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ASSESSMENT OF CLIMATE CHANGE IMPACTS ON INTERNAL MIGRATION IN BURKINA FASO

BY

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CERTIFICATION

I hereby declare that this submission is my work towards the Ph.D. in Climate Change and Land Use and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material that has been accepted for the award of any other degree or diploma at Kwame Nkrumah University of Science and Technology, Kumasi or any other educational institution, except where due acknowledgment is made in the thesis.

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ABSTRACT

This study addresses one of today's most pressing issues: the impact of climate change on migration, with a particular focus on internal migration in Burkina Faso. The research first examines the factors influencing migration and its consequences from the perspective of local actors in the provinces of Comoé, Ziro, Boulkiemdé and Oubritenga. A participatory approach was adopted, with local workshops serving as the main methodological tool to gather insights from affected communities. In addition to exploring the socio-economic and environmental determinants of climate-induced internal migration, the study examines how these migrations affect the well-being of migrants at their destinations. To account for selection bias and to capture the heterogeneity of migration outcomes, the marginal treatment effects methodology was applied. The analysis is based on cross-sectional data collected from 493 households in the province of Comoé. The study also examines the occurrence of droughts and their relationship with internal migration in the provinces of Comoé and Boulkiemdé. The Standardised Precipitation Index (SPI) and the Standardised Precipitation-Evapotranspiration Index (SPEI) were used over 3-, 6- and 12-month time scales to assess drought conditions, while the Pearson correlation matrix was used to assess the relationship between drought and migration.

From the perspective of local stakeholders, several key factors contribute to migration from areas of origin. Socio-economic constraints such as poverty, lack of employment opportunities, inadequate vocational training, population growth, and land scarcity, alongside environmental stressors such as drought and soil degradation, are identified as primary drivers of migration. Each of these factors was classified as being of greatest importance, receiving a weight of **3** in stakeholder assessments. Conversely, destination areas attract migrants primarily due to the availability of water and land, as well as favourable rainfall patterns. These factors were also assigned the highest importance level by stakeholders, with a weight of 3. While push factors are both socio-economic and environmental, pull factors are predominantly environmental. This pattern reflects the occupational profile of most migrants, who are primarily farmers seeking regions with climatic and environmental conditions more conducive to agricultural activities. Stakeholders further identified the most significant future repulsive factors for migration in specific provinces. In Oubritenga, drought and the absence of incentives or political interventions were cited as the most critical factors likely to drive further out-migration. In Boulkiemdé, land scarcity and inadequate vocational training emerged as the primary deterrents to long-term

settlement. These findings underscore the complex interplay of environmental, economic, and policy-related factors shaping internal migration patterns in Burkina Faso.
The results of the econometric analysis reveal that environmental stressors are important migration drivers, especially insufficient rainfall, ongoing droughts, and soil infertility. Higher asset values are accumulated by migrants than by non-migrants, highlighting migration as a tactic for achieving economic resilience. The consequences of migration on remittances, however, are not uniform; although it reduces remittance flows for migrants, it may have favourable implications for non-migrants. The study emphasizes how migration can be both a vulnerability and an adaptation strategy, particularly for households that depend on agriculture. While migration supports income diversification and asset accumulation, those unable to migrate remain trapped in worsening conditions

Drought assessment reveals distinct regional patterns: Comoé, located in the Sudanian zone, experiences less frequent but more intense droughts, whereas Boulkiemdé, in the Sudano-Sahelian zone, endures prolonged and severe droughts. The study highlights the relationship between drought conditions and migration. In 1985, Comoé experienced slightly wet conditions, with a strong positive correlation between SPEI6 and inflows (r=0.81) and SPEI6 and net migration (r=0.80), indicating that wetter conditions were associated with increased migration inflows and a higher net migration rate. Conversely, Boulkiemdé faced drier conditions, with SPI12 showing a strong negative correlation of -0.912 with net migration, suggesting that declining SPI12 values were linked to reduced net migration. Pearson correlation analyses confirm a strong relationship between drought and migration trends. In 1996, the SPEI12 in Comoé showed a moderately negative correlation (-0.68) with inflows, indicating that prolonged droughts were expected to reduce incoming migration. However, migration data revealed an increase in inflows from 15.44% in 1985 to 17.11% in 1996, contradicting this expectation. Similarly, in Boulkiemdé in 2019, the SPI12 exhibited a very strong positive correlation (0.92) with inflows, suggesting that as SPI12 increased, inflows should also rise. Yet, migration data did not align with this trend, as inward migration declined from 22.94% in 2006 to 10.69%. This paradox underscores that while drought conditions influence migration patterns, they do not act in isolation. Instead, internal migration results from a complex interplay of environmental constraints and socio-economic factors, emphasizing the need for a multi-dimensional approach to understanding climate-induced migration dynamics.

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LIST OF ABBREVIATIONS AND ACRONYMS

AC	Ash Content
AK2	Adenylate Kinase 2
ANOVA	Analysis of Variance
APOS	Allocation at Point of Substitution
ARDL	Autoregressive Distributed Lag Model
ASTM	American Society for Testing and Materials
AU	Allocation Unit
B.Sc.	Bachelor of Science
BBD	Box Behnken Design
BR	Binder Ratio
CCA	Clean Cooking Alliance

CCD	Central Composite Design
CD	Compressed Density
Chi2	Chi-Square
CSS	Cassava Starch
CV	Calorific Value
DIN	German Institute for Standardization
DT	Dwell Time
EF	Environmental Footprint
EN	European Norm
FAO	Food and Agricultural Organization
FC	Fixed Carbon
FM	Few Properties Meet the Standards
FU	Functional Unit
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GHV	Gross Calorific Value
HHV	Higher Heating Value
HND	Higher National Diploma
IEA	International Energy Agency
IIA	Independent of Irrelevant Alternative
IRI	Impact Resistance Index
ISO	International Organization for Standardization
IUCN	International Union for Conservation of Nature
JSCE	Junior Secondary School Certificate
L	Lignin
LBH	Locust Bean Husk
LBP	Locust Bean Pulp
LCA	Life Cycle Assessment
LGAs	Local Government Areas
LPG	Liquefied Petroleum Gas
LR	Log Likelihood Ratio

M.Sc.	Master of Science
MC	Moisture Content
MM	Most Properties Meet the Standards
MPa	Megapascal
Mt	Megatonnes
NCV	Net Calorific Value
NGOs	Non-Governmental Organizations
OAT	One At a Time
ÖNORM	Austrian Standard Institute
Ph.D.	Doctor of Philosophy
PPL	Sweet Potato Peel
PS	Particle Size
R2	R-square
RH	Rice Husk
RSM	Response Surface Methodology
SDG	Sustainable Development Goal
SSCE	Senior Secondary School Certificate
STIRPAT	Stochastic Impacts by Regression on Population, Affluence, and Technology
UN	United Nations
USA	United States of America
VM	Volatile Matter
WB	With Bark
WoB	Without Bark

DEDICATION

To my beloved parents, who laid the foundation of my education with their unwavering love, sacrifices, and encouragement, and who have been my guiding light every step of the way.

To my wonderful wife, whose endless patience, support, and belief in me made this journey possible. You are my rock, my inspiration, and my greatest source of strength.

To my two beautiful children (Fatimata Chirine Firdaous and Ashraf Imad), whose smiles and laughter have been my greatest motivation. May this work remind you that with determination and hard work, anything is achievable.

This achievement is as much yours as it is mine.

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CHAPTER 1 : GENERAL INTRODUCTION

1.1 Background

One of the key findings of the Sixth Assessment Report (AR6) by the Intergovernmental Panel on Climate Change (IPCC) is that climate change is becoming increasingly widespread, rapid, and intense. Human activities have unequivocally driven global warming. The *Summary for Policymakers* by Working Group I (WGI) of AR6 emphasizes: "Each of the past four decades has been successively warmer than any decade since 1850",(IPCC, 2021). This persistent warming has disrupted the climate system, with severe consequences, including more frequent and intense heatwaves, prolonged droughts, rising sea levels, and catastrophic cyclones. These changes place significant pressure on food production and access, particularly in regions already vulnerable to climate stressors, posing a serious threat to food security and nutrition.

In regions with moderate to high vulnerability, global warming of 1.5°C to 2°C, combined with low or insufficient levels of adaptation, is expected to increase the frequency, intensity, and severity of droughts, floods, and heatwaves. These climatic events will exacerbate risks to food security (Linong et al., 2022). Furthermore, if global warming exceeds 2°C in the medium term, the risks to food systems will intensify, leading to heightened malnutrition and micronutrient deficiencies. Among these vulnerable regions, sub-Saharan Africa stands out due to its heightened vulnerability to climate stressors and limited capacity to adapt (Shackleton et al., 2015). In particular, the Sahel region is highly vulnerable to climate variability, characterised by unpredictable rainfall patterns, desertification and an over-reliance on rainfed agriculture, all of which contribute to a precarious socio-economic landscape(Zougmoré et al., 2023). Burkina Faso, a landlocked country in the Sahel, exemplifies these challenges. Approximately 80% of its population depends on subsistence agriculture, a sector that is increasingly challenged by declining rainfall and prolonged dry spells(Sorgho et al., 2020). This has led to widespread food insecurity, with rural livelihoods stretched to the breaking point.

The impact of climate change goes beyond the immediate economic disadvantages, triggering a cascade of socio-economic challenges, including migration. Migration has historically served as a coping mechanism in the Sahel, with both seasonal and permanent movements reflecting traditional responses to environmental pressures(Rain, 2024; Hoffmann et al., 2022). The scale and nuances of migration are evolving in line with the accelerating impacts of climate change (Selod & Shilpi, 2021). In particular, internal migration has become more prominent as rural populations increasingly move to other rural areas and urban centres in search of economic opportunities and protection from climate-related risks (Thorn et al., 2022).

The causal relationship between climate change and migration has gained significant attention among researchers and policymakers over the past two decades. It has become a prominent topic in public discourse and has been elevated on the global policy agenda (Entwisle et al., 2016; Letta et al., 2022). As early as the First IPCC Report, migration was identified as a potential short-term impact of climate change threatening human settlements (Ferris, 2020; IPCC, 1992). Since then, climate change and its impact on human migration have been at the forefront of research and policy-making (Kaczan & Orgill-Meyer, 2020).

In 2018, the United Nations Global Compact for Safe, Orderly and Regular Migration (GCM), adopted by the UN General Assembly, formally recognised environmental factors and climate change as key drivers of migration (United Nations, 2018). Furthermore, migration has been integrated into the Sustainable Development Goals (SDGs) under Target 10.7, which aims to "facilitate migration and mobility of people in an orderly, safe, and responsible manner, including through the implementation of planned and well-managed migration policies", (United Nations, 2016) Additionally, point 49 of Decision 1/CP.21 of the Paris Agreement on Climate Change called for the establishment of a mechanism ‘to develop recommendations for integrated approaches to prevent, minimize and address displacement associated with the adverse effects of climate change’ (UNFCCC, 2015).

Projections indicate that a global temperature increase of 2°C or more above pre-industrial levels will significantly increase migration flows in the coming decades (Hoegh-Guldberg et al., 2019). Between 2008 and 2021, an estimated 318 million people migrated due to climate change (Sakapaji, 2023). Some projections indicate that the number of people who could move due to climate-related factors by 2050 could reach 1.2 billion (Narayanan et al., 2023). The World Bank's Groundswell report also estimates that there will be around 216 million new climate-induced internal migrants by 2050 in the six World Bank regions: sub-Saharan Africa, North Africa, East Asia and the Pacific, South Asia, Eastern Europe and Central Asia, and Latin America (Clement et al., 2021). The least developed countries, particularly those in the South, are the most affected due to their great vulnerability to the harmful effects of climate change, such as floods, droughts and rising sea levels (Almulhim et al., 2024 ; Sakapaji, 2023).

As one of the most vulnerable regions to climate change (Serdeczny et al., 2017), sub-Saharan Africa is expected to experience a significant increase in displaced populations. According to Müller et al. (2014), the region is particularly at risk due to its high exposure to climate stressors and limited adaptive capacity. The IPCC Sixth Assessment Report projects that with 1.7°C of warming by 2050, between 17 and 40 million people in sub-Saharan Africa could be forced to migrate internally. Drivers of this migration include water stress, declining agricultural productivity, and rising sea levels (Adelekan et al., 2022).

Internal migration has a complex set of positive and negative impacts. It serves as a household resilience mechanism, allowing individuals to seek better economic opportunities and diversify income sources, which can alleviate poverty and reduce inequality (Zoma et al., 2024). It also serves as a strategy for households to diversify income sources and mitigate risks associated with agricultural uncertainty (Zahonogo, 2011). However, this movement also poses challenges, such as increased pressure on urban infrastructure and services, which can lead to overcrowding and the proliferation of informal settlements (Crawley & Teye, 2023). The influx of migrants into certain rural areas has been linked to increased land use change, including deforestation and soil degradation, as migrants clear land for cultivation (Nébié & West, 2019).

1.2 Problem Statement and Justification

Burkina Faso has long been recognised as a country with a strong tradition of emigration (Loada, 2006; Olsen, 2014; Tapsoba et al., 2022) This migratory dynamic dates back to the colonial period, when state policies and economic structures contributed to the movement of populations (Azianu et al., 2023 ;Coulibaly, 1986) The colonial administration was pivotal in structuring labor mobility and regional migration patterns, many of which persist today (Dabire, 2016). In recent decades, climate change has emerged as a significant driver of internal migration in Burkina Faso, exacerbating displacement due to its profound impact on environmental conditions essential for agriculture and livelihoods (De Longueville et al., 2019 ;Nébié & West, 2019). Population census data indicate a steady rise in internal migration, with a 729.69% cumulative increase from 1975 to 2019 and an average annual growth rate of 16.58% .

If unregulated, climate-induced migration could deepen poverty and disrupt development efforts

(Rigaud et al., 2021). Poorly managed and understood, internal migrationcan lead to negative socio-economic and environmental consequences in both areas of origin and destination. Socially, it may contribute to integration challenges in destination communities, particularly in terms of power dynamics and land use (Bauloz et al., 2020; Gausset, 2008). Economically, migration can create labor imbalances and strain resources(Adger et al., 2024), while environmentally, it may drive land degradation and deforestation (Aweda et al., 2024). However, when effectively managed, migration can serve as a catalyst for development, filling labor gaps, fostering innovation, and improving livelihoods through remittances (Bank, 2005; Castañeda et al., 2024). This highlights the need for a proactive and structured migration management approach to harness its benefits while mitigating its risks (Li & Samimi, 2022).

Burkina Faso is highly vulnerable to climate change due to its low economic development and high poverty rates. As of 2021, 41.4% of its population lived in poverty (INSD, 2021), and its Human Development Index (HDI) ranked 182nd out of 189 countries in 2019. The National Climate Change Adaptation Plan identifies agriculture and water resources as the most climate-sensitive sectors, and these vulnerabilities are already driving migration flows. People are moving from degraded agricultural regions in the north, central-north, and Sahel to more fertile areas in the west, southwest, and east (Sanfo et al., 2017).

Despite the growing body of research on climate-related migration, comparative evidence on its influence on internal migration remains scarce (Hoffmann et al., 2024). While existing studies have explored inter-provincial migration patterns and environmental drivers (Henry et al., 2003, 2004a, 2004b), the role of rainfall variability in migration decisions (Smith, 2012), and population perceptions of migration (Sanfo et al., 2017), there remains a significant gap in understanding rural-to-rural migration trends, particularly among farming households facing climate-induced stressors. More recently, Nébié & West, (2019) conducted a case study on migration and land-use change between the provinces of Bam (a departure area) and Sissili (a destination area). While these studies provide valuable insights, they do not fully capture the complex interactions between climate change and rural-to-rural migration, particularly the decision-making processes and future migration trends among rural households.

Furthermore, a critical gap remains in the development of localised migration scenarios that reflect Burkina Faso's socio-economic and environmental realities. Existing global migration models often fail to account for local conditions, leading to inaccurate projections and ineffective policy interventions. Developing context-specific migration scenarios is essential for national and local development planning. Accurate data on migration patterns will enable policymakers to formulate targeted strategies that enhance climate adaptation and migration governance.

This study will address these gaps by examining how climate variability influences internal migration in Burkina Faso, particularly among rural households. By integrating socio-demographic, economic, and cultural determinants of migration, this research will provide empirical evidence to inform sustainable migration policies and climate adaptation strategies.

1.3 Aim and Objectives

1.3.1 Aim

The aim of this study is to develop an integrated approach for assessing the impacts of climate change on internal migration in Burkina Faso.

1.3.2 Specific Objectives

Specifically, the study seeks to:

1. To develop migration scenarios from the perspective of local stakeholders;
2. To analyse the socio-economic determinants and impact of climate-related internal migration on Welfare at migrant's destination and migrant's origin;
3. To assess relationship between climate variables and internal migration.

1.4 Research Questions

1- What are the key factors that will define future internal migration patterns, as perceived by local stakeholders?

2- What are the socio-economic and environmental factors that drive internal migration?

3- How internal migration driven by climate change affects the welfare of households that receive these migrants.
4- Is there a relationship between the trend in internal migration flows and droughts in Burkina Faso?

1.5 Structure of the Thesis

This thesis is structured as follows:

Chapter 1 serves as the general introduction, presenting the background of the study, the research problem, the objectives, and the associated research questions. It also highlights the significance of the study while defining its scope and limitations.

Chapter 2 is dedicated to the literature review, covering key concepts related to climate change, its causes, impacts, and adaptation strategies, with a particular focus on climate-induced migration. It explores migration theories, the relationship between climate change and migration, as well as the socio-economic drivers and consequences of climate-induced migration. Furthermore, this chapter identifies existing research gaps in internal migration studies related to climate change and emphasizes the need to address these gaps.

Chapter 3 describes the study areas and the research methodology used to achieve the study's objectives. It provides an overview of the geographical areas under investigation and details the methodological approaches employed for data collection and analysis.

Chapters 4 to 6 are dedicated to the presentation and analysis of the results, corresponding to the three specific objectives of the study. Each chapter focuses on a particular objective, providing an in-depth examination of the findings and discussing their implications.

Chapter 4 focuses on specific objective one, which aims to develop migration scenarios from the perspective of local stakeholders. It highlights the key factors influencing migration flows and proposes Key future migration factors based on stakeholders' perceptions.

Chapter 5 addresses specific objective two, which seeks to assess the impact of internal migration on the household welfare of climate-induced migrant households in Burkina Faso. It examines the socio-economic and climatic determinants of migration and analyses the effects of migration on the welfare of households in destination areas.

Chapter 6 discusses specific objective three, presenting an analysis of drought and its relationship with migration in the Comoé and Boulkiemdé provinces. This chapter explores the correlation between drought indices and migration trends, illustrating how climatic conditions influence migration decisions in these two regions.

Finally, Chapter 7 presents the general conclusion and recommendations. It synthesises the key findings of the study, provides a broader reflection on climate-induced migration in Burkina Faso, and offers policy recommendations to guide public policies and adaptation strategies.

1.6 Research Scope and Limitation

CHAPTER 2 : LITERATURE REVIEW

2.1 Conceptual Review Definition of Key Concepts

In migration studies, specifically in relation to climate and the environment, the choice of terms is of great importance. In general, the definitions given to the terminologies used in the field of migration are not normative and are not the subject of an international consensus either. But defining them does make it possible to clearly situate the reality or phenomenon being referred to, and thus to better identify its implications in terms of rights and obligations and the players involved.

2.1.1 Migration

Migration is a difficult phenomenon to grasp from both a theoretical and a practical point of view; indeed, any definition of this phenomenon takes into account both temporal and spatial dimensions, hence the diversity of methods of approach.

However, it is defined by the International Organisation for Migration (IOM) as « the movement of persons away from their place of usual residence, either across an international border or within a State » (Sironi & Emmanuel, 2019). In general, time and space are two key criteria taken into account in the definition of migration.

In Burkina Faso, the Institut National de la Statistique et de la Démographie (National Institute of Statistics and Demography) considers time to be a period of at least six months, or with the intention of spending at least six months away from one's usual place of residence. The spatial criterion refers to the crossing of administrative borders (villages, communes, departments, countries, etc.). He therefore defines migration as « any movement of an individual from one administrative entity (the commune being the smallest entity considered) to another for a stay of at least six months or with the intention of residing there for at least six months »(INSD, 2009).

From the above, we define migration as any movement of a person or group of persons from one locality to another within or outside the country, for whatever reason (social, economic, political, environmental or climatic) or in whatever manner (voluntary or forced), for a stay of at least six months or with the intention of residing there for at least six months.

2.1.2 Internal migration

In their glossary of migration, Sironi & Emmanuel, (2019) define it as « the movement of people within a state involving the establishment of a new temporary or permanent residence ». We therefore note that in this form of migration, the movement of migrants is contained within the boundaries of the territory of their country of origin. It should be noted that this migration may be temporary or permanent.

In the context of Burkina Faso, this refers to all movements between administrative entities that result in a stay in the place of arrival of at least six months (or with the intention of residing there for at least six months) (INSD, 2009). Internal migration can take place between regions of the country, in which case it is known as inter-regional migration. Within a region, migration may take place between provinces, in which case it is known as intra-regional or inter-provincial migration. It can also take place between municipalities within provinces, leading to intra-provincial or inter-municipal migration.

It is this particular form of migration within the boundaries of the territory of Burkina Faso that is the subject of this study. But it is not all internal migration that interests us either. We are specifically interested in rural-rural.

2.1.3 Rural-rural migration

This is a form of internal migration defined in the glossary on migration as « the movement of people from one rural area to another for the purpose of establishing a new residence » (Sironi & Emmanuel, 2019).

In this study, rural-rural migration refers to the movement of a person or group of people inside Burkina Faso, from one rural area to another for a variety of reasons.

Although all the reasons for rural-rural migration will be analysed, particular attention is paid to the link between migration and climate and environmental change.

2.1.4 Rural-urban migration

Rural-urban migration is another a form of internal migration defined as « The movement of people from a rural to an urban area for the purpose of establishing a new residence » (Sironi & Emmanuel, 2019).

In our case, it means any movement of people from rural areas of Burkina Faso to urban areas of the same country. As with rural-rural migration, we will be paying particular attention to the link between this form of migration and the climate/environment. This leads us to talk about environmental and climatic migration.

2.1.5 Environmental migration and climate migration

One of the most widely accepted definitions is that given by (Chazalnoël & Randall, 2021). For them, environmental migration refers to « any movement of persons or groups of persons who, mainly for reasons related to sudden or progressive environmental change adversely affecting their lives or living conditions, are forced to leave their usual place of residence or leave it of their own accord, temporarily or permanently, and who, as a result, move within or outside their country of origin or usual residence ». It is important to highlight that the displacement of populations, in this case, is mainly the result of unfavourable environmental conditions.

As for climate migration, they consider it to be a sub-category of environmental migration. It refers to « a particular type of environmental migration, in which the modification of the environment is due to climate change » (Chazalnoël & Randall, 2021). Migration is thus associated with increased vulnerability for the individuals who migrate, especially if it is forced. They point out, however, that migration can also be a form of adaptation to environmental stressors, helping to build the resilience of affected individuals and communities.

For the purposes of this study, we will not make a clear-cut distinction between environmental migration and climate migration, as the two concepts are so closely related and interconnected. It is difficult to clearly dissociate migration induced by environmental change from that induced by climate change. Indeed, environmental changes are impacts of climate change and environmental changes can also exacerbate climate change. As a result, it is not easy to say with certainty whether a migratory movement is caused by environmental change or by climate change. To overcome these difficulties, we will use the terms « climate migration » and « environmental migration » interchangeably, to designate this form of migration induced by sudden or gradual environmental change, climate-induce or not.

2.1.6 Internally displaced persons

The United Nations Commission on Human Rights defines internally displaced persons as "persons or groups of persons who have been forced or obliged to flee or to leave their homes or places of habitual residence, in particular as a result of or in order to avoid the effects of armed conflict, situations of generalized violence, violations of human rights or natural or human-made disasters, and who have not crossed an internationally recognized State border" (UN Commission on Human Rights, 1998).

This case is mentioned here because of the large number of internally displaced persons (IDPs) that Burkina Faso has been experiencing since the security crisis of 2015. This category of people is not taken into account in this study, even though their displacement is limited to within the borders of Burkina Faso.

Following these clarifications of some key terminology, we review the literature on the link between climate/environmental change and migration in the next section.

2.1.7 Drought

Drought is a climatic phenomenon characterized by a prolonged deficit in precipitation, leading to significant hydrological imbalances and negative impacts on ecosystems, agriculture, and human activities. According to Wilhite and Glantz, (1985), "drought is a prolonged period of below-normal precipitation that causes significant hydrological imbalances, resulting in water shortages for ecosystems, agriculture, and human activities." This definition emphasizes the hydrological impact of drought and its consequences on water resources. Similarly, Palmer (1965) defines drought as "a sustained and regionally extensive period of below-average precipitation, leading to adverse effects on soil moisture, water supply, and agricultural productivity." This approach highlights the agricultural and hydrological consequences of precipitation deficits, directly affecting crop productivity and the livelihoods of rural populations. Furthermore, the Intergovernmental Panel on Climate Change states that "drought is a period of abnormally dry weather long enough to cause a serious hydrological imbalance, affecting ecosystems, agriculture, and water supply" (Lavell et al., 2012). This definition incorporates the notion of climatic anomaly and emphasises the duration of the event as well as its widespread effects.

Drought can be defined in many ways, depending on the subject of interest. It is often referred to as meteorological drought, hydrological drought, agricultural drought or even socio-economic drought, depending on whether the water shortage affects meteorological, hydrological, soil or social systems (Ding et al., 2020; Gu et al., 2020; Lu et al., 2017; Shi et al., 2018). In this study, we will limit the scope to 3 main types of drought: meteorological drought, agricultural drought and hydrological drought.

2.1.7.1 Meteorological drought

Meteorological drought is defined as a context marked by a significant decrease in the normal amount of precipitation in a given geographical area over an extended period of time (Wilhite & Glantz, 1985b). In this definition, the importance of precipitation levels and their deviation from the norm is emphasised as the main indicator of meteorological drought. Kaverina et al. (2019) describe it as a stochastic natural hazard caused by a persistent shortage of precipitation, which negatively impacts the physical environment and water systems, disrupting the hydrological cycle of the area. These authors add the environmental and hydrological impacts of reduced rainfall.

2.1.7.2 Agricultural drought

Agricultural drought refers to a significant reduction in soil moisture, necessary for the good development of vegetation (Tadesse et al., 2015). The authors emphasise the complexty of this type of drought because of its slow onset and the vast areas it can affect, with variable spatial effects depending on vegetation cover and specific agro-ecological sub-regions. For Yee-Shan Ku and colleagues, agricultural drought can be understood as a situation where there is a shortage of precipitation, leading to a deficit in soil water and a reduction in the level of groundwater or reservoirs. This ultimately has an adverse impact on agriculture and crop production. In this definition, the crucial role of precipitation and soil water availability is evident (Ku et al., 2013).

2.1.7.3 Hydrological drought

Hydrological drought is defined as a significant reduction in the availability of all forms of water in the terrestrial phase of the hydrological cycle, including surface water, snowmelt, spring discharge and groundwater (Goyal et al., 2017). The main cause of this phenomenon is the prolonged lack of precipitation, which leads to the drying up of lakes, reservoirs and rivers, as well as the depletion of groundwater resources. Tallaksen et al., 2023, for their part, describe hydrological drought as a condition that develops from a prolonged deficit in precipitation, often combined with high evaporation, leading to below-normal levels of flow in rivers, lakes and groundwater. This definition emphasises the meteorological water balance deficit as a precursor to hydrological drought, highlighting the interconnectedness of meteorological and hydrological processes (Tallaksen et al., 2023).

2.1.8 Standardized Precipitation Index (SPI)

The Standardized Precipitation Index is defined as the difference of precipitation from the mean for a specified time period divided by the standard deviation where the mean and standard deviation are determined from past records (McKee, Doesken , & Kleist, 1993). It is bases on probability that represents the degree to which the accumulative precipitation of a specific period departs from the average state (Du, Fang, Xu, & Shi, 2012). The SPI rely on two assumptions: (1) the variability of precipitations much higher than that of other variables, such as temperature and potential evapotranspiration (PET), and (2) the other variables are stationary (i.e., they have no temporal tren) (Vicente-serrano et al., 2010).

2.1.9 The standardized precipitation evapotranspiration index (SPEI)

The standardized precipitation evapotranspiration index (SPEI) was first proposed by Vicente-serrano et al. (2010) as an improved drought index that is especially suited for studies of the effect of global warming on drought severity (Beguer´ıa, 2014). Similar to SPI, SPEI considers surface evapotranspiration due to the background of global warming, and replaces precipitation in SPI with the difference between monthly precipitation and potential evapotranspiration (Liu, Yang, Yang, & Wang, 2021). SPEI has a higher utilization rate than other indices, and its main advantage is the ability to detect the effect of changes in evapotranspiration and temperature concerning global warming (M. Nejadrekabi, 2022). It can be calculated for time steps of as little as 1 month up to 48 months or more (WMO, 2017). The multi-scalar nature of the SPEI enables identification of different drought types and drought impacts on diverse systems (Vicente-Serrano et al., 2012a, 2012b, 2013a, and 2013b). The SPEI method use “climatic water balance”, the difference between precipitation and reference evapotranspiration (P – ET0), instead of precipitation (P) as the input.

2.1.10 Drought propagation

It is possible to move from meteorological drought to agricultural and hydrological drought. This process, which consists of moving drought conditions from their meteorological origin to their agricultural and hydrological impact, is called propagation. It is complex and depends on several factors, including climatic conditions, the characteristics of the basins and human activities. For drought management and mitigation strategies to be effective, they must be based on a good understanding of spread.

2.2 Theories of migration

Sutherland (1975) cited by Weick, (1989) defined theory as "an ordered set of assertions about a generic behaviour or structure assumed to be valid in a significantly wide range of specific instances." Wacker, (1998)asserts that it consists of four parts: conceptual definitions, domain boundaries, relationship building, and predictions. The fundamental issues that are particularly covered by migration theory include: who migrates; why do they migrate; what modes of mobility are used; under what conditions are they used; why do they prefer some destinations to others; and what factors influence return migration. When social scientists utilise theory, they do so to aid in offering a methodical justification for observations (Babbie, 1989). In order to understand social processes and human behaviour, it also involves organising disparate results into a cohesive picture(De Sherbinin et al., 2022).

Early migration theories were rooted in rational choice theory and economic determinism, emphasizing individual decision-making processes and economic motivations for migration. These approaches were primarily centered on the individual or household, often neglecting broader social and political contexts.

2.2.1 Neoclassical economics

The neoclassical approach considers migration as a rational action aimed at maximizing utility. Migration occurs when an individual compares their level of satisfaction in their current location with the potential benefits of relocation, often driven by economic incentives and wage differentials (Rossi, 1955; Piguet, 2013). Migration is therefore one of the options (change of job, family choices, etc.) available to the individual to deal with dissatisfaction (Leslie & Richardson, 1961). It is considered that actors mainly attribute 'utility' to the goods and services they can acquire and the factors explaining migration are therefore approximated by wage differentials. The aggregation of individual decisions then explains migration movements. The movements are from low-wage to high-wage regions. Migration is thus considered as a factor for balancing geographical differences, which is a central property of the neoclassical model. These ideas of rational choice were formalised and extended by the economists (Harris & Todaro, 1970) in their study of rural exodus. In addition to the difference in wages between two locations, they integrated into their model the wage expected by the potential migrant, taking into account his or her profile and the costs associated with the move. Therefore, a probabilistic dimension is integrated into the model and individual characteristics. This gives rise to the important notion of migration selectivity: identical structural conditions may have a different impact on different individuals or groups (Chiswick, 1999). The idea of 'present preference' characteristic of neo-classical economics assumptions is also introduced into the model in the form of a discount rate applied to future migration earnings.

Neoclassical theories of migration have come under considerable criticism (Porumbescu, 2018). For, (OECD, 1978) by focusing on wages and individual actors the neoclassical approach is not able to explain the complexities of migration in today's global society. For him, priority should be given to theories that explain the social and economic processes from which migration emerges. Furthermore, Hunter & Simon, (2022) suggest that environmental processes are increasingly part of the socio-economic context from which migration emerges and that they deserve to be taken into account in a more coherent way.

