Figure 4.30). Indeed, changes in LULC are causing an increase in pressure on forage trees (71.2% of respondents), in night watching of transhumant herds (90.4% of respondents), migration in unusual destinations (38.4% of respondents), modification in transhumance routes and schedule depicted by respectively 29.2% and 52.8% of respondents. In the province, the international transhumance route is occupied in several levels by croplands. Plate IX and X depict the occupation of the number 2 transhumance corridor of ECOWAS within Kompienga district by a building (Plate IXa), croplands (Plate IXb, IXc, Xb) and soil extraction (Plate Xa). Faced with this situation, farmers are obliged to follow alternative routes, for example along electricity network where human activities are prohibited (Plate Xc).

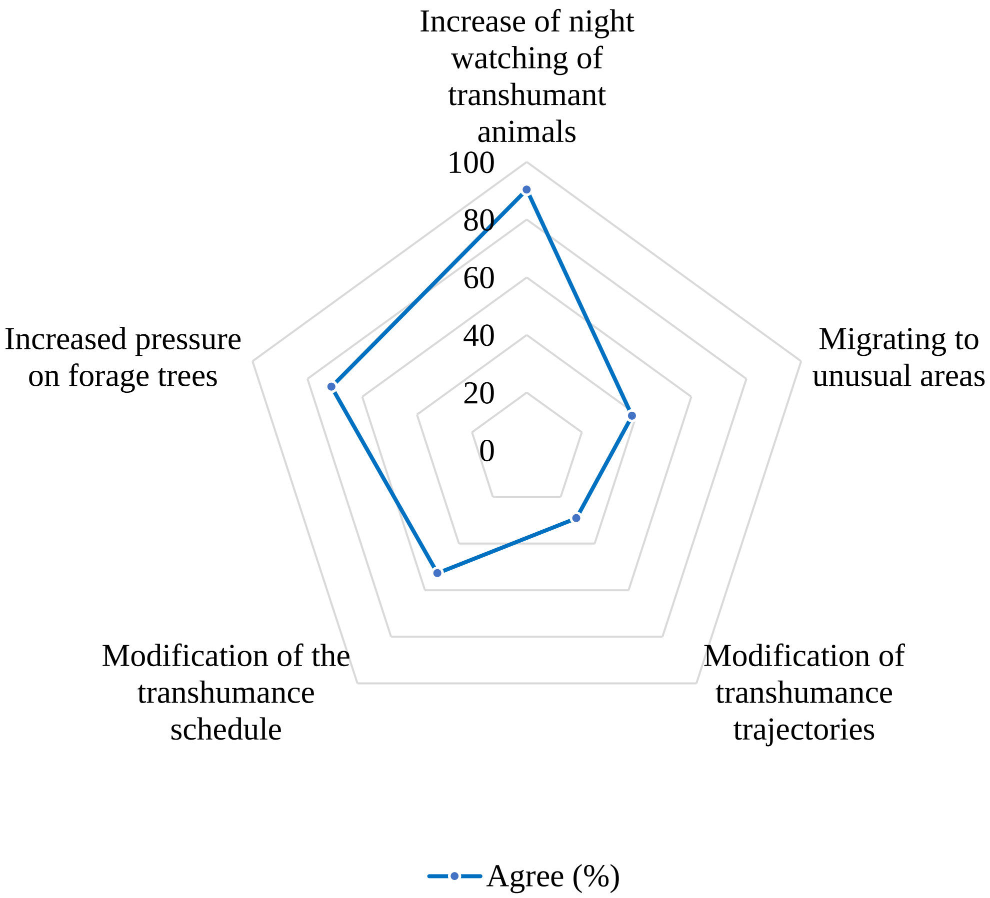


Figure 4.30: Impacts of LULC dynamics on pastoral practices

(a) Building on transhumance route

(b) and (c) Boundary marker in the heart of croplands (Kompienga city and Tagou village)

Plate IX: Encroachment of transhumance routes within Kompienga province

(a) Degradation of ECOWAS transhumance route

(b) Closeness of croplands and livestock routes

(c) Alternative livestock routes (Diabiga)

Plate X: Overview on other constraints related to pastoral areas

Besides individual surveys and group discussions with pastoralists, viewpoints of public services and Non-Governmental Organisations (NGOs) were also collected (Appendix E). All of them specified numerous changes in climate conditions namely: a decrease and high variability in rainfall, an increase in temperature with strong heat, an increase occurrence of drought and strong wind over Kompienga province. Otherwise they reported a great pressure on land in the province that fuels the recent land use and cover dynamics. These dynamics involve: (i) a rapid conversion rate of pastoral areas (pasture and livestock routes) into croplands; (ii) the occupation of grazing reserves by artisanal gold mining with a high risk of poisoning herds through a contamination of soil, pasture and water bodies by toxic products used by miners; (iii) change of grazing areas into Village Areas of Hunting Interest. Changes both in climate conditions and in land use and cover affect negatively the availability and the quality of forages for livestock use. Indeed, they noticed a decline of yearly forage biomass, a disappearance of the most desirable species and the proliferation of unpalatable species within grazing reserves. Similarly, Kimiti *et al.* (2016) reported a disappearance of preferred forage species within Kajiado County of Kenya indicating a deterioration over time, of pasture quality as well as grazing lands.

Given that Kompienga is a transit zone with ECOWAS transhumance routes, livestock pressure is gradually high on the residual pasture in such a way that the carrying capacity is quite permanently exceeded. This situation was also similarity depicted by Kimiti *et al*. (2016). For these author, the reduction of grazing areas and the degradation of pasture resources reflect croplands expansion and the increased grazing pressure as suggested by the respondents.

In such conditions herders develop news adaptation strategies. These refer to : (i) early transhumance despite the prohibition of crossing host countries boundaries before the dates set; (ii) increase pressure on fodder trees through cutting of leaves, fruits and branches due to scarcity of pasture; (iii) grazing within protected areas richer in pasture; (iv) permanent migration of herders toward host countries which is a loss for the Burkina Faso; (v) Before any transhumance, some herders go on preliminary surveys in the host countries to inquire about the occupation of the land and to ensure the progression of the livestock and the availability of suitable spaces for herd.

4.4. Respondents' Perceptions on the Future Land Use and Cover and its Implication for Pastoralism

4.4.1. Future degradation of pastoral resources

All the respondents asserted that Kompienga province will experience in the future, a further degradation of pastoral resources. The main reasons will be population growth (98.9%), cropland expansion (82.3%) and to a lesser extent, the decline in rainfall (5.9%), fire wood collection (2.6%), increase in temperature (1.1%) (Figure 4.31).

Facing the future deterioration of pastoral resources, respondent's strategies will be mainly the abandonment of pastoral rearing (67.2%), the reduction of herds size (65.3%) and activities diversifications (4.8%) (Figure 4.32). It appears therefore, obvious that pastoralism might have few chance to survive if the tendency of deterioration of pastoral resources is maintained. The abandonment of pastoral herding, herds size reduction will reduce herders' mobilities southward, thus emptying this herding mode of its content. Indeed, pastoralism, for a long time consisted of a jointly exploitation of the Sahelian, South Sudanese and Guinean pastures.

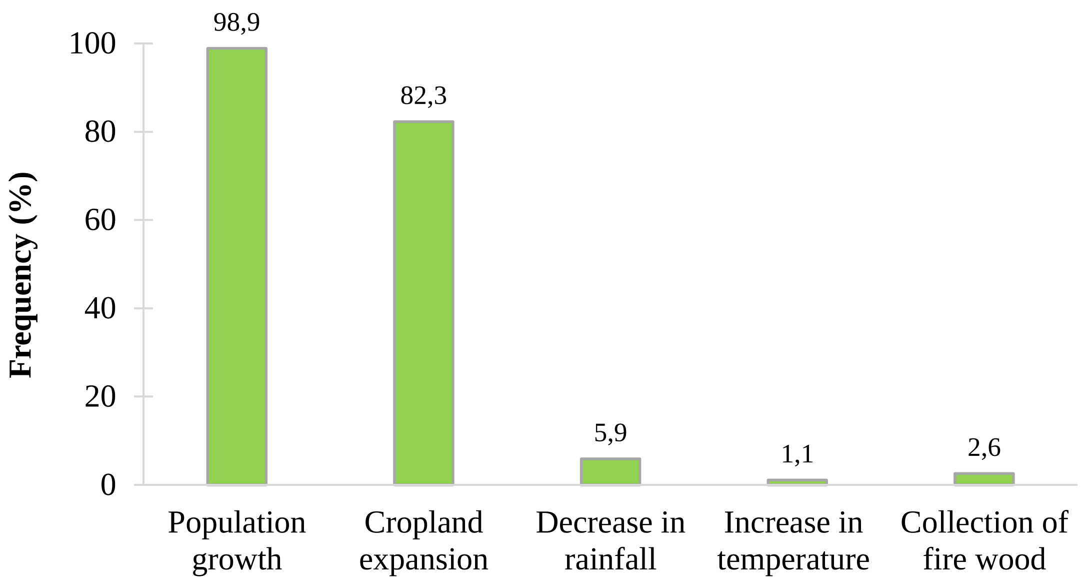
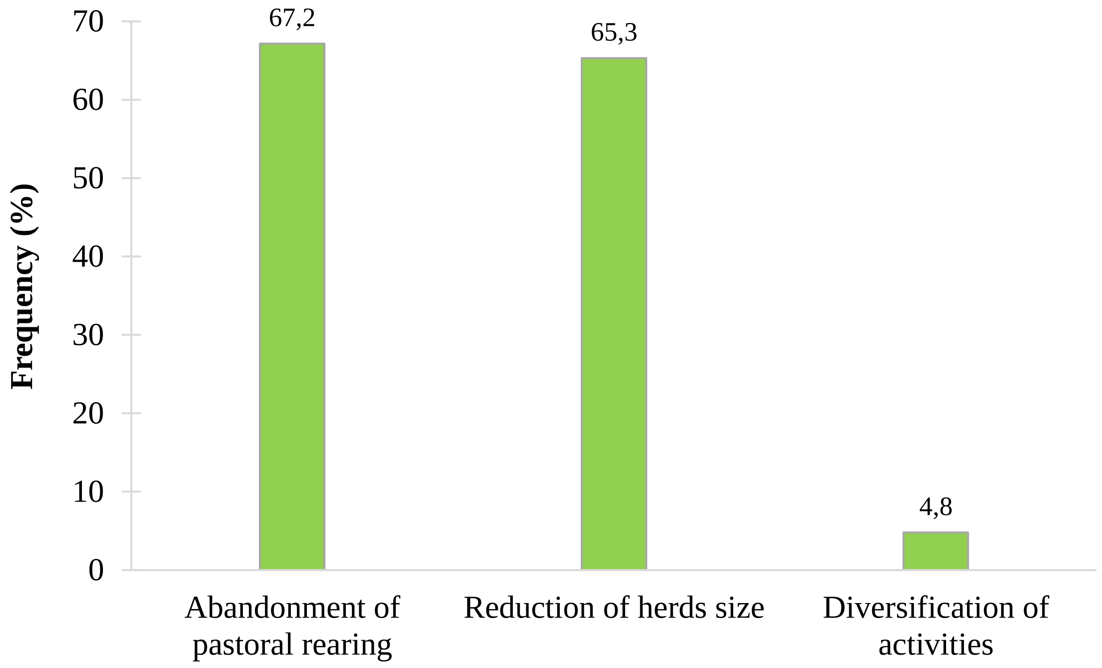


Figure 4.31: Drivers of future deterioration of pastoral resources



Future 4.32: Adaptation strategies to future pastoral resources degradation

4.5. Adaptation Measure to LULC Changes Impacts

To adapt to land use and cover impacts, pastoralists and agro-pastoralists develop numerous strategies (Table 4.26). The main strategies are: the increase in rate of cross border transhumance (98.2%), the use of agro-industrial by-products (97.4%), mowing and conservation of natural fodder (93.0%), splitting of herds (91.5%), diversifying activities (74.9%).

Table 4.26: Respondents' adaptations measures to impacts of land use and cover changes on pastoral activities

Strategies adopted	Agree (%)	Disagree (%)	Unchanged (%)	No idea (%)
Increase in rate of cross border transhumance	98.2	1.5	0.4	0.0
Shifting to small ruminant species	42.1	57.6	0.4	0.0
Use of agro-industrial by-products	97.4	2.6	0.0	0.0
Splitting herds	91.5	8.5	0.0	0.0
Diversifying activities	74.9	25.1	0.0	0.0
Grazing within protected area	7.4	91.9	0.0	0.7
Pasture production	18.1	81.9	0.0	0.0
Mowing and conservation of natural fodder	93.0	7.0	0.0	0.0

Source : Author's field work, 2017

4.6. Adaptation Measures to Climate Changes Impact and their Effectiveness

4.6.1. Respondents adaptation measures to climate change impacts

Respondents adopt some practices to cope with the negative effects induced by climate hazards and their impacts (Table 4.27). The most important strategies to adapt to drought are: Feed supplement (99.3%), the transhumance (96.3%), prayers and other rites (94.5%), the use of crop residues (93.7%), fattening/destocking (88.2%), the use of forage trees (76.8%), the use of ground water (65.3%). To adapt to the lack of grazing, the major strategies are: food supplement (98.2%), transhumance (97.0% respondents), use of crop residues (93.4%), fattening/destocking (87.1%), use of fodder trees (77.1%). Against the lack of water, prayers and other rites (92.3%), transhumance (90.8%) and the use of ground water (65.3%) are the principal strategies adopted by respondents. These adaptation strategies were quite similar that found by (Kiema *et al.*, 2013) and (Zampaligré *et al*., 2013). However, the results were quite different from findings of Kima (2014) and Kima et *al.* (2015). The authors reported similar adaptation strategies consisting in the use of crop residue (98.4%), the use of fodder trees (42.3%), herd destocking (44.8%). Furthermore, the authors indicated more adaptation strategies beyond that mentioned by respondents such as : the adoption of agro-pastoralism (89.5%), the use of concentrated feed (80.6%) and vaccination (91.9%).

Table 4.27: Adaptations measures to main climate hazard and their impacts on pastoral activities

Adaptation measures	Drought	Lack of grazing	Lack of water	Livestock diseases
Use of crop residues	93.7	93.4	0.0	1.8
Use of fodder trees	76.8	77.1	0.0	1.5
Rainwater harvesting	1.8	0.0	17.3	0.0
Use of ground water	65.3	3.0	65.3	0.0
Forage cropping	4.4	19.6	0.0	0.0
Fattening/Destocking	88.2	87.1	46.9	3.3
Transhumance	96.3	97.0	90.8	37.3
Abandonment of pastoral herding	3.7	12.5	8.9	6.3
Prayers and other rites	94.5	32.8	92.3	39.5
Food supplement	99.3	98.2	2.6	32.8

Source : Author's field work, 2017

4.6.2. Effectiveness of adaptation measures

Figure 4.33 bellow depicts the effectiveness of adaptation measures to climate hazards and their impacts on pastoral activities. From the point of view of respondents, the use of crop residues (78.2%), fodder trees (68.3%) and ground water (60.1%), the destocking/fattening (75.3%), the transhumance (72.7%), prayers and other rites (63.5%) and food supplement (83.4%) are efficient adaptations actions to drought. Efficient adaptations measures to the lack of grazing are: crop residues (77.5%), forage trees (69.4%), destocking/fattening (73.4%), transhumance (72.0%), food supplement (83.0%). To the lack of water, the efficient adaptation measure is the use of ground water (56.8%), transhumance (60.8%), prayers and other rites (54.6%). Finally, against the occurrence of livestock diseases, none adopted measure appeared to be effective to the recrudescence of animal diseases. The effectiveness of ground water to adapt to climate changes is confirmed by Masike (2007). Moreover, the effectiveness of livestock mobility, forage cropping, supplemental feeding and the use of well water were found to be an efficient adaptation practices to climate change and the extreme events (Asian Development Bank, 2013).