From a neoclassical macro perspective, Kerr, (2017) estimates that environmental/climatic characteristics can shape migration in a neoclassical framework through the impact of environmental amenities on wages and market rents. Cragg & Kahn, (1999) support this view and refer to the attractiveness of moderate climates and the adjustment of wages and market rents to these quality of life factors. (Albouy, 2008) explains it very well in these terms: "workers will live in a place where real wages are low if their lower consumption of market goods is compensated by higher consumption of non-market amenities".

2.2.2 Migration Systems as an Analytical Lens

Like neoclassical economics, migration systems approach involves equilibrium concepts as they focus on stable groups of countries (or other geographic units) that send and receive migrants (e.g., Fussell, Curtis and DeWaard 2014a). Early articulations of migration systems drew heavily upon functionalist social theory with emphasis on systems as important elements of societal structure (Bakewell, de Haas and Kubal 2012). As compared to neoclassical perspectives, migration systems approaches incorporate a broader array of migration influences through more direct integration of the cultural, social, and political aspects of flows and counterflows between two or more places (e.g., Mabogunje 1970). Such flows include not only people but also goods, services, information. and ideas, and systems perspectives focus analytically on the factors that stimulate, direct, and sustain these origin-destination flows (Massey et al. 1998). While systems perspectives are as "old as the scientific study of migration" (Fawcett 1989, 671), data improvements in the 1980s increased scholarly interest in this approach, and substantial theoretical and empirical progress has been made since then (DeWaard and Ha 2019; Hauer, Holloway and Takashi 2020b).

Social networks have arguably received the most attention in examination of migration systems, especially regarding the perpetuation of migration flows (e.g., Massey et al. 1998). Networks represent structured sets of social relationships that act as pathways through which information and resources move in both directions (Gurak and Caces 1992). This information and resource sharing reduces the costs associated with migration and facilitates movement by, for example, easing the search for jobs and housing and providing information on policies and useful programs (Massey 1988). Importantly, the flows representative of migrant systems develop momentum over time, allowing them to function independently of their originating forces (Haug 2008).

Like neoclassical migration theories, the systems approach is not without critiques (e.g., de Haas 2010), many of which emphasize the lack of investigation of the emergence of systems in efforts to study their perpetuation (Bakewell 2010). Critics also argue that little is known about why systems sometimes do not emerge following the moves of pioneer migrants (de Haas 2010). In addition, Bakewell (2010) argues that little attention has been paid to the shifts in the initial social and economic context following the development of a migration system, while the factors that shape system decline are also underexplored (de Haas 2010). We build upon these critiques by arguing that environmental factors represent an underexamined aspect of migration systems, potentially playing a role in system emergence, perpetuation, and decline.

2.2.3 Push-Pull perspectives on Migration

The above review of migration through the perspectives of macro-scale neoclassical economics and migration systems delved into the factors that instigate and perpetuate aggregate migrant flows. Moving now to a micro-perspective, we consider the factors that shape people's migration decision-making and, ultimately, migration decisions. Lee's (1966) "push-pull" framework offers one theoretical perspective at the micro level. It is often grouped with neoclassical migration theory and, according to some researchers, represents more of a general framework or post-hoc descriptive model (Hochleithner and Exner, 2018). Here, push factors characterize origins and can include low employment opportunities, wage levels, and high cost of living, all of which are commonly noted by migrants as primary factors in their decision-making (Black et al. 2013). Other factors can be political and include the effectiveness of governance, presence of conflict, and/or the state of immigration policy (Alvarado and Massey 2010). Simultaneously, characteristics of destinations can pull would-be migrants, such as better employment prospects and political stability.

In response to critiques of push-pull as overly determinist (e.g., De Haas, 2010)de Haas 2010; Skeldon 1990), Van Hear et al. (2018) present a useful framework dubbed "push-pull plus." To better characterize interactions across drivers at all scales, they outline migration's predisposing, proximate, precipitating, and mediating drivers. Migration's predisposing drivers shape the context from which migration may occur. Economic disparities between places represent a predisposing factor (e.g., Abel et al. 2019; Cohen 2018). As compared to these broad contextual factors, proximate drivers are more direct, such as a localized economic downturn (Bank, Fröhlich and Schneiker 2017). Even more direct are precipitating drivers, such as a factory closure embedded within that local economic downturn (Van Hear, Bakewell and Long 2018). The influence of predisposing, proximate, and precipitating factors on migration is further shaped by mediating factors, which enable or constrain migration, such as transportation, communications, and resource infrastructures, as well as household capital (Garip 2008; Palloni et al. 2001). The absence of such mediating factors can constrain movement even in the face of severe precipitating drivers (Van Hear, Bakewell and Long 2018).

2.2.4 New Economics of Migration (NEM)

At least in part a result of the critiques of the neoclassical migration theories described above, migration scholars, including those analyzing the environmental dimensions of migration, have employed an alternative theoretical model, the new economics of labor migration, which expands understandings of who migrates and why (e.g., Stark and Bloom 1985). The new economics of labor migration (NELM) acknowledges that wage differentials are not the sole factor motivating individual migration (Stark and Bloom 1985). In fact, in contrast to neoclassical theories, NELM focuses not on individuals but on households and families as the primary unit of decision-making (Stark and Bloom 1985). Much of the work using this framework has focused on international migration, illustrating why households in lower-income settings may want to send a migrant abroad (e.g.,Gray 2009). Households, this work shows, may use temporary and circular migration to diversify income sources and minimize the risks associated with fluctuations and uncertainties in local markets (e.g., Mendola 2012). Given households' limited access to credit and capital in many developing countries, remittances from a migrant abroad may also serve as supplemental income that can be put toward large household purchases or (re)investments in agricultural- or business-related improvements (Lindstrom and Lauster 2001; Massey 1999).

When a household decides to send a migrant to diversify income and minimize risks, it makes intuitive sense that they may prioritize the household member with the highest likelihood of success in both reaching the desired destination and securing employment. It is through this lens that we consider the question of who migrates. This question is inherently about migrant characteristics and the selective nature of the migration process. Indeed, migration scholars have demonstrated that migrants are often different from their non-migrant counterparts, finding some consistent selection patterns by age, sex, race/ethnicity, education, and health, as well as considerable variation in these relationships across settings and types of migration (e.g., Griga and Hadjar 2014; Morey et al. 2020; Riosmena, Wong and Palloni 2013). To fully summarize these findings is beyond this article's scope, so for this section, we focus on Mexico-US migration.

Stark and Taylor's (1991) analysis of rural households in Michoacán, Mexico, offers insight into the patterns of such livelihood migration. For example, when compared to internal migrants and non-migrants in the area, international migrants to the United States were more likely to be male, to come from larger, wealthier households, and to have family or friends already in the United States (Stark and Taylor 1991). These findings are robust in other areas of Mexico as well.

Indeed, Lindstrom and Lauster (2001) illustrate that both internal and international migrants came from more marginalized municipalities with fewer wage-earning opportunities, thereby fueling the need for income diversification and risk reduction among households in these areas.

When compared to other theoretical models, NELM has proven to be one of the best at predicting who migrates from Mexico (Massey and Espinosa 1997). However, Garip (2012) illustrates that migrants' socio-demographic characteristics vary by period and cohort. In addition, gender scholars have critiqued the lack of consideration of gendered norms and unequal power relations, which negatively impact women's ability to migrate (Oishi 2005). Along similar lines, Hughes (2021, 388) suggests that the NELM framework is essentially too simplistic in its reliance on "straightforward, optimized, microeconomic calculations" and neglects the complexity of cultural, political, and institutional forces. Thus, the answer to who migrates from within a household in Mexico is largely contingent on both the temporal and spatial context, begging the question of how the environment may influence these migrant decision-making processes in combination with other complex contextual forces related to culture and political economy.

2.2.5 Network theory and social capital

The consideration of the links between interpersonal connections and migration is linked to the classic concepts of the migratory chain on the one hand (OECD, 1978) and social capital on the other (Portes, 1998). There has been a shift from the dominant conception of migration as a rupture to that of migration as constitutive of transnational links across space (Massey, 1990; Faist, 2021). The individual faced with the decision to migrate is now seen as connected to a social structure constituted by close and extended family, by people from the same region, the same cultural group or more broadly by friends and acquaintances. These networks facilitate migration by being sources of information and providers of help and support for the journey and settlement in a destination country (Salifu, 2007). However, some networks can also act as a brake by disseminating information that dispels illusions about migration prospects or by implying additional constraints for the migrant (Faist, 2021). The two related concepts of the cumulative effect and the migratory channels make it possible to explain the maintenance of the migration phenomenon even if the factors that led to its emergence cease. They also make it possible to explain the return or non-return of migrants.

Criticism of network approaches is linked to the fact that they focus too much on the family as the decision-making unit of reference (Hermanu, 2006). Also, some studies have identified networks as the dominant factor in explaining migration to the detriment of structural factors such as labour market demand.

The various theoretical approaches mentioned above, historically supported by specific social and political movements, have long been opposed to each other (Piché, 2014). However, these oppositions are less marked nowadays because each type of factor is recognised as an integral part of any migration theory(Boyd, 1989; Massey et al., 1999 ; Piché, 2013). We thus speak of theoretical pluralism, integrating levels of analysis (macro, meso, meso) and the various migration factors at both origin and destination.

2.2.6 Theoretical pluralism

The main theoretical approaches from the scientific literature to understand migration at the individual and household level have been presented in the previous sections. It emerges, as (Piguet, 2013) has pointed out, that migration is a multidimensional phenomenon. Socio-political and economic considerations, social networks, and even stereotypes or a geographical imaginary interact in a complex way in a process of choice that is always carried out under constraint (Lu, 1999) and results in migration or non-migration (Piguet, 2013). According to Ndione, (2009), the willingness and ability to migrate are at the same time the result of the personality and socio-economic trajectories of the person who wishes to migrate, his or her social environment, the information channels to which he or she is exposed, the migration networks and the political and economic contexts of the host country. However, as (Piguet, 2013) points out, we are not suggesting that the migration phenomenon cannot be theorised, since its causes are of all kinds. Rather, it is the theoretical pluralism suggested by Massey et al., (1993)n that is considered in this study.

Explanatory factors from several disciplinary traditions will first be mobilised at the same time, in order to propose a system of hypotheses, and the different factors will then be weighted by empirical investigations. The effect of the different factors will not be simply additive but will result from contextual combinations (Piguet, 2013). For it to start, there are necessary but not sufficient conditions, threshold effects that manifest themselves and lead to non-linear relationships. For example, the relationship between household income and the propensity to leave may adopt a 'bell-shaped' profile when only those who reach a certain income level (neither the poorest nor the richest) consider leaving. Theoretical pluralism also makes it possible to account for the temporal evolution of migration phenomena and their self-sustaining or cyclical nature. It also integrates the macro, meso and micro levels of analysis, as well as the various factors of migration at both origin and destination (Piché, 2014).

The choice of theoretical pluralism in this study certainly means admitting less overall coherence than an approach referring strictly to a specific current. However, it has the advantage of being more flexible in accounting for the complexity and diversity of environmental/climatic migrations.

2.3 Climate change/Environmental change and Migration nexus

Since the IPCC and Stern publications (IPCC, 2007; Stern, 2007) on future 'flows' of substantial numbers of environmental migrants (Piguet, 2022), the relationship between environmental change and migration has been a focus of debate in the media and political discourse over recent years (Bettini, 2013). The same interest from the scientific community in the question can be seen with a significant body of empirical evidence being produced on environmental and climate-related migration (Piguet et al., 2018 ; Hoffmann et al., 2018). In this section, we present a review of literature on the link between migration and climate/environmental change.

2.3.1 Nexus in studies around the world

At global level, many researchers have looked into this issue. Some of these studies have been reviewed.

Backhaus et al., (2015) have worked on the contribution of climatic variations to international migration around the world. They used a set of panel data from 142 countries of origin and 19 countries of destination from 1995 to 2006 in a gravity model incorporating average temperature to make their estimate. They concluded that there was a positive correlation between migration and climate change. Increases in temperature and precipitation in a country of origin lead to an increase in the outflow of migrants. The study suggests that the dependence of the country of origin on agriculture could be a determining factor in the migration response to changes in temperature.

In the same vein, Wesselbaum, (2021) looked at the direct effect of temperature, precipitation and extreme events on the migration of Africans to OECD countries. In his study, he used aggregated time series on annual migration flows from all African countries from 1980 to 2015 to 16 OECD countries. His analyses show that climate can either drive or inhibit migration, depending on the scale of the thermal shock. Temperature has non-linear effects on migration. As in the work of (Backhaus et al., 2015), countries that rely more heavily on agriculture experience greater migration flows in a climate change situation. And weather-related disasters also have a significant effect on international migration.

Mahajan & Yang, (2020) examined the impact of hurricanes on the flow of migrants to the United States from 159 countries around the world, using data from forty years of migration. The results show that, on average, countries with large proportions of migrants to the United States are the most affected by hurricanes. This migratory response to hurricanes is greater in countries with a large diaspora living in the United States. This highlights the importance of migratory networks in this form of migration.

In India, Dallmann & Millock, (2017) studied the impact of climate variability on internal migration. To do so, they compared climate data with data from the 1991 and 2001 Indian censuses on migration. Their results indicate that inter-state migration in India increases as the frequency of droughts in the state of origin increases. This effect is stronger in agricultural states, and in these states, the severity of drought also significantly increases inter-state migration. We noted that rural-rural interstate migration is most affected by drought frequency.

In their multilevel/panel study, Sedova & Kalkuhl, (2020) examined rural migration in India by combining meteorological data (temperature and rainfall) with panel data from the Human Development Survey. Using linear probability models and multinomial logit models, they established a complex causal relationship between temperature and rainfall anomalies and overall migration. Adverse weather shocks increase interstate migration to cities but decrease rural-rural migration and international migration. On the other hand, positive weather shocks favour international migration and intra-state migration to cities.

Oliveira & Pereda, (2020) used a spatial equilibrium model to analyse the impact of projected climate change under the business-as-usual scenario on internal migration and population distribution in Brazil. The results of the simulations reveal that migration rates are expected to be

9.65% higher, with a further 0.9 million people migrating from one region to another under future climate conditions. In addition, the country's regional inequalities are likely to be exacerbated, with the most developed regions (the north-east of the country) gaining in population and well-being, and the least developed regions (the south-east of the country) losing out.

Cameron, (2018) assessed climate change's impact on the spatial distribution of New Zealand's population, focusing on the effects of climate on the dynamics of internal migration. Overall, the results suggest that, although statistically significant, changes in the distribution of weather conditions will have an insignificant effect on the distribution of New Zealand's population at a regional level. These results probably reflect New Zealand's great capacity to adapt to climate change. They also suggest that there are non-climatic determinants of migration that are more important for internal migrants.

In their article, Roeckert & Kraehnert, (2022) examined the effects of extreme weather events on internal migration in Mongolia. They exploited exogenous variations in the intensity of extreme winter events over time and space to identify their impacts on permanent internal migration. The results obtained show that extreme winter events cause significant and important permanent emigration from the provinces affected for up to two years after the event.

Mastrorillo et al., (2016) investigated the impact of spatiotemporal variability in temperature and rainfall on internal migration flows in post-apartheid South Africa, using a gravity approach. South African census data and climate data were combined to construct a panel database that covers the 1997-2001 and 2007-2011 periods. Contrary to the findings of (Cameron, 2018) in New Zealand, the results globally show that an increase in positive temperature extremes as well as positive and negative excess rainfall in the areas of origin have a ripple effect and increase emigration. However, there is considerable variability in this effect of climate depending on the characteristics of the migrants: the migration of black and low-income South Africans is strongly influenced by climate variables, whereas this influence is weak for white and high-income South Africans.

Thiede & Gray, (2017) analysed the impact of climate on migration by matching Indonesian Family Life Survey data with high-resolution climate data. They concluded that the impact of temperature anomalies, rainfall levels and monsoon timing on intra- and inter-provincial migration does not operate systematically as a push factor and varies by gender, agricultural household membership and location.

Suckall et al. (2017) examined the impact of climate change on migration decisions in rural Malawi. To do so they used a framework based on migration aspirations and capacities, and survey data collected from rural and urban residents. The results show that climate change is likely to increase barriers to migration rather than increase migration flows in countries with largely rural economies such as Malawi. Climatic stresses do not increase the desire of rural dwellers to migrate; however, they can reduce the capacity to migrate by reducing human, financial and social capital. Acute shocks, for their part, reduce both the aspirations and the migration capacities of potential migrants.

2.3.2 Nexus in West Africa

West Africa is no slouch when it comes to studies on the link between climate change and migration. Numerous studies have been carried out on the links between climate change and migration, even if the contribution of climate change remains difficult to separate from other factors in migration (Teye & Nikoi, 2022).

Grolle, (2015) has proposed historical case studies on famines and migrations in the West African Sahel. He considers three episodes (1953-1954, 1972-1973, 1983-1985) based on existing literature and official archives as well as oral narratives collected from village chiefs, farmers, traders, etc. The studies conclude that the savannah has a historical function as a refuge for populations subject to environmental constraints. These populations take refuge there to satisfy their needs for wild food, fodder and firewood (rural-to-rural migration), which coincides with rural-to-urban mobility. The author stresses the importance of contexts and policies, and expresses concern about the sustainability of traditional forms of adaptation based on mobility.

Afifi, (2011) was interested to know whether the decision to migrate by Nigeriens is influenced by purely economic or environmental problems. He based his analyses on Niger's main environmental problems (drought, loss of Lake Chad's surface area, problems with the River Niger, etc.), as major push factors that could influence people's decision to migrate. His analyses led him to conclude that it was the deterioration in the economic situation as a result of environmental problems that influenced migration. This led him to use the term "environmentally induced economic migration".

Doevenspeck, (2011) studied the migration of farmers from regions with degraded soils in north-west Benin to the centre of the country, using a mixed quantitative and qualitative approach. The data used were from a survey carried out between November 2000 and May 2005. The study showed that spatial differences in terms of fertile and well-preserved agricultural land are not the exclusive explanatory factor for internal migration in rural areas of Benin. Like Afifi, (2011), it supports the view that environmental degradation is only one element of the structural conditions at the origin of migration in the areas of departure.

Van der Geest et al., (2010) have established a link between the dynamics of vegetation cover and human mobility. In their study, they used a statistical method that cross-referenced the destination of one hundred and ten migrants in Ghana with the Normalized Difference Vegetation Index (NDVI). The authors conclude that North-South migration is linked to better vegetation cover. Access to natural resources appears to be a key factor in the choice of destination.

Abu et al., (2014) examined internal migration intentions in response to climatic stresses and in the forest-savanna transition zone of Ghanan, using data from the Climate Change Collective Learning and Observatory Networ project. The results of the binary logistic regression used indicate that although climate-related events are presented as the stress factor that affects populations the most, these events do not appear to directly explain migration intentions. Socio-demographic factors such as age, household size and current migration status are significant predictors of migration intentions. We conclude that there are multiple drivers of migration, and in areas of perceived environmental stress, climate-related events may not be the main motivation for migration intentions.

Codjoe et al., (2017) investigated the relationship between coastal flooding and migration intentions in three coastal communities in the Volta Delta of Ghana. They used survey data to conduct bivariate and multivariate analyses. The results of the analyses allowed the authors to conclude that emigration is more related to community, economic and political factors than to exposure to flooding.

2.3.3 Nexus in Burkina Faso

In Burkina Faso, the literature on the link between climate change is not as abundant as elsewhere in the world, but it is growing.

(Henry et al., 2003) studied interprovincial migration in Burkina Faso, focusing on population outflows from ecologically poor areas. Using statistical methods, they modelled migration data and measured the relative weight of sociodemographic and biophysical variables. The results show that, although environmental variables have a significant weight in explaining interprovincial migration, it is slightly less than that of sociodemographic variables. In fact, this form of migration is influenced by high literacy and economic activity rates at origin and destination, the sex ratio at origin and destination, as well as by rainfall variability, land degradation and land availability at origin, and favourable conditions at destination for these variables.

Henry et al., (2004a) tested the influence of environmental changes on migration in Burkina Faso. They described individual migration pathways over the period 1960-1999 in Burkina Faso, using environmental typologies of origins and destinations based on rainfall variations and soil degradation. The study combined data from a national longitudinal (retrospective) survey with fine-resolution rainfall and land degradation data. Their results suggest that environmental factors influence, but in different ways, both the probability of migrating and the choice of destination once the decision to migrate has been taken. Migration seems to be more influenced by a slow process such as land degradation than by episodic events such as droughts.

Henry et al., (2004b) used a historical analysis approach to study the impact of rainfall conditions (a crucial environmental factor for the livelihoods of Sahelian households) on the probability of first departure from a village in Burkina Faso. It was necessary to classify migrations according to destination and duration in this investigation. The analyses reveal that the people most likely to undertake temporary and permanent migration to other rural areas are those from drier regions. Moreover, in the short term, the risk of long-term migration to rural areas is increased by rainfall deficits. On the other hand, they reduce the risk of short-term migration towards distant destinations.

Kniveton et al., (2011) conducted an in-depth study of the role of environmental factors in migratory decisions in Burkina Faso. An agent-based model incorporating the theory of planned behaviour was used to project future changes in migration. The results show that a trend towards a drier climate lead to an increase in total international migration flows. These flows are greatest when they are combined with inclusive and connected changes in social and political governance. On the other hand, the lowest international migration flows are generated by a wetter climate combined with exclusive and diversified governance scenarios.

Smith, (2012) in his thesis developed an agent-based model drawing on the theory of planned behaviour, to quantify the influence of future climate change (using rainfall as an indicator) on migration patterns in Burkina Faso. He used retrospective migration data and responses from respondents in focus groups conducted across Burkina Faso. The results of his study suggest that medium rainfall conditions produce the highest migration rates, while dry and wet conditions result in reduced migration flows.

(Neumann et al., 2015) studied environmental migration in drylands using cluster analysis on spatially explicit global data. Their analyses were based, on rainfall, aridity, drought, land degradation, soil constraints and availability of cropland and grazing land as potential environmental drivers of migration. The results of the investigation indicate that the importance of migration factors depends on the scale of analysis. Thus, cluster analysis at the global scale suggests that land degradation is the most severe environmental constraint for the two hotspots studied (Burkina Faso and north-east Brazil). However, analyses at the national level for Burkina Faso revealed that rainfall variability and land degradation are determining factors of roughly equal importance for intraprovincial migration. Furthermore, the results show a strong interdependence between economic and environmental factors and highlight the difficulty of determining the root causes of migration.

Gray & Wise, (2016) studied the impact of climate variability on human migration by linking 6 years of internal and international migration data on 9812 households of origin in five countries, including Burkina Faso, to high-resolution climate data from both station and satellite sources. The analyses show that in Burkina Faso, temperature has a negative impact on both internal and international migration, much of which is to neighboring countries. This suggests that certain populations in a climate change situation find themselves trapped with no possibility of migrating.

Nawrotzki & Bakhtsiyarava (2016) have analysed the impact of climate on migration in rural areas of Burkina Faso and Senegal. To do that, they combined census data with high-resolution climate data. This enabled them to construct four threshold-based climate indicators to study the effect of heat waves, cold waves, droughts and excessive rainfall on the probability of international migration at household level. The results of the multilevel logit models show that heat waves lead to a reduction in international migration. This shows that heat waves have an inhibiting effect on this form of migration.

Sanfo et al., (2017) investigated the major environmental factors responsible for farmers' inter-village migration in south-west Burkina Faso. Their analyses were based on survey data, semi-structured interviews, life stories and focus group discussions. According to their results, the key push factors for environmental migration in this part of Burkina Faso are soil degradation, land tenure insecurity and lack of rainfall. The key pull factors are land fertility, good productivity, abundant rainfall and security of tenure.

(De Longueville et al., 2019) assessed the direct and indirect effects of the environment on migration in Burkina Faso from 1970 to 1998. Using a structural equation model, they shed light on the interactions between migration factors and their joint contribution to the migration decision of individuals in rural areas of Burkina Faso. The results of their research show that environmental degradation increases the probability of short-term migration to rural and urban areas. However, it reduces the likelihood of long-term migration to rural areas and abroad.

Nébié & West, (2019) studied the link between migration and changes in land use and land cover in the provinces of Bam and Sissili in Burkina Faso. They combined a time series of data on land use change and land cover transformation with demographic data and local narratives in the two provinces from 1975 to 2013. Their analyses reveal that the area showing the greatest environmental degradation is the province of Sissili, which is a migrant-receiving area. On the other hand, the changes are moderate in Bam, which is a departure zone. This dynamic could at some point stabilise or even reverse the trend in migration dynamics between the two provinces.

In general, the studies reviewed confirm the role of climatic/environmental factors in migration. However, in most cases, environmental variables only appear as one driving force among others, with which they interact (Backhaus et al., 2015; Mahajan & Yang, 2020). These factors are economic, social, demographic and political (Black et al., 2011). This confirms the idea that 'pure' climate/environmental migration does not exist and that multi-causality is the norm (Piguet, 2022).

We also note that despite the growing number of studies on the subject, empirical knowledge in the field remains varied and uneven (Hunter et al., 2015; Piguet et al., 2011). The wide variety of methods used in the studies makes it difficult to compare their results (Van der Land et al., 2018). So far, there is no clear consensus on the direction and extent of the influence of climate/environment on migration. Some authors such as (De Haas, 2011) attribute a limited and rather indirect role to it, others such as (Marchiori & Schumacher, 2011).

The body of literature on climate/environment-induced migration is now very extensive and continues to grow. However, empirical studies that have addressed it in the context of Burkina Faso have paid limited attention to analyses at the local level, in particular to the determinants and impacts of internal migration from rural to rural areas. Existing research has tended to focus on national or regional trends (Tapsoba et al., 2022b), neglecting the nuances of the local context. Furthermore, the perspective of local actors, who nevertheless exert influence on migration processes, has received scant attention. Migration analyses are subject to methodological biases, particularly the neglect of selection biases (Abel et al., 2019 ; De Longueville et al., 2020 ; Neumann & Hermans, 2015). Moreover, few studies have adopted a participatory approach in their analyses of migration. These gaps are particularly evident in the context of Burkina Faso, a Sahelian country where populations are predominantly rural and the economy is primarily agricultural.

The next section is devoted to the state of the art on the impact of migration.

2.4 Impacts of migration

Researchers have been very interested in the economic, social and political impacts of migration. In this section we will examine the work that has already been done in order to gain a better understanding of the subject and to identify any gaps that our study will contribute to filling.

2.4.1 Impact of migration on research around the world

While there is an abundant literature on the impacts of migration worldwide.

De Brauw & Harigaya, (2007) used panel data methods to determine the contribution of seasonal migration to the improvement in living standards of Vietnamese households during the 1990s. They mainly measured living standards in relation to per capita expenditure, historical variables and latent networks as instruments of migration. The result of their analyses indicates that the increase in migration led to a 5.2% growth in annual household expenditure. Cuong & Linh, (2018) used fixed-effects regression to study the impact of remittances and migration on the welfare of Vietnamese households. Their results show that household income and expenditure are positively impacted by international remittances.

Mukhtar et al., (2018), used primary data collected from the four main districts of Lahore, Pakistan, to assess the quality of migrant workers' employment and its effect on rural households' welfare. Their results show that migrant workers' incomes and living conditions have improved in their new urban environment, but they have very poor social protection. Moreover, migration appears to be a good option for improving the quality of employment and income of rural households. In the same country, Javed et al., (2017)used the propensity score matching method to study the impact of remittances on household welfare in Toba Tek Singh district of Punjab. The study found that migrant households' expenditure on food and non-food items increased significantly as a result of remittances, thereby improving the welfare of recipient households.

De Brauw et al., (2018) used tracking data of migrants and non-migrants from 18 villages in Ethiopia between 1994 and 2009 to examine the impact of internal migration on welfare. The results of their analyses revealed a substantial improvement in migrants' well-being, with an increase in their non-food consumption of at least 145%. Their diet was also found to be of better quality than that of non-migrants. In the same country, Assaminew et al., (2011) used the binary outcome model to analyse the impact of migration and remittances on poverty from 1971 to 2009. They concluded that international remittances contributed to poverty reduction in urban households.

2.4.2 Impact of migration on research in West Africa

As one of the regions where there is a significant flow of both internal and international migrants, many researchers have looked into the impact of these migratory movements.

Eshetu et al., (2023) applied endogenous multinomial regression as an analytical model in southern Ethiopia to analyse the impact of rural emigration on household poverty. The results of their research show that the incidence, depth and severity of poverty are lower in households of international migrants. They also suggest that international migration increases household consumption per adult equivalent by 29.8%.

Gupta et al., (2009) examined the impact of remittances on poverty and financial development in sub-Saharan Africa. They concluded that remittances increase the income of recipient households and have an impact on reducing poverty and inequality. A 10% increase in remittance flows is associated with a 1% reduction in the level of poverty per capita and the dispersion of per capita income.

Fonta et al., (2011) looked at the link between remittances, poverty and income inequality in Nigeria. Using poverty decomposition and Gini techniques, they were able to show that, regardless of the geographical and political region (south-south; south-west; centre-north; centre-south, etc.), remittances reduce household poverty. They also found that the contribution of remittances to reducing income inequality was greater in urban areas (0.1) than in rural areas (0.02). (Akanle & Adesina, 2017) also examined the effects of remittances on household welfare in Nigeria, using ordinary least squares (OLS) estimation. They concluded that remittances positively influence household welfare.

Ackah & Medvedev, (2012) used regression techniques to assess the determinants of migration and its impact on household welfare in Ghana. They did this by exploiting a dataset compiled on migration and remittances in Ghana. Their results reveal that rural households in Ghana are better off if they have a family member who has migrated to the city. On the other hand, they find that the welfare of households whose members have migrated elsewhere in rural areas is no better than that of those who have not migrated at all.

Owusu, (2007) investigated the impacts of rural-rural migration in the destination areas of Brong Ahafo. The results of his investigation show that migrants generated income through the initial felling of trees and the more or less intensive use of rented land. The leases also generated additional income for the indigenous people of the Upper East region who leased their land. The living conditions of the migrants' families are also improved in the regions of origin thanks to remittances that support education and food. All these benefits have led Owusu to describe migration as a "victory" for the region and the migrants themselves.

2.4.3 Impact of migration on research in Burkina Faso

While there is an abundant literature on the impacts of migration worldwide and in Africa (Siddiqui, 2012), there is less in Burkina Faso.

Roland, (2015) examined the impact of migration on rural income inequality using survey data on the living conditions of rural households in Burkina Faso in 2011. The findings indicate that the departure of migrants has no effect on rural income inequality. On the other hand, migrant remittances contribute to increasing inequalities when migrants come from well-off households and to reducing them when migrants come from poor households.

Tapsoba et al., (2022) carried out a descriptive analysis of the results of the quantitative survey carried out by the MIDEQ (Migration for Development and Equality) project, with the aim of identifying the inequalities associated with Burkina Faso-Côte d'Ivoire migration. Their analyses show that, in the short term, remittances increase income inequalities between families able to send migrants abroad and benefit from remittances, and those unable to do so. However, in the long term, the reduction in the costs of emigration as a result of the creation of networks, migrants and the funds they transfer would make it possible to reduce inequalities, by helping less wealthy households to send some of their members abroad.

An analysis of data from three series of Household Living Conditions Surveys and Demographic and Health Surveys carried out in Burkina Faso shows that households with a higher proportion of migrants have a better standard of living and a higher secondary school attendance rate (Tapsoba et al., 2022a).

In his book, Wouterse, (2006) analyses the determinants and effects of migration for rural households in four villages in the Central Plateau of Burkina Faso. He concludes that in an imperfect market environment, remittances from intercontinental migration help households to improve their well-being considerably. As for continental migrants, their departure has a negative impact on the income generated by labour-intensive activities, and household well-being improves only slightly due to the reduction in household size induced by migration.

Zahonogo, (2011) analysed the relationship between migration and agricultural production in Burkina Faso using the new economy model of labour migration. The results show that the average agricultural income of households with migrants is lower than that of households without migrants; but households with migrants have an average non-agricultural income is higher than that of households without migrants. This result suggests that migration has a negative impact on agricultural income but has a positive impact on non-agricultural activities in rural areas.

In their article, (Tapsoba et al., 2023) assessed the impact of migrant remittances and and climate variability on household food security in Burkina Faso, using an original database constructed from the 2009 World Bank survey. Their results suggest that remittances enhance food security and mitigate the negative effect of the standardised precipitation and evapotranspiration index (SPEI) on food security.

2.5 Relationship between drought and migration

Drought has surfaced as a crucial factor driving internal migration globally, affecting the relocation of populations in search of improved living conditions. The connection between drought and migration is complex, typically shaped by socio-economic influences, governance practices, and the degradation of environmental quality. Globally, research has indicated that severe climatic events, particularly extended periods of drought, drive at-risk populations to relocate in their quest to access vital food and water resources, enhance their economic conditions, and avoid conflicts that are aggravated by the lack of resources (Black et al., 2011; Zickgraf, 2018).

In the context of West Africa, characterized by pronounced climatic variability, drought has emerged as a particularly adverse phenomenon, resulting in the displacement of communities reliant on rain-fed agricultural practices (Mastrorillo, M., et al. 2016). The IPCC report from 2014 highlights that, the Sahel are experiencing an uptick in both the frequency and severity of droughts, which significantly jeopardizes food security and economic stability, consequently driving people from rural areas to cities in search of better prospects in urban settings.

In Burkina Faso, the effects of drought on internal migration are observable, as the nation struggles with continuous food crises tied to climatic shifts. Research suggests that populations in the Sahelian region are progressively vacating their residences in pursuit of more dependable agricultural conditions and enhanced access to resources (Schraven et al., 2019). Migration patterns in Burkina Faso typically involve the movement from rural areas to urban centers, with males exhibiting a notable tendency to leave their residences in search of job and educational opportunities (Gray & Mueller, 2012). Additionally, there are significant instances of internal migration within rural areas, where families relocate to different communities in pursuit of better agricultural land or more favorable climatic conditions (Zougmor et al., 2019). Migration patterns in Burkina Faso typically involve the movement from rural areas to urban centers, with males exhibiting a notable tendency to leave their residences in search of job and educational opportunities (Gray & Mueller, 2012). Additionally, there are significant instances of internal migration within rural areas, where families relocate to different communities in pursuit of better

agricultural land or more favorable climatic conditions (Zougmor et al., 2019). Consequently, comprehending the dynamics of drought-induced migration is imperative for policymakers striving to formulate sustainable adaptation strategies and bolster resilience against prospective climatic disturbances.

This literature review shows that the impact of migration is generally approached from the angle of remittances and their impact on inequality, income, poverty and the well-being of migrant households in the countries/regions/cities of origin. Also, it is the remittances of international migrants that are most often studied. Very few, apart from Owusu, (2007) have looked at the impact of internal migration on the well-being of migrants in their destination areas and on the means of production of family members left behind. This represents a gap in research on the impacts of migration, which if addressed will shed more light on understanding the impacts of internal migration.

CHAPTER 3 : STUDY AREAS AND METHODOGY OF RESEARCH

3.1 Study area

3.1.1 Location of study sites

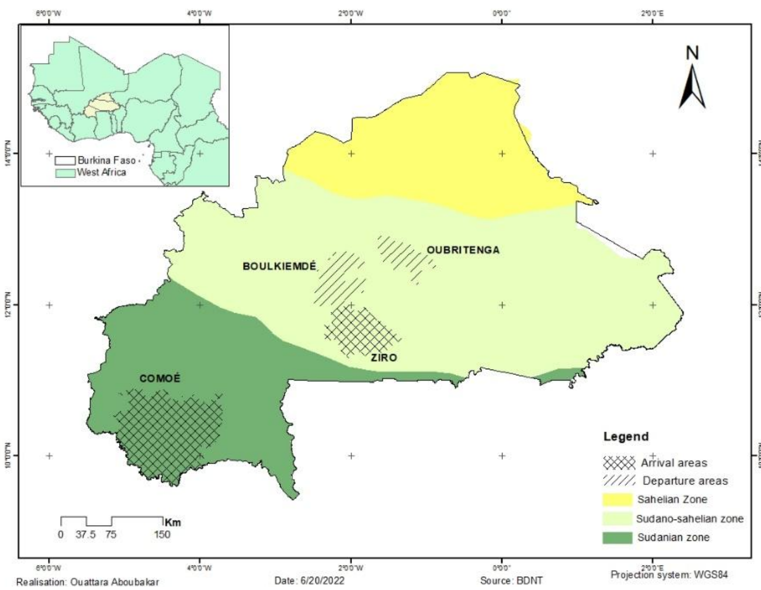

Figure 3.1: Map of the study sites
Source: BNDT 2012

This study was carried out in Burkina Faso at 4 sites, including 2 migrant origin sites and 2 migrant destination sites.

The departure sites, Oubritenga and Boulkiemdé provinces, are located in the Sudano-Sahelian zone. The province of Boulkiemdé lies between 12°14'59" north latitude and 2°22'03" west longitude. Located in the centre-west of the country, it is bordered to the north by the provinces of Passoré and Kourwéogo, to the west by the province of Sanguié, to the south by the provinces of Sissili and Ziro, to the south-east by the province of Bazèga and to the east by the provinces of Kadiogo and Kourwéo-go. It covers an area of 4,269 km2. The Boulkiemdé is situated within the Sudano-Sahelian zone, characterised by a semi-arid climate with a shorter rainy season lasting 4 to 5 months (Guinko, 1984; Zoundi et al., 2024). The annual rainfall ranges between 600 and 900 mm,while average annual temperatures range from 20°C to 37°C (INSD, 2022c; Zoundi et al., 2024). The local economy is also centred on agriculture; however, it is less diversified due to water scarcity and limited agricultural potential (Coly et al., 2024; Zoundi et al., 2024). These environmental, climatic and economic constraints have resulted in high levels of out-migration (INSD, 2022b).

La province de l'Oubritenga est située entre 12°35'00'' de latitude nord et 1°25'00'' de longitude ouest. Située au Centre du pays, elle est limitée au Nord et au Nord-Est par la province du Sanmatenga, au Nord-Ouest par la province du Passoré, à Ouest par la province du Kourwéogo, au sud par la province du Kadiogo, au Sud-Est par les provinces du Kadiogo et du Ganzourgou et enfin à l'Est par la province du Ganzourgou. Elle couvre une superficie de 2 778 km2 et est composée de sept (7) communes. Tout comme le Boulkiemde, la province de l'Oubritenga à un climat de type soudano sahélien marqué une pluviométrie moyenne annuelle qui varie entre 600 et 800 mm d'eau(Guinko, 1984; Zoundi et al., 2024). Les températures moyennes annuelles sont comprises entre 18°C et 39° C, soit une amplitude thermique de 21° C.

The province of Oubritenga is located between 12°35′00″ north latitude and 1°25′00″ west longitude. Situated in the central part of Burkina Faso, it is bordered to the north and northeast by the province of Sanmatenga, to the northwest by the province of Passoré, to the west by the province of Kourwéogo, to the south by the province of Kadiogo, to the southeast by the provinces of Kadiogo and Ganzourgou, and to the east by the province of Ganzourgou. Covering an area of 2,778 km², the province consists of seven municipalities. The province experiences a Sudano-Sahelian climate, similar to that of Boulkiemdé, characterized by an annual rainfall ranges between 600 and 800 mm, (Guinko, 1984; Zoundi et al., 2024). The average annual temperatures vary between 18°C and 39°C, resulting in a thermal amplitude of 21°C. Oubritenga is an important agricultural zone, with the majority of the population engaged in rain-fed farming and livestock rearing. The province's strategic location near the capital, Ouagadougou, fosters economic exchanges and migration. However, climate variability, water scarcity, and land degradation pose significant challenges for sustainable development and food security.

The destination sites are the Comoé, and the Ziro province. The province of Comoé lies between 10°14′32″ north latitude and 4°23′58″ west longitude. Located in the extreme southwest of Burkina Faso, it is bordered to the north by the province of Houet, to the north-west by the province of Kénédougou, to the north-east by the province of Bougouriba, to the west by the province of

Léraba, to the east by the province of Poni and to the south by the Republic of Côte d'Ivoire. It covers an area of 15405 km^2. Its lies within the Sudanian zone, characterised by a tropical climate with a relatively extended rainy season, lasting approximately 5 to 6 months (Guinko, 1984; Sodore et al., 2023). Annual rainfall averages between 800 and 1,200 mm, while average annual temperatures range from 17°C to 36°C, with a thermal amplitude of 19°C (INSD, 2022; Sodore et al., 2023). Economically, Comoé Province is predominantly agrarian, relying heavily on rain-fed agriculture (92.2% of households), with key crops including maize, millet, and legume(INSD, 2023)s. Livelihoods are largely based on subsistence farming and livestock rearing, making the region vulnerable to prolonged droughts(Coly et al., 2024). However, its relatively abundant natural resources and agricultural opportunities contribute to a higher degree of resilience compared to more arid regions. This economic and ecological advantage has made Comoé a key destination for internal migrants seeking improved agricultural opportunities and better living conditions (INSD, 2022b).

The province of Ziro is located between approximately 11°23′00″ north latitude and 2°47′00″ west longitude. Situated in the centre-west of Burkina Faso, it shares borders with the province of Boulkiemdé to the north, the province of Bazèga to the east, the province of Sissili to the south, and the province of Sanguié to the west. Covering an area of around 5,139 km², Ziro lies in the transition zone between Soudanian and Sudano-Sahelian zone (Worou et al., 2019), characterized by an annual rainfall ranging between 700 and 1,000 mm, while average temperatures fluctuate between 18°C and 38°C, resulting in a significant thermal amplitude(Etongo et al., 2015). Economically, Ziro is predominantly agrarian, with the majority of households engaged in rain-fed agriculture and livestock farming (Worou et al., 2019). Despite periodic climate variability, the province of Ziro remains an important agricultural hub, attracting seasonal and permanent migration from neighboring areas in search of better farming opportunities (Nana, 2018).

3.1.2 Demographic characteristics of the study sites

According to the final results of the 2019 general population census (INSD, 2022), the provinces from which the migrants depart, Oubritenga and Boulkiemdé, have 314,609 and 6,870,709 residents respectively. In the province of Oubritenga, 52.19% of the population are women, and in Boulkiemdé they represent 52.19% of the population. For example, in the province of Oubritenga

86.13% of households live in rural areas, and in Boulkiemdé this figure is 67.69%. Population densities in the provinces of Oubritenga and Boulkiemdé are 110.7 inhabitants/km^2 and 161.3 inhabitants/km^2 respectively. These values are well above the national average of 75.1 inhabitants/km^2. These migrant departure areas are therefore among the most densely populated provinces in Burkina Faso.

The provinces of destination for migrants, Comoé and Ziro, have 633,043 and 241,731 residents respectively. Women represent 51.5% of the population in Comoé and 52.17% in Ziro. The majority of households in these provinces live in rural areas (70.7% in Comoé and 85.5% in Ziro). Population densities in Comoé and Ziro are 42.8 inhabitants/km^2 and 45.7 inhabitants/km^2 respectively. Far below the national average of 75.1 inhabitants/km^2, these values place these destination areas among the least densely populated provinces in the country.

The 'Plateau Central or Plateau Mossi', which includes our two migrant departure sites in this study, is known to be an important emigration region in Burkina Faso (Nébié & West, 2019 ; Reij et al., 2005). People from this area, mostly of Mossi ethnic group, used to migrate to Côte d'Ivoire, although this has decreased over time and with the political upheavals that this country has experienced (Deshingkar, 2012; Konseiga, 2004; Songre et al., 2018). Kazianga & Wahhaj, (2020) conducted migration surveys in the Central Plateau and Centre-West regions of Burkina Faso, regions in which the two migrant departure sites in this study are located. The results of their survey, which covered 20 villages, show that 83% of rural households in these areas have at least one permanent or temporary migrant.

The first internal migratory flows date back to the 1970s and 1980s, when Burkina Faso experienced droughts (Nana, 2018; Ouedraogo et al., 2010). At that time, internal migrants came mainly from the 6 main emigration centres, namely the provinces of Yatenga, Sanmatenga, Boulkiemdé, Passoré, Kadiogo and Oubritenga l'Oubritenga (Nébié, 1996; Zongo, 2009). These flows were mainly directed towards the country's old cotton-growing zone, the heart of which is located in the Mouhoun, Banwa, Tuy Balé, Houet and northern Kénédougou provinces, (Ouedraogo et al., 2009; Paré et al., 2008; Zongo, 2009).

The provinces of Comoé and Ziro recorded the first arrivals of internal migrants at that time, but these flows remained relatively moderate until the early 1990s (Nana, 2018; Ouedraogo et al., 2010). The old cotton-growing zone became saturated in the 1990s, and migrants faced insecurity of land tenure (Claims/Issp, 2005; Nana, 2018). This area, which used to be a destination for internal migrants, is gradually losing migrants to the new pioneer front, including the provinces of Comoé and Ziro. With the socio-political and land crisis that broke out in Côte d'Ivoire in early 2000, the Comoé and Ziro provinces also recorded the arrival of international migrants returning from Côte d'Ivoire. They also received migrants from the central plateau. This marked the beginning of an intensification of migrant flows towards the provinces of Comoé and Ziro (Nana, 2018; Zongo, 2009).

3.1.3 Migration dynamics in the study sites

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3.2 Research method

3.2.1 Specific objective 1: Development of migration scenarios from the perspective of local stakeholders

3.2.1.1 Migration analysis method

In this study, we have adopted the participatory approach to analyse migration. The adoption of this method by researchers in the study of migration has been slower than in other areas of social science (Torres & Carte, 2014). It is a very common approach in many fields, especially in public health studies (Sullivan et al., 2005; van den Muijsenbergh et al., 2020). However, it has not been widely used in migration studies (Torres & Carte, 2014). Nevertheless, it has the potential to provide a good understanding of the multiple and complex drivers of migration and its effects.

To analyse migration with stakeholders, we opted to use workshops. Workshops are a participatory analysis technique commonly used, similar to focus groups (Skop, 2006). They have the potential to generate spontaneous exchanges and interactions that lead to unexpected results, reflexivity, and reciprocal learning. For the development of scenarios, the Story and Simulation (SAS) approach (Alcamo, 2008) have been adapted.

There are two main steps in this analysis: (i) identification and selection of the key stakeholders to be involved in the process at the four study sites, and (ii) organisation of workshops with the stakeholders identified at each site.

3.2.1.2 Identification and selection of key stakeholders

A three-stage approach was adopted to identify stakeholders. The first involved identifying the initial stakeholders and contacting them by telephone. The second consisted of a physical meeting with these stakeholders and the identification of other stakeholders using the snowball method. The third consisted of choosing the most relevant stakeholders to involve in the study.

- **Identification of the first stakeholders:** The first stakeholders to be identified were the government's technical services, which are responsible for managing migration, agricultural production and the environment. These technical services were contacted via the technical services in charge of the environment, which acted as our gateway. A schedule of meetings was drawn up with these stakeholders.
- **Field trips to make contact and identify stakeholders:** Field trips were then made to each of the sites to meet the stakeholders. During these meetings, we presented the objectives of the study, which was to carry out a multi-actor analysis of migration in a context of environmental/climatic change. We emphasised the need for the scenarios to be developed by the stakeholders themselves so that they reflected the reality on the ground as closely as possible. Based on the information they have received, they are asked to suggest other relevant stakeholders who could be involved in the study. In this way, we identified other stakeholders who were suggested to us. A database of people likely to be involved in the process was thus created.
- **Choice of stakeholders:** The list of participants in the workshops was drawn up on the basis of the database that could be associated with them, compiled during the field trips. State technical services, local authorities, traditional authorities, NGOs, researchers, migrants and farmers' organisations were chosen.

The choice of state technical services is justified by the fact that, as representatives of the various ministerial departments, they are responsible for implementing Burkina Faso's various policies at local level. They are therefore key actors in addressing migration, agricultural, environmental and social issues.

Local collectivities have been chosen because, in the context of decentralisation, they are the bodies responsible for social and economic development and for maintaining the ecological balance at local level. Local development is designed, planned and implemented by local collectivities. Migrants therefore always settle in a local collectivity that welcomes them and creates the conditions for their integration and socio-economic development. In this respect, local collectivities are key actors.

The choice of traditional authorities is justified by the fact that, in the context of Burkina Faso, they are of great importance. They enjoy a certain legitimacy among the population, who recognise them and identify with them. Tradition and social cohesion are guaranteed by them. They are the ones who hold the land and give it to the migrants. As such, they are the relevant actors to involve in this process.

Researchers have been involved because they are responsible for investigating societal problems and phenomena, in order to understand and explain them and find solutions to inform and guide policies.

The choice of NGOs/CSOs is due to the citizen watch role they play. Thus they are very close to the people. They are therefore aware of the ills that undermine society. They are therefore important players to take into account when we seek to understand a phenomenon as complex as migration.

Migrants: they are the first to be affected and it would be inconceivable not to involve them. They were chosen during the identification of key migration stakeholders in each of the four provinces, using the snowball method. They are opinion leaders in their communities (formal or informal leaders of migrant groups). Given their position as leaders, they have a holistic knowledge of migrants' issues and are able to express their opinions publicly.

Farmers' organisations: these are the umbrella organisations that bring together the actors in a particular field of activity. They promote their activities and defend their interests. These structures bring together migrants to carry out their activities. They are therefore important to be taken into account in order to better understand the difficulties faced by migrants.

3.2.1.3 Migration analysis workshops

The migration analysis workshops at local level lasted two (02) days and brought together around fifteen participants at each of the four sites (see lists of workshop participants in the appendix) from different localities in each of the provinces. The workshops with local stakeholders were held mainly in plenary sessions.

First, the workshop objectives, working methodology and expected results were presented. This provided an opportunity to explain to the participants the work that was going to be done and what was expected of them. As many of the participants were not fluent in French, the speeches were translated into Dioula and/or Mooré, the two local languages spoken by all the participants in the study sites. This gave everyone the freedom to speak in the language of their choice (French, Mooré or Dioula). This ensured that the participants had a good understanding of the issues addressed and were able to participate fully in the discussions.

Secondly, the participants exchanged views openly on the topics discussed throughout the workshop. The consensual answers to the various questions asked were written down on Craft paper, which was then used to produce a summary of the discussions.

The topics or themes addressed during these workshops included brainstorming, identifying migration stakeholders, identifying migration factors, identifying the impacts of migration, identifying stakeholders' needs, and proposing solutions for better migration management.

- **Brainstorming**

Before starting the brainstorming, in each site, the participants are first asked to give the migratory status of the area, i.e. to say whether we are in a migrant departure zone or a migrant arrival zone. This was used to validate the choice of migrant departure and destination sites.

The brainstorming consisted in giving the floor to the participants so that they could express themselves freely, without restriction or particular orientation (experiences, perceptions, problems, advantages, etc.). This helped to build participants' confidence, through everyone's involvement in the discussions. The result was an overview of the migration phenomenon in each province.

- **Identification of stakeholders.**

The identification of stakeholders consisted in asking the question: who are the people involved in the migration phenomenon? To make it accessible to the participants, the question was posed in several different ways: Who do you work with when you migrate? Who do you turn to when you are new to a locality, who do you turn to when you have problems, who do you work with on your activities?

- **Identification of migration factors**

At this level, we are interested on the one hand in the factors that have influenced migration in the past and in the present, and on the other hand in the factors that will influence migration in the future (next twenty years). These factors include push factors in areas of origin and pull factors in areas of destination.

- **Identifying the impacts of migration**

To identify these impacts, participants were first asked to cite the advantages, benefits or positive aspects of migration. Secondly, they were asked to name the disadvantages, losses or negative aspects associated with migration.

- **Identifying stakeholders' needs**

Each of the stakeholders identified was asked to state their needs, or to say what was required, to better deal with the migration of farmers.

- **Development of scenarios**

After identifying the main factors attracting migrants to each of the provinces over the next twenty years, they were asked to classify the factors in order of importance. The two most important factors were chosen in each province to develop four scenarios. Migration and the socio-economic and political environment were described for each scenario.

3.2.2 Objective 2: analysis of the socio-economic determinants and impacts of climate-related internal migration on Welfare at migrant's destination

3.2.2.1 Conceptual Framework

Climate variability has emerged as a critical factor of socioeconomic transitions in vulnerable regions, particularly in the Sahel. Burkina Faso households face recurring environmental stressors, such as water scarcity, prolonged droughts, and soil degradation, which disrupt their livelihoods and agricultural productivity. These conditions often compel households to adopt internal migration as a coping mechanism. The conceptual framework seeks to explore the mechanisms and relationship between these climate-induced stressors, migration choices on the welfare outcomes: Total value of assets and remittance. Climate fluctuations serve as a significant driving force, altering traditional farming methods and limiting resource availability. Environmental shocks, such as low rainfall or barren farmlands, frequently force households to migrate in search of alternate livelihoods (Black et al., 2011). Poverty, a lack of credit, and poor education all contribute to vulnerability, making migration a plausible choice. Local economic conditions and household demographic features, such as family size or household heads' ages, also influence migration decisions (Aslany & Sommerfelt, 2020).

Internal migration develops as both an adaptive response and a risk to households. Migration enables households to diversify their income sources, minimize reliance on climate-sensitive agriculture, and seek better climatic conditions in other areas (Maharjan et al., 2020). However, migration's success is determined by the availability of social networks, the capacity to integrate into the destination's economy, and the expenses of relocation. Migration can help households by improving income, remittances, and access to services, but it can also make them more vulnerable by altering family structures or raising household debt.

Household welfare is conceptualized in terms of economic resilience, which is quantified using assets such as livestock, land value, durable items, and savings. Migration affects these welfare outcomes via influencing income creation, savings accumulation, and the ability to invest in productive activities. For example, remittances received by migrants may allow households to strengthen their resilience by purchasing assets or improving agricultural methods (Jalal et al., 2017). In contrast, unsuccessful migration may diminish household resources, making them more vulnerable to future climate shocks. The relationship between climate variability, migration, and household welfare is mediated by several mechanisms:

- Environmental Push: Climate-induced environmental degradation forces households to migrate as a survival strategy.
- Socioeconomic Mediators: Variables such as pre-migration asset levels, access to credit, and household composition shape the decision to migrate and the potential benefits derived from it.
- Institutional and Spatial Factors: Proximity to urban centers, migration policies, and institutional support influence migration's effectiveness in improving welfare. For example, better access to infrastructure in urban areas increases the likelihood of positive outcomes.

To maximize the benefits of migration while limiting its risks, tailored measures are required. Investments in rural infrastructure, climate adaption measures, and access to financial services can all help to lessen the need for distress migration while also supporting migrants at their destinations. Policies that encourage sustainable land use and climate-smart agriculture can address the core causes of migration by increasing resilience to climatic unpredictability. By evaluating this interaction, the framework emphasizes migration's dual significance as a both coping mechanism and a potential vulnerability for climate-affected households. The framework also highlights the importance of targeted policies to address the socioeconomic and environmental drivers of migration, ensuring that migration contributes positively to household welfare.

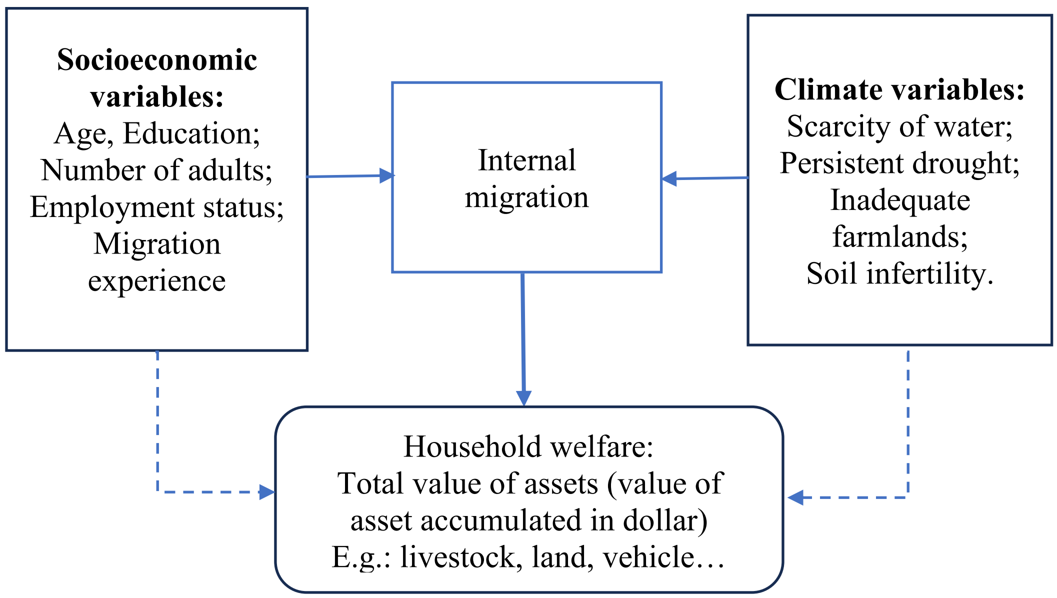


Figure 3.2: Conceptual framework on climate induced internal migration, and is impact on welfare

Source: Authors

3.2.2.2 Empirical strategy

The marginal treatment effect (MTE) is a useful approach to estimate the impact of migration on assets by accounting for both observable and unobservable factors that influence migration decisions. The MTE framework allows for heterogeneity in responses to migration across individuals and helps identify the impact of migration for individuals who are indifferent to migrating (i.e., marginal migrants).

The empirical strategy for estimating marginal treatment effects (MTE) involves understanding how individuals or entities respond to a treatment at the margin, typically under conditions of selection bias or heterogeneous treatment effects. This is often used in contexts where traditional approaches like randomized controlled trials are not feasible, and unobservable factors may influence both treatment and outcomes. MTE estimation relies on the availability of instrumental variables that influence the likelihood of treatment but do not affect the outcome directly except through the treatment. These instruments help separate the variation in treatment assignment driven by unobservable factors from that driven by observable factors.

The empirical challenge is that migration may be endogenously determined. To address this, we use the instrumental variables (IV) approach, where the decision to migrate is modeled as a function of both observed and unobserved characteristics. The IV strategy identifies variation in migration that is exogenous to household asset accumulation.

The MTE framework models the migration decision (treatment) as a function of an unobserved latent variable that determines whether a household migrates or not. The migration decision equation is:

$$M_i = 1 \; if \; Z_i \gamma + U_i > 0 \quad (1)$$

where M_i is the migration status, Z_i is a vector of instrumental variables, γ is a parameter vector, and U_i is the unobserved component affecting migration.

The outcome equation, modeling the effect of migration on assets, is specified as:

$$Y_i = X_i \beta + \delta M_i + \varepsilon_i \quad (2)$$

where Y_1 is the household's asset level, X_i is a set of control variables, M_i is the migration status, δ is the treatment effect (impact of migration on assets), and ε_i is the error term.

The first Stage: Estimate the propensity score

We first estimate the probability of migrating (propensity score) using a probit model:

$$P\,(M_i = 1 | \; Z_i, X_i) = \boldsymbol{\phi} \; (Z_i \gamma + X_i \beta) \quad (3)$$

This propensity score represents the likelihood of migration for each household given the instruments and control variables.

The Second Stage: Estimate Marginal Treatment Effects

The MTE is estimated by plotting the treatment effect at different quantiles of the unobserved component of migration decisions (e.g., different values of U_i . This is done by estimating treatment effects at various values of the propensity score $P(Z_i)$, which reflects the likelihood of migration for marginal households. The MTE at each quantile can be expressed as:

$$MTE(u) = \partial \, (u) \; where \; u = P(Z_i) \quad (4)$$

This allows for capturing how the impact of migration on assets varies for individuals with different levels of unobserved factors influencing migration. To obtain consistent estimates of the treatment effect, we implement a two-stage IV approach:

First stage: Regress the migration decision M_i on the instruments Z_i and controls X_i.

Second stage: Regress household assets Y_i on the predicted migration status from the first stage, along with the control variables. The MTE framework provides a nuanced understanding of the impact of migration on household assets, capturing heterogeneity in treatment effects. This approach can help policymakers design targeted interventions that consider which households benefit most from migration and how migration affects asset accumulation for marginal migrants.

3.2.2.3. Data

The study utilized cross-sectional survey data collected in May 2024 from populations in 13 villages across 3 communes in the Comoé province. To gather data on migrants, a comprehensive questionnaire was developed as the primary research tool. This questionnaire, designed to capture both qualitative and quantitative data, included a mix of closed-ended and open-ended questions. The closed-ended questions provided predetermined categories for responses, such as binary options ("yes" or "no," "male" or "female") or a list of alternatives from which respondents could choose. Open-ended questions allowed farm households to elaborate in their own words, particularly for complex issues that required more detailed explanation, such as information on consumption expenditures. The data used for this study was collected using an interview method, either face-to-face or via telephone. Through these interviews, factors influencing households' migration decisions were identified. Additionally, responses regarding household assets (wealth), commonly used to assess welfare, provided insights into household welfare conditions. The questionnaire consisted of four subsections, labeled A through D. Section A gathered basic respondent identification details, including location, interview date, and the names of the respondent and enumerator. Section B focused on the socioeconomic characteristics of the household, while Section C captured data on both migrants and non-migrants. Section D collected information on household assets.

3.2.2.3.1. Sample size determination

To determine the sample size, we used Cochran's formula (Cochran, 1967). The choice of this formula is explained by the fact that we know the size of the population of the province of Comoe, but we do not know the proportion of migrants in the population of the province of Comoe. In such a situation, according to Chaokromthong and Sintao, (2021), Cochran's formula is adapted. This formula is as follows:

$$n = \frac{Z^2 \times p(1-p)}{e^2} \quad (5),$$

where n is the sample size; Z is the Z-score corresponding to a standard deviation of 1.96 for a 95% confidence level; p is the estimated proportion of migrants. In our case, this proportion in unknown, so, it is assumed to be 0.5 and e is the margin of error (5% in our case). Based on the formulae sample size calculated for the study is 384, However, 109 sample size was added bringing the samples size to 493.

$$n = \frac{1.96^{\,2} \times 0.5(1-0.5)}{0.05^2} = 384 \quad (6)$$

3.2.2.3.2. Sample techniques

The sampling technique used is multi-stag sampling.

First stage: we purposively selected the province of Comoé, based on statistics from the 4th and 5th General Population and Housing Census (GCPH) in Burkina Faso. In the 4th GCPH, Comoé province was the third most important destination for internal migrants, accounting for 5.7% of internal migration flows, after Kadiogo (30.1%) and Houet (11.6%), where the country's first and second largest cities are located respectively (INSD, 2009). The region in which Comoé province is located recorded a positive migratory sole of 29,076. This proves that the area is indeed a destination for internal migrants (INSD, 2022c). It should be noted that the province is the smallest unit of analysis of migration by the INSD. It is therefore the last administrative subdivision for which data on migration in Burkina Faso are available.

Second stage: identification and selection of data collection municipalities in the province of Comoe. These choices were made based on information received on the presence of migrants in the communes, following the field trips that were carried out. The literature review also helped to guide the choice (Boyer & Néya, 2015;. Nana, 2018).