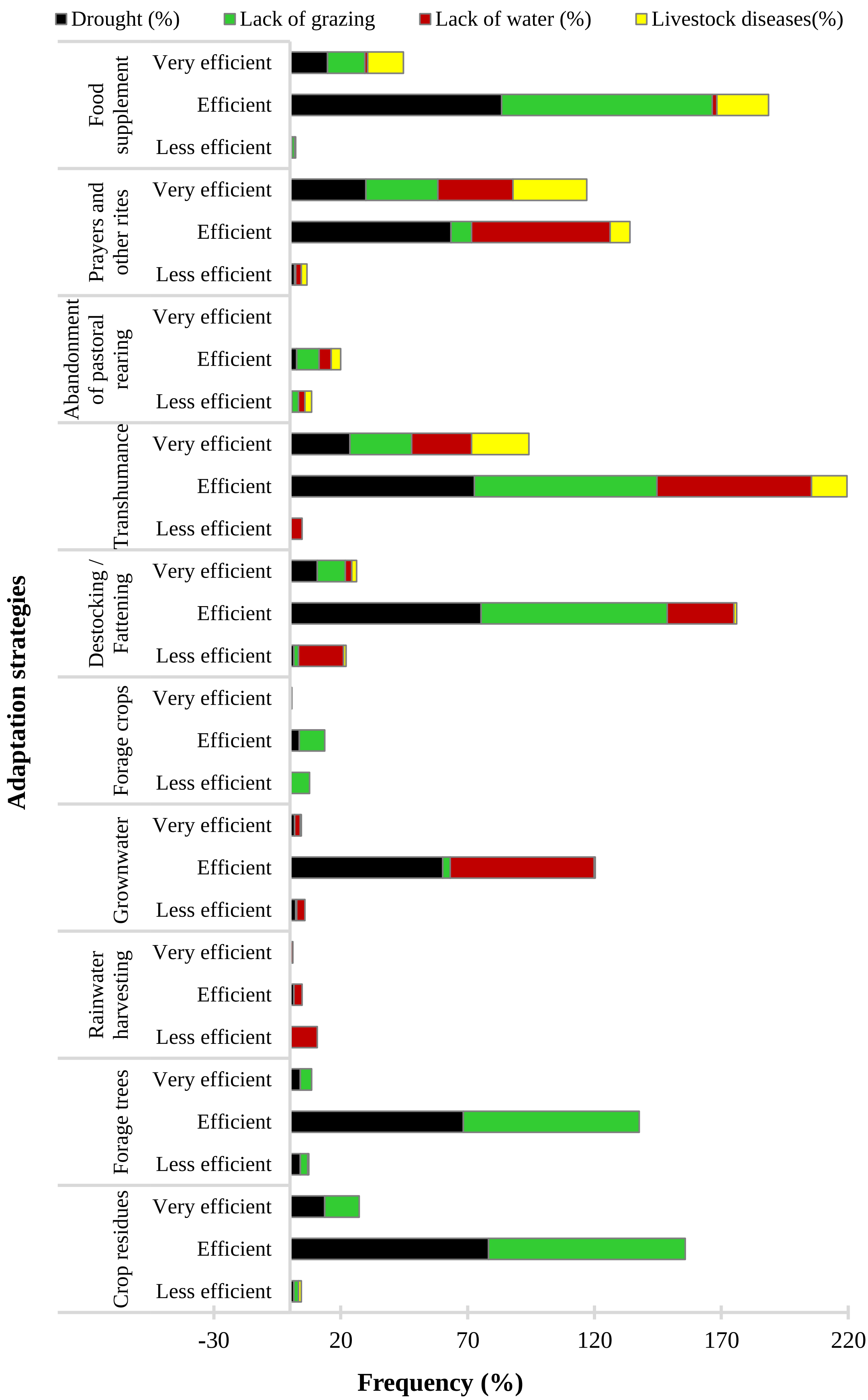


Figure 4.33: Effectiveness of respondents' adaptive strategies to climate change impacts on their activities

4.7. Transhumance Characteristics and Constraints of Pastoralist and Agro-pastoralists

4.7.1. Transhumance characteristics

Figure 4.34 describes transhumance from Kompienga province and its related constraints. Over the last six years (2011-2016) the rainy season in the province last 111 days (3 months and 21 days) with an onset and a cessation of respectively 20th June and 10th October. The rainfall dictates the growth and the establishment of pasture. Its availability, according to respondents, last about four months after the onset (20th June to end of October). Therefore, livestock is facing a long period (about 6 to 7 months) of forage deficit that encourage departure in transhumance.

Transhumants' aims are therefore to find elsewhere pasture and water to fill the fodder gap that the local environment is unable to ensure the availability during the whole year. Unfortunatly, the practice is gradually disturbed during the recent years by numerous constraints. Recently, the main host countries have established official dates of entry and release from their countries. For instance, in 2017, Togo Republic decreed for transhumant an authorized duration of 122 days (4 months) (MAEH, 2016). While Benin Republic decreed (MAEP, 2017) an authorized duration of 91 days (3 months) to 106 days (3 months and 15 days) depending on the departements visited by transhumants (Figure 4.34). These authorized durations are far shorter than the necessary duration (about six months). Indeed, in Benin Republic if the entry date in the country is acceptable (15th December), the release date (30th April) is penible for herds and herders. The month of April is one of the driest months in Burkina Faso and until beginning of June there is no rain. Only around 20th June that rainfall is expected to allow the regrowth of forages. This may take at least two (2) weeks before a gradual establishment of pasture. Both the entry date (30^{th} January) and release date (31 May) from Togo are also hard periods for transhumants. From end of November to end of January and end of May to first half of June, there is no rain in Burkina Faso. During these periods, the majority of biomass established during the past rainy season is completely dried. Thus, grazing lands are characterised by low quality and insuffiscient biomass unable to sustaint even sedentary herds.

Facing a changing climate and the gradual reduction of pasture, transhumance is characterized by new practices. Despite the official dates, herders are, either moving earlier inside the host countries or they move out later. The reason is to prevent the herd from being decimated by lack of forage and or water. For these reasons, transhumants stayed longer (up to July) than allowed in these countries, which exposes them to numerous constraints such as excessive payment of taxes and repressions from authorities, conflicts with crop farmers.

Given the above analysis, it is clear that the new decisions of the host countries will negatively affect pastoral rearing in Burkina Faso, if they remain. According to the respondents the best return period from transhumance is June.

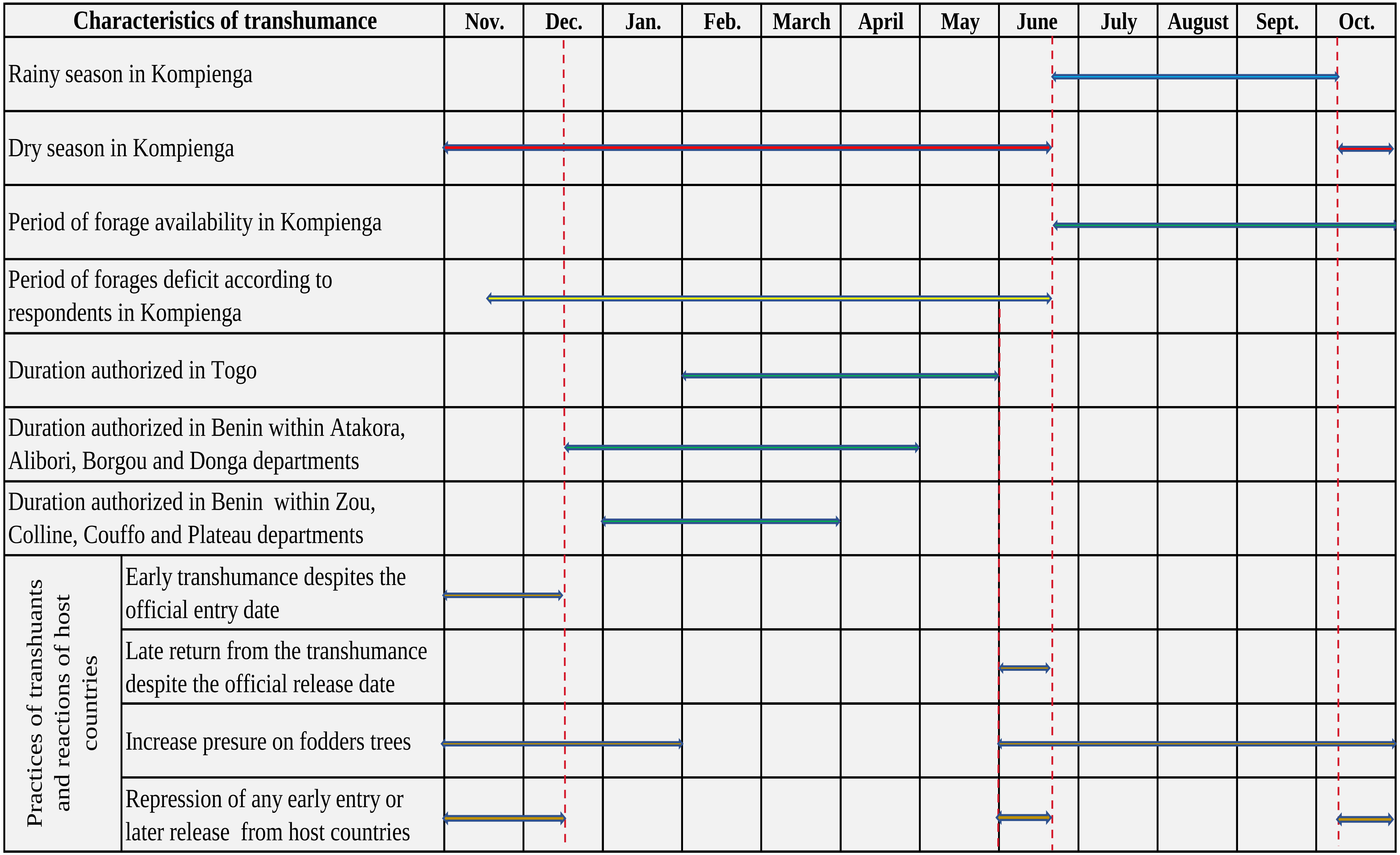


Figure 4.34: Comparison between official authorized period of transhumance and periods of pasture deficit within Kompienga Zone

Figure 4.35 gives an overview on pasture availability for livestock both in departure zone (Kompienga) and destination countries (Togo, Benin, Ghana). It also depicts livestocks performance and transhumant practices and related constraints over three sets of periods : rainy season, dry and cold season and dry and hot season. Over these periods pasture productivity is highly variable in Kompienga. The available pasture in the province during the rainy season allowed to maintain the good conditions of herds coming back from transhumance. In this period livestock are fat and produce enough milk for consumption and sale. At the end of the rainy season, forages biomass decreased and its quality is quickly depreciated by drying. The condition and production performance of herds also decrease gradually.

In order to avoid excessive loss of weigth and abortion of pregnant cows, herders adopt several strategies. Among these startegies there are : the use of agro-industrial by-products, use of fodder trees, vain grazing on crops residues after harvests, early transhumance. Indeed, after harvest, herders practice grazing on crops residues. Once the residues exhausted, they fall back on fodder trees and dry hay generally of poor quality. Some herders afford for agro-industrial by-products as supplementry feed and once in December no more resources and herds are forced to move toward coastal countries.

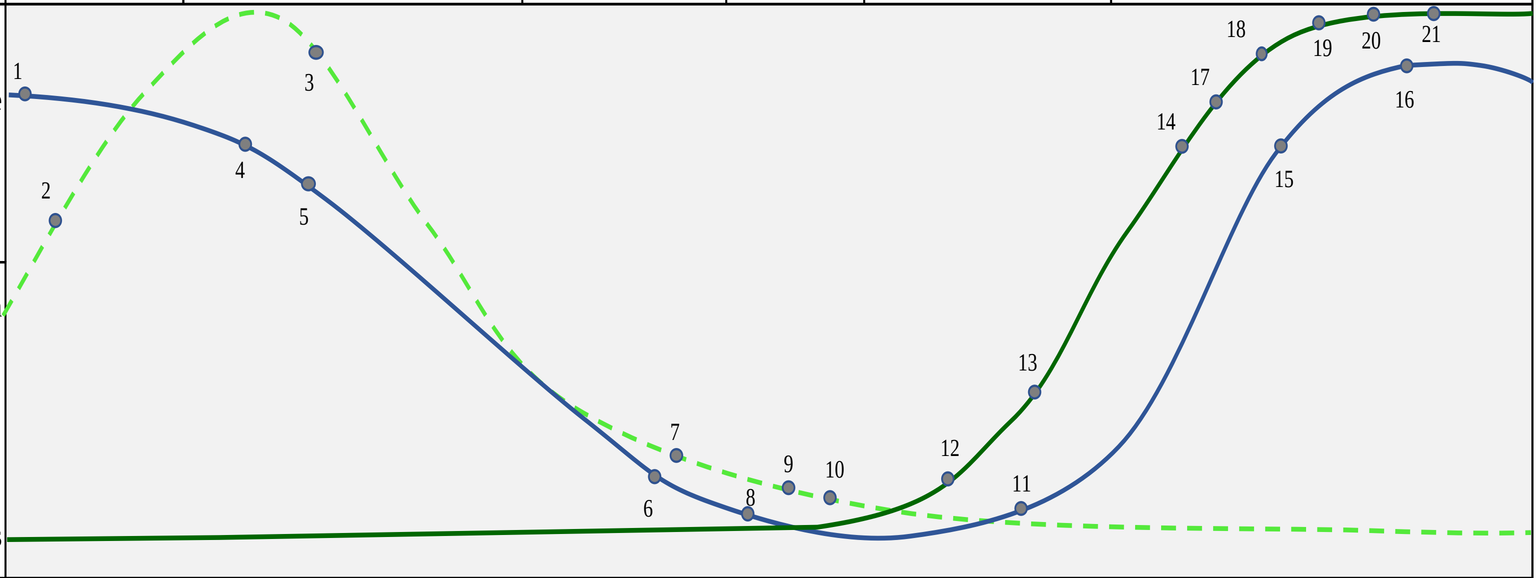
In a context of changing climate, herds and herders travel longer distances southward (within cross-border countries) in search of pasture and water. Grazing on rich pasture within host countries allows a rapid rebuilding of cattle body weight, increases fertility and parturition of cows.

Transhumants practices and associated constraints	2. Later release from host countries	5. Sale of milk and animals	7. Use of by-products	9. Presure on fodder trees 10. Vain grazing	12. Early departure in transhumance 13. Increase physical effort to find pasture	17. Migration to unsusual zone 18. Changes in paths followed 19. Increase nigth monitoring of herds 20. Excesive taxes 21. Violents conflicts (loss of life and herds)

Livestocks production performance

Fodder availability in Burkina

Fodder offer in host countries



Seasons in burkina Faso	Rainy season			Dry cold season		Dry and hot season		
Events in livestocks life	1. Livestock in good conditions	3. Grazing on Sahelian/Sudanian pasture 4. Production (milk, meat)	6. Fertilization of females	8. Loss of weigth	11. Great energy losses in search of pasture and water	14. Grazing on host countries pasture	15. Weight gain	16. Birth and increase in herd size

Figure 4.35: Relationship between forage availability, livestock production and reproduction performance; transhumance practices and related constraints

The reproduction and the increase in herds' size through increased calving rates (25-50 kids by transhumant herd) (Plate XI) is one of the major motivation of herders to risk the multiple constraints on their way for transhumance. Indeed, herders today move toward unusual zones and are sometime constraint to shift from paths usually followed because of croplands. To avoid destructions of crops they assent to increase night monitoring of transhumant herds. Otherwise, their are facing excessive payement of taxes during transhumance.

Finally, herders are also facing violent conflicts with human casualities and losses of livestock both in Burkina Faso and host countries. The words of some victims (Appedix G) of the violent conflicts of 2017 in Togo are illustrative. Diallo Ousmane, a 45-year-old transhumant, was victim of violent conflicts in Namom (Togo) in May 2017 asserted : "*I was a victim, lost 220 oxen that were killed by firearms, moreover a thousand oxen were killed during this conflict.*"

Plate XI: Kids of two transhumant herds coming back from Togo

4.7.2. Grazing reserves, transhumance routes and their hotspots

Within Kompienga province there are six grazing areas among which three are not gazetted: grazing areas of Diabiga, Tambarga and Mamanga. However, beside the grazing areas of Nadiagou and Kompienga, all the others are occupied by crop farmers. The consequences of grazing areas occupation are conflicts between pastoralists and crop farmers.

Biomass production within these grazing areas, is not sufficient to sustain livestock grazing. That situation underpins the magnitude of pastoralists transhumance. Figure 4.36 describes the evolution of transhumant herds size since 2003. Globally, transhumant herds size increase from 2009 to 2015 with pick of 20 347 herds in 2014 for all the ruminants (Cattle, Goat, Sheep). From 2015 a decrease in transhumance is noticed probably due to the increase of recent conflicts within host countries. Conflicts become frequent around grazing reserves and along transhumance route both in Kompienga and host countries (Figure 4.37).

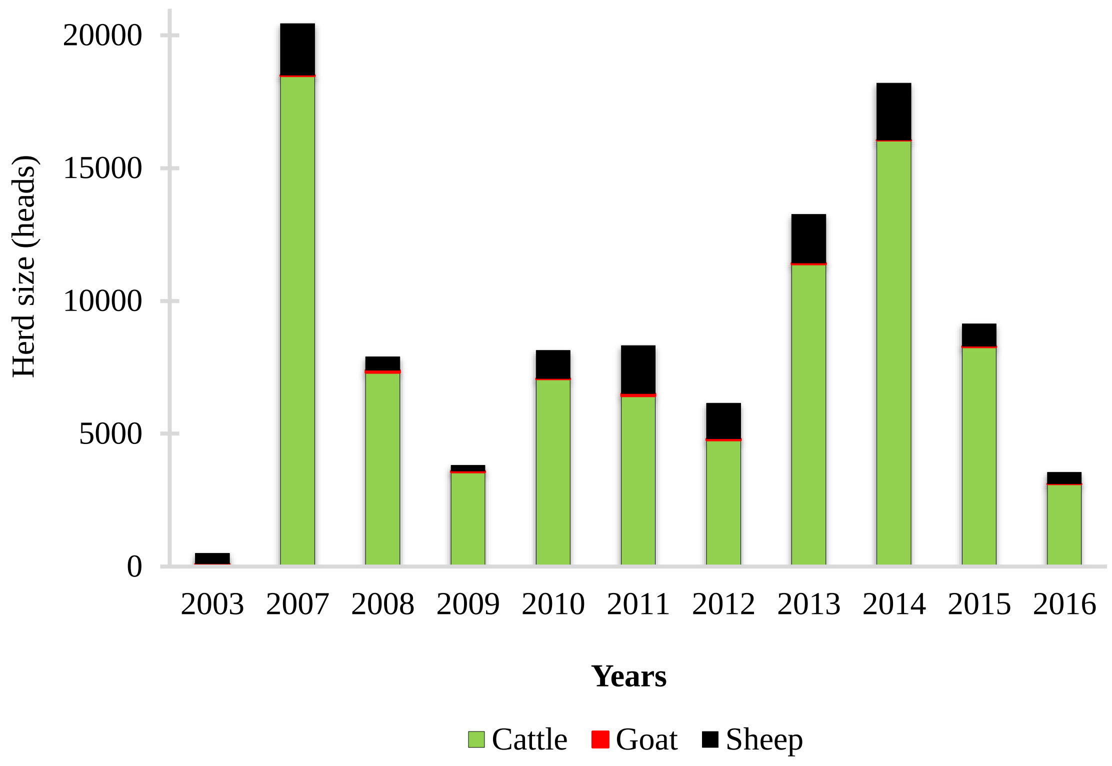


Figure 4.36: Evolution of transhumant herd size in Kompienga province *(sources: Direction Générale des Etudes et des Statistiques Sectorielles (DGESS) du Ministère des Ressources Animales et Halieutiques (MRAH) du Burkina Faso)*

The Figure 4.37 shows transhumance routes from Kompienga province and the localities that have experienced conflits over the last decades. Indeed, on one hand violent conflicts were reported in Nadiagou in 2013, Pama in 2014 and recently in 2015 within villages of Mamanga, Diapienga, Tibadi, Folpodi, Nimoutingou. The last conflict affected 106 Fulani camps, 343 houses burnt, 3.9 tons of by-product destroyed and about 80 tons of hay burnt 35 goats and sheep killed (ZATE, 2015). On the other hand, inside Togo, violent conflits were registered within villages of Kante, Namon and Kouka in 2017, within the village of Borgou in 2014, in the village of Bassar 2016 and 2017 and within the village of Djarakpana over the last five years. Finally, recent conflicts were also reported in Benin Republic (village of Datori) and in Ghana (village of Guschiegu) respectively in 2013 and

2016. These conflicts are characterized by loss of both human and livestock life orchestrated by crop farmers along transhumance routes.

Pastoralists are facing more conflicts and taxes payment within Togo and nevertheless, they prefer moving into this country contrary to Ghana and Benin Republic. According to respondents, Togo offers more suitable environment for a best production and reproduction conditions of livestock. In this perspective, they asserted that rainfall and forage availability are earlier in Togo. Great availability of water and high forage quality in Togo appears also to be two major factors that attract herders more than the other destinations. Indeed, transhumant pastoralists stipulated that forage in Benin Republic is highly contaminated with diseases. Each herd once back from Benin Republic, must be seriously treated to avoid mortalities due to diseases contracted during grazing. Less transhumance is noticed toward Ghana probably due to the distance. Furthermore, over last years, herders seem to move far and far southward within host countries. Therefore, according to respondents, transhumant herds start visiting the village of Djarakpana only this last five (5) years (Figure 4.37).

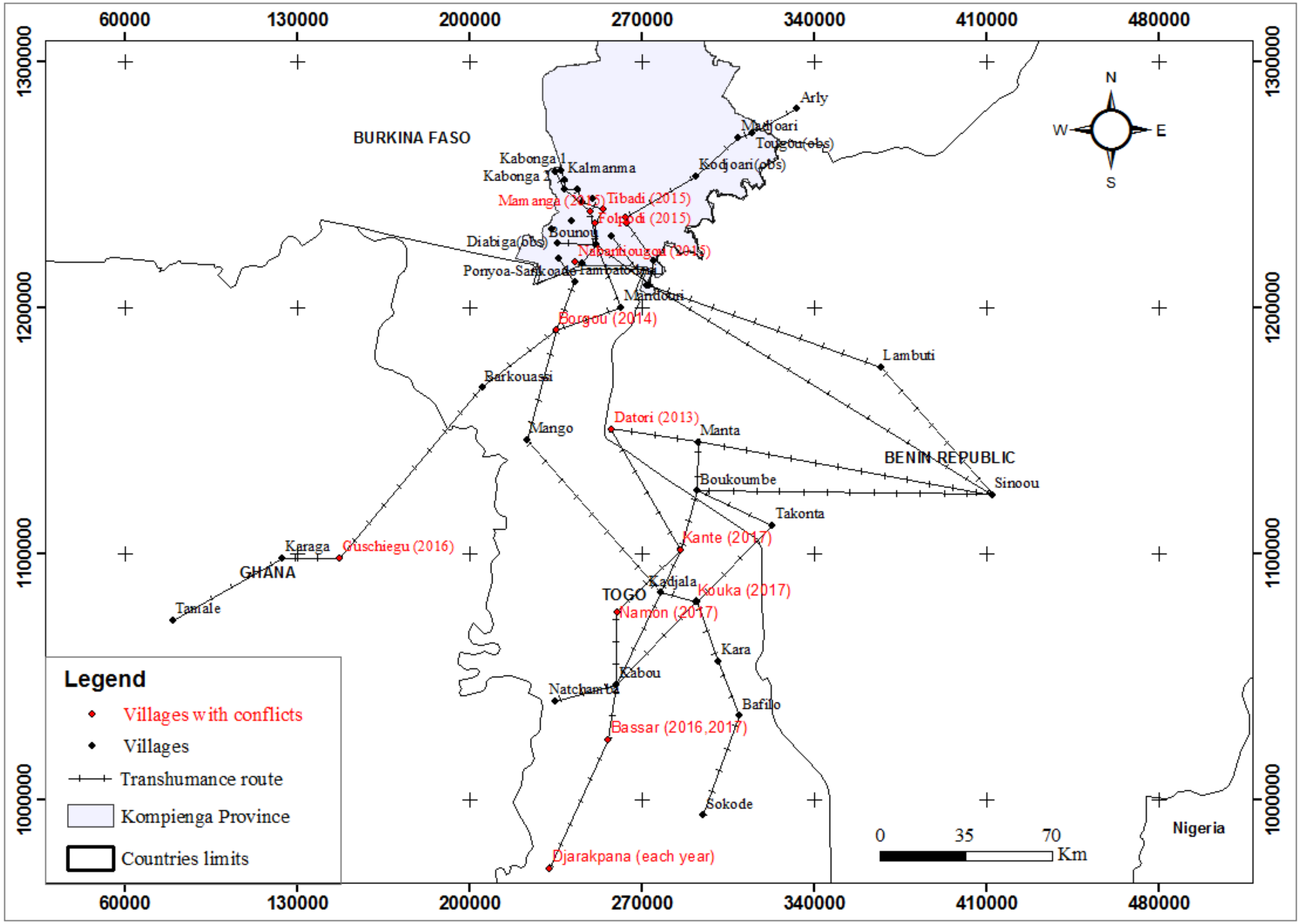


Figure 4.37: Map of transhumance route from Kompienga province

4.7.3. Constraints of pastoralists and agro-pastoralists

A ranking of herders' constraints (Figure 4.38) indicated that the most important is pasture degradation and losses of forage species (26%), one of the main reasons of herds mobilities. This is followed respectively by : (i) insuffisient number of grazing reserves in Burkina Faso (21%); (ii) the interdiction to graze within protected areas (14%); (iii) the lack of forage mowing and conservation tools (12%); (iv) insufficient watering points (6%), animal diseases(6%), long distances to access pasture (6%); (v) violent conflicts and losses of animals (5%); (vi) excessive taxes payable during transhumance (4%).

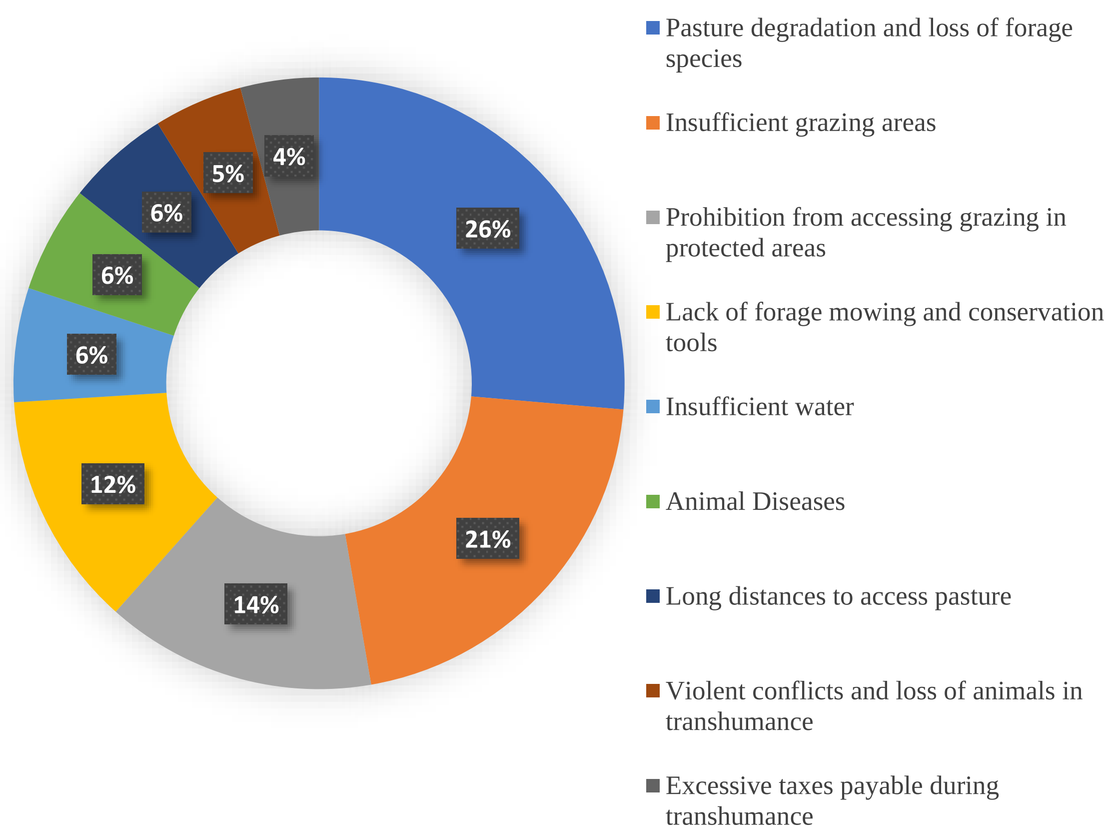


Figure 4.38: Ranking of respondents' constraints

4.8. Prediction of Future Land Use and Cover in Kompienga Province

4.8.1. Validation of the model

The overall accuracy (% of correctness) obtained for the prediction model was 78.5%. Kappa coefficient values of 0.50, 0.87 and 0.58 were obtained respectively for Kappa overall, kappa (histo) and kappa (location). These results, indicate that the model is good enough to predict LULC dynamics over the next coming decades. Indeed, Mondal *et al.* (2016), in their study found that the value of 0.859 for $K_{location}$ was nearly perfect while with $K_{location}$ value of 1 the model is said perfect. Therefore, on this basis $K_{location}$ value of 0.58 obtained in the current study, indicates that the model have a good ability to specify grid cell level location of future change in LULC.

4.8.2. Land use and cover prediction

Based on the past trend (1989-2015), Figures 4.39 and 4.40 show how land use and cover is likely to evolve to the detriment of pasture lands in the next 10 and 20 coming years (Kappa coefficient = 0.7). Major changes could be recorded in vegetation and croplands. Indeed, vegetation that represented 85.9% in 1989 of land area would decreased up to 75.7% and 74.7% in 2025 and 2045. On the contrary cropland areas which amounted 0.8% of land area in 1989 might increase up to 22.1% in 2025 and slightly decrease in 2045 (21.9%) while bare land may experience a net gain of 1.2% of the total land area between 2025 and 2045. Likewise, Abubakar (2015) found that farmland in Nigeria, would increase in area coverage by 2020 while the vegetation, wetland, bare land and water would experience a decrease. This situation might be underpinned by the gradual anthropogenic pressure already noticed on the land and its resources.

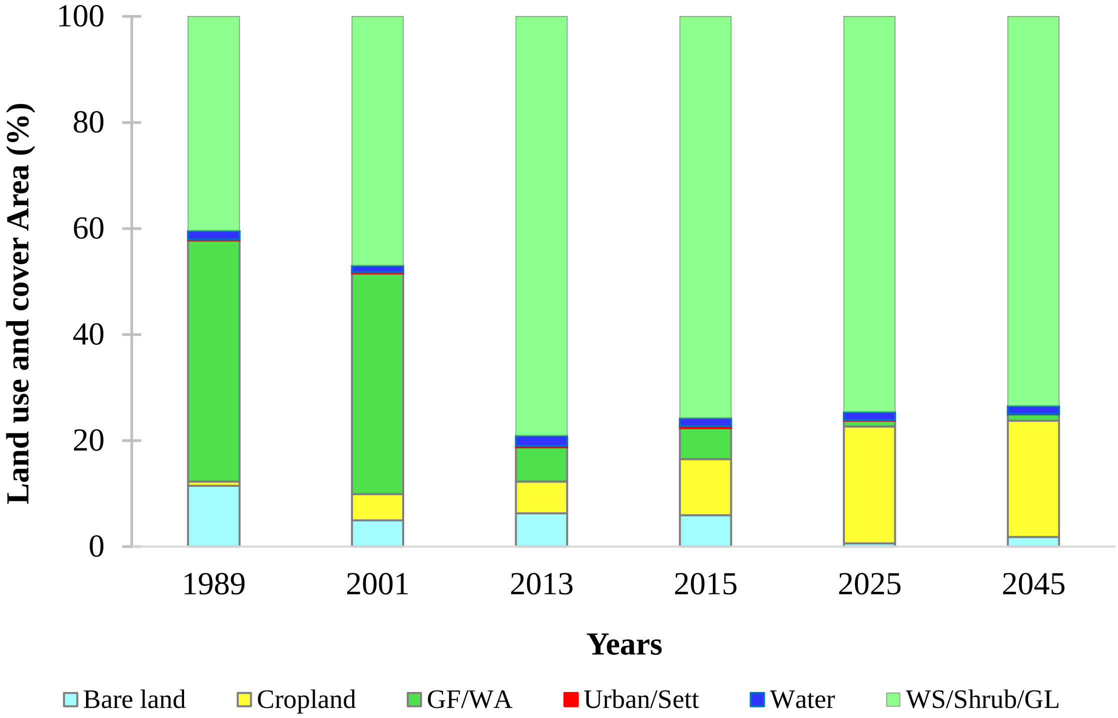


Figure 4.39: Evolution of land use and cover in Kompienga Province between 1989 and 2045

Due to the importance of protected areas, the magnitude of land use/land cover dynamics could intensify and are likely to occur more around Kompienga Dam. However, transgressions are not excluded on protected areas. Thus, the 2025 and 2045 maps show a vulnerability of the reserves to the expansion of the croplands in the north-west and south-central part of the province (Figure 4.40).

Pressure intensification on land is likely to further deteriorate the relationship between crops farmers and herders. In this condition, most of pastoralists, despite the dangers they face in host countries, could migrate permanently to Ghana, Togo and Benin Republic.

This sends a strong signal to planners and policymakers to take urgent action to stem the negative implications that future land use and cover dynamics could bring about in the study area.