Third stage: Selection of villages within these municipalities. This selection was made using the same method used to select the communes. It should be noted that in addition to the presence of migrants in the municipalities and the villages, accessibility in terms of security was a key determinant in the selection of municipalities and villages. Data was collected using the snowball method. The **Error! Reference source not found.** below summarizes the sampling stages:

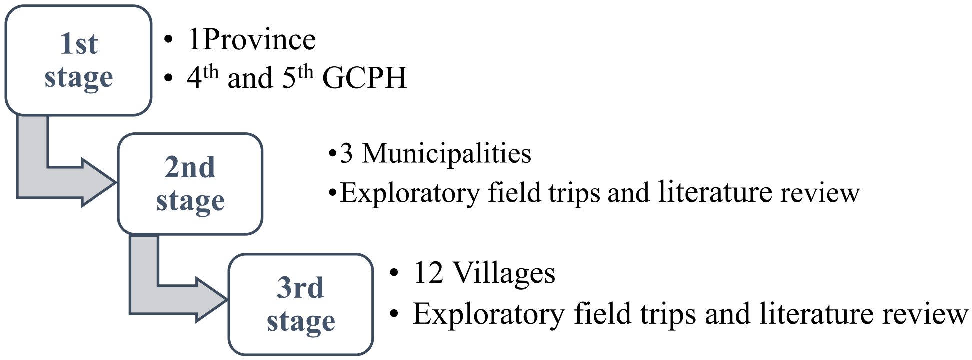


Figure 3.3: Sampling stages
Source: authors

3.2.3 Objective 3: assessing the relationship between climate variables and internal migration

3.2.3.1 Empirical strategy

The empirical framework for the analysis of drought conditions involves several key steps, including: (i) data preprocessing, (ii)the computation of drought indices (SPI and SPEI), (ii) the computation drought trend, intensity, duration, frequency and return level, (iv) the analysis of migration dynamics, and (v) the computation of Pearson correlation coefficient (r).

3.2.3.1.1 Data preprocessing

The initial step in the analysis involves preprocessing the dataset to ensure it is clean and structured for subsequent computations. The average daily temperature (T_{avg}) is computed as the mean of the daily maximum temperature (T_{max}) and minimum temperature (T_{min}):

$$T_{avg,t} = \frac{T_{max,t} + T_{min,t}}{2} \quad (1)$$

Missing values in T_{avg} are addressed using linear interpolation, while missing precipitation values (RR_t) are replaced with zeros. This ensures a complete and continuous dataset, which is critical for accurate index calculations.

3.2.3.1.2 Calculation of drought indices

Two indices are calculated to measure drought condition: the Standardized Precipitation Index (SPI) and the Standardized Precipitation-Evapotranspiration Index (SPEI). Both indices are computed over multiple time scales (s=1,3,6,12) to capture both short-term, medium-term and long-term drought conditions.

- **SPI calculation**

The SPI quantifies drought conditions based solely on precipitation data aggregated over a specific time scale (s). The SPI for a given time scale is calculated as:

$$SPI_s = F^{-1}\big(G(RR_{t:t+s})\big) \qquad (2)$$

Were: $RR_{t:t+s}$, is the total precipitation over the s-month time scale; *G* is the cumulative probability distribution of precipitation for the time series and F^{-1} is the inverse of the standard normal distribution.

- **SPEI calculation**

The SPEI incorporates the water deficit, which is the difference between precipitation and potential evapotranspiration (PET_t), to provide a more comprehensive drought measure. The water deficit over a given time scale is expressed as:

$$SPEI_s = F^{-1}\big(G(RR_{t:t+s} + PET_{t:t+s})\big) \qquad (3)$$

The potential evapotranspiration (PET_t), is calculated using the Thornthwaite method:

$$PET_{t:t+s} = \ 16\left(\frac{10T_{avg,s}}{I}\right)^{a} \qquad (4)$$

Here *I* is the annual heat index, a function of monthly average temperatures; a is an empirical parameter derived from

3.2.3.1.3 Trend analysis

To evaluate temporal trends in drought conditions, two methods are employed: linear regression and the Mann-Kendall test.

- **Linear regression**

Linear regression is used to quantify trends in SPI and SPEI over time. The regression equation is specified as:

$$Index_s(t) = \beta_0 + \beta_1 . t + \epsilon \qquad (5)$$

Where: $Index_s(t)$ is the SPI or SPEI at time *t*; *β0* is the intercept; *β1* is the slope of the trend line, which indicates the direction and magnitude of the trend; ϵ is the error term.

- **Mann-Kendall test**

The Mann-Kendall test is a non-parametric method used to detect monotonic trends in the indices. The hypotheses for the test are:

- H_0: No trend exists in the time series.
- H_1: A monotonic trend exists in the time series.

- **Sen's slope:**

The trend in drought indices is estimated using the Sen's slope method, which calculates the median of pairwise slopes between all data points:

$$Sen's\ slope: S = median\left(\frac{y_{j-}yi}{x_j - x_i}\right) \times 100 \qquad (6)$$

For j>i, and here, y_j and y_i are drought index values at times x_j and x_i.

3.2.3.1.4 Drought intensity analysis

Drought intensity measures the magnitude of drought conditions across severity categories. This helps to evaluate how severe droughts are over the study period. It is classified based on the values of SPI or SPEI. The thresholds for classification are as follows:

$$Severity = \begin{cases} Extreme\ drought, & Index < -2.0 \\ Severe\ frought, & -2.0 \leq Index < -1.5 \\ Moderate\ drought, & 1.5 \leq Index < -1.0 \\ Mild\ drought, & -1.0 \leq Index < -0. \\ No\ drought, & otherwise \end{cases} \qquad (7)$$

For each severity category, statistical summaries are computed:

$$Mean\ intensity\ (\mu): \mu = \sum_{i=1}^{n} Index_i \qquad (8)$$

Where n is the number of events in a given severity category.

The median intensity is the middle value of the index distribution for a severity category.

$$\text{Range} = \{Min, Max\} \qquad (9)$$

3.2.3.1.5 Drought duration analysis

Drought duration quantifies the persistence of drought events, measured as the number of consecutive months during which the drought index remains below zero.

Drought events were identified as followed:

$$\text{Drought event indicator} = \begin{cases} 1, & if\ Index < 0 \\ 0, & otherwise \end{cases} \qquad (10)$$

Consecutive months with a drought indicator of 1 are aggregated using run-length encoding (RLE):

$$Duration = \sum_{t=1}^{T} I(Index_i < 0) \qquad (11)$$

Where *I* is an indicator function that equals *1* if $Index_t$<0, and T is the total number of months.

The mean duration was calculated as follow:

$$Mean\ duration = \frac{1}{n}\sum_{i=1}^{n} \text{Duration} \qquad (12)$$

The median duration is the middle value of drought durations, and the maximum duration refers to the longest observed drought event.

3.2.3.1.6 Drought frequency analysis

Drought frequency refers to the number of drought events observed over the study period, categorized by severity. This measure provides insights into the occurrence patterns of droughts.

The frequency of drought events is calculated as:

$$Frequency = \left(\frac{\text{Number of events by severity}}{\text{Total observations}}\right) \qquad (13)$$

Where: Number of events by severity is the count of drought events within each severity category (e.g., mild, moderate, severe, extreme); Total observations refers to the total number of data points in the time series.

Relative frequency is expressed as a percentage of all events and calculated as:

$$Relative\ Frequency\ (\%) = \left(\frac{Count\ by\ severity\ total\ events}{Total\ events}\right) \times 100 \qquad (14)$$

3.2.3.1.7 Return Level Estimation

- **Combined drought index**

The combined drought index, which integrates the SPI and SPEI over different time scales (3, 6, and 12 months) to provide a holistic view of drought severity, is a preliminary step in estimating the return level. It was calculated using the following formula:

$$\text{Combined Index} = \frac{1}{2}[0.2 \cdot (\text{SPI3} + \text{SPEI3}) + 0.2 \cdot (\text{SPI6} + \text{SPEI6}) + 0.1 \cdot (\text{SPI12} + \text{SPEI12})] \quad (15)$$

To weight the combined drought index, higher weights have been assigned to shorter time scales and lower weights to longer time scales. Thus, the SPI3/SPEI3 and SPI6/SPEI6 indices, which reflect the variability of short-term and medium-term droughts respectively, are given a higher weight of 0.20 in order to emphasise the immediate effects of drought conditions. In contrast, SPI12 and SPEI12, which reflect long-term trends, are assigned a lower weighting of 0.10 to avoid over-representing persistent droughts. This approach ensures a balanced representation of short- and long-term drought impacts in the combined index.

- **Gumbel distribution**

The intensity of extreme drought events was estimated for specified return periods using extreme value theory (EVT). This involves fitting a Gumbel distribution to the drought index data and deriving the return periods. To do this, the Gumbel distribution is first used to model the behaviour of extreme drought indices.

The Gumbel distribution cumulative distribution function (CDF) is:

$$F(x) = \exp\left(-\exp\left(-\frac{x-\mu}{\beta}\right)\right) \quad (16)$$

Where: x is the combined drought index; μ is the location parameter, indicating the central tendency of the distribution; β is the scale parameter, reflecting the spread of the distribution.

The probability density function (PDF) is:

$$f(x) = \frac{1}{\beta}\exp\left(-\frac{x-\mu}{\beta}\right)\exp\left(-\exp\left(-\frac{x-\mu}{\beta}\right)\right) \quad (17)$$

- **Return period and return level**

The relationship between the return period (T) and return level (R_T) is derived from the CDF of the Gumbel distribution.

Return period:

The return period (T), is the expected time interval between events exceeding a certain threshold (R_T). It is linked to the return level (R_T) by the following equation:

$$T = \frac{1}{1 - F(R_T)} \qquad (18)$$

Return level:

The return level (R_T) for a given return period (T) is calculated as:

$$R_T = \mu - \beta ln\left(-\ln\left(1 - \frac{1}{T}\right)\right) \qquad (19)$$

Where R_T is the return level for a return period T (e.g., 2, 5, 10, 20, 50, 100 years).

Fitting the Gumbel distribution

The Gumbel distribution is fitted in 3 stages:

- data input: the combined drought index values (x) from the dataset are used as input data for the analysis. To focus specifically on extreme drought events, a threshold can be applied to filter the data (for example, by selecting values where $x<-1$);
- Parameter estimation: the parameters of the Gumbel distribution, namely the location parameter (μ) and the scale parameter (β), are estimated using the maximum likelihood estimation (MLE) method. This ensures the best fit of the distribution to the observed data;
- Calculation of the return level: once the parameters μ and β have been estimated, they are used to calculate the return levels (R_T) for different return periods (T). Return levels represent the intensity of drought events that are expected to occur, on average, once every T years.

3.2.3.1.8 Migration dynamics: empirical strategy

Migration flows were modeled as a time series to capture temporal trends. The migration model is defined as:

$$M_t^p = \{I_t^p, O_t^p\}, \quad for\ t = 1985.1996, 2006, 2019 \qquad (20)$$

Where M_t^p is the migration dynamics for province *p,* in year *t*; *p* is the province; t is the year of observation; I_t^p Inflows of migrants at time *t*, in province *p*; O_t^p is Outflows of migrants at time *t*, in province *p*.

To know whether the province is gaining or losing population due to migration, net migration (N_t^p) is used. It is defined as the difference between inflows (I_t^p) and outflows (O_t^p) of migrants:

$$N_t^p = I_t^p - \ O_t^p \qquad (21)$$

When $N_t^p > 0$, the province has a net gain in population due to migration and when $N_t^p < 0$, the province has a net loss in population due to migration. The time series of net migration is computed for each province: $N_t^p,$ $\quad$ for t = 1985,1996,2006,2019 $\quad$ (22)

3.2.3.1.9 Pearson correlation matrix computation:

The Pearson correlation matrix measures the strength and direction of the linear relationship between multiple variables: SPI (3, 6, and 12) SPEI (3, 6, and 12), inflows, outflows, and net migration. Its coefficient (r) quantifies the linear relationship between two variables X and Y. The formula is:

$$r_{XY} = \frac{Cov(XY)}{\sigma_X\ \sigma_Y} \qquad (23)$$

Where, r_{XY}, is the Pearson correlation coefficient between X and Y; Cov (X,Y) is the covariance between X and Y, and calculated as:

$$\mathrm{Cov(X,Y)} = \frac{1}{n}\sum_{i=1}^{n}(X_i - \bar{X})(Y_i - \bar{Y}) \qquad (24)$$

Where $\sigma_X\ \sigma_Y$ are standard deviations of *X* and *Y*, respectively; $\bar{X}\ and\ \bar{Y}$ are the mean values of *X* and *Y*; *n* is the number of data points.

To standardized the variables, each variable is mean-centered and scaled by its standard deviation:

$$Z_X = \frac{(X - \bar{X})}{\sigma_X}, \frac{(Y - \bar{Y})}{\sigma_Z} \qquad (25)$$

The correlation coefficients are computed using the following formula:

$$r_{XY} = \frac{Cov(XY)}{1} \qquad (26)$$

(Since Z_X and Z_Y are standardized, their standard deviations are 1.)

3.2.3.2 Data and tools

This study relies on two primary datasets: climatic data and migration data. The climatic dataset includes daily precipitation records and daily minimum and maximum temperatures, obtained from the National Meteorological Agency (ANAM). For Comoé Province, data were collected from the climatological station in Banfora (10° 38' 9.6" N, 4° 45' 39.6" W), while for Boulkiemdé Province, data were sourced from the synoptic station in Koudougou (12° 15' 5.04" N, 2° 24' 1.8" W). The dataset spans a 62-year period from January 1, 1960, to December 31, 2022.

To ensure data accuracy and completeness, a pre-processing phase was conducted to identify and address missing values. Spatial proximity imputation was applied using a climatic analogy approach, which transfers data from nearby stations within the same climatic zone to preserve consistency. Specifically, missing records from Banfora station (Comoé) were supplemented with data from Bérégadougou station, located less than 20 km away in the Sudanian climatic zone. Similarly, missing values from Koudougou station (Boulkiemdé) were replaced using data from Ouagadougou station, approximately 100 km away, situated within the Sudano-Sahelian climatic zone.

Migration data were obtained from the National Institute of Statistics and Demography (INSD), covering internal migration flows (inflows, outflws, and net migration) for Comoé and Boulkiemdé provinces. These data were collected during four General Population and Housing Censuses conducted in 1985, 1996, 2006, and 2019.

For the climatic analysis, precipitation and temperature data were processed using R statistical software (version 4.4.2; R Core Team, 2023). Specifically, we calculated the Standardized

Precipitation Index (SPI) and the Standardized Precipitation-Evapotranspiration Index (SPEI) using the climpact package, which is tailored for climate impact assessments.

RESULTS

Chapters 4 to 6 present the results and discussions for the three specific objectives described in chapter 1.

CHAPTER 4 DEVELOPMENT OF MIGRATION SCENARIOS FROM THE PERSPECTIVE OF LOCAL STAKEHOLDERS

This study has analysed the factors and impacts of migration in both departure and destination areas. This was done through a participatory approach with local workshops as the main methodological technique used. It presents the main actors involved in managing internal migration at local level, the drivers of migration and its impacts, and local scenarios for migration.

4.1 Results

4.1.1 Actors of migration

The main actors identified in the various study sites are more or less the same and include migrants; tutors; the host community, i.e. the population of the host locality; state technical services (departments in charge of humanitarian action, environmental, agricultural), NGOs and CSOs; traditional authorities (landlords, village chief, land chief, lineage chief).

An analysis of these stakeholders reveals four main groups of stakeholders involved and interacting in migration management.

The first group consists of the local population, made up of migrants, the migrants' hosts, village chiefs, landowners, customary leaders and the populations themselves. This is the first level in migration management. It is the day-to-day living environment, where the success or failure of the migrant's social and economic integration is determined. This is where problems arise, and this is also where the first steps are taken to manage them under the authority of the village chief.

The second group is made up of state actors, represented by the prefecture/haut commissariat, justice, security (police/gendarmerie) and technical services (agriculture, livestock, environment, humanitarian action, etc.). It is through these actors that the State guarantees migrants' rights and provides them with technical and humanitarian support.

The third group is made up of local collectivities. Within their territorial jurisdiction, they are responsible for spatial planning and management, and for planning and implementing local development initiatives in line with national policies. In some cases, therefore, they are responsible for settling migrants and providing them with a healthy and pleasant living environment. Where necessary, they provide humanitarian assistance to migrants.

The fourth group is made up of civil society organisations and NGOs. This group is mainly involved in technical and humanitarian assistance and conflict prevention and management. They also often provide technical and financial support to state actors and local authorities through projects, and help in implementing development policies and plans.

As well as interacting with migrants, as we have shown, all these groups interact with each other. Local populations and state actors are privileged partners. Migration management policies and actions initiated by state actors are for the benefit of the local population. To ensure the success of their interventions, state actors rely on some of the local population, in particular opinion leaders (traditional chiefs, religious leaders, etc.). Local people also call on state actors for various forms of support, which may be technical or financial. This partnership can be seen most clearly in the Village Land Tenure Conciliation Commissions (CCFV), which are bodies made up entirely of local stakeholders, but institutionalised by the State through Act no. 034-2009/AN of 16 June 2009 on rural land tenure and Decree no. 2012-263/PRES/PM/MATDS/MJ/MAH/MEDD/MEF of 03 April 2012. Populations also interact strongly with local collectivities, as they are the ones who are administered by local collectivities. Municipal councils are set up by these local actors, who delegate the management of the community to them. So, the decisions, measures and any other action taken by the local collectivities in terms of migration management are, in a way, measures decided and or ratified by the local actors.

Local populations and civil society organisations (CSOs) and NGOs interact on a daily basis. The former share their concerns and difficulties relating to migration, while the latter (particularly CSOs), in their role as watchdogs, bring these concerns to the attention of those entitled to do so. They also provide solutions to the problems of local stakeholders through development or humanitarian projects.

Local collectivities and state actors interact in the area of the transfer of funds and skills as part of the implementation of decentralisation. The State transfers the skills and funds required by the local collectivities to deal with the migration issue properly. They also receive technical support from the State's technical services. Local collectives also create the conditions for the success of interventions by state actors, by mobilising and raising awareness among the population.

CSOs and NGOs provide technical and financial support to local collectivities, which in turn create the conditions for the successful implementation of CSO and NGO activities in the communes. Discussions with stakeholders resulted in the stakeholder map shown in **Error! Reference source not found.**.

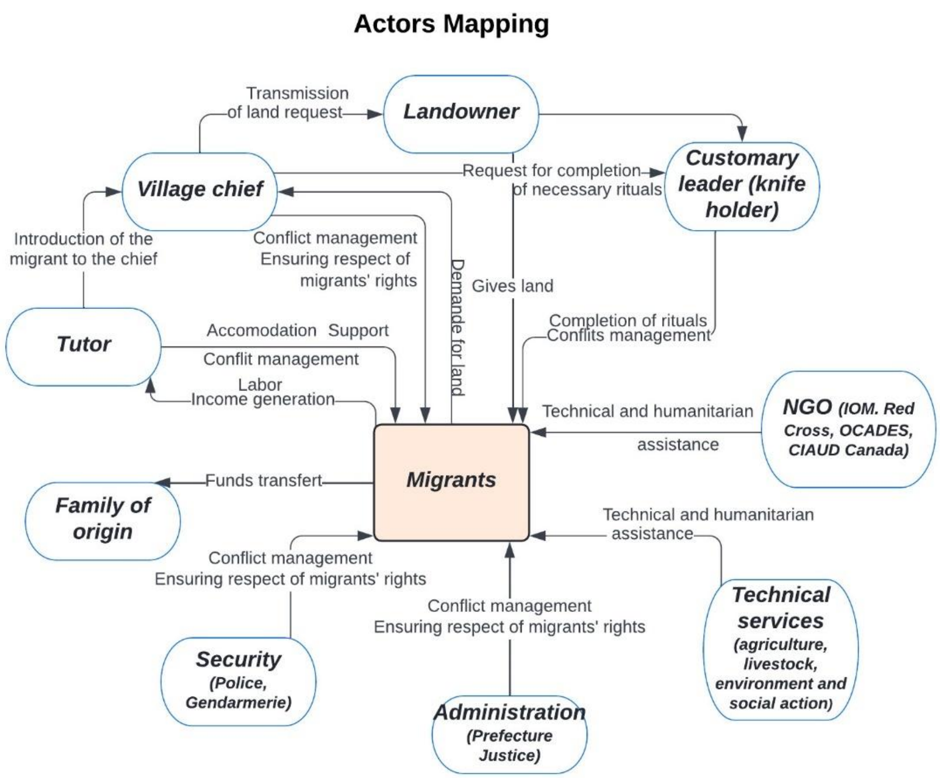


Figure 4.1: Actors Mapping

Source : Author

4.1.2 Migrants' origins and destinations

Discussions with stakeholders helped to identify the main origins and destinations of migrants. The discussions also made it possible to identify the main activities carried out by migrants in the destination areas. The main regions of origin of migrants in the provinces of Comoé and Ziro were classified from 1 to 3, with 1 corresponding to a small flow, 2 to a medium flow and 3 to a large flow. The same logic was applied to the departure provinces of Boulkiemde and Oubritenga in order to identify the main destination provinces. **Figure 4.2** below summarises the regions of origin for migrants in the provinces of Comoe and Ziro (destination areas) and Figure 4.3 summarises destinations for migrants' frome Boulkiemde dans Oubritenga provinces (departure areas):

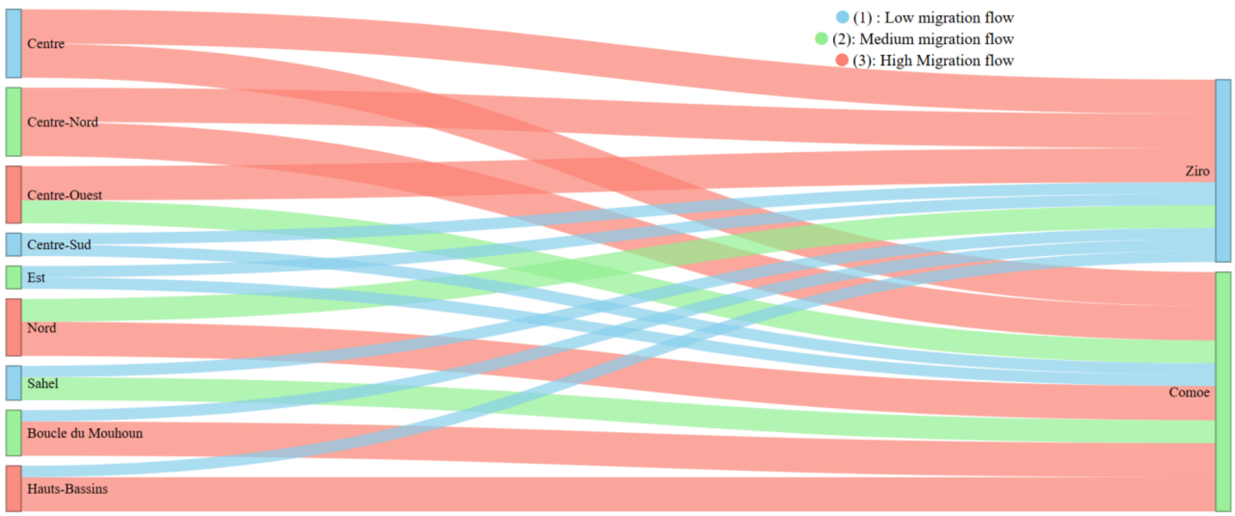


Figure 4.2: Mains origin of migrants in Comoé and Ziro provinces

Source: Author's construct

The main regions of origin of migrants in the province of Comoé are the Centre, Haut-Bassin, North, Centre-North and North regions, each with a weight of 3, which corresponds to a large flow of migrants. In Ziro, migrants come mainly from the Centre, Centre-North and Centre-West regions. There are similarities and differences between these two provinces. Both provinces have large numbers of migrants from the Centre and Centre-North regions. They also both have small numbers of migrants from the East and Centre-Bassins regions, which have many natives in the province of Comoé but very few in the province of Ziro.

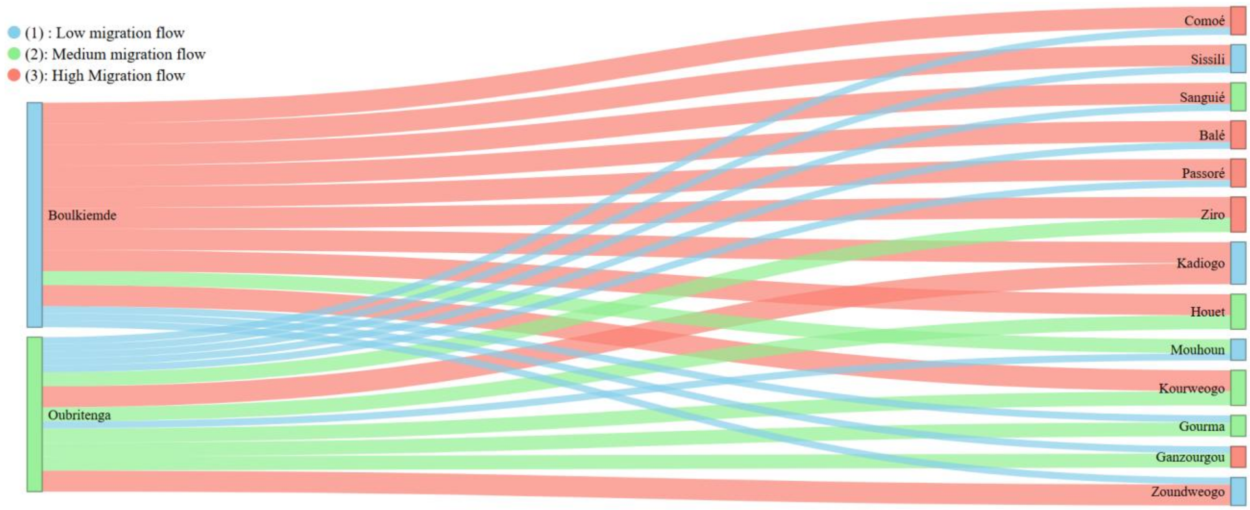


Figure 4.3: Mains destination of migrants from Boulkiemdé and Oubritenga provinces
Source: Author's construct

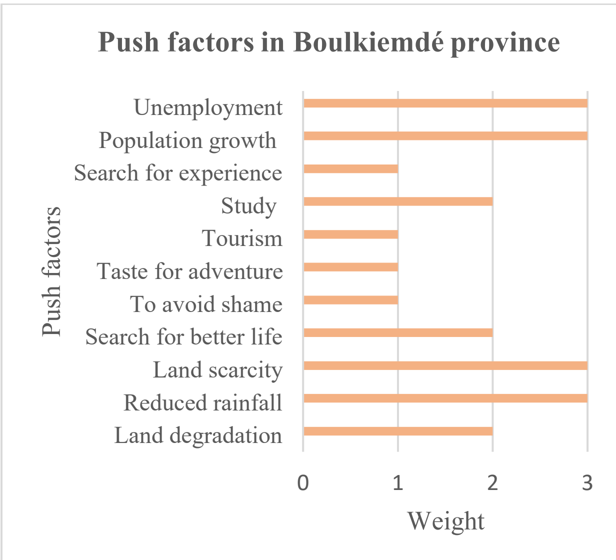
In terms of destination, emigrants from the province of Boulkiemdé mainly go to the provinces of Ziro, Kadiogo, Houet, Sissili, Sanguié, Kadiogo and Passoré, each with a weight of 3. In Oubritenga, migrants mainly go to the provinces of Kadiogo, Zoundwéogo, Ziro and Houet, each with a weight of 3. There are also similarities between these two provinces. Each of these provinces sends a large number of migrants to Kadiogo, Ziro and Houet. But there are also differences: Zoundwéogo attracts many migrants from Oubritenga, whereas very few migrants from Oubritenga go there. The same is true of Sissili and Sanguié, as well as Passoré, which receive large numbers of migrants from Boulkiemdé, while few emigrants from Oubritenga go there.

4.1.3 Identification of migration factors

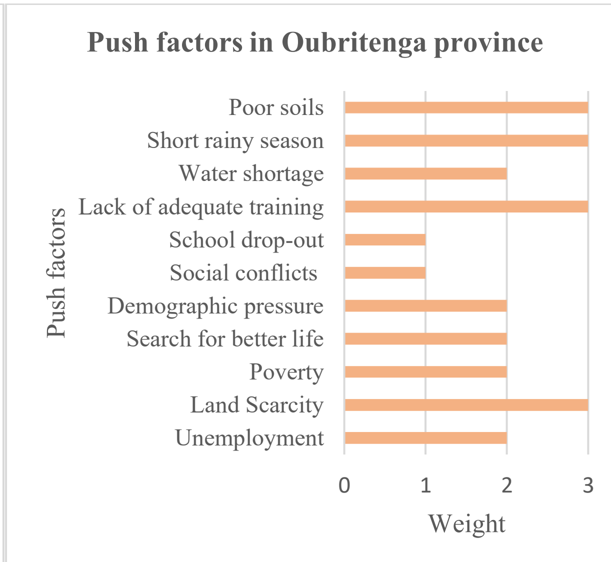
4.1.3.1 Push factors in the migrant's departure areas

In the migrant departure areas, the push factors cited by the participants are economic, socio-demographic, environmental and political. The economic factors are poverty, poor employment opportunities, insufficient arable land, the search for better living conditions and the attraction of gold panning. Socio-demographic factors include high population growth (demographic pressure), social conflicts (banishment, family conflicts), children are dropping out of school, the desire to avoid shame, a taste for adventure, tourism, study trips and the search for experience. The environmental factors mentioned are drought, poor soil, insufficient arable land, shorter rainy season, insufficient arable land, insufficient water resources due to poor maintenance of water infrastructures and drought. On the political front, there is insufficient and inappropriate professional training, and children are dropping out of school.

In the destination areas, the factors cited by the migrants as the reasons for their departure from their areas of origin are comparable to those cited by the participants in the departure areas.



3.5a: Push factors in Boulkiemdé province



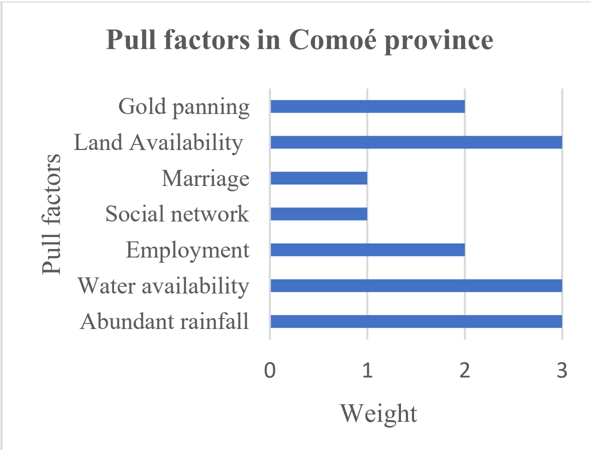
3.5b: Push factors in Oubritenga province

Figure 4.4:Push factors in the Boulkiemdé and Oubritenga provinces
Source: Author

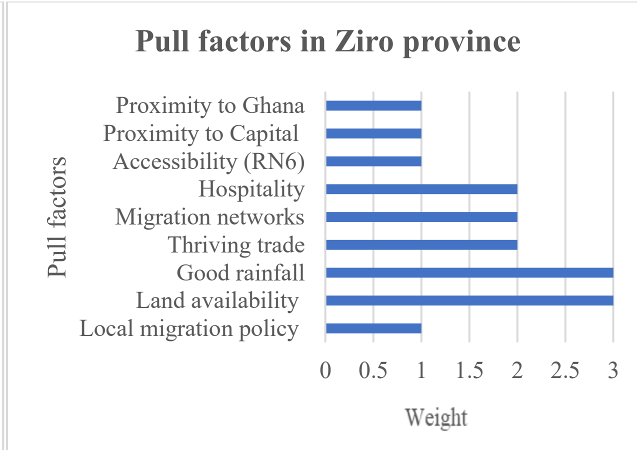
4.1.3.2 Pull factors in destination areas

In the migrant destination areas, the discussions revealed that the factors encouraging the arrival of migrants are also social, economic and environmental.

On the economic front, participants identified the existence of job opportunities, the availability of arable land, flourishing trade and the existence of gold panning sites. Social reasons included the existence of social networks to spread information and create favourable conditions for the arrival of candidates for migration, marriage, the existence of a local migration policy (noted by the chief of Sapouy as being very important) and the hospitality of the population in the destination areas. In environmental terms, good rainfall, the availability of water resources and the availability of arable land were identified. In addition to these factors, there are geographical factors such as the accessibility of the destination sites, with National Road 6 linking Ouagadougou-Sapouy-Léo to the Ghana border, and National Roads 1 and 7 linking Ouagadougou-Bobo-Dioulasso and Bobo-Banfora to the Ivory Coast border.