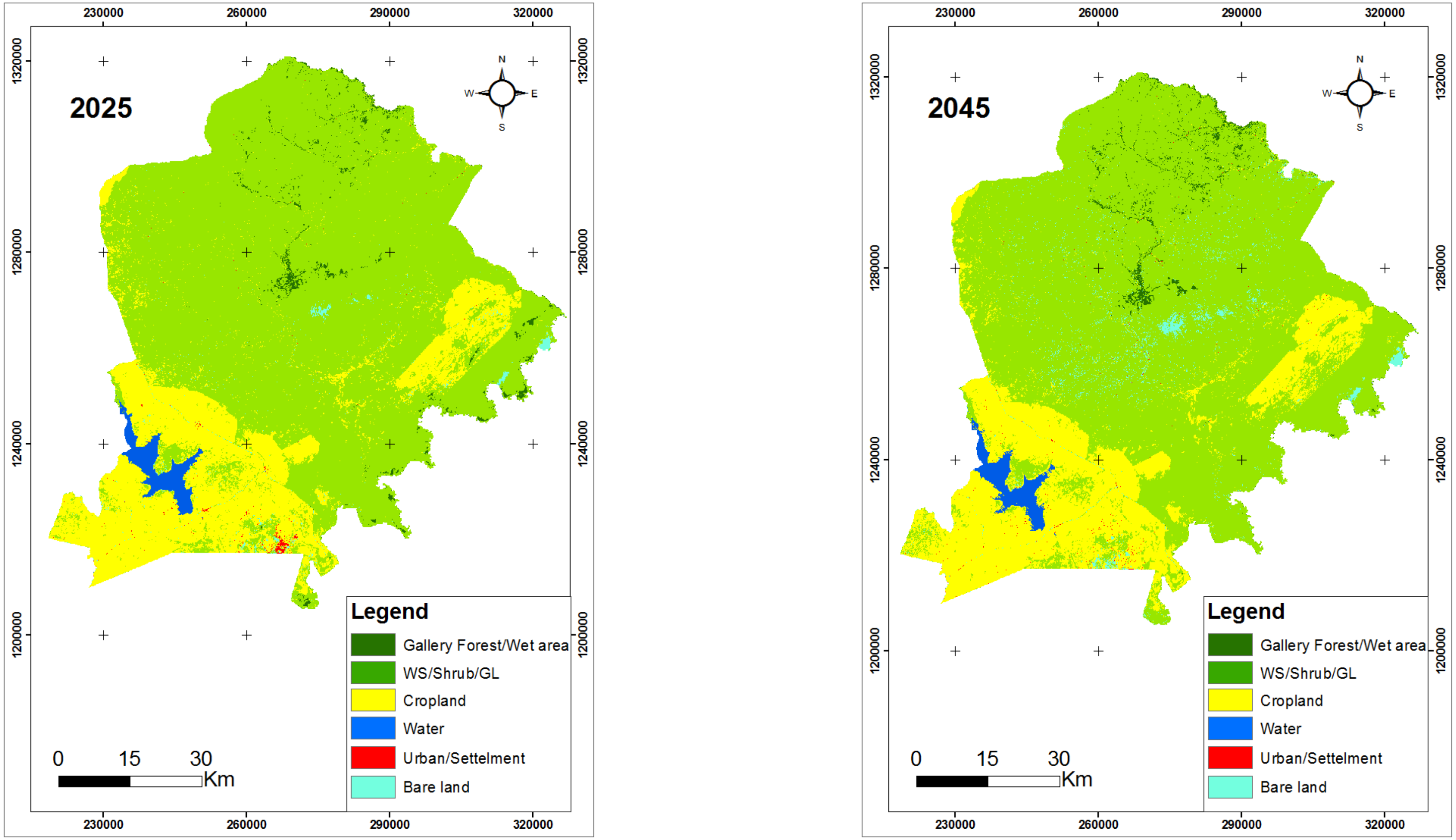


Figure 4.40: Predicted land use and cover in 2025 and 2045

CHAPTER FIVE

5.0. CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

Based on the results of this study, the following conclusions were made:

(1) There are changes in climate conditions over the last decades within Kompienga province. The changes were such that rainfall is decreasing but temperature, relative humidity, and evapotranspiration were all increasing. This situation might affect pastoral resources availability over the province.

(2) Similarly, land use and cover have undergone significant changes over the last decades, the most important being changes in cropland (gain of 32,431.7 ha) and grazable area, which suffered a loss of 27,527.0 ha. These recent land use dynamics explain the gradual pressure and competitions for lands that negatively impacts pastoral resources and practices.

(3) The consequencies of land use/land cover and climate changes were well recognised by the farmers. These changes were regarded as detrimental to availability of pastoral resources and to pastoral practices. It is also noted that farmers are adapting certain measures to minimise the impacts of changes in climate and land use/land cover, however, these adaptation measures are not sufficient.

(4) Land use and cover prediction depicted further reduction of pastoral areas within the coming decades (2025 and 2045) mostly for the benefit of croplands.

5.2. Recommendations

In view of the mentioned observations, it is recommended to :

(1) Design and implement REDD+ (Reducing Emission from Deforestation and Forest Degradation) projects at national and local levels to contribute to the mitigation of climate change.

(2) Delineate and protect grazing reserves from other land use encroachment . This action may need several steps as follow: (i) inventory of all the pastoral areas threatened through a participatory approach. These consultations should involve all the actors: opinion leaders, land owners, herders, crops farmers, traditional leaders and village administrative authorities; (ii) diagnose the root causes that led to the incompliance of rules and regulations that guide the protection of grazing lands; (iii) Conduct a comprehensive study of the grazing land availability and usage employing participatory rural appraisal tools (PRA).

(3) Create enough official grazing reserves and livestock routes within each region of the country, that could reduce and or delay cross border transhumance;

(4) Provide all the grazing reserves with necessary facilities including adequate and continuous water supply and regenerate the pastures;

(5) Authorize and organize fodder collection from reserves and protected areas and encourage/support pasture cropping or hay making by herders. This will increase forage availability for livestock.

(6) As a short-term copping strategies, create an effective cross-border dialogue framework between Burkina Faso and host countries of transhumant with clear mandate to achieve a diagnosis of the constraints in each municipality crossed by the international transhumance routes and obtain the formulation of durable solutions with and for the local and pastoral communities which should ultimately reduce conflicts between herders and crop farmers.

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APPENDICES

Appendix A: Research questionnaire

Name of the Village…………………………………
Date of the interview_ _ / _ _ / _ _
Phone number of the respondent……………
Geolocation (UTM):
Altitude: _ _ / _ _ / _ _ Latitude: _ _ / _ _ / _ _ Longitude: _ _ / _ _ / _ _
Time of the survey:
Start: ………..h…………mn
End: ………...h…………mn

1. General information

Labels and descriptions	Categories of answers	Answer codes
1.1. Name of the Interviewee		
1.2. Gender	1=male; 2=female	
1.3. Age range	1= less than 20 years	
	2= between 20 and 30 years	
	3= more than 30 years	
1.4. Ethnic group	1= Peul	
	2= Gourmantche	
	3= Mossi	
	4= Other	
1.5. Level of education	*1= Illiterate; 2= Literate; 3= Primary school 4 =Secondary school*	
1.6. Household size	|___|___|	
1.7. What is your main activity?	1= pastoralisme |___|; 2= agro pastoralisme |___|;	
1.8. What are your secondary activities?	3= agriculture |___| ;4=fishing |___|; 5=trading|___|, 6= *Worker* |___|, 7= Artisan|___|	
1.9. Herd size	Cattle |___|___|___| Goat|___|___|___| Sheep|___|___|___| Others ………|___|___|___|	
1.10. Experience in herding	1= less than 5 years	
	2= between 5 and 10 years	
	3= between 10 and 15 years	
	4= between 15 and 20 years	
	5 =more than 20 years	

1.11. Herder status	1=owner; 2=co-owner; 3= herder	
1.12. What is your relationship with the owner?	1=family relationship; 2= employee	
1.13. Name of the organisation?		
1.14. Is the respondent native of the village?	1=Yes; 2=No	
1.15. Locality of origin?		
1.16. How long does the household live in the village?		

2. Climate change

2.1. Farmers' Perception on climate change and variability

What do you think about the following events?

Labels and descriptions	**Categories of answers**	**Answer codes**
2.1.1. Temperature trend	1=increased; 2=decreased; 3=No change; 76=Do not know; 77=No answer	
2.1.2. Annual rainfall amount	1=increased; 2=decreased; 3=No change; 76=Do not know; 77=No answer	
2.1.3. Intensity of rain	1=increased; 2=decreased; 3=No change; 76=Do not know; 77=No answer	
2.1.4. Length of rainy season	1=increased; 2=decreased; 3=No change; 76=Do not know; 77=No answer	
2.1.5. Onset of rain	1=earlier; 2=later; 3=No change; 76=Do not know; 77=No answer	
2.1.6. Cessation of rain	1=earlier; 2=later; 3=No change; 76=Do not know; 77=No answer	
2.1.7. Wettest month over last decades	1=changed; 2=No change; 76=Do not know; 77=No answer	
2.1.8. Occurrence of Strong wind	1=increased; 2=decreased; 3=No change; 76=Do not know; 77=No answer	
2.1.9. Flooding occurrence	1=increased; 2=decreased; 3=No change; 76=Do not know; 77=No answer	
2.1.10. Drought occurrence	1=increased; 2=decreased; 3=No change; 76=Do not know; 77=No answer	

2.1.11. Growing season	1=shorter; 2=longer; 3=No change; 4=shifted 76=Do not know; 77=No answer	
2.1.12. Occurrence of diseases outbreak	1=increased; 2=decreased; 3=No change; 76=Do not know; 77=No answer	
2.1.13. Occurrence of famine	1=increased; 2=decreased; 3=No change; 76=Do not know; 77=No answer	

2.2. Impact of climate change on pastoral resources

Labels and descriptions	Categories of answers				Answer codes
2.2.1. How pastures have evolved over the past {5, 10, 20} years? Why?	1=increased; 2=decreased; 3=No change; 76=Do not know; 77=No answer	5 years	10 years	20 years	
	Reasons: (answer on the note pad by specifying the number of the question)				
2.2.2. How has access to water changed over the past {5, 10, 20} years? Why?)	1=increased; 2=decreased; 3=No change; 76=Do not know; 77=No answer	5 years	10 years	20 years	
	Reasons: (answer on the note pad by specifying the number of the question)				
2.3.3. Disappearance of the most palatable or threatened forage species? (Indicate the species on the notepad by specifying the number of the question)	1=Yes; 2=No	Herbaceous fodder			
		Fodder tree			
2.3.4. Decrease in the nutritional quality of fodder	1=Yes; 2=No	Herbaceous fodder			
		Fodder tree			
2.3.5. Decrease in availability / accessibility of crop residues?	1=Yes; 2=No				
2.3.6. List in order of importance 5 constraints	*Answer on the note pad by specifying the number of the question*				

related to the exploitation of forage resources		
2.3.7. How did your seasonal migrations change during the {5, 10, 20} years? Why	1 = changed 2 = unchanged 3 = earlier 4 = later 5 = increased 6 = decreased Pastoral practices / 5 years / 10 years / 20 years: Reception zones visited Transhumance routes Date of departure Duration of journey Duration in reception zone *Answer on the note pad by specifying the number of the question*	
2.3.8. Reason of livestock mobility	1 = lack of pasture; 2 = lack of water; 3 = avoid conflicts; 4 = others	
2.3.9. Increased number of transhumant livestock?	1=increased; 2=decreased; 3=No change; 76=Do not know; 77=No answer	
2.3.10. Period of lack of forage (grass)?	1=Jan /__/; 2 = Feb./__/; 3 = Mars / __ /; 4 = April / __ /;5 = May / __ /; 6 = June / __ /; 7 = July / __ /; 8 = August / __ /; 9 = Sept / __ /; 10 = Oct / __ /; 11 = Nov / __ /; 12 = Dec / __ /	

Sub-table for 2.3.7:

Pastoral practices	5 years	10 years	20 years
Reception zones visited			
Transhumance routes			
Date of departure			
Duration of journey			
Duration in reception zone			

2.3. Dynamics of land use and land use and their impacts on pastoral resources and practices

Labels and descriptions	Categories of answers	Answer codes
2.3.1. 3.1. Types of occupation and land use 30 years ago	1 = Bush; 2 = fields; 3 = fallow; 4 = pastures 5 = water; 6 = bare floors; 7 = cities / villages	
2.3.2. Changes in land use and cover?	1 = increased 2 = decreased 3 = unchanged	
2.3.3. Type of land use and land use that have the most increased over the past 30 years?	1 = Bush; 2 = fields; 3 = fallow; 4 = pastures 5 = water; 6 = bare floors; 7 = cities / villages	
2.3.4. Major reasons for this increase? (if several put in order of importance)	1 = population growth; 2 = development of the cash crop; 3 = decrease in rainfall; 5 = increase in temperature; 6 = exploitation of the fire wood	

Sub-table for 2.3.2:

1 = Bush	<10 years	10-20 years	20-30 years
2 = Fields			
3 = Fallow			
4 = pastures			
5 = Water			
6 = bare land			
7 = Cities / village			

2.3.5. Type of land use and land use that have the most decreased over the past 30 years?	1 = Bush; 2 = fields; 3 = fallow; 4 = pastures 5 = water; 6 = bare floors; 7 = cities / villages	
2.3.6. Major reasons for this decrease? (if several put in order of importance)	1 = population growth; 2 = development of the cash crop; 3 = decrease in rainfall; 5 = increase in temperature; 6 = exploitation of the fire wood	
2.3.7. Impacts of land use and cover changes on Pastoral Resources	Lands degradation	
	Pastoral areas reduction	
	Obstruction of livestock route	
	Reduced access to watering points	
	Reduced Access to Pasture lands	
2.3.8. Impacts of land use and cover changes on pastoral practices?	Increased night watching of transhumant herds? 1. Yes 2. No	
	Migration toward unusual areas? 1. Yes 2. No	
	Changes in transhumance routes? 1. Yes 2. No	
	Changes in transhumance schedule 1. Yes 2. No	
	Increase pressure on fodder woody? 1. Yes 2. No	

2.4. Impacts of climate change on livestock and herders

Labels and descriptions	Categories of answers	Answer codes
On livestock		
2.4.1. Animals travel longer distances to feed and drink?	1= Yes, 2 =No, 3= No change, 76=Do not know; 77=No answer	
Decrease in the number of births per year?	1= Yes, 2 =No, 3= No change, 76=Do not know; 77=No answer	
2.4.2. Drop in milk production?	1= Yes, 2 =No, 3= No change, 76=Do not know; 77=No answer	
2.4.3. Excessive loss of weight?	1= Yes, 2 =No, 3= No change, 76=Do not know; 77=No answer	
2.4.4. Increase of infectious and parasitic diseases?	1= Yes, 2 =No, 3= No change, 76=Do not know; 77=No answer	
2.4.5. Appearance of new animals' diseases	1= Yes, 2 =No, 76=Do not know; 77=No answer	
On herders		
2.4.6. Decrease in incomes?	1= Yes, 2 =No, 3= No change, 76=Do not know; 77=No answer	
2.4.7. Regression of animal heritage?	1= Yes, 2 =No, 3= No change, 76=Do not know; 77=No answer	

2.4.8. Food insecurity?	1= Yes, 2 =No, 3= No change, 76=Do not know; 77=No answer		
2.4.9. Increase in physical effort in herding?	1= Yes, 2 =No, 3= No change, 76=Do not know; 77=No answer		
2.4.10. Loss of prestige	1= Yes, 2 =No, 3= No change, 76=Do not know; 77=No answer		
2.4.11. Increase of conflicts during animal's mobility towards reception areas over the last 10 years?	1= Yes 2=No	Conflict herder-crop farmer	
		Conflict herder-herder	
		Conflicts between herders and forestry officers?	
		Other	
2.4.12. Causes of conflicts over the last 10 years?	Answer on the note pad by specifying the number of the question		
2.4.13. Regression of values of solidarity among farmers and herders?	1= Yes, 2 =No, 3= No change, 76=Do not know; 77=No answer		

2.5. **Adaptation of pastoralist and agro-pastoralists to climate changes and LULC changes**

Labels and descriptions	Categories of answers	Answer codes
3.1.1. Increase in rate of internal mobility of livestock?	1= Yes, 2 =No, 3= No change, 76=Do not know; 77=No answer	
3.1.2. Increase in rate of cross border transhumance	1= Yes, 2 =No, 3= No change, 76=Do not know; 77=No answer	
3.1.3. Shifting to small ruminant species	1= Yes, 2 =No, 3= No change, 76=Do not know; 77=No answer	
3.1.4. Migration to escape to the climatic hazards	1= Yes, 2 =No, 3= No change, 76=Do not know; 77=No answer	
3.1.5. Use of agro-industrial by-products	1= Yes, 2 =No, 3= No change, 76=Do not know; 77=No answer	
3.1.6. Destocking	1= Yes, 2 =No,	
3.1.7. Livestock species concerned by destocking	1=Cattle; 2=Sheep, 4=Goat	
3.1.8. Splitting herds	1= Yes, 2 =No	
3.1.9. Diversifying activities	1= Yes, 2 =No, 3= No change	
3.1.10. Grazing within protected area	1= Yes, 2 =No, 3= No change, 76=Do not know; 77=No answer	
3.1.11. Pasture production	1= Yes, 2 =No	
3.1.12. Mowing and conservation of natural fodder	1= Yes, 2 =No	

3.1.13. Do you benefit from government assistance to deal with drought?	1= Yes, 2 =No	
3.1.14. Government assistance?	1 = Food subsidy; 2 = Information; 4 = creation of grazing areas; 5 = creation of water points	
3.1.15. Which assistance do you want to have?	1 = Food subsidy; 2 = Information; 4 = creation of grazing areas; 5 = creation of water points	
Perceptions of the future of pastoralism		
3.1.16. Further deterioration of Pastoral resources in the future?	1 = Yes, 2 = No, 3 = no change, 76 = none idea; 77 = no answer	
3.1.17. Major reasons for the future deterioration of pastoral resources?	1=population growth 2=excessive expansion in farmland 3=decrease in rainfall 5= increase in temperature 6= trade of woods	
3.1.18. What is likely to happen if the pastoral system if the trend of resource deterioration continues?	1=abandon of pastoral rearing; 2=diversification of activities 3= reduction of herds size	

6. Effectiveness of adaptation measures to climate change

a) Usage: 0 = Do not use this practice; 1 = Use this practice
b) Efficacy level: 1 = Not effective; 2 = less effective; 3 = Effective; 4 = More effective
5 = Very effective; 76 = no idea; 77 = No answer

Adaptation measures	Drought		Lack of pasture		Lack of water		Diseases	
	use	Efficiency	use	Efficiency	use	Efficiency	use	Efficiency
Crop residues								
Fodder trees								
Rainwater harvesting								
Ground water								
Forage cropping								
Destocking/Fattening								
Transhumance								
Abandonment of pastoral rearing								
Prayers and other rites								

Appendix B: Description of pastoral areas

Types of pastoral areas		Descriptions
Special developped pastoral areas		Special developed pastoral are areas identified as such by the national, regional, or provincial planning schemes or by the development master plan and allocated to the carrying out of pastoral development operations.
Areas dedicated to livestock grazing		These are rural areas traditionally used for pastoral activities. They include village or inter-village grazing lands, natural salt licking areas and bourgou areas.
Areas open to livestock grazing involves three kinds of pastoral areas	Forest areas open to grazing	These are protected and classified forests. Livestock have access to these areas only when the classification acts or management plans authorize grazing in accordance with the provisions of the forestry legislation in force Unprotected protected forest areas are considered as silvopastoral areas. They are therefore used without prior authorization for the grazing of the animals
	Fallow	They are agricultural lands, temporarily kept to rest for the natural restoration of soil fertility
	Post-harvest fields	Cultivated areas considered as grazing areas only after harvesting periods for the purpose to exploit postharvest tailings.
Resources access routes		Consist in pathways used for the movement of animals, enabling livestock to access watering points, pastures, sanitary facilities and dwellings.
Transhumance routes/tracks		transhumance tracks are pathways assigned to the circulation of transhumant herds with a view to the exploitation of the water points, the pastures and the natural salt lick.
Marketing routes		They are pathways designed for herds movement, allowing their displacement on foot from production areas to consumption centres and / or livestock markets

Source: Ministry in charge of Animal Resources Burkina Faso (MRA, 2002)

Appendix C: Characteristics of satellite images used for the study

Satellite	Sensors	Path/Row	Spatial resolutions	Spectral resolution	Temporal resolution	Acquisition dates	Band combination
Landsat 5	TM	193/052	30 30 30 30 30 120 30	Band 1: 0.45–0.52 (blue) Band 2: 20.52–0.60 (green) Band 3: 0.63–0.69 (red) Band 4: 0.76–0.90 (NIR) Band 5: 1.55–1.75 (SWIR) Band 6: 10.40–12.50 (TIR) Band 7 : 2.08–2.35 (MIR)	16	1989	(4,3,2)
Landsat 7	ETM+	193/052	30 30 30 30 30 60 30 15	Band 1: 0.45–0.52 (blue) Band 2: 0.52–0.60(green) Band 3 :0.63–0.69 (red) Band 4: 0.77–0.90 (NIR) Band 5: 1.55–1.75(SWIR-1) Band 6: 10.40–12.50 (TIR) Band 7 : 2.09–2.35 (SWIR-2) Band 8 : 0.52–0.90 (PAN)	16	2001	(4,3,2)
Landsat 8	Operational Land Imager	193/052	30 30 30 30 30 30 30 15 30 100 100	Band 1: 0.43–0.45 (coastal aerosol) Band 2: 0.45–0.51 (blue) Band 3: 0.53–0.59 (green) Band 4: 0.64–0.67 (red) Band 5: 0.85–0.88 (NIR) Band 6: 1.57–1.65 (SWIR-1) Band 7: 2.11–2.29 (SWIR-2) Band 8: 0.50–0.68 (PAN) Band 9: 1.36–1.38 (Cirrus) Band 10: 10.60–11.19 (TIRS-1) Band 11: 11.50–12.51(TIRS-2)	16	2013, 2015	(5,4,3)

Source : Author's compilation, 2017

Appendix D: Land use and cover dynamics within Kompienga province

Villages/Hamlet	LULC in 1987	LULC in 2017	Changes	Implications
Tambarga	- reduced size of village - small sizes of croplands - enough space for livestock - existence of non-gazetted grazing reserve	- existence of administrative infrastructures - more cropland area - less pastoral areas - larger village space - livestock route - livestock resting area - extension of Konkombouri national park	-rapid conversion of pastoral area into croplands - conversion of numerous croplands and settlement into forest '-conversion of pastoral area into forest	- increase number of conflicts between herders and crop farmers - inexistence of livestock resting area along the transhumance route
Kaboanga 2	- reduced size of village and population - small sizes of croplands - enough space for livestock - existence of gazetted grazing reserve	- increase in spatial concentration of croplands - reduced grazing area - reduced fallow areas - larger village space - existence of gazetted grazing area	- increase in village area - gradual conversion of pastoral areas in croplands areas	- more conflicts between herders and crop farmers
Mamanga	- reduced size of village and population - small sizes of croplands - enough space for livestock - existence of non-gazetted grazing reserve	- existence of administrative infrastructures - reduced pastoral areas - larger village space	- increase in village area - gradual conversion of pastoral areas in croplands areas	- violent conflicts between herders and crop farmers in 2015 with losses of animals, agro-industrial by-products and hay - farmers want pastoralists to leave the Mamanga grazing area permanently - inexistence of livestock routes to access water and pasture lands - disappearance of forage

				species - occupation of the grazing reserve by crop farmers - the majority of the herds have definitely migrated within Togo by lack of space
Nadiagou	- reduced size of village and population - small sizes of croplands - enough space for livestock	- existence of administrative infrastructures - reduced pastoral areas - larger village space - existence of gazetted grazing reserve - livestock routes	- increase in village area - gradual conversion of pastoral areas in croplands areas - decrease in water bodies	- conflicts between herders and crop farmers - livestock routes obstruction
Oumpougoudeni	- reduced size of village and population - small sizes of croplands - enough space for livestock	- existence of administrative infrastructures - creation of village areas of hunting interest - reduced pastoral areas - larger village space - existence of gazetted grazing reserve - livestock routes	- increase in village area - gradual conversion of pastoral areas in croplands areas	- grazing reserve carrying capacity is exceeded - more conflicts between herders and crop farmers - livestock routes obstruction
Kompienga	- reduced size of village and population - small sizes of croplands - enough space for livestock	- existence of administrative infrastructures - more cash cropland areas - reduced pastoral areas - larger village space - existence of gazetted grazing area	- increase in village area - gradual conversion of pastoral areas in croplands areas - increase in settlement	- violent conflicts between herders and crop farmers - livestock transhumance routes obstruction by croplands and settlements - reduced access to water despite the dam construction - unsuccessful concertation to

				create livestock access route to water
Diabiga	- reduced size of village and population - small sizes of croplands - enough space for livestock	- existence of administrative infrastructures - more cash cropland areas - reduced pastoral areas - larger village space	- rapid conversion of pastoral areas in cropland due to cash crop development and population growth - increase in village area - gradual conversion of bush/forest areas in croplands - increase in settlement	- misunderstandings and bloody confrontation narrowly avoided during the demarcation of the grazing reserve of Diabiga in 2016
Bonou	thirty years ago, the village is occupied by the Kompienga dam	- increase of croplands in the new site	- increase in village area - gradual conversion of bush/forest areas in croplands - gradual conversion of pastoral areas in croplands areas	- more conflicts between herders and crop farmers
Bombontangou	- reduced size of village - small sizes of croplands - enough space for livestock	- existence of administrative infrastructures - more cropland area - less pastoral areas - larger village space - livestock route - existence of gazetted grazing reserve	- increase in village area - gradual conversion of bush/forest areas in croplands - gradual conversion of pastoral areas in croplands areas - increase in settlement	- more conflicts between herders and crop farmers - occupation of gazetted grazing reserve - livestock routes obstruction

Kodjoari	- reduced size of village - small sizes of croplands - enough space for livestock	- more cropland area - less pastoral areas - larger village space - livestock route	- increase in village area - gradual conversion of bush/forest areas in croplands - gradual conversion of pastoral areas in croplands areas	- more conflicts between herders and crop farmers - livestock routes obstruction

Source : Author's field work, 2017

Appendix E: Viewpoints of technical services and NGOs on the effects of climate and LULC changes on pastoral resources and practices

Institutions	Climat conditions	Land use and cover Dynamics	Pastoral resources	Pastoral practices and contraints
Livestock and Fishery Department of the East Region (DRRAH, DPRAH, ZATE)	- increased duration of drought sequences	- drying of soils leading to the formation of more and more bare surfaces - grazing areas and livestock route seriously encroached by croplands - change of grazing areas into Village Area of Hunting Interest - occupation of grazing reserves by artisanal gold mining	- decline of forage biomass - woody and herbaceous forages species become scarce, - disappearance of the most desirable species - proliferation of unpalatable species within grazing reserves - high pressure on forages biomass with transhumant in transit	-strong annexation by farmers despite a presidential decree prescribing the liberation of the grazing area of Kaboanga2 - permanent migration of pastoralists due to lack pasture - water scarcity within grazing and livestock resting areas - early departure in transhumance despite the official dates - violent conflicts with losses in human life and livestock in Togo - grazing within protected areas - search for alternative routes - important taxes to pay within destination zones - permanent migration toward host countries - vain grazing on croplands after harvest -preliminary surveys of herders within host countries before departure in transhumance

				- use of fodder trees over the period of scarcity
NGO "Communication Network on Pastoralism (*Réseau de Communication sur le Pastoralisme* (RECOPA))"	- a decrease in rainfall	- most livestock routes are obstructed by croplands - occupation of grazing reserves even gazetted	- high pressure on forages biomass and water with transhumant in transit - woody and herbaceous forages species become scarce,	-early transhumance despite the prohibition of crossing the boundaries before the dates set - herders involved in violent and frequent conflicts
NGO "ROUGA"		- ECOWAS livestock routes are obstructed by croplands and house building - rapid increase of croplands to the detriment of pastoral areas	-Disappearance of plant species, particularly fodder crops	- violent conflicts with losses in human life and livestock in Togo - loss of livestock due to accidents on tarred road
Department in charge of environment	- great variability of rainfall - delay in rain onset over the last decades	- decrease of grazing areas - grazing areas and livestock route seriously encroached by croplands	-Disappearance of forage species in grazing areas such as *Acacia aegyptiaca; Afzelia Africana; Andropogon gayanus*	- increase pressure on fodder trees through mutilation of leaves, fruits and branches due to scarcity of pasture - grazing within protected area rich in pasture

Regional Support Project to pastoralism in the Sahel (PRAPS-BF)	- changes in climat conditions	- conversion of pastoral areas into croplands - extension of cultivated areas to the detriment of pastoral areas	- decrease of forage biomass through the reduction of grazing areas	- departure in transhumance more and more early and important - an increase pressure on fodder trees - limitation of transhumant herds size by locality in the host countries

Source : Author's field work, 2017

Appendix F: Data collection

(a) GPS data collection

(b) Group discussion in Mamanga

(c) Participatory LULC mapping in Kompienga

(a) Individual interview

(b) Individual interview

(c) Group discussion in Kompienga

Appendix G: Pastoral herding characteristics and constraints

(a) Extension of cropland

(b) Checking the limits of grazing reserve (Bombantangou)

(c) Encroachment of grazing reserve by a farm land (Bombantangou)

(a) Herders' housing

(b Transhumant herd

(c) Transhumant stopover

Pastoral herding a way of life

Appendix H: Violent conflicts and consequences in Kompienga and Togo

(a) Sonde Assane, 51-year-old, an immigrant herder in Togo for 35 years

(b) Diallo Ousmane, 45-year-old transhumant

(c) Diallo Issiaka 29-year-old transhumant

Victims of violent conflict in Togo; 2017

(a) Losses of houses

(b) Loss of forage agro - industrial by-product

(c) Remains of a calcined animal

Damages of violent conflict in Kompienga province (ZATE, 2015)

Appendix I: Conference paper

Diagnostic study of climate change and variability for the period 1981-2016 in South-eastern Burkina Faso, West Africa

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Abstract
This research work aims to study the variabilities/changes in rainfall and temperature over the last thirty-six years (1981-2016) within Gourma and Kompienga provinces, south-eastern region of Burkina Faso. In order to achieve this aim, climatic data (1981-2016) was retrieved from National Office of Meteorology and analysed. First of all, rainfall categories analysis was done and the frequency of each categories over the last six years were compared to that of the climatology in each province. Standard Anomalies Index (SAI) analysis was conducted on rainfall and temperature data. Furthermore, rain onset, cessation, Length of Rainy Season (LRS) and Number of Rainy Days (NRD) were computed from daily rainfall data. In addition, interannual and seasonal coefficient of variation were computed. Moreover, a Principal Component Analysis (PCA) was carried out to compare rainfall pattern of Gourma province with that of Kompienga province over six periods of six years from 1981 to 2016. Annual rainfall amount was finally computed in both provinces and compared to the values of climatology. The results show a global variability in rainfall categories but more in Gourma than in Kompienga. The period studied was characterized by more wet years (17%) than dry years (14%) while the normal years were predominant (69%) in Kompienga province. Gourma province was characterized by predominant normal years (72%) followed by dry years (17%) and wet years (11%). The inter-annual temperature showed high anomalies over the 36 years (1981-2016). In addition, rain onset, cessation, LRS varied compared to those of the climatology in both provinces. The results show less (CV<20%), moderate (20%<CV<30%) and high (CV>30%) variability in annual and seasonal rainfall over the period 1981-2016 rather than a change in yearly rainfall. Both Coefficient of variation and PCA showed that the rainfall was highly variable over the different periods but more variable in Gourma than in Kompienga. Over the last six years, annual rainfall amount in Kompienga was found lower than that of the climatology, while in Gourma it was higher than that of the climatology in 2012 and 2015.
Keywords: Anomalies, Climate Variability, Coefficient of variation, Principal Component Analysis, Rainfall, Temperature.

1. Introduction

West Africa is characterized by very peculiar climate patterns and unfortunately, by limited availability of historical data over the region (Joiner *et al.*, 2012). However, in the last decades, evidences have shown that this region is undergoing great modification in its climate pattern due to global warming. Indeed, since the 1950s, this region, as well as at global scale, has been experiencing unequivocal warming resulting to increase in atmospheric and oceanic temperatures. This global warming is induced by an excessive increase in atmospheric concentration of greenhouse gases since 1750 due to anthropogenic activities (IPCC, 2013).

One major consequence of climate change, is the decrease in rainfall pattern which is the most determinant factor of Africa and in particular, West African countries' economy. Indeed, except in Guinean coast where rainfall has increased at a rate of 10 % (Nicholson *et al*., 2000), a decline trend (nearly 4 %) of rainfall have been detected in the region since the 1960s (Chappell and Agnew, 2004, Dai *et al*., 2004, Nicholson *et al*., 2000, IPCC, 2007). This decrease in rainfall caused by a changing climate over West Africa, have numerous negative repercussions on people and their livelihoods. Alongside this decline in rainfall, the region is confronted with several other constraints such as extreme climatic events and their recurrent disastrous impacts over the last thirty years. It is in this context that West Africa is described as one of the most vulnerable regions in the world (Niasse *et al*., 2004). Furthermore, West African populations will become more vulnerable due to spatio-temporal variability of rainfall because of their reliance on climate-dependant activities namely herding and rain-fed cropping (Joiner *et al*., 2012).

Concerning the future climate pattern of the West African region, the climatic models are quite divergent. However, majority of these models agree on: (i) an overall global warming trend with an average temperature increase rate of 0.5 ^{0}C per decade, (ii) an overall rainfall decrease of 0.5 % to 4.0 % by 2050 at an annual average rate of 10 % to 20 %, and (iii) a projected sea level rise of 0.5 to 1 m over the next century (USAID, 2008). Rainfall will likely be more variable and unpredictable (Connolly-Boutin & Smit, 2016). In Burkina Faso, the future climate will experience a decrease in rainfall (-3.4 % by 2025 and -7.3 % by 2050) coupled with a very strong seasonal and inter-annual variability of climatic factors (World Bank, 2009). Over the south-eastern region of the country, the decades of 1991-2000 and 2001-2010, although relatively wetter than the previous decade (1981-1990), experienced a significant variability of precipitation with increasingly recurrent dry sequences over the south-eastern region of Burkina Faso (Soulama *et al*., 2015). Decline in climate conditions will further impact crop farming and livestock farming within the region. It is therefore, paramount to understand more, how climate is evolving over the last decades. A good understanding of the recent climate conditions, will allow policymakers to anticipate climate risks and ensure producers' resilience. It is in this perspective that the current research is conducted and aims to highlight recent changes occurred in rainfall and temperature over the last thirty-six years (1981-2016) within the south-eastern Burkina Faso.