3.6a: Push factors in Boulkiemdé province



3.6b: Push factors in Boulkiemdé province

Figure 4.5: Pull factors in the Comoé and Ziro provinces
Sourc: Author

4.1.3.3 Push factors in the next 20 years

In order to identify these factors, participants were asked to project into the next 20 years whether the provinces of origin would remain departure zones or whether they would become destination zones. Participants felt that Oubritenga and Boulkiemdé would remain departure areas over the next 20 years.

The main factors identified as being the cause of departures from the province of Oubritenga are drought, insufficient incentives or political action, and insufficient water resources. In Boulkiemdé province, it is the shortage of land due to land predation, the return of migrants and demographic growth, the inadequacy of training/education, drought and the lack of employment that are likely to cause migrants to leave.

Of these factors, drought and the insufficiency of incentives or political action were presented as the 2 most important factors of future repulsion in Oubritenga. In Boulkiemdé, insufficient land and unsuitable training were identified as the two most important factors of repulsion in the future.

4.1.3.4 Pull factors in the next 20 years

Looking ahead to the next 20 years, the participants in the workshops in the migrant destination areas felt that these areas will remain destination sites. In the province of Comoé, the participants identified the development of integrated farms, the development of processing units, good rainfall, gold panning and the development of the province's agricultural potential as the main pull factors in the province. In Ziro province, the main pull factors identified are the availability of land, relatively good rainfall, hospitality and flourishing trade.

The two most important pull factors in the future, in the opinion of stakeholders in Comoé, are rainfall and gold panning. In Ziro, on the other hand, relatively good rainfall and the availability of land are seen as the two most important factors.

4.1.4 Impacts of migration

Discussions with workshop participants revealed that migration has both positive and negative impacts.

4.1.4.1 Positive impacts of migration

In the areas of departure, the workshop participants felt that migration had many advantages for the people who stayed behind. They mentioned the support they receive from emigrants, such as remittances. The important contribution of migration to the development of livestock farming and job creation was noted. This is done through investments made by migrants for their own accounts and those made for their families. Migration is also recognised as helping to strengthen family ties through the various forms of support that migrants provide to family members. In addition, it helps to improve the quality of housing through the construction of more modern and comfortable houses thanks to the money acquired by migrants. Food for families, schooling for children and health care are also provided through the support received from emigrants. The funds transferred by migrants are also used to pay off debts. The role of migration in the acquisition and transfer of skills was also highlighted. In short, it helps to improve living conditions and the well-being of families in the areas of departure.

In destination areas, migration is recognised as a driver of economic development. According to the participants in the workshops in these areas, it has helped to increase agricultural production, improve people's nutritional status and boost trade. In fact, the majority of migrants in these areas are Mossi, who are known to be very hard workers.

4.1.4.2 Negative impacts of migration

Although it has many advantages, as listed in the previous section, migration also has negative effects.

In the areas of departure, they include the loss of able-bodied workers, as most migrants are young, the weakening or breakdown of family ties, poor education of children due to the absence of one of the parents, acculturation of migrants, breakdown in the transmission of cultural heritage, numerous social problems such as children of disputed paternity, break-up of households, marital conflicts and children dropping out of school.

As for migrants, their health is negatively affected by migration. Many emigrants return home ill and completely destitute. The difficulty of integrating migrants in their destination area, and the failure of migration. In this context, some of them become delinquents/Bandits. The exploitation of migrants was noted as a major problem linked to migration. They are underpaid for their work, and are victims of property-grabbing both at destination and during their journeys.

In the destination areas, the negative impacts listed relate to social cohesion, in particular the non-respect of customs, demographic pressure, the adoption of bad cultural practices such as excision, and the absorption of local languages by the languages of the majority migrants. In Ziro, this is the case for Morée, the language spoken by Mossi migrants, which seems to be more widely spoken in the area than Nouni, the local language. Other factors include demographic pressure, pressure on natural resources, land conflicts with the expropriation of migrants after several years' occupation of the land (in the case of those who have not been allocated land), and the withdrawal of valorised land. The erosion of social cohesion, leading to conflict, is also a major problem. Water and land pollution caused by gold panning by migrants is a serious environmental and public health problem.

In the opinion of workshop participants in the areas of departure, migrants who practise agriculture, animal husbandry or trade in their destination area are much more successful than those who practice gold panning.

4.1.5 Local scenarios developed from the stakeholders' point of view

The scenarios were constructed on the basis of the two push and pull factors considered to be the most important over the next 20 years. Table 4.1 shows the two push factors in each departure zone and the two pull factors in each destination zone, for the next 20 years.

Table 4.1: The two main push and pull factors over the next 20 years in each province

Provinces	Type of factors	1st factor	2nd factor
Oubritenga	Push factor	Drought	Incentive or political actions
Boulkiemdé	Push factor	Lands availability	Inadequate training
Comoé	Pull factor	Good rainfall	Gold pannig
Ziro	Pull factor	Good rainfall	Land availlability

Source: study data

In each province, the two most important push or pull factors over the next 20 years were used to develop 4 scenarios. Figure 4.6 show the scenarios developed for each site.

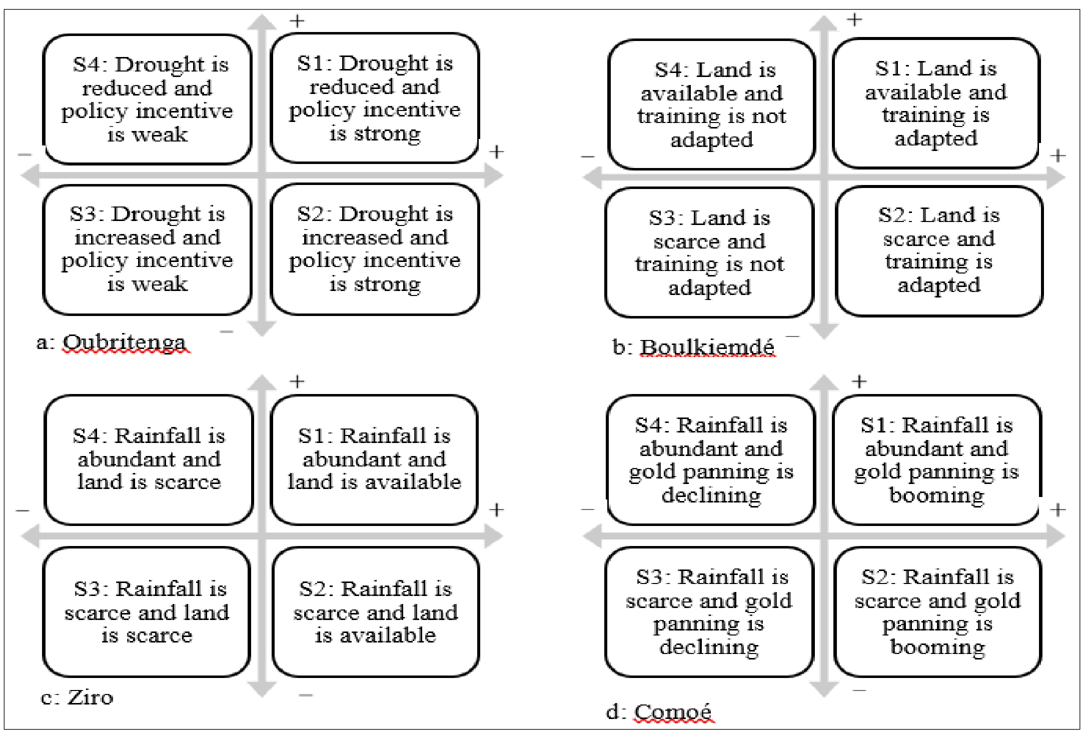


Figure 4.6: Local Scenarios for migration in the study sites

In Figure 4.6, the image ***a*** shows the following 4 scenarios developed for the Oubritenga province. S1: Drought is reduced and political incentive is strong; S2: Drought is worsened and there is a strong political incentive; S3: Drought is worsened and there is a weak political incentive and S4:

Drought is reduced and there is a weak political incentive. The following 4 scenarios developed for the Boulkiemdé province are showed by the image ***b*** S1: Land is available and the training is adapted; S2: The land is scarce and the training is adapted; S3: Land is scarce and the training is not adapted and S4: Land is available and the training is not adapted. The image ***c*** shows the following 4 scenarios developed for the Ziro province: S1: Rainfall is abundant and land is available; S2: Rainfall is scarce and land is available; S3: Rainfall is scarce and land is scarce; S4: Rainfall is abundant and land is scarce. For the Comoé province, the image ***d*** shows the following 4 scenarios developed: S1: rainfall is abundant and gold panning is booming; S2: rainfall is scarce and gold panning is booming; S3: rainfall is scarce and gold panning is declining; S4: rainfall is abundant and gold panning is declining.

4.2 Discussion

The study revealed that migration factors are mainly economic, social, demographic, environmental and even geographical. These factors most often interact to result in the departure or arrival of migrants in a given locality. For this reason, De Longueville et al., (2019) and Piguet, (2013) describe migration as a complex phenomenon, resulting from the combination of several economic, social, political and environmental factors.

In departure areas, numerous push factors have been identified. The results showed that the main economic factors driving people in these areas to emigrate are poverty, poor job opportunities, land scarcity and the search for better living conditions. In south-west Burkina Faso, low incomes and the lack of farmland have been presented as factors leading to farmer migration (Sanfo et al., 2017). In Ghana, in the transition zone between Forest and Savannah, poverty and unemployment have been identified as the main economic factors driving migration among populations that are mainly farmers (Abu et al., 2014). Looking at the push factors for rural families in Afghanistan, Ahad Hakim & Boz, (2020) found that lack of employment was the most important factor leading rural populations to migrate. In addition to lack of employment, low income and poor quality (condition) of life are the major factors driving rural populations in Uttarakhand, India, to migrate to the urban center of Dehradun (E. M. Hoffmann et al., 2019).

With regard to social and demographic factors, the study showed that demographic pressure, marriage, social conflicts (banishment, family conflicts, etc.), the desire to avoid shame, a taste for adventure, tourism and the search for experience are at the origin of people's departure. Czaika & Reinprecht, (2022), have also identified marriage and social conflicts as among the main factors driving emigration in Burkina Faso.

On the environmental front, the study revealed that drought, soil poverty, land and water scarcity are the main environmental factors driving people to leave their areas of origin. Henry et al., (2003) noted in their analysis of interprovincial migration in Burkina Faso, that rainfall variability, soil degradation and land availability are major factors driving populations from provinces located in the Central Plateau to emigrate. Sanfo et al., (2017) also found that intervillage migration in the south-east of the country is influenced by land degradation and insufficient rainfall. In Niger, drought and lack of water resources have also been presented as among the most important push factors (Afifi, 2011).

The study reveals that the factors driving migration are mainly economic, social, demographic and environmental. The same finding was made by (Czaika & Reinprecht, 2022 ; De Longueville et al., 2019 ; Piguet, 2013). For them, migration is a complex phenomenon, resulting from a combination of multiple factors. In the departure areas, the main factors identified include poverty, poor employment opportunities and the temptation of gold panning. There is also demographic pressure, marriage and social conflict. In addition, drought, poor soil, insufficient land and water resources are among the most important factors of repulsion. As for the results in the areas of arrival, they show factors of attraction which are curiously like a positive expression of the factors of push in the areas of departure. These include, for example, the existence of employment opportunities and gold panning sites, good rainfall and the availability of arable land. This naturally brings us back to the push-pull model of (Lee, 1966). Lee explains that people migrate because of the gap between available economic opportunities at their destination and the lack of opportunities at their place of residence. Another very interesting result is the identification of social networks as a factor in destination areas. As Czaika & Reinprecht, (2022) and Ritchey, (1976) assert, these networks, made up of relatives, friends and acquaintances, enable information to be disseminated and create favourable conditions for the arrival of potential migrants. The migration factors identified in this study are very similar to those identified by (Czaika & Reinprecht, 2022). Indeed, unemployment, marriage, demographic pressure and social conflict were identified in their study as being among the main factors driving emigration in Burkina Faso.

Earlier, Boutillier et al., (1977) et Cordell et al., (1996) identified similar socio-economic and demographic factors. With regard to environmental factors, the results of this study are perfectly consistent with those obtained by many other authors on Burkina Faso. These include (Nébié & West, 2019) , (De Longueville et al., 2019) , (Sanfo et al., 2017), and (Henry, Schoumaker, et al., 2004). All of these authors note that land degradation, land availability, drought or rainfall variability are the main factors prompting people to leave localities or move to other localities. Henry et al., (2003), for example, note that the regions with the worst soil degradation are the departure points for migrants heading for regions with little soil degradation in Burkina Faso. Abu et al., (2014) in Ghana and Afifi, (2011) in Niger present the lack of employment, poverty, demographic pressure, insufficient rainfall and low soil fertility as the main factors driving people to migrate. Their results are also in perfect coherence with those obtained in this study.

Of the scenarios developed, Scenario 1 for each site represents the most favourable situation likely to occur. Under these scenarios, the areas of departure would experience low population outflows. In the destination areas, on the other hand, there would be large inflows of migrants. Scenarios 3 present the most unfavourable situations. They would result in high emigration flows in the departure zones and low migrant arrivals in the destination zones. Destination areas would continue to record migrant arrivals even under harsh environmental conditions. This is due to the comparative advantage they have over the departure areas in environmental terms.

The results obtained thanks to the participatory approach adopted are significant. We can therefore say, as (Torres & Carte, 2014), that participatory approaches, especially workshops, can be used to analyse and better understand migration.

4.3 Conclusion and recommandation

This study confirms that migration is a multifaceted phenomenon driven by a combination of economic, social, demographic and environmental factors. The push-pull dynamic highlighted by Lee's (1966) model remains a robust framework for understanding migration patterns. In areas of origin, factors such as poverty, lack of employment opportunities, land scarcity and environmental stressors such as drought and land degradation play an important role in driving migration. Conversely, destination areas attract migrants through better employment prospects, arable land, favourable climatic conditions and the presence of social networks that facilitate integration and information exchange. The study emphasises that migration is not a response to isolated factors, but rather an interplay of different economic, environmental and socio-economic conditions. In addition, the participatory approach used in this research has proved effective in capturing nuanced local realities, thereby enhancing our understanding of migration dynamics. Scenarios developed during the study illustrate the potential variations in migration flows under different conditions. While favourable scenarios predict reduced outflows from areas of origin and increased inflows to areas of destination, unfavourable scenarios highlight the resilience of migrants who continue to move despite environmental challenges, driven by the relative advantages of destination areas.

In conclusion, the study highlights the importance of addressing root causes such as poverty, unemployment and environmental degradation in areas of origin, while harnessing the potential of social networks and economic opportunities in destination areas.

In light of the above, we recommend that policymakers in Boulkiemdé Province urgently develop and implement local policies to address land grabbing. Such policies must prioritise the protection of agricultural land for local people, ensuring their access to and control over arable land, which is essential for their livelihoods. The government and NGOs should strengthen vocational training initiatives in provinces with high rates of emigration. These programmes should focus on equipping individuals with skills tailored to local economic opportunities, thereby reducing the incentive to migrate by improving employment prospects within the region. They should promote sustainable land management practices to combat land degradation and improve land productivity in rural areas. This could include community-based programmes focusing on soil conservation, afforestation and efficient water management techniques. Researchers should invest in more detailed studies of internal migration patterns within Burkina Faso. These studies should aim to identify specific spatial features, such as migration flows, emigration hotspots and settlement patterns, to enable the development of tailored and effective local migration policies.

CHAPTER 5 : ASSESSING THE IMPACT OF INTERNAL MIGRATION ON THE HOUSEHOLD WELFARE OF CLIMATE-INDUCED MIGRANT HOUSEHOLDS IN BURKINA FASO

This chapter examines how internal migration brought on by climate change affects household wellbeing in Burkina Faso, concentrating on the causes and effects of this migration. The study uses marginal treatment effects methodology to account for selection biases and identify the heterogeneity in the consequences of migration, based on cross-sectional data gathered from 475 families in the province of Comoé. It first presents the results of descriptive statistics, including the Pearson chi-square test and the t-test. It then presents the empirical results, including the drivers of climate-induced internal migration and the determinants of outcome variables. Finally, the results are discussed.

5.1 Results and discussion

5.1.1 Descriptive results

5.1.1.1 Association between internal migration and climate induced variables

Table 5.1 provides data on the association between internal migration and various climate-related variables, using Pearson Chi-square tests to assess the significance of these relationships as well as the key implications of the findings presented: Inadequate Rainfall: shows a significant association between internal migration and inadequate rainfall ($p < 0.01$). Migrants are more likely to come from areas with inadequate rainfall (94.18%) compared to non-migrants (5.82%). This suggests that rainfall shortages may be a critical driver of migration, potentially due to its impact on agricultural productivity and livelihoods. Poor Soils indicates a significant relationship between poor soils and migration ($p < 0.01$). A higher percentage of migrants (93.56%) come from areas with poor soil conditions. This implies that soil fertility problems contribute to internal migration as people move in search of more arable land or better economic opportunities. Also, Persistent Drought is another climate factor closely linked to migration. The report highlights that 97.39% of migrants come from areas experiencing persistent drought ($p < 0.01$). Drought impacts agriculture, which could force people to migrate in search of better livelihoods.

The relationship between land degradation and migration is also significant ($p < 0.01$). Implying that, areas suffering from land degradation see a higher proportion of migrants (96.12%), further emphasizing the environmental challenges driving migration. Meanwhile, Extreme weather conditions show a notable association with migration ($p < 0.05$). About 87.80% of migrants come from areas affected by extreme weather, compared to 70.58% of non-migrants. Inadequate Farmlands and Water Scarcity also shows a significant relationship of ($p < 0.01$) and ($p < 0.05$) with migration respectively. This also confirms that majority of migrants come from areas with these challenges, reinforcing the role of resource scarcity in driving migration. While wildfires, floods, and erosion show high percentages of migrants from affected areas, the associations are not statistically significant. This indicates that, while these factors may be present in migration-prone regions, they are not as strong drivers as other variables like drought or poor soil. Poor Crop Yields as well Insufficient Resources: Poor crop yields, insufficient natural pasture, water for animals, and precipitation show highly significant relationships with migration ($p < 0.01$). Migrants overwhelmingly come from areas where these agricultural resources are lacking, pointing to the pressures that reduced agricultural productivity places on households, leading them to migrate. The table indicates that soil infertility is strongly associated with migration ($p < 0.01$), with 95.65% of migrants coming from areas where this problem is prevalent. Overall, the Environmental Stressors findings suggest that, particularly those affecting agricultural productivity, are key drivers of internal migration. Inadequate rainfall, soil degradation, and persistent drought are especially influential. The data implies the need for targeted policies that address climate-related vulnerabilities, particularly in regions experiencing severe droughts, poor soils, and resource scarcities. Hence, the strong association between migration and environmental degradation highlights the urgency for promoting sustainable agricultural practices, such as soil conservation and water management, to reduce the need for migration.

Table 5.1: Association between internal migration and climate variables

Climate variables	Status of migration			Pearson Chi-square
	Non-Migrants N=138 (27.99%)	Migrants N=355 (72.01%)	Total	
Inadequate rainfall				
No	127	177	304	74.7520***
	41.78	58.22	100.00	
Yes	11	178	189	
Total	5.82	94.18	100.00	
Poor soils				
No	125	166	291	78.8929***
	42.96	57.04	100.00	
Yes	13	189	202	
Total	6.44	93.56	100.00	

Persistent drought				
No	135	243	378	47.9437***
	35.71	64.29	100.00	
Yes	3	112	115	
Total	2.61	97.39	100.00	
Land degradation				
No	134	256	390	37.5442***
	34.36	65.64	100.00	
Yes	4	99	103	
Total	3.88	96.12	100.00	
Extreme weather conditions				
No	133	319	452	5.5362**
	29.42	70.58	100.00	
Yes	5	36	41	
Total	12.20	87.80	100.00	
Inadequate farmlands				16.8143***
No	136	305	441	
	30.84	69.16	100.00	
Yes	2	50	52	
Total	3.85	96.15	100.00	
Scarcity of water				
No	136	331	467	5.6113**
	29.12	70.88	100.00	
Yes	2	24	26	
Total	7.69	92.31	100.00	
Wildfires				
No	138	351	489	1.5676
	28.22	71.78	100.00	
Yes	0	4	4	
Total	0.00	100.00	100.00	
Floods				
No	138	351	489	1.5676
	28.22	71.78	100.00	
Yes	0	4	4	
Total	0.00	100.00	100.00	
Erosion				
No	138	350	488	1.9636
	28.28	71.72	100.00	
Yes	0	5	5	
Total	0.00	100.00	100.00	
Poor crop yields				
No	127	150	277	100.0119***
	45.85	54.15	100.00	
Yes	11	205	216	
Total	5.09	94.91	100.00	
Insufficient natural pasture				
No	133	312	445	14.0043***
	29.89	70.11	100.00	
Yes	5	43	48	
Total	10.42	89.58	100.00	
Insufficient water for animals				
No	133	312	445	8.1492***
	29.89	70.11	100.00	

Yes	5	43	48	
Total	10.42	89.58	100.00	
Insufficient precipitation				
No	131	290	421	13.9619***
	31.12	68.88	100.00	
Yes	7	65	72	
Total	9.72	90.28	100.00	
Soil infertility				
No	135	289	424	22.2516***
	31.84	68.16	100.00	
Yes	3	66	69	
Total	4.35	95.65	100.00	

*** denotes significance at 1% level, ** denotes significance at 5% level, * denotes significance at 10% level
Source: Authors' computations

5.1.1.2 Descriptive statistics of variables used in the regression models

Table 5.2 describes the socioeconomic and climate variables associated with migration, comparing characteristics between migrants and non-migrants. Based on the table, Total Value of Assets: Migrants tend to have higher asset values (mean = 1256.65) compared to non-migrants (mean = 719.58). However, the mean difference (-537.07) is statistically significant, implying that non-migrants hold significantly fewer assets than migrants. This suggests that migration could be a strategy employed by wealthier individuals or families to protect or increase their assets. Migrants are significantly older (mean = 50.27 years) than non-migrants (mean = 43.08 years), with a mean difference of -7.19. This indicates that migration might be more common among older individuals, possibly because they have had more time to accumulate resources, build family networks, or develop a greater need for relocation to improve livelihoods. Also, the average level of education is much higher among non-migrants (mean = 4.91) compared to migrants (mean = 2.04), with a significant mean difference of 2.87. This suggests that less-educated individuals are more likely to migrate, potentially seeking opportunities that they cannot access locally due to their lower education levels. For Family Structure, Migrants tend to have more dependents (mean = 9.74) than non-migrants (mean = 7.14), with a significant difference of -2.60. This suggests that larger family sizes might drive migration, possibly as a survival strategy to secure more resources or improve living conditions for dependents.

Similarly, migrants have more under-aged members in their families and more adults, which could indicate higher responsibilities and a need for better income-generating opportunities through migration. Non-migrants are more likely to be employed (mean = 0.82) compared to migrants (mean = 0.68). The mean difference of 0.14 suggests that migration could be motivated by a lack of stable employment in origin areas, with individuals moving to seek better job prospects. Moreso, Migrants are much more likely to have migration experience (mean = 0.71) compared to non-migrants (mean = 0.13), with a large mean difference of -0.58. This points to a cycle where those with prior migration experience are more likely to migrate again. The significant difference in skills acquisition (-0.07) indicates that migrants may move to enhance their skills, which could provide better economic opportunities elsewhere. Migrants have significantly larger farm sizes (mean = 2.65 hectares) than non-migrants (mean = 0.46 hectares). This suggests that migration might be a strategy employed by those with more extensive agricultural investments to either expand their operations or find better land conditions. Livestock ownership is slightly higher among migrants (mean = 0.48) compared to non-migrants (mean = 0.38), further emphasizing that migrants tend to have more agricultural assets.

Exclusion Restriction Variable: The distance from destination to origin is much greater for migrants (mean = 291.53) compared to non-migrants (mean = 92.22). This large mean difference (-199.30) implies that migrants travel much farther, suggesting that migration is a significant decision likely driven by large-scale economic or environmental challenges. Climate Variables and Migration such as Insufficient Water for Animals suggest that Migrants are more likely to face challenges related to water scarcity for animals (mean = 0.12) than non-migrants (mean = 0.04). This implies that climate-induced water shortages may be pushing people to migrate. The significant difference in the scarcity of water between migrants (mean = 0.07) and non-migrants (mean = 0.01) shows that water shortages in general are a key factor driving migration. Also, Migrants are more likely to come from areas experiencing persistent drought (mean = 0.32) than non-migrants (mean = 0.02), highlighting the role of drought in driving migration, likely because of its severe impact on agricultural productivity and livelihoods. Migrants are also more likely to be from regions with inadequate farmlands (mean = 0.14) and infertile soils (mean = 0.19), both of which significantly differ from non-migrants (means = 0.01 and 0.02, respectively), suggesting that deteriorating land quality is a crucial factor in the decision to migrate. Finally, Migrants appear to have more agricultural assets but face significant environmental challenges. Migration may be seen as an economic strategy to mitigate risks associated with climate variability, seek better employment opportunities, and expand agricultural operations while climate factors, water scarcity, drought, and soil infertility are major drivers of migration, underscoring the critical role of climate change in shaping migration patterns. Adaptation measures, such as improving water access, enhancing soil fertility, and increasing farm productivity, could reduce migration pressures.

Table 5.2: Descriptive characteristics of variables used in the regression models

Variables	Definitions of variables	Migrants N=355 (72.01%)		Non-Migrants N=138(27.99%)		Mean Difference
		Mean	SD	Mean	SD	
Outcome variables						
Total value of assets	Value of Household accumulated assets including livestock, farm land, vehicles… in dollars	1256.65	2791.20	719.5789	1169.40	-537.07**
Remittances	Value of remittances in dollars	205.44	400	69.17	201.13	-136.27***
Socioeconomic variables						
Age	Number of years of respondents	50.27	13.68	43.08	12.92	-7.19***
Age squared	(Age x Age)/100	27.13	14.22	20.22	11.60149	-6.92***
Gender	1 if respondent is a Male, 0 otherwise.	0.90	0.02	0.94	0.02	0.04
Education	Number of years of formal education	2.04	3.88	4.91	5.28	2.87***
Number of under-age	Number of members in the household who are less than 18years	4.131	3.67	3.07	3.03	-1.05***
Number of Adult	Number of members of household aged 18 or over	5.67	4.39	4.36	3.19	-1.32***
Number of dependents	Count of individuals who rely on the head of household	9.74	7.04	7.14	5.67	-2.60***
Employment status	1 if respondent is employed, 0 otherwise.	0.682	0.47	0.82	0.39	0.14***
Number of years Migration	Number of years spent in the current destination	56.17	539.77	2.86	7.10	-53.31
Migration experience	1 if it's respondent first time of migrating, 0 otherwise.	0.71	0.46	0.13	0.34	-0.58***
Sociocultural links	1 if respondents have Sociocultural links, 0 otherwise	0.076	0.27	0.029	0.17	-0.05*

Lack of commercial opportunities	1 Lack of commercial activities, 0 otherwise	0.13	0.33	0.07	0.26	-0.05*
Skills acquisition	1 if the respondent has acquired skills, 0 otherwise.	0.10	0.30	0.04	0.19	-0.07**
Farm size	Cropland area in hectares	2.65	6.01	0.46	2.40	-2.19***
Livestock	Number of live stocked	0.48	0.50	0.38	0.49	-0.09*
Climate Variables						
Insufficient water for animals	1 if respondents have experience Insufficient water for animals, 0 otherwise.	0.12	0.33	0.04	0.19	-0.08***
Scarcity of water	1 if respondents have water scarcity, 0 otherwise	0.07	0.25	0.01	0.12	-0.05**
Persistent drought	1 if respondents have experience persistent drought, 0 otherwise	0.32	0.47	0.02	0.15	-0.29***
Inadequate farmlands	1 if respondents have inadequate farmlands, 0 otherwise	0.14	0.35	0.01	0.12	-0.13***
Soil infertility	1 if respondents have soil infertility, 0 otherwise	0.19	0.39	0.02	0.15	-0.16***
Exclusion Restriction						
Distance from Destination to Origin	Distance from the destination to origin of migrants	291.53	191.64	92.22	192.91	-199.30***

*** denotes significance at 1% level, ** denotes significance at 5% level, * denotes significance at 10% level
Source: Author's computations
Conversation rate: 1 dollar=625 FCFA

5.1.2 Empirical results

5.1.2.1 Factors influencing climate-induced internal migration

Table 5.3 presents the results of both selection and outcome model analyzing the drivers of internal migration among destination households. Table 5.3 presents the results of both selection and outcome model analyzing the drivers of internal migration among destination households., with the following significant variables emerging:

Education of migrants has a negative and significant impact on migration, suggesting that higher education levels reduce the likelihood of migration. This reflect that better-educated individuals are more likely to find opportunities in their place of origin, reducing their need to migrate Studies have shown that education can be a key factor in retaining individuals in local areas, especially where economic conditions allow for professional employment (Asad & Garip, 2019). Furthermore, better education often correlates with a stronger social safety net, reducing the pressure to migrate for economic reasons. The number of years an individual has spent migrating has positive and significant coefficient, indicating that the longer an individual has been migrating, the more likely they are to continue migrating internally. This might suggest a form of path dependency, where initial migration leads to further relocations due to accumulated knowledge and social networks in new regions (Charles-edwards et al., 2019).

Once individuals gain migration experience, they are better equipped to navigate challenges, making future migrations more probable. Also Experience with initial migration is highly significant, with a strong positive effect, suggesting that having experience with an initial migration significantly increases the likelihood of subsequent migrations. Early migration could provide individuals with crucial skills and networks, lowering the barriers to future moves. Evidence suggests that early exposure to migration increases mobility later in life (Bryceson & Vuorela, 2020). The findings also reveal a positive significant relationship between sociocultural links and migration. Suggesting that Migrants are more likely to relocate to areas where they have existing networks of friends or family. These findings align with the literature on "network migration," which shows that social ties play a crucial role in providing support and reducing risks for migrants (Massey, 2020). Thus, strong sociocultural links can act as a "pull factor," drawing individuals toward familiar areas. Moreso, the lack of commercial opportunities has a negative impact on migration, indicating that when there are fewer economic opportunities in the origin location, people are less likely to migrate. This might seem counterintuitive, but it reflects a common trend where very limited resources may trap individuals in place, making migration financially impossible. Recent research in migration economics has discussed the concept of "immobility poverty," where the poorest individuals are unable to migrate due to a lack of resources (De Haas, 2021). The exclusion restriction variable 'Distance from Destination to Origin' revealed a positive coefficient for distance indicating that longer distances between origin and destination increase the likelihood of migration. This result may indicate that distance alone isn't a major deterrent to migration when there are other compelling factors such as better opportunities or stronger social links at the destination (Lichner et al., 2024).

The climate-related variables significantly affect migration, highlighting how environmental stressors, especially in rural agricultural communities, impact migration decisions. The variable

‘Insufficient water for animals’ has a significant negative effect on migration, meaning that areas experiencing water scarcity for livestock are less likely to see migration. This could indicate that migration is not an immediate option for individuals in these areas, likely due to the severe impact on livelihoods, which may trap them in place. Similarity, scarcity of water negative effect is seen with water scarcity in general, indicating that water shortages significantly reduce the likelihood of migration. Again, this may reflect the concept of "trapped populations," where extreme resource scarcity makes migration more difficult (Cattaneo & Peri, 2016). However, Persistent drought has a strong positive effect on migration. This implies that drought conditions are a major driver of migration, likely due to the devastating impacts on agriculture and livelihoods. Inadequate farmlands also significantly increase the likelihood of migration. This suggests that when people can no longer sustain themselves through farming due to land limitations, they are more likely to migrate in search of better agricultural opportunities or non-farming employment. Lastly, Soil infertility is another significant factor driving migration, reflecting the critical role that land quality plays in sustaining rural livelihoods. As soil fertility declines, migration becomes a necessary strategy to cope with reduced agricultural productivity (Pankhurst et al., 2013).

These results point to a complex interaction between socioeconomic, environmental, and network factors that influence internal migration. This emphasizes the importance of addressing both economic and environmental drivers to manage migration flows effectively.