2 Method

2.1. Study area

The study was carried out in Kompienga and Gourma provinces (Figure 1), located in the eastern part of Burkina Faso. Kompienga province located in south Sudanian is made up of three districts: Pama (capital of the province), Madjoari and Kompienga. It is bordered by Gourma province in the North, Topoa province in East, Koulpélogo province in West and in the South by Togo and Benin Republic. It is located between 0°30'4.96" and 1°22'22.25" longitude East, and 10°56'16.85" and 11°27'21.09" latitude North. The province covers an area of 6 998 km^2 (INSD, 2014) about 1/3 of which is occupied by forest reserves and about 1/3 (223,000 ha) by wildlife reserves (Gomgnimbou, *et al*., 2010). It represents 2.6 % of the country's total area (274,200 km^2). Gourma province comprises six districts (Fada N'Gourma, Matiakoali, Yamba, Tibga, Diapangou, and Diabo). It is located in Northern Sudanian among seven provinces: Tapoa in the East, Kompienga and Koulpélogo in the South, Gnagna and Komandjari in the North, Boulgou and Kourittenga in the West. It represents 4.1% of the country's area (11, 145 km^2) and lies between 11°40'15.27" and 12°45'49.49" latitude North and between 0°7'9.54" longitude West and 1°19'57.40" longitude East. The climate of the study area is Sudanian, the rainy season varies from 5 to 6 months (May to September/October) and the dry season from six to seven months (October/November to April). The dry period is dominated by dry and warm wind known as harmattan (Dipama, 2011; Soungalo, 2016), while the rainy season is characterized by moist winds (monsoon), the annual rainfall fluctuates between 700 and 1000 mm on average. The average annual temperatures range from 30.7° to 39.7° C for the maximum and 17.5°C to 26.3°C for the minimum. Higher temperatures are recorded in March (38.9 ° C) and April (39.7 ° C) while lower temperatures are recorded in December (17.6 ° C) and January (17.5 ° C) (Soungalo, 2016). According to the General Population and Household Census in 2006 (*"Recensement Général de la Population et de l'Habitation (RGPH*)"), the population of Kompienga was estimated at 75,867 (38,357 men and 37,510 women) with 13,053 households. While the population of Gourma province was estimated at 305,936 (148,270 men and 157,666 women) belonging to 48,898 households (INSD, 2008).

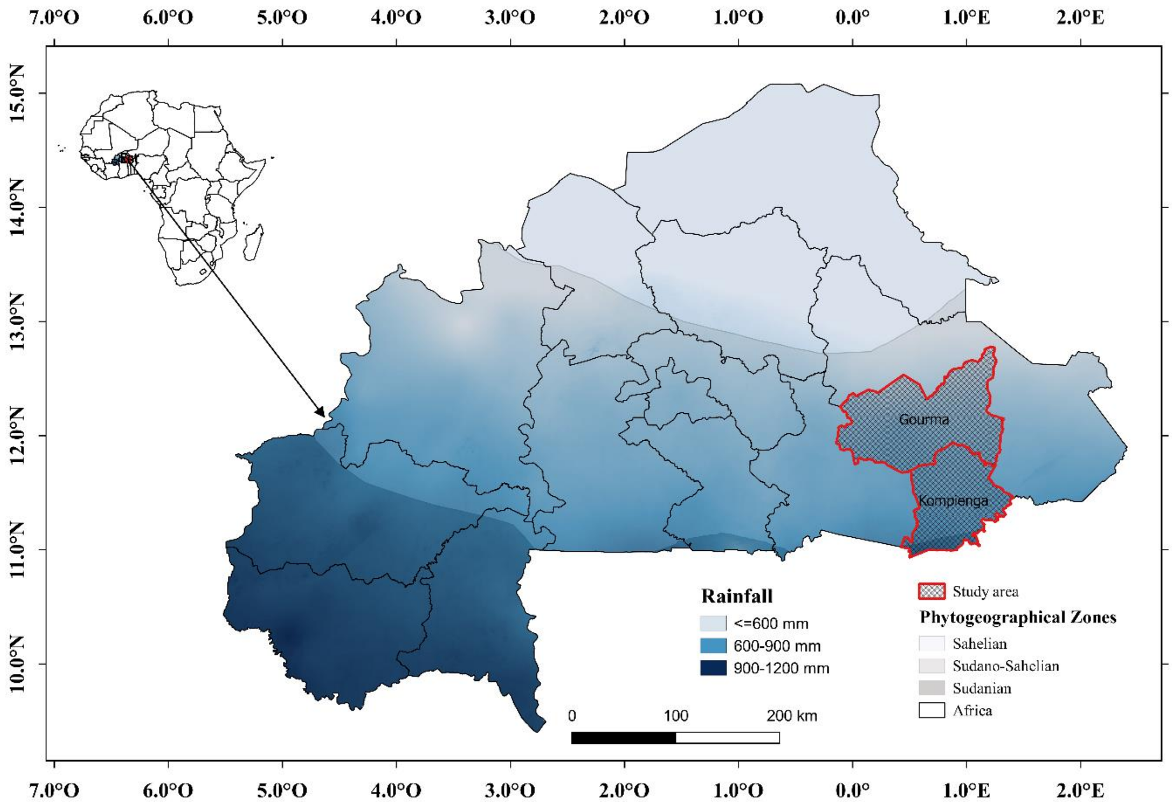

Figure 1. Study area in south-eastern Burkina Faso (source: http://gfc.ucdavis.edu/data/bfa/) *(Authors, 2018)*

2.2. Data collection

Climactic data used in this study composed of rainfall and temperature data over the period 1981-2016. These data were acquired from the national office in charge of climate data (DGM[1]). Data on rainfall were obtained from two meteorological stations (Pama and Fada) while temperature data was provided by only the Fada Station. Two periods, the climatology (1981-2010) and the period (2011-2016) were investigated and the mean of climate parameters were compared over the two periods.

2.3. Data analysis

[1] DGM : Direction générale de la météorologie

In order to assess variabilities/changes in climate condition the following steps were carried out:

i. Rainfall categories were computed for each year in the period (2011-2016) and compared to that of the climatology for both Gourma and Kompienga stations.

ii. Rainfall (Kompienga, Gourma) and temperature (Gourma) anomalies index were calculated using the formula:

$$SAI = \frac{(x-\mu)}{\delta}$$

where χ is the total annual rainfall, μ is the mean of all the series and δ the standard deviation from the mean of the series (WMO, 2012; Hadgu, et *al.,* 2013). The analysis of this index allows the characterisation of dry or wet years on the basis of the Standardized Anomaly Index value (Table 1).

Table 1: Characterisation of years according to the anomalies index values

Index Values	Interpretations
2.0	Extremely wet
1.5 to 1.99	Very wet
1.0 to 1.49	Moderately wet
-0.99 to +0.99	Near normal
-1.0 to -1.49	Moderately dry
-1.5 to -1.99	Severely dry
-2 and less	Extremely dry

Source : McKee *et al.* (1993) ; WMO (2012)

As well as for rainfall data analysis, XLSTAT Version 2014.5.03 was used to determine the standardized anomalies of both minimum and maximum temperatures.

iii. In addition, rain onset (X), cessation (Y), Length of Rainy Season (LRS) (Y-X) and Number of Rainy Days (NRD) were computed from daily rainfall data. Somé and Sivakumar (1994) assumption was used to define the onset and the cessation of the rainy season. Rains onset (X) was determined as the cumulative amount of at least 20 mm of rainfall during three successive rainy days after 1st of April with no dry spell beyond 7 days within the following 30 days. Rains cessation (Y) occurs when there is no rainfall beyond or equal to 5 mm obtained by unit or cumulative rainfalls event over at least 20 successive days after the 1st of September. The duration of the rainy season (Z) is the difference in days between the cessation and the onset of the rainy season (Y-X). The number of rainy days was also computed and its trend determined over the study period.

iv. Furthermore, the variability in rainfall was analysed using the Coefficient of Variation (CV). CV is a statistical assessment of how the individual variable's value deviate from the average value. A larger variability of the variable studied is associated with a greater value of CV and vice versa. It is a good means of categorizing rainfall events as less variable (CV < 20%); moderately variable (20%<CV<30%) and highly variable (CV > 30%) (Hare 1983; Thangamani and Raviraj, 2016). This coefficient is most frequently used to describe the relative dispersion of rainfall events from the mean value. It is computed by dividing the standard deviation by the mean and multiplying the result by 100 (Ekpoh & Nsa, 2011). The formula is:

$$CV = \frac{\delta}{\bar{x}} \times 100$$

where: CV is coefficient of variation; $\bar{x}$ is mean; and δ refers to standard deviation

The CV was calculated over six-year period interval over 36 years rainfall data for the two provinces (Kompienga and Gourma). Moreover, the CV was computed for the rainy season covering the period between June and October (JJASO) for each province.

v. A principal component analysis was carried out on rainfall data provided by the two stations. The purpose was to characterize each province by its rainy conditions. Six periods of six-year sets were considered as observations and variables were constituted in: Standard Anomalies indices (SAI), Number of Rainy Days (NRD), Length of Rainy Season (LRS) and Annual Rainfall Amount (ARA).
vi. Rainfall comparison was carried out between Kompienga Province and Gourma province all located within the South-eastern Region of Burkina Faso within Sudanian zone.

3. Results and discussion

3.1. Climate characteristics in Kompienga province (1981 to 2010)

3.1.1. Rainfall categories within Kompienga province

Figures 2 and 3 present five rainfall categories of the climatology compared to that of the last six years (2011 to 2016) over the study (Kompienga, Gourma). In Kompienga, it appears that the rainfall category [0-10mm] is predominant for all the periods. The climatology (1981-2010) constitutes the standard for which the rainfall categories are compared with those of the last six years (2011, 2012, 2013, 2014, 2015 and 2016). The percentages of rainfall category [0-10 mm] over the last six years (59.6%, 61.4%, 56.7% 62.1%, 56.1% and 56.0% respectively) are all greater than that of the climatology (52.6%). For the category [10-20 mm], the percentage is lower over the year 2013 (18.3%) and 2014 (19.0%) than that of the climatology (20.7%). With the exception of the year 2013, the percentage of the rain category [20-40 mm] over 2011 (15.4%), 2012 (15.4%), 2014 (13.8%), 2015 (12.3%) and 2016 (14.0%) are lower than that of the climatology (19.1%). The percentage of the category [40–60 mm] over the years 2011 (1.9%), 2012 (3.5%), 2013 (3.3%), 2014 (3.3%), and 2015 (5.2%) is lower than that of the climatology (6.0%) which is equal to the percentage in 2016 (6.0%). For the rainfall category (>60 mm), the percentages are greater over years 2011 (1.9%), 2012 (1.8%), 2013 (1.7%), 2015 (3.5%), 2016 (2.0%) than that of the climatology (1.6%) except the year 2014 (0.0%). The analysis of these results suggests a negative change in rainfall patterns in recent years with global predominance of the lowest [0-10 mm] and the highest (>60 mm) rainfall categories. Like Kompienga, [0-10 mm] category was the predominant in Gourma province for the climatology and the last six years as well. However, unlike Kompienga a variability was rather observed in all the rainfall categories when comparing climatology to the last six years.

Kiema *et al*. (2013) indicated similar predominance of [0-10 mm] in Diapaga and Kantchari (south eastern Burkina Faso) over two normal periods, 1941-1970 and 1971-2000. However, unlike this study, the frequencies of rainfall categories in Diapaga and Kantchari keep on decreasing while rainfall categories increase over the normal period, 1971-2000. These variabilities in rainfall categories implies that from year to year rainfall characteristics are not identic. This may have negative implications for rain-dependents activities. In addition, years with predominance of rainfall categories lower than 20 mm are likely to be associated with pasture scarcity and poor farming season. Indeed, according to Tchiadeu *et al.*, (1999), it is generally accepted that a rainfall event of 20 mm consists in a useful precipitation or significant rain. This rainfall category is sufficient to start pasture establishment within grazing lands or to ensure the emergence of sowing in agricultural zone (Lahuec, 1991).

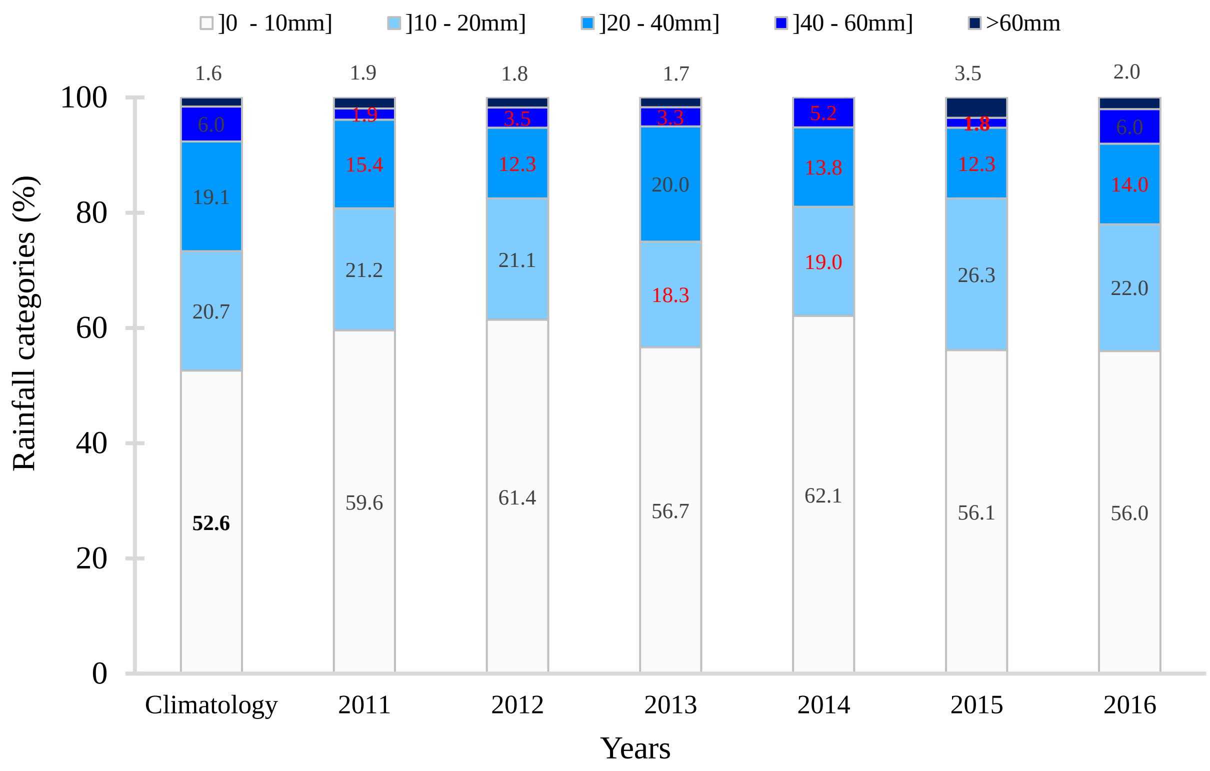

Figure 2. Comparison of rainfall categories between climatology (1981-2010) and years of the period 2011-2016, in Kompienga province (Authors, 2018) (values in red indicate rainfall categories' percentages lower than that of the corresponding categories of the climatology)

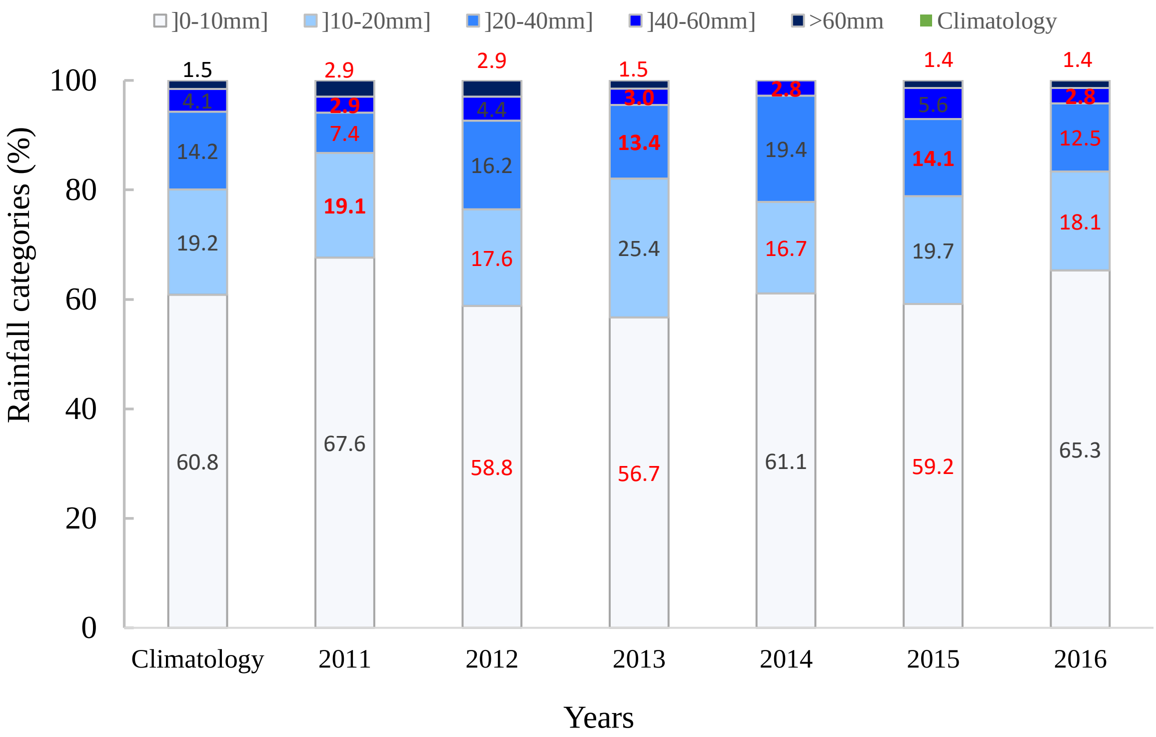

Figure 2. Comparison of rainfall categories between climatology (1981-2010) and years of the period 2011-2016, in Gourma province (Authors, 2018) (values in red indicate rainfall categories' percentages lower than that of the corresponding categories of the climatology)