Table 5.3: Drivers of internal migration by destination households

Variables	Selection	Outcome (Total value of assets)		Outcome (Value of remittances)	
		Migrants N=355 (72.01%)	Non-migrants N=138(27.99 %)	Migrants N=355 (72.01%)	Non-migrants N=138(27.99 %)
Socioeconomic factors					
Age	-0.0046	0.203**	-0.284**	0.37	-0.03
	(0.0350)	(0.095)	(0.113)	0.26	0.21
Age squared	0.0055	-0.214**	0.268**	-0.27	-0.02
	(0.0358)	(0.100)	(0.116)	0.27	0.23
Gender	-0.0895	1.205	0.686	-0.31	0.63
	(0.3228)	(1.215)	(1.331)	2.27	1.94
Education	-0.0512**	0.036	-0.058	0.24	-0.05
	(0.0200)	(0.046)	(0.057)	0.14	0.11
Number of Minors	0.0699	-0.186	0.185	-0.03	0.01
	(0.0475)	(0.130)	(0.157)	0.33	0.28
Number of adults	0.0410	0.021	-0.087	-0.28	-0.01
	(0.0414)	(0.100)	0.121	0.26	0.21

Number of dependents	-0.0223	0.102	-0.025	0.21	0.02
	(0.0380)	(0.084)	(0.109)	0.23	0.18
Employment status	0.3456	-0.284	0.660	-0.78	0.98
	(0.2584)	(0.668)	(0.736)	1.44	0.26
Number of years migration	0.0883***	-0.284**	0.305**	-1.07***	1.02***
	(0.0154)	(0.121)	(0.123)	0.31	0.30
Migration experience	1.1725***	-2.463	2.099	-4.74	5.25
	(0.2287)	(1.821)	(1.960)	3.617	3.36
Socio cultural links	1.1576**	0.724	-0.713	-16.15***	16.07***
	(0.5035)	(1.377)	(1.524)	4.010	3.632
Lack of commercial opportunities	-0.6756**	2.322	-2.521	-0.793	2.394
	(0.3019)	(1.728)	(1.876)	3.61	3.23
Skills acquisition	0.2766	2.636	-2.687	-6.74**	7.78**
	(0.3567)	(1.689)	(1.863)	3.42	3.03
Farm size in hectares	-0.0332	0.308	-0.306	0.64	-0.56
	(0.0261)	(0.196)	(0.200)	0.45	0.43
Livestock	0.2609	-1.100**	1.559***	1.86	-1.01
	(0.1789)	(0.450)	(0.533)	1.14	0.94
Climatic factors					
Insufficient water for animals	-0.9843**	2.297*	-1.575	0.395	-1.264
	(0.4479)	(1.390)	(1.495)	3.802	3.583
Scarcity of water	-1.4130**	1.751	-1.442	12.793	-13.601
	(0.6005)	(5.070)	(5.330)	14.810	14.338
Persistent drought	1.2965***	-2.830	2.999	-12.366	10.778
	(0.4547)	(3.428)	(3.504)	10.267	10.115
Inadequate farmlands	0.9041**	-2.663	2.799	-15.008	15.873
	(0.4385)	(3.714)	(3.871)	11.683	11.293
Soil infertility	0.9011**	0.510	-1.144	-5.218	4.837
	(0.3557)	(2.487)	(2.599)	5.932	5.669
Exclusion restriction					
Distance from Destination to Origin	0.0013***				
	(0.0005)				
Constant	-1.6425*	1.097	6.025	-2.367	1.289
	(0.9066)	(2.276)	(2.780)	6.187	4.891
Statistics					
Test of observable heterogeneity	0.06				
Test of essential heterogeneity	0.17				
Observations	493				

*** denotes significance at 1% level, ** denotes significance at 5% level, * denotes significance at 10% level
Source: Authors' computations

5.1.2.2 Determinants of the outcome variables

Table 5.3 outlines the determinants of the total value of assets and remittances for migrants and non-migrants in relation to various socioeconomic and climate variables. For migrants, age has a significant positive influence on the total value of assets, while for non-migrants, it has a negative influence. Implying that older migrants tend to accumulate more assets, potentially due to experience and savings accumulated over time. In contrast, non-migrants may experience reduced asset accumulation with age, possibly due to fewer economic opportunities in their static environment. This suggests the importance of migration as a strategy for wealth accumulation (Vallejo & Keister, 2020). However, Age squared show a significant negative relationship for migrants and a positive one for non-migrants. This implies that the relationship between age and asset accumulation is nonlinear. For migrants, there may be diminishing returns to asset accumulation with age, while non-migrants may see a slight increase in asset value as they age. This can be tied to the fact that as migrants grow older, they may send remittances or retire, reducing their asset accumulation.

Gender, Education, Number of dependents and Employment Status, none of these factors show significant effects for either group. These variables do not appear to significantly influence asset accumulation. However, the non-significance of these factors may point to the structural challenges both groups face, regardless of gender or education level, highlighting that asset accumulation might be more closely tied to mobility and migration than to these demographic variables (Eroglu-Hawksworth, 2021; Vaira-lucero, 2012).

Migration experience shows a significant negative influence on the total value of assets for migrants, though it is not significant for non-migrants. Years of migration is also significant for both groups but with different effects. This suggests that while short-term migration might boost asset accumulation (since years of migration positively affects non-migrants' asset accumulation), long-term migration could have diminishing returns or adverse effects, possibly due to adaptation challenges or high costs associated with long-term migration (Dustmann & Görlach, 2016). Additionally, Livestock ownership shows significant negative effect for migrants and a positive effect for non-migrants. For non-migrants, livestock is an important asset class, contributing to their overall wealth. However, for migrants, livestock ownership might not be as significant, possibly because they invest more in other forms of assets or they face challenges in maintaining livestock while migrating.

In the case of the climate variables, climate variables, Insufficient water for animals: Migrants who experience water scarcity have a significant positive impact on their total asset value, while for non-migrants, this effect is negative. This indicate that migrants facing water shortages for animals might diversify their income sources, such as selling livestock, leading to temporary asset growth. Non-migrants, in contrast, may be more reliant on livestock and thus experience losses when facing water shortages (Clemens, Michael A. & Pritchett, 2019). Persistent drought and inadequate farmland show no significant results for both groups, although their coefficients indicate potential impacts. The lack of significance may suggest that both groups are somewhat resilient to these climate variables or that they have developed coping mechanisms. However, these factors still carry high economic risk, especially for agricultural-dependent communities.

In the case of remittances, Number of years of migration indicate that, the longer migrants are away from their households, the less likely they are to remit, according to a negative and significant association at 1%. As time goes on, migrants might encounter fewer financial responsibilities to their households, forge closer bonds with their host communities, or deal with rising personal expenses like relocating permanently or starting a family of their own (Mcmillan, 2020). Meanwhile chance or size of remittances increases with the duration of migration, according to a positive and significant connection at 1% for non-migrants. The migrant's stable settlement in the host country may assist non-migrants (household members left behind), increasing their ability to remit over time (Collier et al., 2011). Sociocultural Links also showed a negative and significant relationship at 1% for migrants indicating a stronger sociocultural tie with the origin community, such as shared cultural norms or obligations, reduce remittances. This could result from increased non-monetary obligations or resource allocation to cultural activities rather than financial remittances (Ambrosius & Cuecuecha, 2016). In contrast, a positive and significant relationship at 1% for non-migrants suggests that strong sociocultural links encourage higher remittances. Non-migrants may leverage these links to maintain emotional connections, request financial support, or negotiate remittances through shared networks and traditions (Boccagni & Decimo, 2013). Moreso, the negative relationship at 5% for migrants indicates that skill acquisition reduces remittances. Skilled migrants may prioritize self-investment, career advancement, or other financial goals over remitting funds to households (Docquier et al., 2015). Hower ever, migrants shows that skill acquisition enhances the financial stability of households, leading to greater remittances. Thus, Skilled migrants are more likely to secure higher-paying jobs, increasing their ability to remit (Adams, 2011)>

5.1.2.3 Average Treatment Effects of internal migration on outcome variables

Table 5.4 presents the impacts of migration on household total assets on the baseline model. The Average Treatment Effect (ATE) and Average Treatment on the Treated (ATT) estimates are all significant for the Total value of Assets. Specifically, the results imply that migration significantly increases household wealth by 36.01%. The ATE is 16.66, while the ATT is 22.66. The percentage change of 36.01% indicates that the effect of the treatment on those who actually received it (ATT) is 36.01% higher than the overall average effect (ATE). This suggests that the treatment has a more significant impact on those who were migrated compared to the general population or the average group. The Average Treatment on the Untreated (ATU) is 0.49, which is much lower than the ATE of 16.66. The percentage change of -97.06% shows that the effect of the migration on the non-migrants is drastically lower compared to the overall average effect (ATE). Thus, it’s almost negligible, which means that non-migrants experienced little to no benefit from it. This large negative percentage change implies that the migration is specifically beneficial for those who migrated, but has very limited to no spillover effects on the non-migrants. Overall, comparing the ATT of 22.66 to the ATU of 0.49 results in a percentage change of -97.84%, the significant negative change shows that the impact of migration on non- migrants (ATU) is much smaller than the impact migrants (ATT). In other words, the treatment is highly effective for the treated individuals, but its effect on the untreated group is almost non-existent. This indicates that the intervention is targeted and beneficial for those who participate in it, with minimal external benefits to others. This could be important for policy decisions, as it suggests that expanding the treatment to more individuals could be necessary to maximize its overall societal impact.

Nonetheless, the ATE for remittances is -41.94, indicating that migration has a negative overall impact on remittances. This implies that, generally speaking, migration results in a notable drop in the quantity of remittances that migrants send home, which may be due to adjustments in their income or ability to do so. The impact of migration on people who decide to migrate is much more detrimental than the average effect, according to ATT (-61.71). This suggests that those that migrate are probably the ones who see the biggest drops in remittances, either as a result of shifting financial priorities, lower income, or increased living expenses. It's interesting that non-migrants'

ATU is positive. This implies that remittances may rise for this group as a result of migration, perhaps as a result of better economic possibilities overseas than they currently have.

Table 5.4: Treatment effects of Migration of on outcome indicators

	Total value of assets			Value of remittances		
Treatment effects	Coefficient	Standard Error	Percentage Change (%)	Coefficient	Standard Error	Percentage Change (%)
ATE	16.66**	7.09	16.66	-41.94**	14.98	(-41.94)
ATT	22.66**	9.74	36.01	-61.71**	21.08	(-61.71)
ATU	0.49	0.75	-97.84	6.93***	1.69	6.93)
Test of observable heterogeneity, p-value	0.06			0.00		
Test of essential heterogeneity, p-value	0.17			0.21		

*** denotes significance at 1% level, ** denotes significance at 5% level, * denotes significance at 10% level. The standard errors in parentheses were bootstrapped with 500 replications.
Source: Authors' computations

5.1.2.4 Marginal treatment effect (MTE) curves

The two figures show how the unobserved resistance to treatment (propensity to migrate) affects the Marginal Treatment Effects (MTE) of migration on two distinct outcomes: (1) total asset values (4A) and remittances (4B). The MTE curve illustrates how the treatment impact of migration differs for people with varying degrees of unobserved resistance to migration in the context of total values of assets. The effect starts higher for individuals with low resistance to migration (those more likely to migrate) and decreases as resistance to migration increases. The MTE estimate's 95% confidence interval (CI) is shown by the gray shaded area. More accurate estimations in this range are suggested by the narrowing towards greater resistance. The Average Treatment Effect (ATE), which is consistent throughout the population, is shown by the dashed red line. The MTE is higher than the ATE over the majority of the unobserved resistance distribution, suggesting that migration tends to have greater effects on total assets for those who are more inclined to migrate. As a result, migration constantly raises asset prices, especially for those with minimal resistance to migration. This implies that helping people who are already predisposed to migrate could improve their economic results.

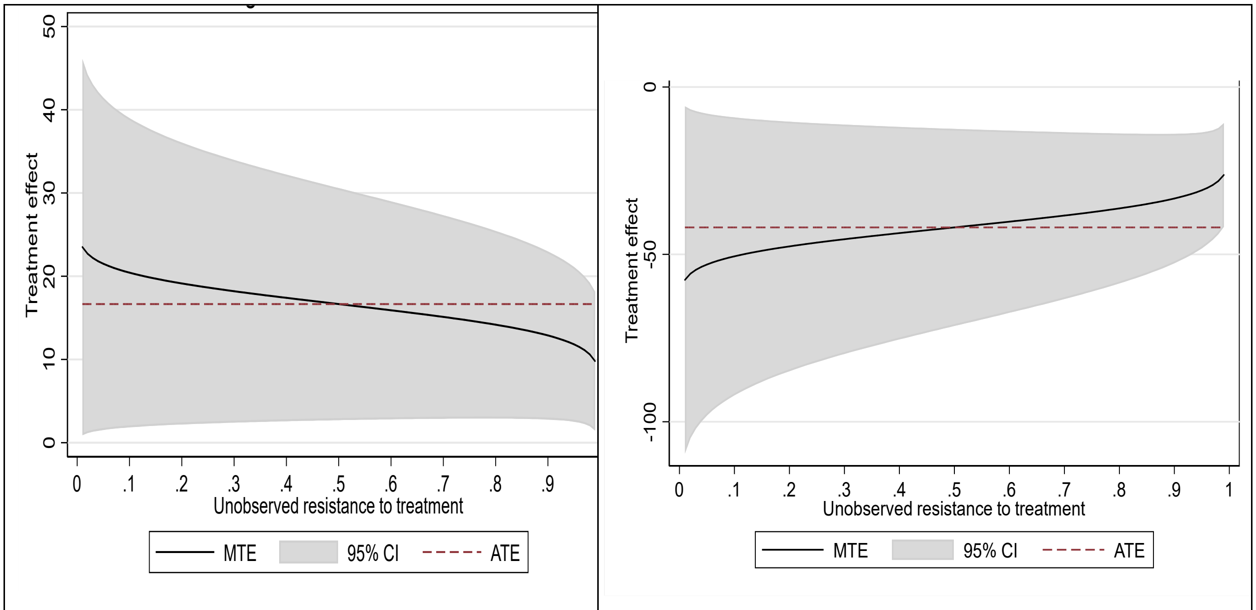


Fig. 5.1A: Marginal treatment effect on total value of assets

Fig. 5.1B: Marginal treatment effect on value of remittances

Figure 5.1: Marginal treatment effect on total value of assets and remittances

Source: Generated from authors' computation

Comparatively, Remittances the black MTE curve starts with negative effects for individuals with low resistance to migration but becomes positive for those with higher resistance. This suggests heterogeneity in the impact of migration on remittances. The wide confidence intervals at low resistance highlight significant uncertainty in the estimated effects for individuals who are more inclined to migrate. The ATE lies above zero, indicating a positive average effect of migration on remittances. However, the MTE suggests that for individuals with high unobserved resistance, the benefits are substantially higher, while for those with low resistance, the effects are negative or negligible. Migration's effect on remittances is more heterogeneous. While high-resistance individuals gain significantly, low-resistance individuals see negative or negligible impacts, potentially due to factors like different financial strategies or migration motives. This indicate, that Migration's effect on remittances is negative or negligible for those with low resistance but positive for high-resistance individuals. This could reflect differing motives for migration (e.g., economic opportunity vs. family reunification) or varying ability to remit funds back home. Migration-related policies ought to take these distinctions into account thus, programs that assist high-resistance persons, for example, who are less likely to migrate independently, may yield higher remittance returns. On the other hand, measures that assist low-resistance people in building assets (such as investing possibilities or financial education) could be more advantageous to them.

Migration seems to have a more consistent positive effect on asset accumulation than on remittances. This could imply that migrants often prioritize building their wealth in their host towns rather than sending money back home. The negative effects of migration on remittances for low-resistance individuals might stem from factors like: Higher consumption in the host towns, longer family reunification processes reducing the need for remittances. Lack of a stable financial foundation to remit significant amounts.

5.2 Conclusion and Policy Recommendation

Climate-induced internal migration in Burkina Faso is primarily driven by environmental factors such as inadequate rainfall, soil degradation, and persistent droughts, which severely affect agricultural productivity. The study confirms that migration is an important adaptation strategy for households in regions facing climate variability, particularly for those heavily reliant on agriculture. Migrants generally accumulate more assets than non-migrants, indicating that migration can be a means to secure better livelihoods and enhance household wealth. However, this opportunity is not accessible to all, as extreme environmental degradation in some areas limits people's ability to migrate, trapping them in poverty. The findings highlight the complex interplay between environmental stress, socio-economic factors, and migration decisions, and underscore the importance of understanding these dynamics for more effective policy interventions.

Hence, we recommend the enhancement of climate-resilient agricultural practice to mitigate the drivers of migration, Burkina Faso should invest in climate-resilient agricultural technologies and practices, such as improved irrigation systems, drought-resistant crops, and soil conservation techniques. These measures can help stabilize agricultural productivity in areas affected by climate variability, reducing the need for migration. Moreso, the government, in collaboration with development partners, should implement programs aimed at improving soil fertility, preventing land erosion, and rehabilitating degraded lands. This will reduce migration pressures by improving local livelihoods. Since water scarcity is a key driver of migration, especially in agricultural communities, there should be an emphasis on improving access to water through the development of water storage, rain water harvesting. Nonetheless, Policies promoting efficient water use for farming and livestock will be essential to maintain agricultural productivity.

Migration Support Programs that provide support in terms of access to affordable housing, social services, and integration into the labor market are essential. These initiatives can help migrants secure better livelihoods in their new locations, while also mitigating the socio-economic disparities between migrant and non-migrant populations (Chen et al., 2024; Sammain et al., 2024; Renzaho et al., 2024)

National and local governments need to integrate migration considerations into their climate change adaptation strategies. This includes preparing for both the risks and opportunities associated with internal migration, ensuring that migration is part of a broader strategy for building resilience in climate-vulnerable regions. Thus, these policy actions can help alleviate the pressures of climate-induced migration and ensure that migration, when it occurs, is more of a choice than a necessity driven by climate change

CHAPTER 6 : COMPARATIVE ANALYSIS OF DROUGHT AND ITS RELATIONSHIP WITH MIGRATION IN THE COMOE AND BOULKIEMDE PROVINCES

The chapter 6 analyses drought dynamics and their influence on migration patterns in the provinces of Comoé and Boulkiemdé, Burkina Faso, using Standardized Precipitation Index (SPI) and Standardized Precipitation-Evapotranspiration Index (SPEI) across multiple temporal scales.

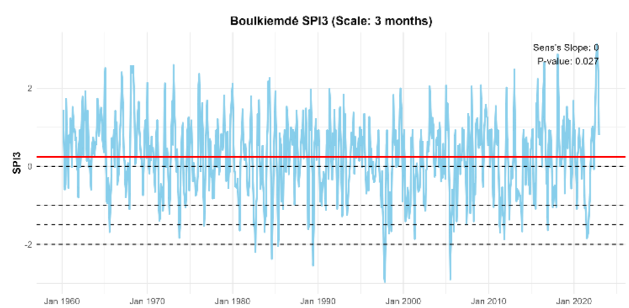
6.1 Results and Discussion

6.1.1 Drought trends based on SPI and SPIE in Comoé and Boulkiemdé

The Standardized Precipitation Index (SPI) and Standardized Precipitation-Evapotranspiration Index (SPEI) are utilized to analyze drought trends in the provinces of Comoé (Sudanian zone) and Boulkiemdé (Sudano-Sahelian zone) across different temporal scales. While these indices are similar, the SPEI incorporates evapotranspiration, enabling a more comprehensive assessment of hydrological anomalies in the context of climate change. The trends revealed by the SPI and SPEI, validated through Sen's slopes and associated p-values, highlight distinct climatic dynamics across periods of analysis and regions studied.

6.1.1.1 Meteorological Droughts (SPI3 and SPEI3)

Meteorological droughts, measured through SPI3 and SPEI3 (short term), reflect significant reductions in precipitation relative to short-term averages in the provinces of Comoé and Boulkiemdé.



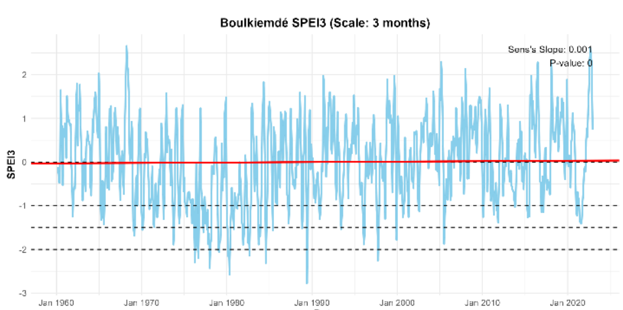


Figure 6.1 illustrate the trend of this type SPI3 and SPEI3 in both provinces.

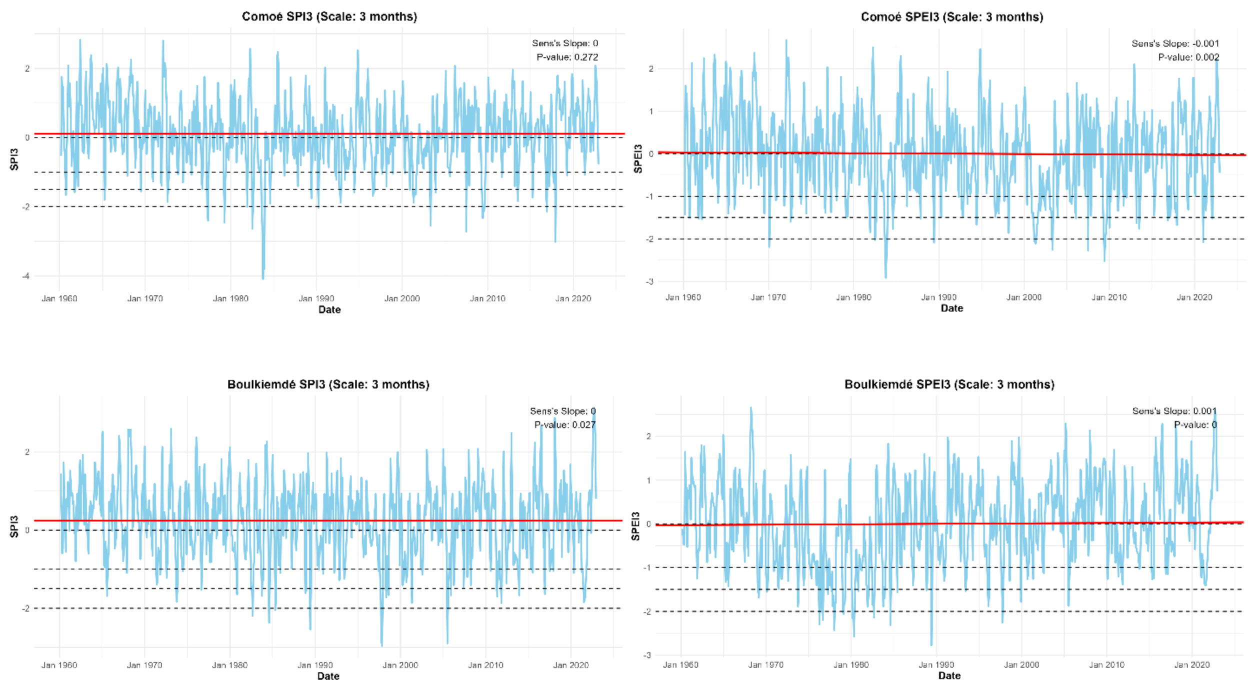


Figure 6.1: Trends in SPI3 and SPEI3 in the provinces of Comoé and Boulkiemdé

SPI3 and SPEI3 display regular fluctuations around zero, indicating alternating wet (positive values) and dry (negative values) periods in the short term. In Comoé, SPI3 exhibits no significant trend (Sen's slope = 0, p-value = 0.144), suggesting relative stability despite recurrent climatic anomalies. Conversely, SPEI3 demonstrates a slight negative trend (Sen's slope = -0.001, p-value = 0.002), indicating a minor but statistically significant deterioration in hydrological conditions. This discrepancy reflects the increasing influence of evapotranspiration, highlighting heightened sensitivity to rising temperatures. These findings suggest a progressive increase in short-term droughts in this region, consistent with observations of greater sensitivity to climatic disruptions in Sudanian zones, as reported by Dardel et al. (2014).

In Boulkiemdé, SPI3 shows a statistically significant trend (p-value = 0.026) despite a neutral Sen's slope. SPEI3 reveals a slight improvement in hydrological conditions (Sen's slope = +0.001, p-value = 0.000). These results suggest that the Sudano-Sahelian region occasionally benefits from localized rainfall, although the impact of rising temperatures remains moderate in the short term. These observations align with the work of Diasso and Abiodun, (2017), , who noted that Sudano-

Sahelian zones, despite their high climatic variability, sometimes benefit from favorable seasonal precipitation.

6.1.1.2 Agricultural Droughts (SPI6 and SPEI6)

Agricultural droughts, measured through SPI6 and SPEI6 (medium term), refer to significant reductions in soil moisture required for optimal vegetation growth (Tadesse et al., 2015). Figure 6.2 presents SPI6 and SPEI6 trends for both provinces.

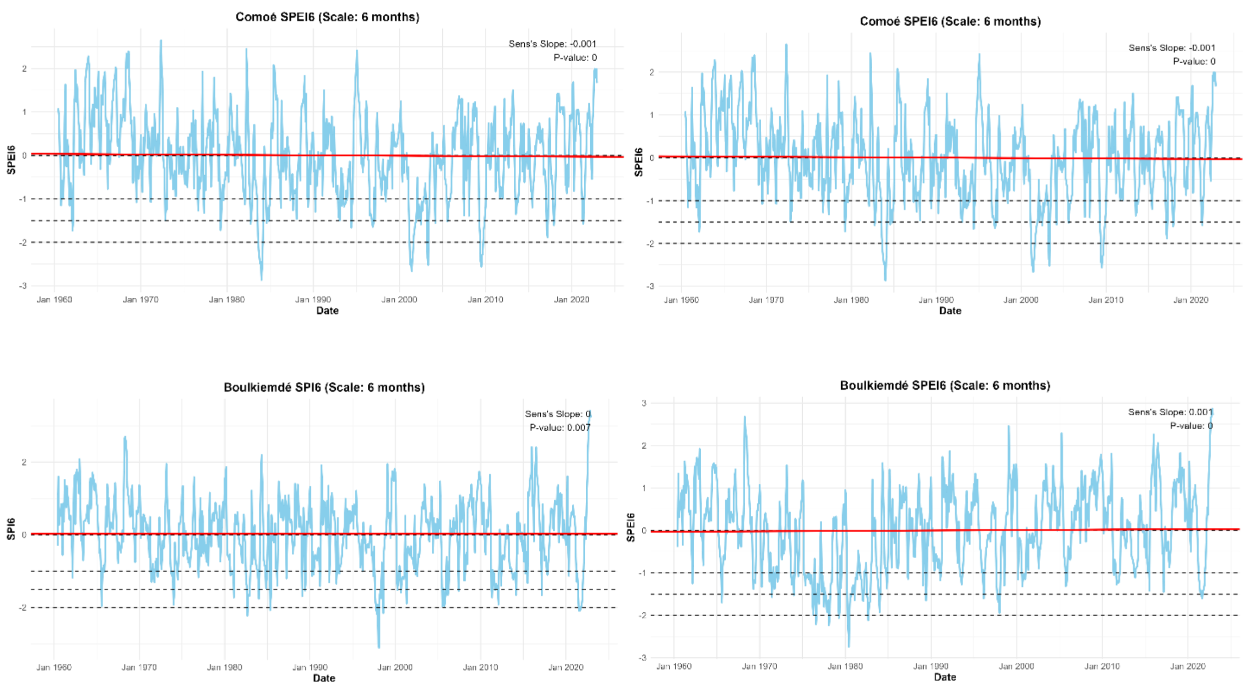


Figure 6.2: Trends in SPI6 and SPEI6 in the provinces of Comoé and Boulkiemdé

SPI6 and SPEI6 reveal pronounced alternations between dry and wet periods in the medium term, consistent with historical droughts in the 1970s, 1980s, and 2000s. In Comoé, both indices exhibit slight negative trends (SPI6: Sen's slope = -0.001, p-value = 0; SPEI6: Sen's slope = -0.001, p-value = 0), reflecting continuous degradation in hydrological conditions exacerbated by the effects of evapotranspiration. These observations align with those of Dardel et al. (2014), who documented intensifying droughts in Sudanian zones, often amplified by anthropogenic pressures.

In Boulkiemdé, both SPI6 and SPEI6 exhibit statistically significant trends (SPI6: Sen's slope = 0, p-value = 0.007; SPEI6: Sen's slope = +0.001, p-value = 0). This apparent resilience reflects the region's capacity to adapt to irregular precipitation, supporting the conclusions of (Diasso & Abiodun, 2017), who highlighted the potential for increased variability to foster hydrological recovery in some cases. These findings also align with Zhao and Dai, (2015), who demonstrated that certain Sudano-Sahelian zones benefit from localized precipitation, compensating for medium-term deficits.

6.1.1.3 Hydrological Droughts (SPI12 and SPEI12)

Hydrological droughts, measured through SPI12 and SPEI12 (long term), refer to significant reductions in the availability of all forms of water in the terrestrial phase of the hydrological cycle, including surface water, snowmelt, spring runoff, and groundwater Goyal et al. (2017). Figure 6.3 illustrate SPI12 and SPEI12 trends in both provinces.

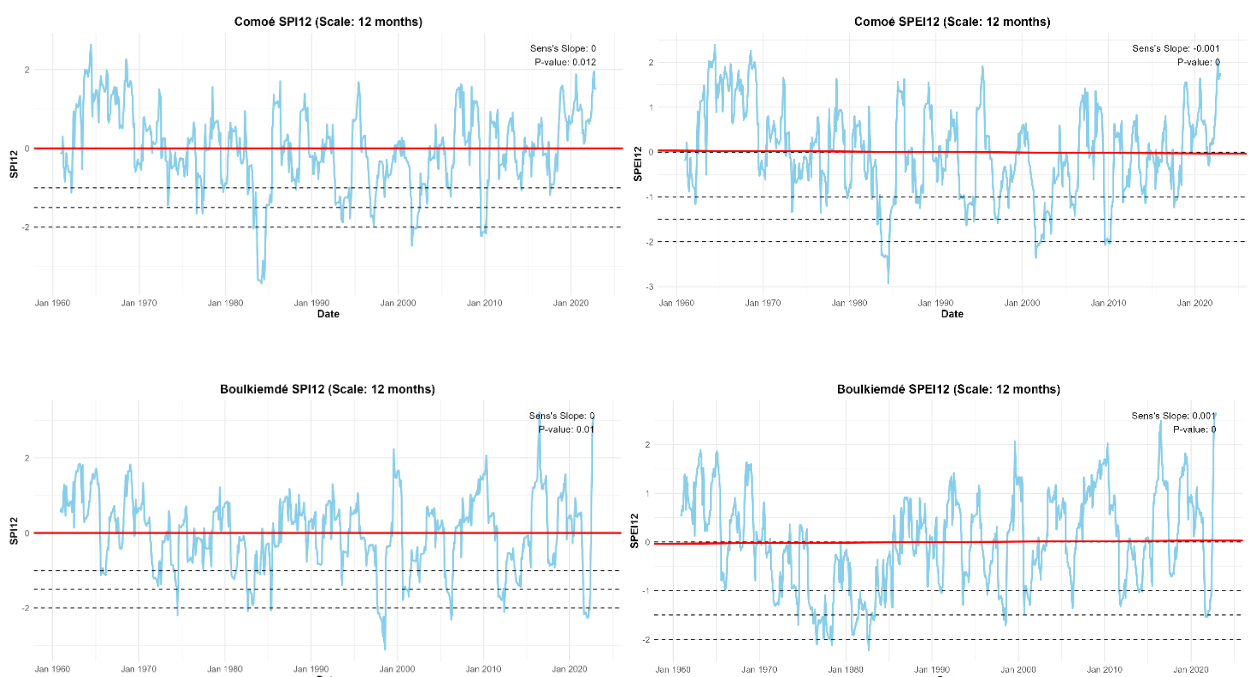


Figure 6.3: Trends in SPI12 and SPEI12 in the provinces of Comoé and Boulkiemdé

SPI12 and SPEI12 display regular oscillations around zero, reflecting alternating prolonged periods of drought and wet conditions. In Comoé, both indices indicate significant long-term hydrological degradation (SPI12: Sen's slope = 0, p-value = 0.012; SPEI12: Sen's slope = -0.001, p-value = 0). This deterioration is more pronounced in SPEI12, underscoring the increasing impact of evapotranspiration on long-term anomalies. These findings align with the work of Nicholson et al. (2018), which documented worsening long-term droughts in Sudanian zones of West Africa, driven by climatic variability and anthropogenic pressures.

In Boulkiemdé, both indices reveal statistically significant trends (SPI12: Sen's slope = 0, p-value = 0.01; SPEI12: Sen's slope = +0.001, p-value = 0). This dynamic may be attributed to localized intensification of seasonal rainfall in the Sudano-Sahelian zone, characterized by increased climatic variability and opportunities for hydrological recovery, as Zhao and Dai, (2015) suggested. These results confirm greater resilience in this region, where irregular rainfall supports relative stability even under climate change impacts.

6.1.1.4 Comparing SPI and SPEI

The differences between SPI and SPEI underscore the importance of incorporating evapotranspiration into climate trend analyses. SPEI, which accounts for rising temperatures, is particularly relevant in the context of global warming (Cook et al., 2014). These observations align with Huang et al. (2016)who demonstrated that increasing temperatures often exacerbate drought intensification in arid and semi-arid regions. In Sudanian zones such as Comoé, the findings are consistent with Dardel et al. (2014), who identified intensifying prolonged droughts exacerbated by anthropogenic pressures and rising temperatures. The greater sensitivity of SPEI compared to SPI in this region highlights increased vulnerability to climate change impacts. In Sudano-Sahelian zones such as Boulkiemdé, trends revealed by SPI and SPEI corroborate observations by Nicholson et al. (2018), who noted that increased climatic variability can sometimes support localized hydrological recovery. The slight positive trends in SPEI within this region suggest that temperature impacts are less pronounced than in Sudanian zones, possibly due to more intense and localized precipitation events.

6.1.2 Drought Intensity Based on SPI and SPEI in Comoé and Boulkiemdé

Drought intensity was assessed according to the thresholds proposed by McKee et al. (1993) and Mehr et al. (2020). The same threshold values were used for both indices. These thresholds are shown in **Error! Reference source not found.**.

Table 6.1: Thresholds used to classify drought intensity

Values (threshold)	Classification (Intensity)
0 <SPI/SPEI<− 1.49	Mild drought
− 1.49<SPI/SPEI<− 1.0)	Moderate drought
− 1.50<SPI/SPEI<− 2.0	Severe drought
SPI/SPEI>− 2	Extreme drought

Source: McKee et al. (1993) and Mehr et al. (2020)

The evaluation of the SPI (Standardised Precipitation Index) and SPEI (Standardised Precipitation-Evapotranspiration Index) at different time scales (3, 6 and 12 months) in the provinces of Comoé (Sudanese zone) and Boulkiemdé (Sudano-Sahelian zone) reveals significant variations in drought intensity due to specific climatic conditions.

6.1.2.1 Intensity of Meteorological Droughts (SPI3 and SPEI3)

The first temporal assessment scale is the meteorological drought intensity measure, i.e. short-term drought. In this section, it is assessed using the SPI3 and SPEI3. Figure 6.4 summarises the results.

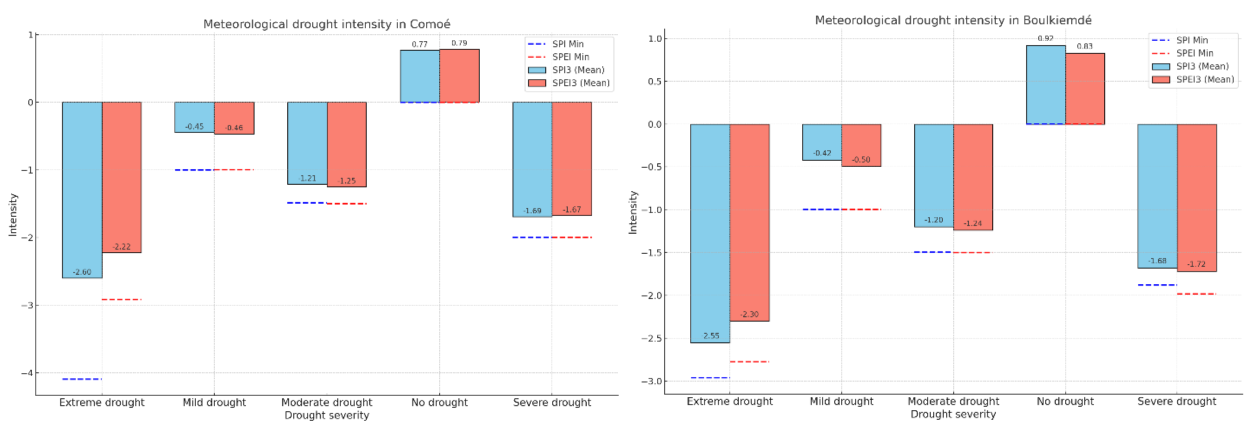


Figure 6.4: Intensity of meteorological drought (SPI3 and SPEI3) in the provinces of Comoé and Boulkiemdé.

Extreme droughts in Comoé have an average intensity of -2.6 and a maximum intensity of -4.1 for SPI3, compared to an average of -2.2 and a maximum intensity of -2.92 for SPEI3. This difference is due to the fact that SPI3 only measures precipitation anomalies, whereas SPEI3 also takes into account evapotranspiration, which moderates perceived water deficits. Moderate droughts have a maximum intensity of -1.49 for SPI3, comparable to that measured by SPEI3 (-1.50). Mild droughts have a maximum intensity of -0.99 for SPI3, similar to SPEI3 (-0.98).

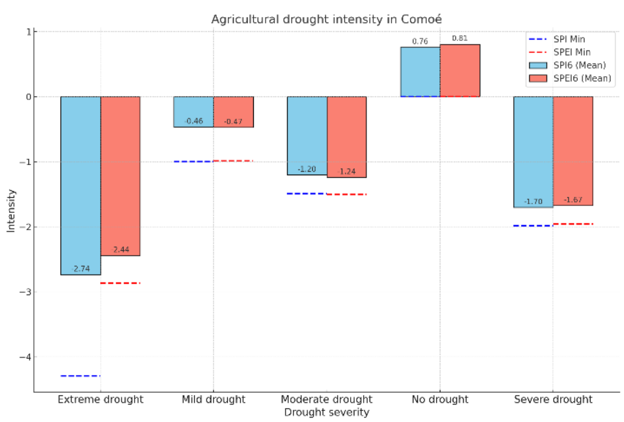
These results are consistent with the observations of Sanogo et al. (2015), who highlighted the importance of integrating evapotranspiration to assess droughts in tropical humid zones. Furthermore, Panthou et al. (2018) emphasised that climate oscillations, such as ENSO, strongly influence drought intensities measured by SPI in West Africa.

In Boulkiemdé, extreme droughts reach a maximum intensity of -2.96 for SPI3 and -2.3 for SPEI3, reflecting the moderating effect of temperatures and evapotranspiration included in SPEI. Moderate droughts reach a maximum intensity of -1.23 for SPI3 and -1.24 for SPEI3, while mild droughts have a maximum intensity of -0.99 for SPI3 and -0.98 for SPEI3.

These observations are consistent with the findings of EO et al., (2024) and Ceccherini et al., (2017), who showed that high temperatures amplify extreme and moderate droughts in the Sudano-Sahelian zone.

6.1.2.2 Intensity of Agricultural Droughts (SPI6 and SPEI6)

The second temporal scale measures the intensity of agricultural drought, i.e. drought in the medium term. In this section it is assessed using the SPI6. Figure 6.5 summarises the results.



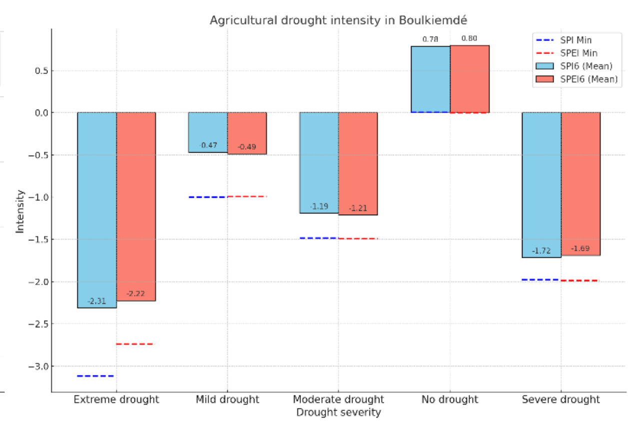


Figure 6.5: Intensity of agricultural drought (SPI6 and SPEI6) in the provinces of Comoé and Boulkiemdé.

Extreme droughts reach a maximum intensity of -4.29 for SPI6 compared to -2.87 for SPEI6. This reflects the ability of SPI6 to capture more intense rainfall deficits, while SPEI6 moderates these results by including water losses due to evapotranspiration. Moderate droughts show similar maximum intensities for both indices (-1.49 for SPI6 and -1.50 for SPEI6). Although less intense, mild droughts have maximum values of -0.99 for SPI6 and -0.98 for SPEI6.

These results are in line with studies by Ndehedehe et al. (2016) and Spinoni et al. (2019), who showed that SPEI is particularly suitable for capturing moderate and mild droughts that are exacerbated by rising temperatures.

In Boulkiemdé, extreme droughts reach a maximum intensity of -3.12 for SPI6 and -2.74 for SPEI6, highlighting a significant attenuation due to the inclusion of temperatures in SPEI. Moderate droughts show similar maximum intensities for both indices (-1.23 for SPI6 and -1.24 for SPEI6). Mild droughts have maximum intensities of -0.99 for SPI6 and -0.98 for SPEI6.

These results confirm the conclusions of Panthou et al., (2018) and Ceccherini et al., (2017), and highlight the importance of taking temperature into account when assessing the impact of droughts in semi-arid zones.

6.1.2.3 Intensity of Hydrological Droughts (SPI12 and SPEI12)

The last temporal assessment scale in this study is the measure of hydrological drought intensity, i.e. long-term drought. In this case, it is assessed using the SPI12. Figure 6.6 summarises the results.

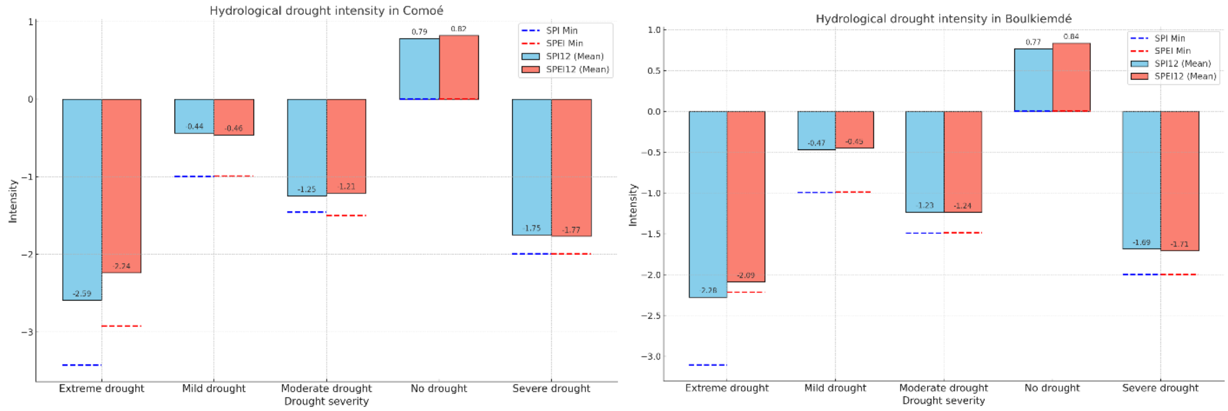


Figure 6.6: Intensity of hydrological drought (SPI12 and SPEI12) in the provinces of Comoé and Boulkiemdé.

On an annual scale, extreme droughts reach a maximum intensity of -3.43 for SPI12 compared to -2.93 for SPEI12. Moderate droughts show maximum intensities of -1.49 for SPI12 and -1.50 for SPEI12, while mild droughts reach -0.99 for SPI12 and -0.98 for SPEI12. The moderating effect of evapotranspiration on drought intensity is particularly evident at this scale.

These results corroborate the observations of Nauditt et al. (2022), who showed that tropical humid regions are mainly affected by prolonged moderate droughts due to cumulative water deficits.

In Boulkiemdé, extreme droughts reach a maximum intensity of -3.11 for SPI12 and -2.93 for SPEI12. Moderate droughts show similar maximum intensities (-1.23 for SPI12 and -1.24 for SPEI12). Mild droughts have maximum intensities of -0.99 for SPI12 and -0.98 for SPEI12.

These observations are consistent with the findings of Sayat et al. (2025) and Venturi et al. (2025), who showed that the integration of temperature into SPEI is essential to capture prolonged droughts in semiarid regions.

6.1.2.4 Global Comparison Between SPI and SPEI

In both provinces, the SPI generally measures higher drought intensities, especially for extreme events. This is due to SPI's exclusive reliance on precipitation anomalies, which amplify water deficits. Conversely, SPEI, by integrating evapotranspiration, moderates intensities but detects a greater number of mild and moderate droughts, particularly in areas where high temperatures exacerbate water losses.

In Comoé, a wetter region, SPI tends to overestimate extreme water deficits, while SPEI is more relevant for capturing mild and moderate droughts. In Boulkiemdé, prolonged and severe droughts captured by SPEI highlight the need for temperature integration to understand the real impacts in Sudano-Sahelian zones.

6.1.3 SPI an SPEI based drought frequency and distribution in Comoé and Boulkiemdé provinces

The analysis of the frequency of meteorological, agricultural and hydrological droughts in the provinces of Comoé and Boulkiemdé, based on the SPI and the SPEI, reveals significant differences in the frequency and distribution of droughts linked to the climatic specificities of each region. The SPI and SPEI provide complementary insights into drought dynamics by including or excluding evapotranspiration in the calculations.

6.1.3.1 Frequency and intensity distribution of meteorological droughts

Meteorological droughts based on SPI3 show clear differences between the provinces of Comoé and Boulkiemdé over the 63 years of the study (756 months). Comoé experienced 319 months of drought and 337 months without drought, while Boulkiemdé recorded 316 months of drought and 440 months without drought. This indicates that Boulkiemdé has experienced a significantly higher number of drought-free months than Comoé, reflecting greater resilience to short-term meteorological droughts. Although the total number of drought months is similar between the two regions, Comoé has a slightly higher number of drought months (319) than Boulkiemdé (316), suggesting greater vulnerability to short-term water deficits in the Sudanese zone. The analysis shows a more balanced distribution of drought and non-drought months in both provinces using SPEI3, which includes the effects of evapotranspiration. Comoé experienced 369 months of drought and 367 months of no drought, while Boulkiemdé recorded 380 months of drought and 376 months of no drought. In this case, both provinces show a near equilibrium between dry and wet periods, reflecting a stable short-term climatic variability. However, Boulkiemdé shows a slightly higher frequency of drought periods (380) compared to non-drought periods (376), which contrasts with the SPI3 results where it showed better resilience.

The comparison between SPI3 and SPEI3 shows that the inclusion of evapotranspiration in the drought analysis changes the distribution dynamics. Boulkiemdé, despite its higher resilience indicated by SPI3, shows a slightly higher frequency of droughts under SPEI3, highlighting the role of evapotranspiration in exacerbating short-term water deficits in the Sudano-Sahelian zone. Conversely, Comoé maintains a consistent pattern of slightly more frequent droughts, reinforcing its vulnerability to short-term climatic variability even under wetter conditions. Figure 6.7 shows the distribution of meteorological drought intensities in the provinces of Comoé and Boulkiemdé, based on SPI3 and SPEI3 values.

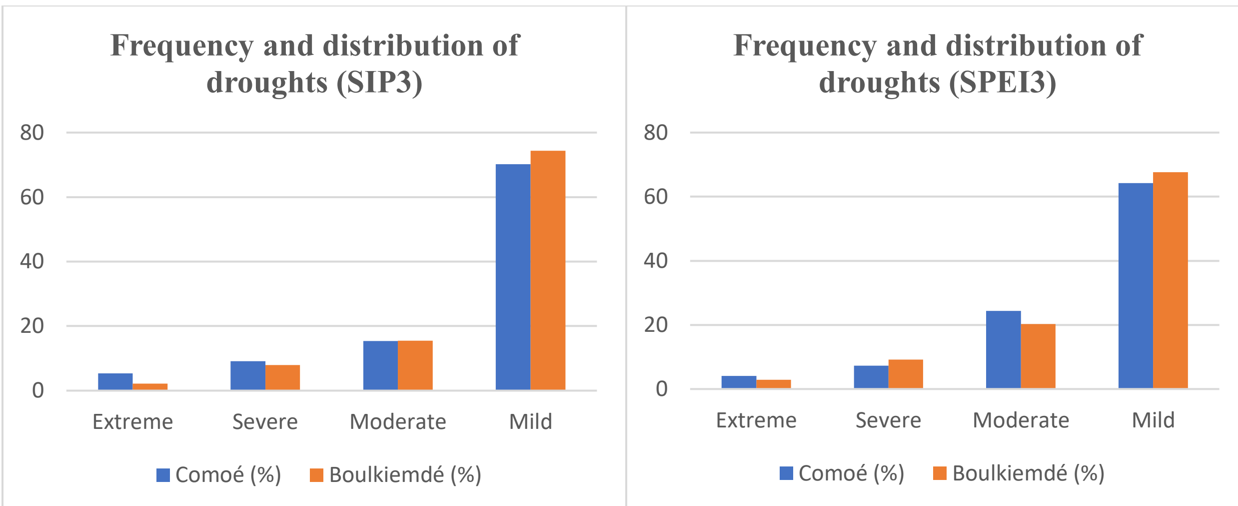


Figure 6.7: Meteorological droughts (SPI3 and SPEI3) Frequency and distribution in the provinces of Comoé and Boulkiemdé.

Mild droughts dominate in both regions, accounting for about 60.5% of events in Comoé and 61.2% in Boulkiemdé. Moderate droughts account for 23.1% in Comoé and 22.9% in Boulkiemdé, while severe and extreme droughts are less frequent, with 11.9% and 4.5% in Comoé compared to 12.3% and 3.6% in Boulkiemdé. In contrast, the SPEI3 shows a slightly different distribution due to the influence of evapotranspiration. In Comoé, light droughts account for 64.23%, followed by moderate (23.38%), severe (7.32%) and extreme (4.07%) droughts. In Boulkiemdé, light droughts also dominate with 67.63%, while moderate droughts decrease to 20.27%, severe droughts increase to 9.21% and extreme droughts decrease to 2.89%.

These results suggest that the inclusion of evapotranspiration in the SPEI reduces the apparent intensity of extreme droughts, especially in Sudanese zones such as Comoé where temperatures are moderate. These trends are consistent with Sanogo et al. (2015), who showed that droughts in humid tropical zones are often dominated by moderate but frequent precipitation deficits.

6.1.3.2 Frequency and intensity distribution of Agricultural droughts

The analysis of agricultural droughts based on SPI6 shows identical frequencies for Comoé and Boulkiemdé provinces over 63 years, with both experiencing 363 months of drought and 393 months without drought. This symmetry reflects a remarkable uniformity in the impact of climate variability on agriculture, suggesting similar levels of vulnerability and resilience to medium-term water deficits in the two regions. The results differ slightly between the two provinces when calculated using SPEI6, which incorporates the effects of evapotranspiration. The province of Comoé experienced 379 months of drought and 377 months without drought, indicating a marginal predominance of drought conditions and highlighting the increased vulnerability to agricultural water deficits in this Sudanese zone. In contrast, Boulkiemdé recorded 364 months of drought and 394 months without drought, showing a significant reduction in the frequency of droughts compared to meteorological droughts (SPEI3) and an increase in the number of non-drought periods. This improvement suggests increased resilience to agricultural drought in the semi-arid Sudano-Sahelian region.

The comparison shows that while both provinces have comparable drought dynamics under SPEI6, the inclusion of evapotranspiration in SPEI6 reveals nuanced differences. Boulkiemdé benefits from a better balance between drought and non-drought periods, reflecting greater agricultural resilience to drought. Conversely, Comoé's slightly higher frequency of droughts in SPEI6 highlights its increased sensitivity to medium-term water deficits, requiring targeted agricultural and water management interventions to mitigate potential impacts. Figure 6.8 shows the distribution of meteorological drought intensities in the provinces of Comoé and Boulkiemdé, based on SPI6 and SPEI6 values.

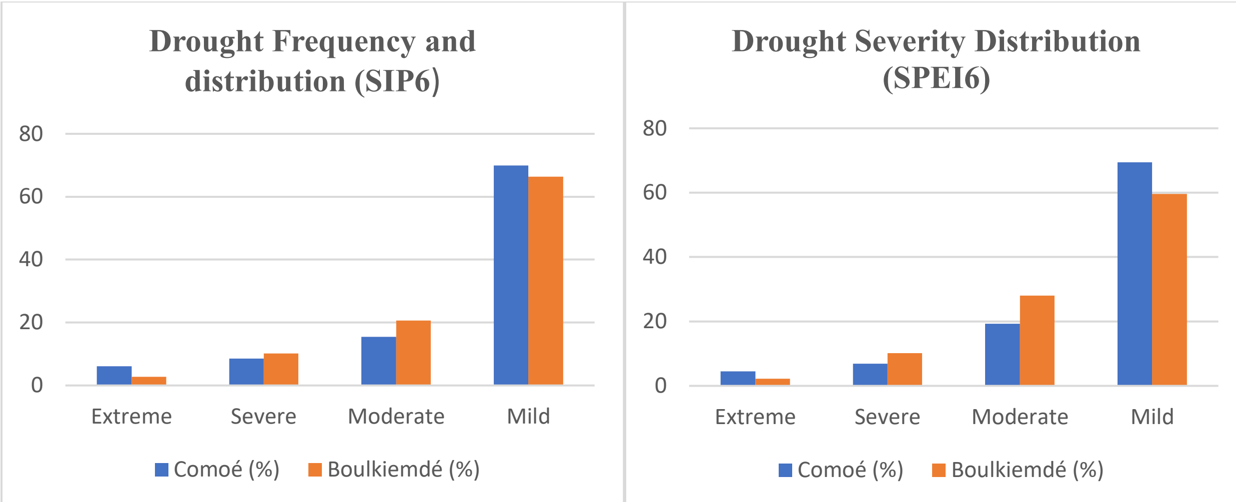


Figure 6.8: Agricultural droughts (SPI6 and SPEI6) Frequency and distribution in the provinces of Comoé and Boulkiemdé.

Agricultural droughts measured by the SPI6 show a predominance of Mild droughts in both provinces. In Comoé, Mild droughts account for 62.4%, followed by moderate (21.5%), severe (11.8%) and extreme (4.3%) droughts. In Boulkiemdé, light droughts dominate with 60.2%, followed by moderate (23.8%), severe (12.0%) and extreme (4.0%) droughts.

The use of SPEI6 changes this distribution slightly, particularly in Comoé, where light droughts increase to 69.39%, while moderate droughts decrease to 19.26%, severe droughts to 6.86% and extreme droughts increase slightly to 4.49%. In Boulkiemdé, SPEI6 shows an increase in moderate (28.02%) and severe (10.16%) droughts, while light droughts decrease to 59.62%. Extreme droughts remain stable at around 2.20%. These results underline the increasing influence of temperature on agricultural deficits in semi-arid areas. Similar observations were made by Ceccherini et al. (2017), who demonstrated that prolonged heat waves exacerbate the impact of agricultural drought in the Sudan-Sahelian region.

6.1.3.3 Frequency and intensity distribution of hydrological droughts

Based on the SPI12 index, Comoé experienced 372 months of drought and 384 months of no drought, while Boulkiemdé experienced 355 months of drought and 401 months of no drought. This indicates that Boulkiemdé had a slightly higher number of dry months than Comoé, reflecting the overall greater resilience to hydrological drought in the semi-arid Sudano-Sahelian region. When analysed using the SPEI12 index, Comoé experienced 382 months of drought and 374 months without drought, while Boulkiemdé experienced 379 months of drought and 377 months without drought.

These results show a relatively stable drought frequency in both provinces compared to shorter-term indices such as SPEI3 and SPEI6, which show greater variability. However, Comoé's slightly higher drought frequency (382) compared to non-drought periods (374) underscores its increased vulnerability to long-term water deficits, potentially exacerbating risks to water resources and ecosystem services in the Sudan zone. In contrast, Boulkiemdé shows a slightly better balance between drought (379 months) and non-drought periods (377 months) under SPEI12, suggesting slightly greater resilience in the Sudano-Sahelian region. These findings highlight that while both provinces are exposed to hydrological droughts, Sudan's Comoé province is more vulnerable to long-term drought impacts, emphasising the need for targeted water resource management strategies to mitigate potential risks. Figure 6.9 shows the distribution of meteorological drought intensities in the provinces of Comoé and Boulkiemdé, based on SPI12 and SPEI12 values.

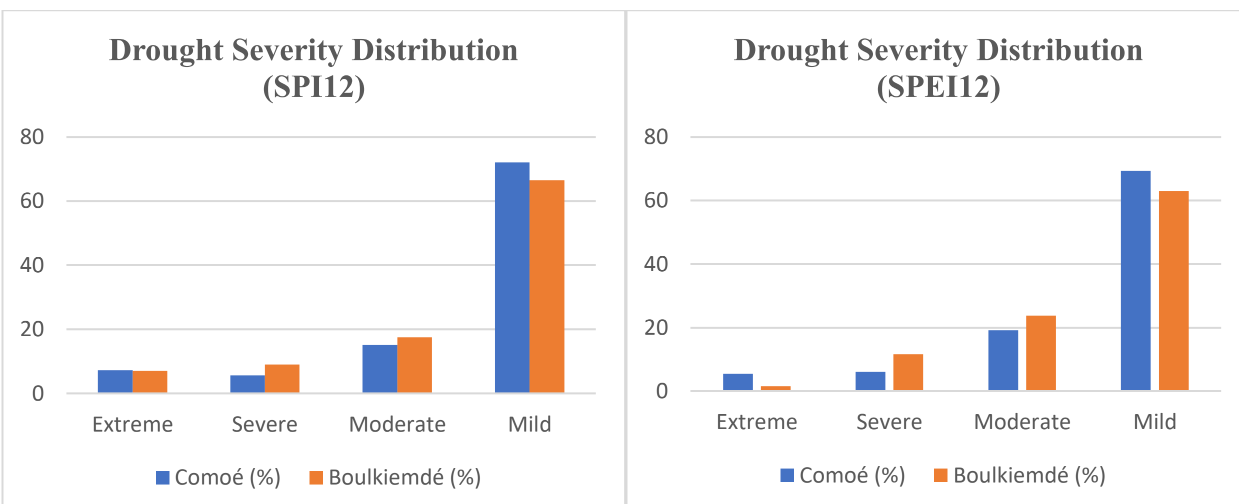


Figure 6.9: Agricultural droughts (SPI12 and SPEI12) Frequency and distribution in the provinces of Comoé and Boulkiemdé.

The analysis of hydrological droughts using SPI12 and SPEI12 shows differences in the frequency of prolonged droughts. In Comoé, SPI12 records 364 months of drought and 392 months without drought, with light droughts dominating (63.2%), followed by moderate (20.4%), severe (11.5%)

and extreme (4.9%) droughts. In Boulkiemdé, SPI12 shows a similar distribution with 62.1% light, 22.6% moderate, 12.3% severe and 3.0% extreme droughts.

However, SPEI12 shows slightly different trends. In Comoé, light droughts increase to 69.37%, while moderate droughts decrease to 19.11%, severe droughts to 6.02% and extreme droughts increase slightly to 5.50%. In Boulkiemdé, light droughts represent 63.06%, moderate droughts increase to 23.75%, severe droughts to 11.61% and extreme droughts decrease to 1.58%. These results confirm that incorporating evapotranspiration into SPEI enhances moderate and severe droughts, especially in semi-arid areas where high temperatures exacerbate water deficits. Zhang et al. (2019) support these observations, showing that prolonged droughts are often exacerbated by elevated temperatures, leading to significant hydrological deficits.

These results highlight the distinct dynamics of droughts in the provinces of Comoé and Boulkiemdé. Incorporating evapotranspiration into the SPEI tends to reduce the proportion of extreme droughts while increasing moderate and severe droughts, particularly in semi-arid zones such as Boulkiemdé. This highlights the importance of using combined indices to better characterise droughts and develop adaptation strategies for these regions.

6.1.3.4 Comparative Analysis of SPI and SPEI droughts frequencies

Regarding the extreme droughts, the SPEI generally indicates slightly lower proportions of extreme droughts compared to the SPI, except for SPI12 in both Comoé and Boulkiemdé.

In the Comoé province, the proportion of extreme droughts decreases from 5.33% (SPI3) to 4.07% (SPEI3). This reduction likely reflects the mitigating effect of evapotranspiration, which offsets some rainfall deficits. For the Boulkiemdé province, the extreme droughts measured by SPEI are significantly lower for long-term indices (SPEI12: 1.58% compared to SPI12: 7.04%), suggesting improved water management or less pronounced deficits over extended periods.

The SPEI highlights contrasting trends in severe droughts regarding. In the Boulkiemdé, severe droughts increase under SPEI, rising from 9.01% (SPI12) to 11.61% (SPEI12). This suggests that evapotranspiration exacerbates water deficits in this semi-arid region, where water availability is already limited. Severe droughts decrease slightly under SPEI, from 9.09% (SPI3) to 7.32% (SPEI3) in Comoé province, reflecting a reduced impact of evapotranspiration in this region with more favorable hydrological conditions.

The proportion of moderate droughts consistently increases with the SPEI, particularly in Boulkiemdé. For example, moderate droughts rise from 20.66% (SPI6) to 28.02% (SPEI6). This trend is attributed to heightened evapotranspiration in the Sudano-Sahelian zone, which amplifies water deficits, making moderate droughts more pronounced. The SPEI reduces the proportion of mild droughts across all categories, as the integration of evapotranspiration accentuates deficits. In the Boulkiemdé, they decrease from 66.48% (SPI12) to 63.06% (SPEI12), indicating increased water stress due to higher temperatures and evaporative demand.

The SPEI, which incorporates evapotranspiration, highlights the critical role of atmospheric demand in shaping water deficits. This is particularly evident in regions like Boulkiemdé, where semi-arid conditions amplify the impact of evapotranspiration. The province of Comoé shows resilience to moderate and severe droughts but faces a slight rise in extreme droughts under SPEI, likely due to more favorable climatic conditions and reduced evapotranspiration impacts. The Boulkiemdé shows heightened vulnerability to severe and moderate droughts under SPEI, reflecting greater susceptibility to water deficits exacerbated by evapotranspiration. The SPEI also shifts drought classifications, reducing the prevalence of mild droughts while increasing moderate and severe droughts. This trend underscores the importance of considering both rainfall deficits and atmospheric demand when assessing drought impacts.

The comparative analysis of SPI and SPEI highlights the need for tailored drought mitigation strategies. In regions like Boulkiemdé, where evapotranspiration significantly exacerbates water stress, measures such as improved irrigation efficiency, water conservation techniques, and agroforestry could mitigate impacts. In Comoé, efforts should focus on managing extreme droughts and maintaining resilience to severe droughts, leveraging favorable climatic conditions to sustain agricultural productivity and water availability.