3.1.2. *Anomalies in rainfall and temperature*

Rainfall anomalies

The analysis of rainfall Standardised Anomaly Index (SAI) in the study area from the two stations (Pama and Fada) over the period 1981-2016 is described in Figure 4. For the SAI closed to zero value, the corresponding years are said to be normal, while the indices far above or below the value zero are qualified to be either wet or dry years. Thus, for indices between -0.99 to +0.99, the corresponding years are near normal; for indices of ±1.0 to ±1.49 the corresponding years are moderately wet/dry; for indices of ±1.5 to ±1.99, the corresponding years are said to be very wet/severely dry. Finally, for SAI value of ±2 the corresponding years are qualified as extremely wet/dry. On this basis, 25 out of the 36 years were normal years according to Pama station. The years 2002 (SAI=-1.2) and 2004 (SAI=-1) were moderately dry while 1983 (SAI=-1.7), 1984 (SAI=-1.7) and 1993 (SAI=-1.5) were severely dry years. On the contrary, 2003 (SAI=+1.2), 2008 (SAI=+1.0), 2009 (SAI=+1.0) were moderately wet; 1991 (SAI=+1.7), 1994 (SAI=+1.8) were very wet and 1998 (SAI=+2.4) was extremely wet. Therefore, the number of moderately wet and extremely wet years were greater than that of moderately dry and extremely dry years. The predominance of normal years (69%) followed by wet years (17%) and dry years (14%) indicates that the yearly rainfall amount was globally not different from the long-term average over the last 36 years. Thus, rainfall in Kompienga have experienced a variability in rainfall rather than a change. This in line with Soungalo *et al.* (2015), which depicted variabilities in climate conditions over the period (1981-2010) within the same locality. Within Gourma province, 26 out of 36 years were found normal (station of Fada). Year 1994 (SAI=+3.6) was extremely wet; 2003 (SAI=+1.58) was very wet and year 1991 (SAI=+1.26) was moderately wet. Severely dry year in the province was 1990 (SAI=-1.66) while year 1983 (SAI=-1), year 1984 (SAI=-1.14), year 1986 (SAI=-1.37), year 1987 (SAI=-1.15), year 2002 (-1.14) were found moderately dry. In a nutshell, normal years were predominant (72%) followed by dry years (17%) and wet years (11%). Likewise, Kompienga province the yearly rainfall amount in Gourma province, was globally not different from the long-term average over the last 36 years. Moreover, more dry years were noticed in Gourma than in Kompienga but the number of severely dry years in Kompienga were higher (3 years:1982, 1983, 1992) than that of Gourma (1 year: 1990). Furthermore, the last six years (2011-2016) in Kompienga shows only negative values of SAI unlike Gourma province who showed two years of positive values of SAI. These results reveal that Kompienga, despite its location in the southern Sudanian zone is experiencing more variability in its rainfall pattern than the Gourma province located in the Northern Sudanian Zone.

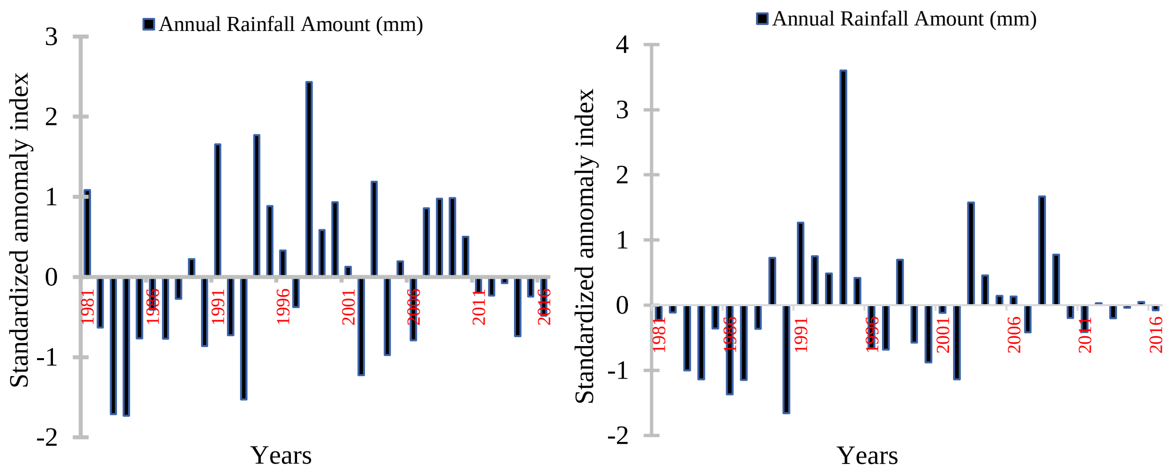

Figure 4. (a) standardized time series anomalies of annual rainfall from Pama Station and (b) standardized time series of annual rainfall from Fada Station (1981 to 2016) (Authors, 2018)

Temperature anomalies

Maximum temperature anomalies in Kompienga Province over 36 years (1981-2016) is hereby presented in Figure 5a. The lowest (-1.93 °C) and the highest (1.7°C) anomalies were obtained in 1994 and 1987 respectively. Between 1981 and 2004, the majority of the anomalies over 16 years out of 24 years, showed negative values with a variation amplitude of between -0.04°C and -1.93°C. This period was then less hot than the average temperature of the 36 years (1981-2016) under study. From 2005 to 2016, the anomalies are positive (except in 2008 with -1.34 anomaly index), depicting a global hotter period (2005-2016) than the average maximum temperature of the period, 1981-2016. The values of maximum temperature of the period between 2000 and 2004 and in years 1984, 1995, 1997 and 1998 were closer to the long-term average temperature with anomalies values fluctuating between -0.2°C to 0.18°C. For the minimum temperature (Figure 5b), two major periods of negative anomalies (1981 to 2001) and positive anomalies (2002 to 2016) were observed with anomalies values varying between (-0.03°C; -1.86°C) for the first period and (+0.29°C; +1.87°C) for the second period. The minimum temperature values of 1990 (-0.06 °C) and 1997 (-0.03°C) were the closest to the long-term average over 1981-2016.

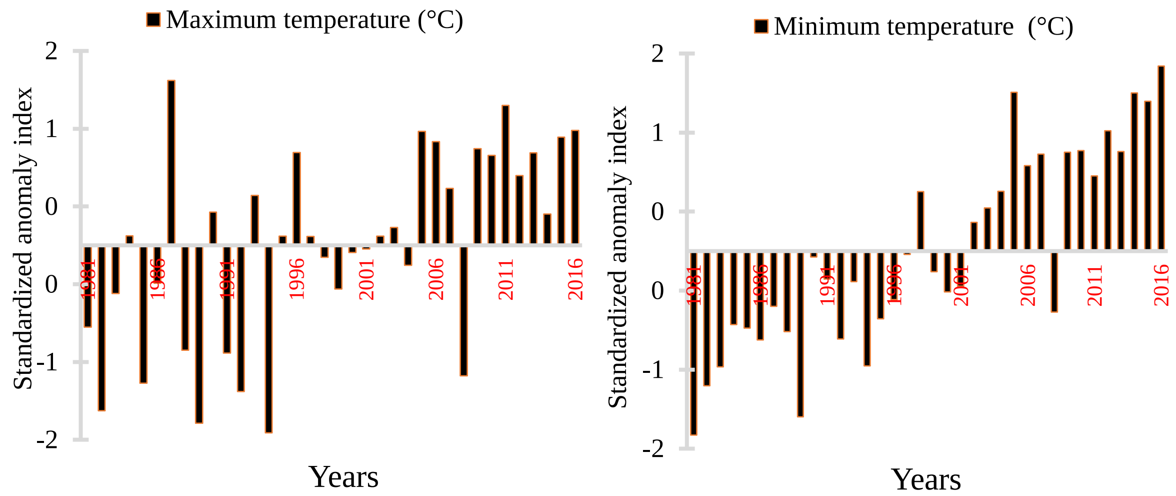

Figure 5. (a) standardized time series anomalies of maximum temperature within Kompienga province and (b) standardized time series of minimum temperature within Kompienga Province (19801 to 2016) (Authors, 2018)

3.1.3. Onset, cessation, number of rainy days and length of rainy season within Kompienga and Gourma province

The onset, cessation, length of the rainy season, number of rainy days, and annual rainfall amount in Kompienga and Gourma Provinces from 1981 to 2016 are presented in Table 1 and Table 2 respectively. Among these parameters rainy season length, onset and cessation appear to be paramount for both crop production and pasture growth and availability for herds.

The pattern of the earliest and the most delayed rainfall onset and cessation in the two provinces were similar. There are more than three months between the earliest onset and the most delayed onset and more than one month between the earliest cessation date and the most delayed one in both provinces. In Kompienga, the averages onset and cessation are 16th June± 9 days and 15th October ± 9 days respectively. The earliest onset (28th April) over the last 36 years occurred in 2012 while the most delayed onset (5th August) was noticed in 2003. In addition, the earliest cessation (12th September) and the most delayed cessation (31th October) occurred respectively in 1991 and 1982. In the Gourma province, the onset and cessation averages are 14th July and 14th October respectively with a standard deviation of 9 days each. The earliest onset (27th April) and the most delayed onset (23th August) over the last 36 years occurred in 1991 and 2012 respectively. The earliest cessation (20th September) occurred in 1992, 2009 and 2012, while the most delayed cessation (30th October) was experienced in 1994.

Kiema *et al*., (2013) conducted similar study in Kantchari and Diapaga districts over two normal periods 1941-1970 and 1971-2000. For the period 1941-1970, the rainfall onset in the Kantchari district (17th June ±27 days) was similar to that of Kompienga province (16th June±9 days). However, there were dissimilarities between Kantchari and Gourma (14th July±9) rainfall onsets. The rainfall onset was observed to be earlier (9 June ±29 days) in the Diapaga district and Gourma province (10 June±18) (Sarr et *al.*, 2011; Kiema *et al*., 2013). In the Gourma province, rainfall cessation is getting earlier. While this study observed cessation date of 14th October±9 days, Sarr *et al.*, (2011) found that cessation date was between 16th and 21st October. The cessation was observed to be earlier in Kantchari (30 September±11 days) and Diapaga (5 October ±8 days) districts than in Kompienga. Rainfall onset (9th June±18 days) and cessation (7th October±9days) in Boulgou Province (Kima, 2014) were earlier than that of Kompienga and Gourma provinces. For the normal period (1971-2000), the onset dates found by Kiema *et al.,* (2013) in Kantchari (20th June ±22 days) and Diapaga (and 18 June ±29 days) were quite similar to that in Kompienga. However, rain cessation dates were earlier in Kantchari (23rd September±12 days) and Diapaga (22nd September ±13 days) than in Kompienga. In addition, Gourma province experienced a later onset (14th July ±9 days) and also a later cessation (15th Oct ±9 days).

Besides, onset and cessation, the length of rainy season and the number of rainy days were determined to characterise each province. Indeed, Kompienga province was characterised by a rainy season length of 111±27 days, 55±8 rainy days and 867.0±164.3 mm of annual rainfall on average. On the contrary Gourma province experienced shorter rainy season (99±34days) and lower (747±135mm) annual rainfall on average but a greater number of rainy days (69±6 days).

Kiema *et al*., (2013) in their study found out for the normal period (1941-1970), a longer rainy season length in Diapaga (117±30 days) than in Kompienga (111±27 days) and Gourma province (99±34 days). However, in Kantchari, they indicated a bit shorter rainy season length (105±34 days) than in Kompienga but still longer than that of Gourma. For the normal period (1971-2000), the length of the rainy season was observed to be longer in Kompienga than in Kantchari (95±26days) and Diapaga (97±35 days) but quite similar to that of Gourma (99±9 days). The rainy days in Kompienga is not so different from that found by the authors in Kantchari (52 rainy days) and Diapaga (50 rainy days) but it was observed to be shorter than that experienced in Gourma province (69±6 days).

Furthermore, Longer rainy season length was also found by Kima, (2014) and Sarr et *al.*, (2011) respectively in Boulgou (119±21days), Fada (120±23) than in Kompienga (111±27 days) and Gourma province (99±34 days). Except in Boulgou with 50 rainy days, the number of rainy days was quite similar for Kompienga (55 rainy days), Kantchari (54 rainy days) and Diapaga (56 rainy days). Gourma province experienced a greater number of rainy days (69±6 days). The results demonstrated marked variations in rainfall onset and cessation of both provinces.

Table 1. Rain onset, cessation, length of the rainy season, number of rainy days, and annual rainfall amount in Kompienga Province from 1981 to 2016

Parameters	Mean	Standard deviation	Minimum	Maximum
Onset	16th June	9	28 h April	5th August
Cessation	15th Oct.	9	12th Sept.	31th Oct.
Length of rainy season	111	27	63	181
Number of Rainy Days	55	8	33	78
Rainfall amount (mm/year)	867.0	164.3	582.5	1266.7

Source: Values computed from data provided by the General Directorate of Meteorology of Burkina Faso (1981-2016)

Table 2. Rain onset, cessation, length of the rainy season, number of rainy days, and annual rainfall amount in Gourma Province from 1981 to 2016

Parameters	Mean	Standard deviation	Minimum	Maximum
Onset	14th July	9	27th April	23th August
Cessation	14th Oct.	9	20th Sept.	30th Oct.
Length of rainy season	99	34	28	175
Number of Rainy Days	69	6	53	80
Rainfall amount (mm/year)	747	135	523	1141.2

Source: Values computed from data provided by the General Directorate of Meteorology of Burkina Faso (1981-2016)

3.1.4. Inter-annual rainfall variability

The overall coefficient of variation of annual rainfall in Kompienga and Gourma were 18.9% and 18.5% respectively while the seasonal coefficients of variation were 20.0% and 20.4% for Kompienga and Gourma provinces respectively. This means that over the 36 years (1981-2016), the inter-annual rainfall for each province is less variable (CV<20%) while the seasonal rainfall is moderately variable (20%<CV<30%). Looking at reduced ranges (six years' intervals), more variability in rainfall pattern was noticed (Figures 6 and 7). Indeed, in seasonal rainfall, a high variability (CV>30%) over the period [1993-1998] was recorded. This means that the area was highly vulnerable to drought over this period. Except for the periods [1981-1986] and [2011-2016] both annual and seasonal rainfall have been more variable in Gourma province over each six-year periods between 1986 and 2010. This might be due to the location of Gourma province within the northern part of Sudanian zone more vulnerable to the shift of isohyets southward. For both provinces after the period [1993-1998] a decrease in the variability of rainfall was noticed up to 2016. This implies that rainfall patterns are experiencing less variabilities over the last two decades. The period of moderate (CV>20%) to high (CV>30%) variabilities in rainfall noticed over some periods within both provinces have negative implications for rain-fed activities. Indeed, rainfall variabilities affect agricultural calendar in such a way that farmers cannot plan their cropping activities well, compelling them to sow twice at the beginning of rainy season in some years. Pasture availability for livestock is also very unpredictable as it is aligning with rainfall variability. The variability disturbs pastoral or transhumance calendar and pastoral communities as in some years, they are compelled to move earlier in transhumance to find forage within areas that experienced earlier rainfall onset, which cause conflicts between farmers in reception zones and transhumants.

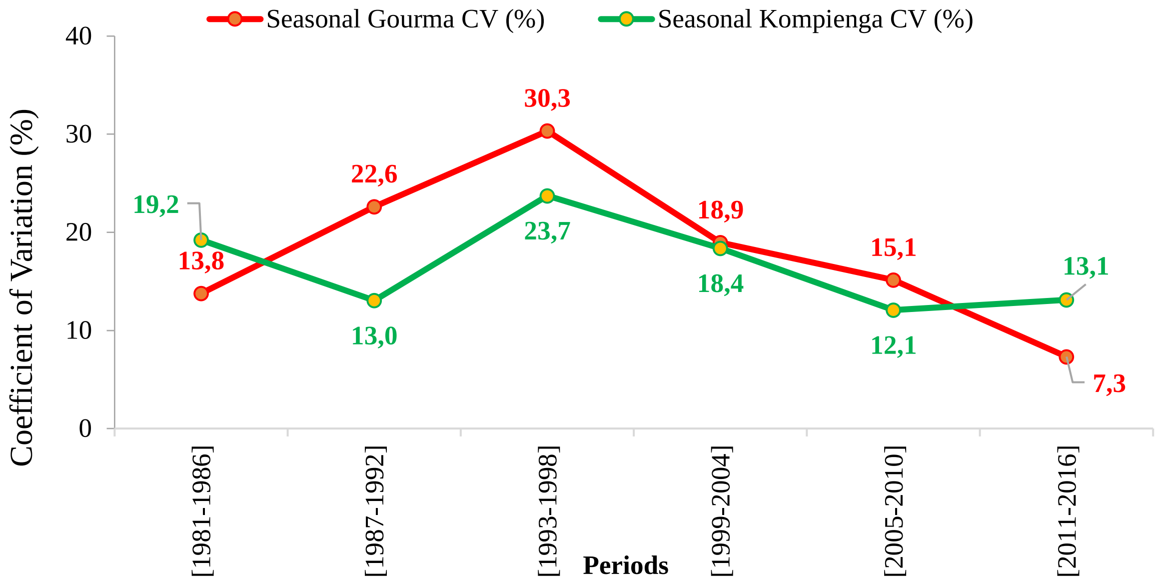

Figure 6. Seasonal variation of rainfall in Kompienga and Gourma province (Authors, 2018)

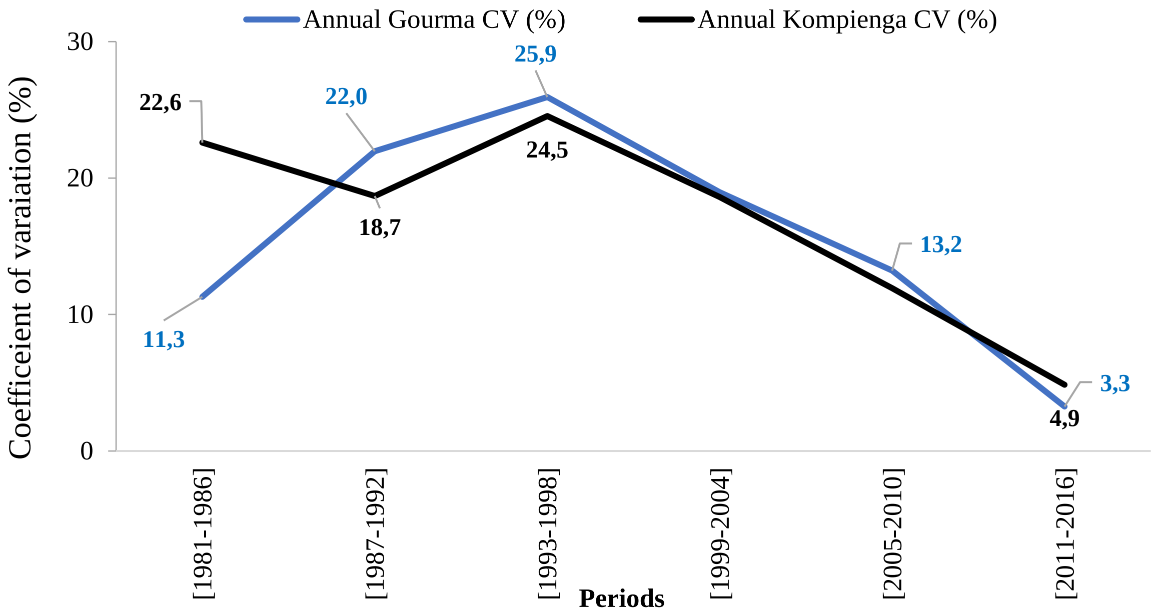

Figure 7. Annual variation of rainfall in Kompienga and Gourma province (Authors, 2018)

3.1.5. Comparison of rainfall characteristics between Pama and Fada over the last 36 years (1981 to 2010)

Principal component analysis

A principal component analysis (PCA) indicates that the first two axes explain 84.8 % of the variability among individuals (localities according to six-year intervals over the period 1981-2016) (Figure 8). The superposition of the projections of precipitation parameters and individuals (localities / period) in a plane formed by the 2 axes makes it possible to define the axis 1 as being that which indicates temporal rainfall distribution and the axis 2 representing quantity of rainfall (Figure 9). Period 1 (1981-1986) and Period 6 (2011-2016) differ from the four other periods in their aridity. Period 3 (1993-1998) was the wettest period within the two localities (Kompienga 3 and Gourma3). Periods 4 (1999-2004) and 5 (2005-2010) were wetter in Kompienga than Gourma; Period 2 (1987-1992) was slightly damp in Kompienga and slightly dry in Gourma. It appears that the rainfall was highly variable over the different periods but more variable in Gourma than in Kompienga. Globally, Gourma registered more dry periods (4 periods) than Kompienga (2 periods). Contrary, over all the periods, Gourma experienced more rainy days than Kompienga while the LRS was found to be longer in Kompienga than in Gourma. These results show an unequal spatio-temporal distribution of rainfall in South eastern Burkina Faso. The implication is negative on rain-fed dependent activities such that, for instance agricultural calendars will be shifting depending on localities. This disrupts the coordinated interventions of the government and Non-Governmental Organisations (NGOs) at the regional level. It could also disrupt the pastoral calendar and lead to an earlier movement of livestock from Gourma towards Kompienga, likely creating conflicts between herders and farmers.

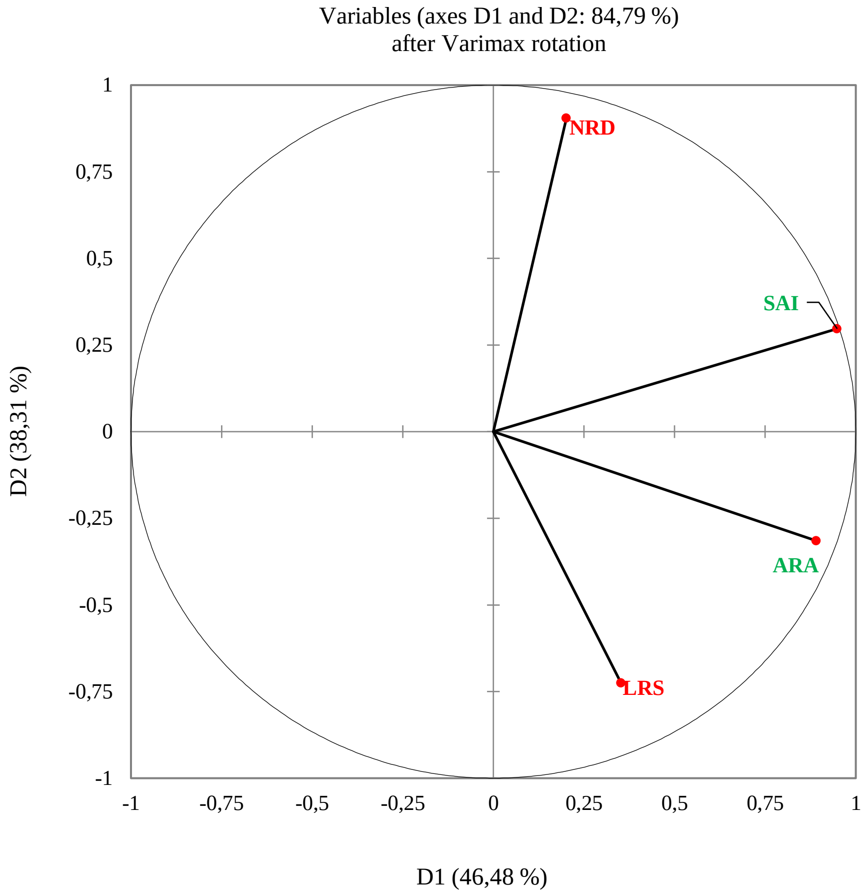

Figure 8: Factorial maps of rainfall parameters and in Kompienga and Gourma Provinces: ARA : Annual Rainfall Amount ; NRD : Number of Rainy Days ; LRS : Length of Rainy Season ; SAI : Standardized Annomaly Index (Authors, 2018)

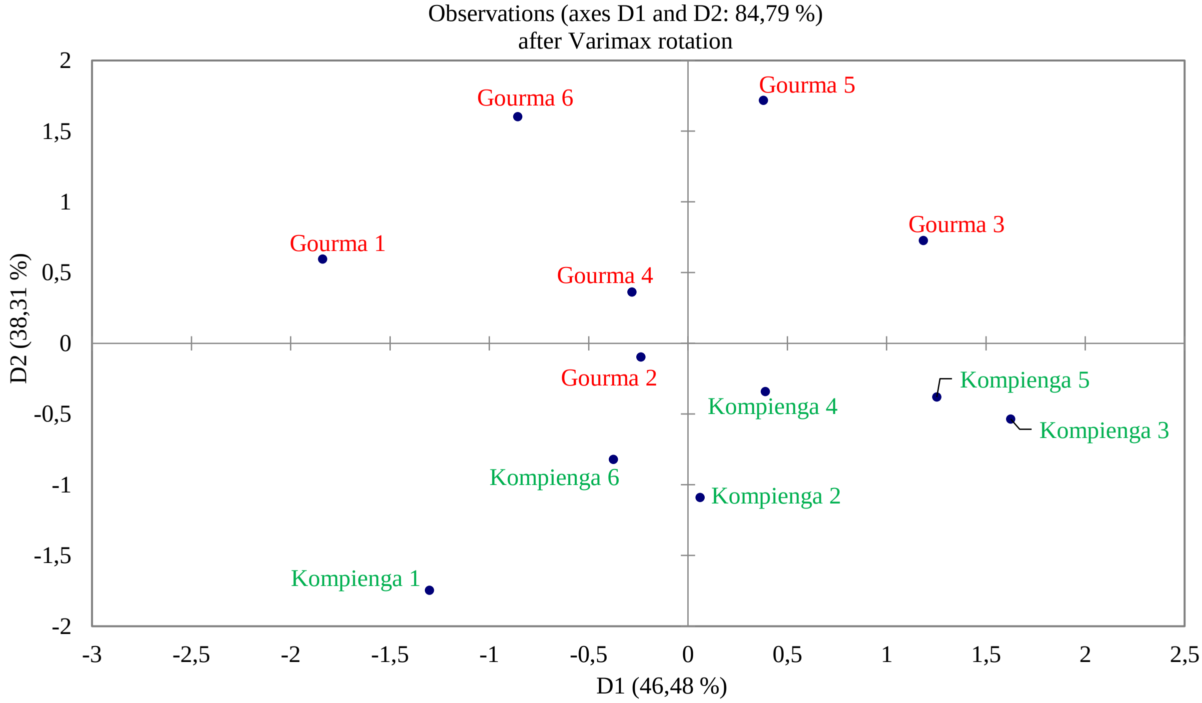

Figure 9: Sites according to the climatic periods in Kompienga and Gourma Provinces (Authors, 2018)

Mean annual rainfall amount

Unlike in Gourma province, annual rainfall amount in Kompienga province, is continuously decreasing over the period (2011-2016) compared to the climatology (1981-2010). In Gourma years 2012 (824.2mmm) and 2015 (826.8mm) were found to be more wet than the climatology (823mm). Despite the location of Kompienga, which is further in south of the Sudanese area compared to Gourma, years 2014 and 2016 appear to be wetter in Gourma than in Kompienga. From these observations a change might have been experienced in rainfall conditions in Kompienga while in Gourma rainfall have been rather variable compared to the reference climatology.

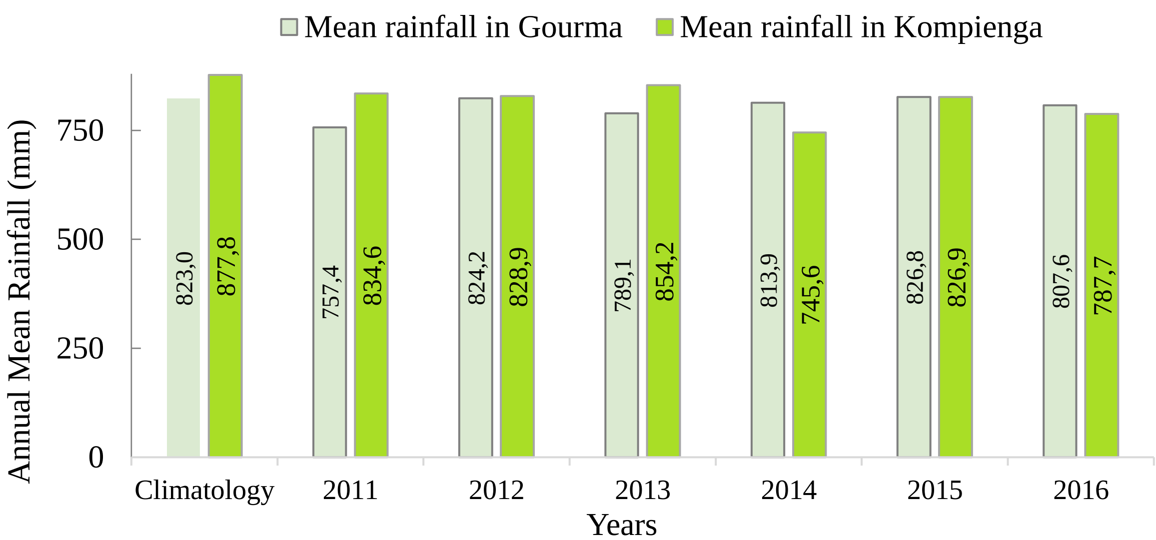

Figure 10: Compared annual rainfall between climatology and the period 2011-2016 (Authors, 2018)

3.2. Implications of climate change and variabilities in populations livelihoods and recommendations for policies makers

Variability in rainfall was experienced in the study areas over the 36 years studied. This variability has several negative implications on rain-fed dependent activities. Indeed, Space-time variability of rainfall amounts and the onset and cessation of the rains affect negatively agriculture production (Camberlin and Diop, 2003) and certainly pasture. The shortage of pasture due to the early cessation of rainfall results in an early departure of herds in cross-border transhumance, with all the risks that this may cause to pastoralists. Unfortunately, the major host countries (Togo, Benin), have set official dates of entry and departure of transhumant herds from their territories. The spatio-temporal variabilities of rainfall would therefore, affect crop and livestock farmers' livelihoods. In addition, the increase in monthly temperature especially in October might cause the low quality of pasture during this month, which coincides with the cessation of rainfall. Furthermore, the increased temperature in the study area had negative impacts on water bodies. This might be responsible for the earlier dry out of livestock watering points through heavy evaporations. This will affect livestock performance (milk, body weight gains and meat). Facing the related constraints of climate parameters variability/change the Government of Burkina Faso and local authority have to search for solutions to stem these constraints. Among recommended actions to be undertaken by the Government or NGOs include: (i) Design and implement REDD+ (Reducing Emission from Deforestation and Forest Degradation) project at national and local levels to contribute to the mitigation of climate change. This will contribute to sustainable development; (ii) Encourage and support hay making from natural pasture; (iii) encourage the utilisation of improved seeds which adapt to recent temperature conditions; (iv) encourage research for the selection of new breeds resistant to recent climate conditions; (v) provide all the grazing reserves with necessary facilities including adequate and continuous water supply and regenerate the pastures; (vi) sensitize herders on the necessity of destocking during years of low rainfall and (v) encourage the diversification of activities so as to not rely solely on rain-dependent activities.

Conclusion

Variabilities were noticed in rainfall within the study area; similarly, annual temperature was found increasing in the study areas during the last years compared to the long-term mean temperature. If in Gourma a continuous decrease was not noticed in annual rainfall amount compared to the climatology, this was not the case in Kompienga province. In this province, it was observed that over the last six years, there has been gradual decrease in annual rainfall amount compared to climatology. Climatic variabilities and or deterioration, contribute to land degradation and their related resources (water, forests, pasture…). This situation underpins the decline in agricultural and livestock production and the increasing pressure/competitions for natural resources with its corollary of conflicts. Facing that situation, sound and comprehensive actions must be undertaken by policy makers: (i) to mitigate climate change through the implementation of REDD+ projects at national and local levels, (ii) to encourage and support hay making from natural pasture; (iii) to support research in order to improve animal breeds and crops seeds that are resistant can adapt to new climatic conditions; (iv) to provide all the grazing reserves with necessary facilities including adequate and continuous water supply and regenerate the pastures; (v) to sensitize herders on the necessity of destocking during years of low rainfall; (vi) to support activities diversification in rural communities as alternative to rain-fed activities so as to not rely solely on rain-dependent activities. These actions would definitively contribute to build sustainable resilience for rural communities.

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