6.1.4 SPI an SPEI based drought duration in Comoé and Boulkiemdé provinces

6.1.4.1 Meteorological droughts duration

In the Comoé region of the Sudanese climate, meteorological droughts assessed by SPI3 are relatively short. Moderate droughts last an average of 3.76 months, while severe droughts last 6.12 months, with a maximum of 10 months. Conversely, SPEI3 indicates longer durations for all classifications, with moderate droughts lasting an average of 5.65 months and severe droughts lasting 14.33 months, with a maximum of 32 months. This significant difference between SPI3 and SPEI3 highlights the impact of temperature-induced evapotranspiration, which prolongs droughts even in humid climates such as Comoé. These findings are in line with research by Bontogho et al. (2022), who showed that in Burkina Faso, indices that include evapotranspiration, such as SPEI, provide a more comprehensive picture of drought dynamics. Their study showed that temperature variability plays a critical role in extending the duration of droughts, especially in humid regions where rainfall alone is insufficient to mitigate hydrological stress. Similarly, Araujo Bonjean et al. (2023) noted that climate variability and evapotranspiration are pivotal in determining drought persistence in West Africa, supporting the observed discrepancies between SPI3 and SPEI3 in Comoé.

Boulkiemdé province

In Boulkiemdé, a semi-arid Sudano-Sahelian zone, SPI3 shows slightly longer durations of climatic drought compared to Comoé. Mild droughts last on average 4.76 months, while extreme droughts last about 6.43 months, both with a maximum duration of 10 months. However, the SPEI3 indicates significantly longer durations, with severe droughts lasting on average 15.36 months and reaching a maximum of 26 months. This discrepancy highlights the cumulative effects of temperature-induced evapotranspiration in prolonging drought conditions. These findings are in line with the observations of Noureldeen et al. (2020), who reported that evapotranspiration significantly prolongs drought duration in semi-arid Sahelian regions when assessed using SPEI rather than SPI. Figure x shows the average and maximum duration of droughts as a function of their severity, calculated on the basis of the SPI3 and SPEI3 in the provinces of Comoé and Boukiemdé. Figure 6.10 shows the average and maximum duration of droughts as a function of their severity, calculated on the basis of the SPI3 and SPEI3 in the provinces of Comoé and Boukiemdé.

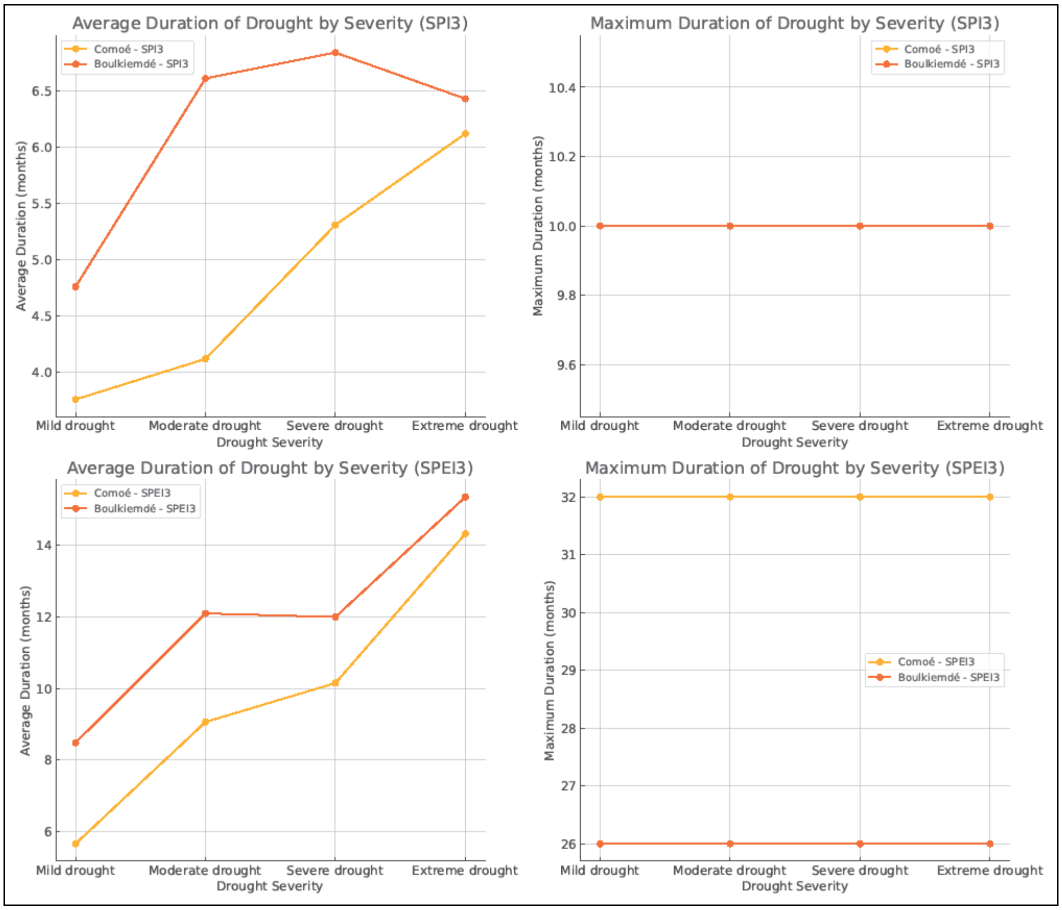


Figure 6.10: Drought duration by severity calculated from SPI 3 and SPEI 3

The plots for SPI3 and SPEI3 provide a detailed comparison of drought duration by severity in the provinces of Comoé and Boulkiemdé. For SPI3, the first plot (a) shows the average duration of droughts for each severity level (mild, moderate, severe and extreme). Boulkiemdé shows longer average durations than Comoé for moderate and severe droughts. The second plot (b) highlights the maximum duration of droughts, which remains constant at 10 months across all severity levels for both provinces. For SPEI3, the third plot (c) shows the average duration of droughts, with Boulkiemdé having longer durations than Comoé for all severities. This trend is particularly pronounced for extreme droughts. The fourth (d) graph shows the maximum duration of droughts, where Comoé has a longer duration of 32 months compared to 26 months in Boulkiemdé. These visualisations underline the different drought characteristics in the two provinces, with Boulkiemdé generally experiencing longer average drought durations and Comoé showing more prolonged maximum droughts under certain conditions.

6.1.4.2 Agricultural Droughts duration

In Comoé, agricultural drought measured utilizing SPI6 demonstrates comparatively brief durations, with severe aridity enduring an average of 5.31 months and extreme aridity continuing for 6.12 months, both with a maximum of 10 months. SPEI6, however, discloses markedly longer durations, with severe aridity averaging 10.15 months and extreme aridity extending to 14.33 months on average, with a maximum of 32 months. The incorporation of evapotranspiration in SPEI underscores the compounded influence of temperature-induced water losses on agrarian systems, particularly during the cultivation season. Dardel et al., (2014) discerned analogous patterns in Sudanian zones, where elevated temperatures and erratic precipitation patterns intensify soil moisture deficits, resulting in prolonged agricultural aridity. Their investigation illustrated that SPEI offers a more precise representation of aridity dynamics in comparison to SPI. Similarly, Faye et al. (2022) found that SPEI offered a more accurate representation of agricultural aridity than SPI. The extended drought durations observed with SPEI were attributed to the increasing influence of evapotranspiration, which has become a dominant factor in determining water deficits in the semi-arid climate of West Africa. These findings support the results observed in Comoé, where SPEI revealed longer durations of agricultural droughts compared to SPI.

In Boulkiemdé, SPI6 findings indicate extended durations for agricultural aridity relative to Comoé, with severe aridity lasting an average of 6.84 months and extreme aridity persisting for 6.43 months, both with a maximum of 10 months. SPEI6 unveils even greater durations, with severe aridity averaging 12.00 months and extreme aridity continuing for 15.36 months on average, with a maximum of 26 months. The prolonged durations reflect the impact of semi-arid conditions and evapotranspiration on agricultural aridity persistence. 00971 565905114

These observations are congruent with conclusions drawn by Diasso and Abiodun, (2017), who demonstrated that semi-arid zones undergo extended agricultural aridity due to elevated evapotranspiration rates. For Sayat et al. (2025), the SPI frequently minimises drought durations in these regions, as it fails to consider the water losses induced by temperature. Ceccherini et al. (2017) underscored that rising temperatures in the Sudano-Sahelian region exacerbate soil moisture deficits, rendering SPEI an essential instrument for comprehending agricultural aridity. Figure 6.11: shows the average and maximum duration of droughts as a function of their severity, calculated on the basis of the SPI6 and SPEI6 in the provinces of Comoé and Boukiemdé.

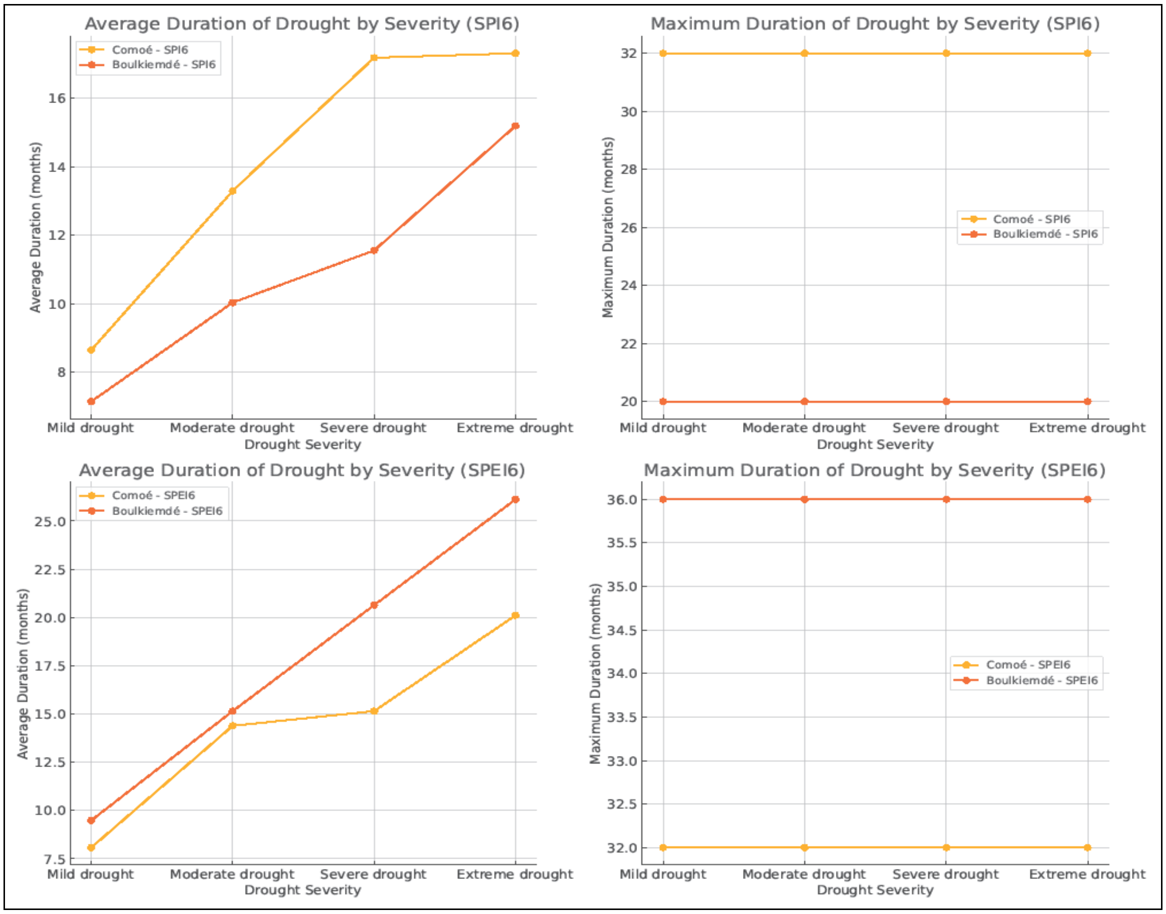


Figure 6.11: Drought duration by severity calculated from SPI6 and SPEI6

The plots for SPI6 and SPEI6 provide a detailed comparison of drought duration by severity in Comoé and Boulkiemdé provinces. For SPI6, the first plot shows the average duration of droughts across severity levels, including mild, moderate, severe and extreme droughts, in both provinces. While the average durations are similar, the maximum duration of droughts, shown in the second plot, shows that Comoé consistently reaches a maximum of 32 months, while Boulkiemdé experiences shorter maximum durations of 20 months. For SPEI6, the third plot highlights the average duration of droughts, showing longer durations in Boulkiemdé compared to Comoé, especially for severe and extreme droughts. The fourth plot shows the maximum duration of droughts, with Boulkiemdé reaching a maximum of 36 months, exceeding the maximum of 32 months recorded in Comoé. These plots provide a clearer and more nuanced understanding of drought dynamics in the two provinces, showing the differences in both severity and duration depending on the indicator used.

6.1.4.3 Hydrological droughts duration

In Comoé, SPI12 reveals hydrological droughts lasting up to 35 months for extreme events, with severe droughts averaging 31.67 months. SPEI12 shows even longer durations, with extreme droughts averaging 34.81 months and reaching a maximum of 43 months. These results highlight the importance of cumulative water deficits and the influence of evapotranspiration in prolonging drought duration. As observed by Zhang et al. (2019), similar patterns were found in tropical areas, where prolonged droughts are significantly exacerbated by cumulative rainfall deficits and increasing evapotranspiration. Makougoum et al. (2020) further demonstrated that SPEI provides a more holistic understanding of hydrological drought dynamics in humid regions compared to SPI.

In Boulkiemdé, SPI12 implies that extreme hydrological droughts last up to 47 months, with severe droughts lasting on average 34.75 months. SPEI12, on the other hand, shows much longer durations, with extreme droughts lasting an average of 119 months. These longer durations highlight the compounding effects of cumulative precipitation deficits and temperature-induced evapotranspiration in the semi-arid Sudano-Sahelian zone. In their 2020 analysis, Hassan et al. found that SPEI is adept at detecting persistent hydrological droughts in places where evapotranspiration amplifies water scarcity. As highlighted by Nicholson et al. (2018), the combination of rising temperatures and climate variability is exacerbating prolonged droughts, establishing SPEI as an essential tool for in-depth analysis in semi-arid landscapes. In addition, Faye, (2022) further emphasised that SPEI is particularly advantageous for capturing prolonged climatic droughts in West Africa, where temperature increases exacerbate hydrological stresses.

Figure 6.12 illustrates the average and maximum duration of droughts as a function of their severity, calculated on the basis of SPI12 and SPEI12 in the provinces of Comoé and **Boulkiemdé.**

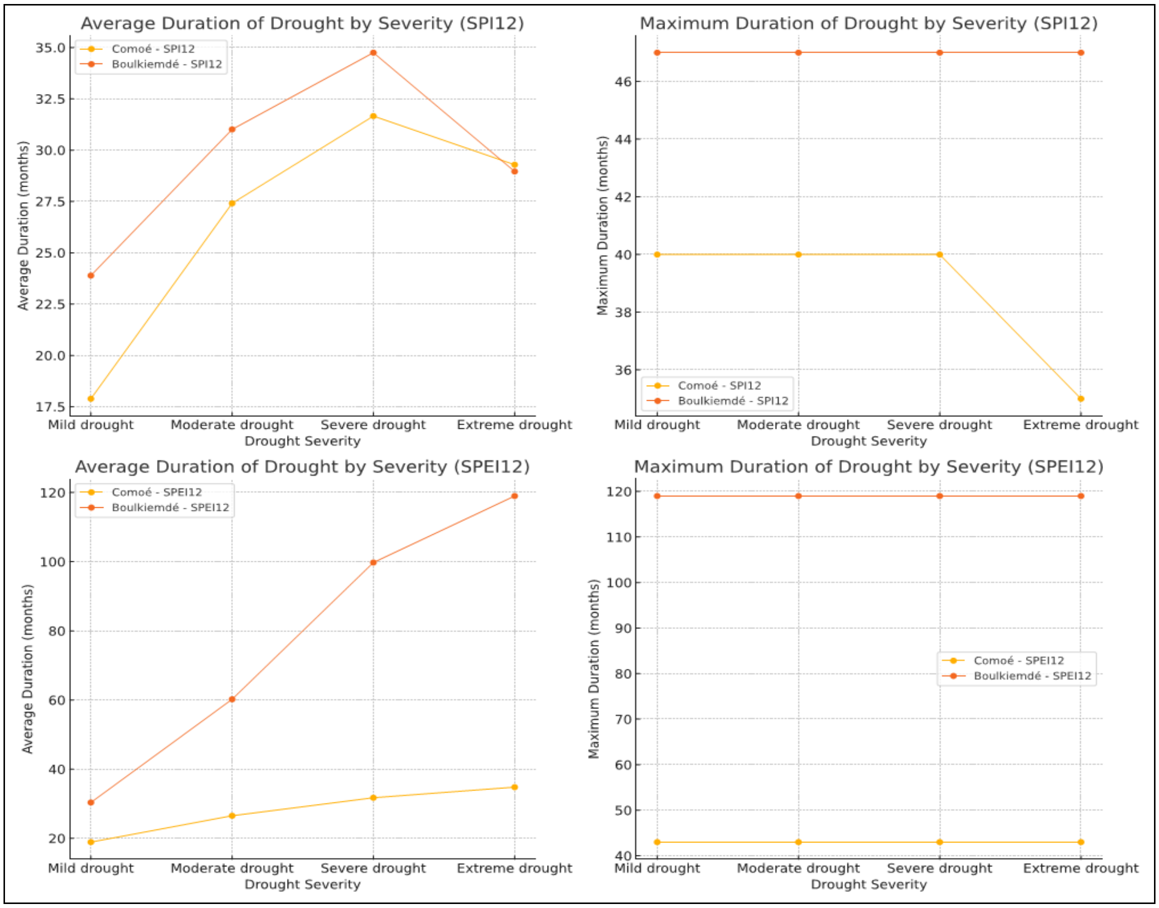


Figure 6.12: Drought duration by severity calculated from SPI12 and SPEI12

The plots for SPI12 and SPEI12 provide a comparative analysis of drought duration by severity in the provinces of Comoé and Boulkiemdé. For SPI12, the first plot highlights the average duration of droughts for each severity level - mild, moderate, severe and extreme. Boulkiemdé has longer average durations than Comoé for all severity levels. The second graph illustrates the maximum duration of droughts, with Boulkiemdé consistently having longer maximum durations than Comoé. For SPEI12, the third plot shows the average duration of droughts, revealing significant differences between the two provinces. Boulkiemdé experiences much longer durations than Comoé, especially for severe and extreme droughts. The fourth plot shows the maximum duration of droughts, with Boulkiemdé having a significantly higher maximum duration (119 months) than Comoé (43 months). These plots provide a comprehensive comparison of drought dynamics at the hydrological scale, highlighting the longer and more severe droughts in Boulkiemdé compared to Comoé.

6.1.5 Analysis of drought return levels using combined indices for Comoé and Boulkiemdé

The analysis of return levels of combined indices (SPI-SPEI) for the provinces of Comoé (Sudanese zone) and Boulkiemdé (Sudano-Sahelian zone) reveals contrasting drought dynamics. These return values, calculated for return periods of 2, 5, 10, 20, 50 and 100 years, allow the intensity of drought events to be assessed in relation to their rarity. The results for each province are compared with similar studies carried out in Burkina Faso and other regions of West Africa.

6.1.5.1 Return levels for Comoé

Figure 6.13 shows the relationship between drought intensity (measured by the combined index) and return period (in years) in the Come province. It relates the combined drought index levels to return periods of 2, 5, 10, 20, 50 and 100 years.

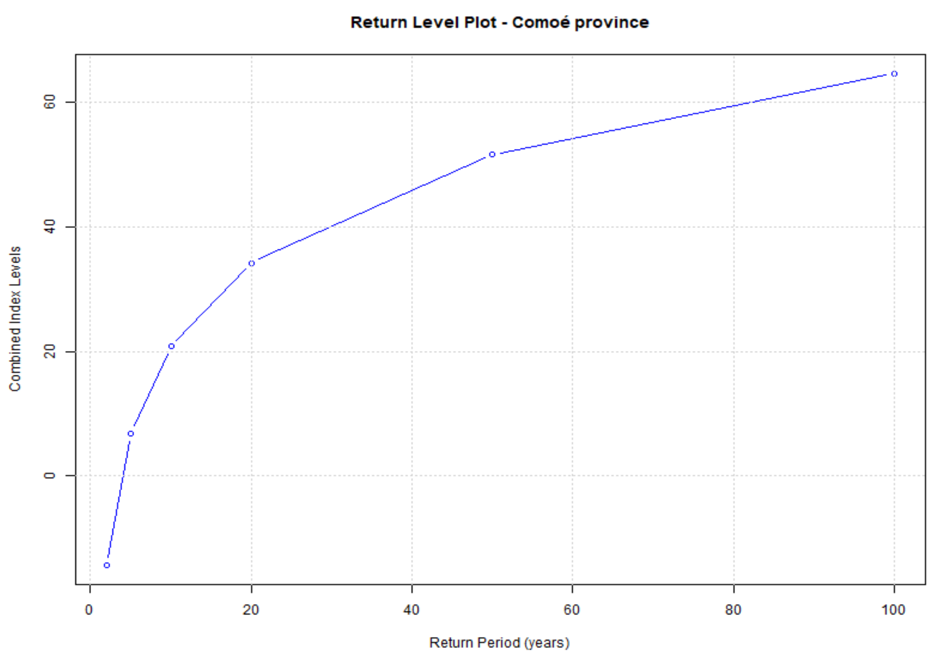


Figure 6.13: Return levels graph for the province of Comoé

In Comoé, return levels show a significant increase in drought intensity with longer return periods. For a 2-year return period, the combined index is negative (-14.25), indicating that frequent droughts in this region are moderate or that excess rainfall compensates for water deficits. These results are consistent with the findings of Bontogho et al. (2022), who showed that in the Massili basin of Burkina Faso, while periodic droughts occur, sufficient rainfall can mitigate the intensity of short-term deficits. From a return period of 5 years, the index becomes positive (6.84) and continues to increase, reaching 20.81 and 34.21 for return periods of 10 and 20 years, respectively. These values reflect the increasing intensity of moderate and severe droughts as their frequency decreases. The observations of Araujo Bonjean et al. (2023) support this trend, showing that in West African regions, medium-term droughts are often the result of combined rainfall deficits and increased evapotranspiration rates. For longer return periods (50 and 100 years), the return values reach 51.55 and 64.55, indicating rare but very intense extreme droughts. These results are consistent with regional analyses by Sy et al. (2021) which demonstrated that in West Africa, prolonged drought events are amplified by extreme climatic anomalies, including heat waves and interannual rainfall variability.

6.1.5.2 Return levels for Boulkiemdé

Figure 6.14 shows the relationship between drought intensity (measured by the combined index) and return period (in years) in the Boulkiemde province.

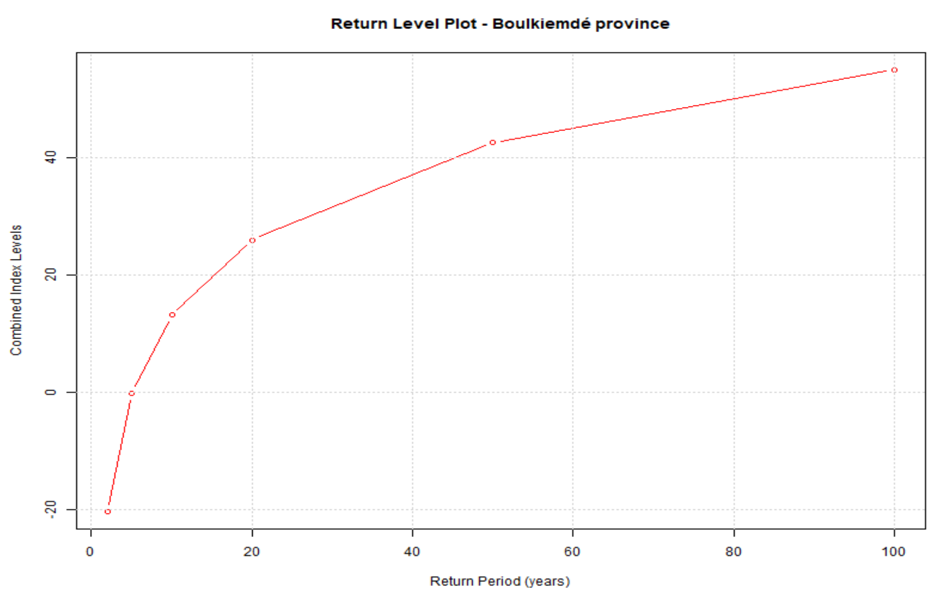


Figure 6.14: Return levels graph for the province of Boulkiemdé

In Boulkiemdé, return levels follow a similar pattern, but with less intensity than in Comoé. For a 2-year return period, the combined index is also negative (-20.22), reflecting mild droughts or occasional rainfall excesses over short periods. This result is consistent with the observations of Abaje et al. (2013), who showed that the Sudano-Sahelian regions are characterised by irregular rainfall patterns, but that water deficits only become significant for less frequent events. For medium return periods of 5 to 20 years, the return levels increase from -0.09 to 13.23 and 26.00. This indicates that moderate droughts are more frequent in this region and that their intensity increases with longer return periods. These findings are consistent with the work of Tefera et al., (2025), who reported that droughts in the Sahel often manifest as moderate but recurrent water deficits due to high rainfall variability. For longer return periods of 50 and 100 years, the return levels reach 42.55 and 54.95, respectively, indicating extreme droughts that are less intense than those in Comoé. This reflects the semi-arid conditions of Boulkiemdé, where droughts are more frequent but rarely catastrophic. These observations confirm the conclusions of Nicholson, (2013), who noted that in Sudano-Sahelian regions, extreme droughts are often mitigated by low soil water retention and vegetation adapted to water deficits.

6.1.5.3 Comparison between Comoé and Boulkiemdé

Figure 6.15 compares the return levels plots for Comoé and Boulkiemdé. It shows at a glance the differences and similarities between the two provinces.

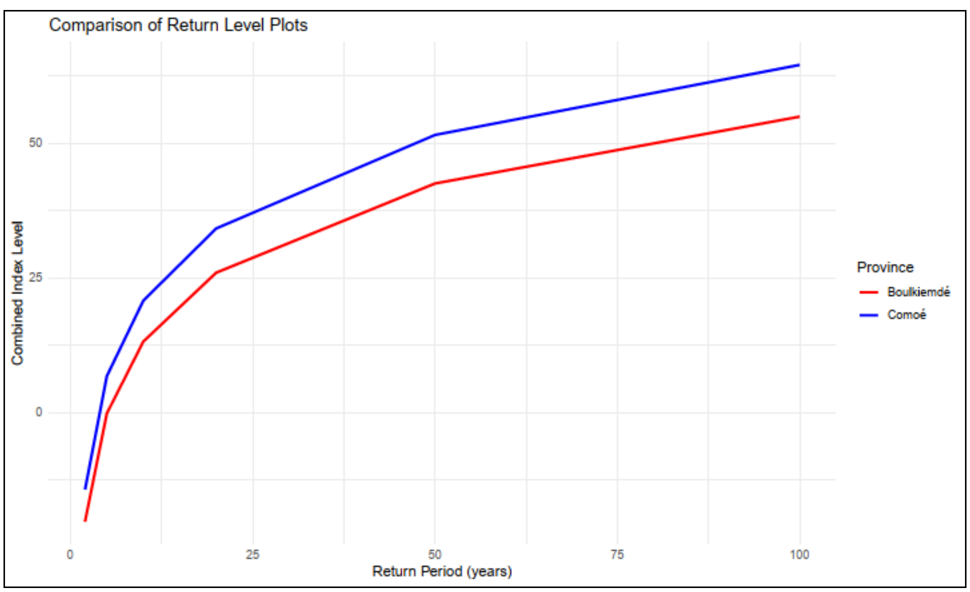


Figure 6.15: Comparative graph of return levels in Comoé and Boulkiemdé

The return levels show significant differences between Comoé and Boulkiemdé. For short return periods (2 to 5 years), the values are negative for both provinces, but those for Boulkiemdé are lower, reflecting the more frequent and milder droughts in this semi-arid region. Starting from medium return periods (10 to 20 years), the return levels become positive for both provinces, but the values increase more rapidly in Comoé. This indicates that prolonged droughts are more severe in the Sudanese region than in Boulkiemdé. For long return periods (50 to 100 years), the return levels peak at 64.55 in Comoé and 54.95 in Boulkiemdé. These differences reflect specific climatic dynamics. Comoé, with higher annual rainfall, accumulates prolonged water deficits during rare events, whereas Boulkiemdé, with lower rainfall, experiences more frequent but less intense droughts. Those results for both provinces are consistent with studies conducted in West Africa. For example, Tefera et al. (2025) showed that extreme droughts are rare but intense in the Sudanese zone, while they are more frequent but moderate in the Sudano-Sahelian zone. Similarly, Marcotullio et al. (2021) highlighted that droughts in tropical humid zones are exacerbated by prolonged heat waves, which explains the higher return levels for long periods in Comoé.

The return levels of the combined indices reveals contrasting drought dynamics between Comoé and Boulkiemdé. In Comoé, droughts are less frequent but more intense, whereas in Boulkiemdé they are more frequent but more moderate.

6.1.6 Migration Dynamics in the Provinces of Comoé and Boulkiemdé

Migration dynamics in the provinces of Comoé and Boulkiemdé show distinct and contrasting trends in terms of inflows, outflows and net migration. Analysed over the years 1985, 1996, 2006 and 2019, these data reflect the socio-economic and environmental contexts specific to each province.

6.1.6.1 Migration dynamics in the province of Comoé

The Comoé province was characterised by consistently positive net migration throughout the period under study. In 1985, net migration amounted to 16,513, with 27,566 arrivals and only 11,053 departures. This situation highlights a relatively stable and attractive province, probably due to the favourable climatic conditions associated with its location in the Sudanese zone. These findings are in line with the work of Henry et al. (2004), who showed that the Sudanese regions of

Burkina Faso attract more people due to higher rainfall and agricultural resources compared to more arid areas.

In 1996, net migration increased to 24,621, driven by a rise in inflows to 41,294, while outflows remained low at 16,673. In 1996, net migration increased to 24,621 people, as a result of an increase in inflows to 41,294 people, while outflows remained low at 16,673 people. This can be explained by the fact that the former cotton-growing area, which was mainly located in the Mouhoun and Houet regions, became saturated in the 1990s, and migrants were confronted with land tenure insecurity (Claims/Issp, 2005; Nana, 2018). This area is gradually losing migrants to the new pioneer front, in particular the Comoé provinces, which began to record large inflows of internal migrants in the 1990s (Nana, 2018; Ouedraogo et al., 2010).

The year 2006 marks a notable peak, with net migration reaching 69,012, supported by exceptionally high inflows of 93,523 and limited outflows of 24,511. The sharp increase in inflows can be explained by two major events (Nana, 2018; Zongo, 2009).The first is the inter-community conflict that broke out in the Ivorian town of Tabou in 1999, which led to the repatriation of thousands of migrants from Burkina Faso. In addition, the outbreak of the politico-military crisis (the rebellion) in Côte d'Ivoire led to the mass departure of migrants from that country. These migrants, mainly from the ‘Mossi plateau’, have mostly returned to settle in the province of Comoé, which has more favourable climatic conditions and is less densely populated than their places of origin.

In 2019, inflows fell slightly to 86,703, but net migration remained positive at 43,511. This slight decline may reflect increased competition from urban areas, which are attracting a growing share of the national migrant population. Schoumaker and Dabiré (2014) confirm this trend, noting that increasing urbanisation in regions such as Bobo-Dioulasso has contributed to attracting some of the migration flows.

The province of Comoé consistently displayed positive net migration in the years analysed (1985, 1996, 2006 and 2019). In 1985, Comoé recorded a net migration of 16 513, with inflows of 27 566 and outflows of 11 053. The province's location in the Sudan zone, which benefits from higher annual rainfall and favourable agricultural conditions, probably contributed to its attractiveness. Research by Nébié and West, (2019) highlights that provinces in the Sudanian zone, characterised by relatively stable climatic conditions and better agricultural potential, are consistently more attractive for migration. These findings are also consistent with Sanfo et al. (2017), who found that productive agricultural zones in Burkina Faso tend to attract rural populations fleeing drier regions.

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2019, while inflows to Comoé decreased slightly to 86,703, the province maintained a positive net migration of 43,511. This slight decline in attractiveness may reflect increased competition from urban areas such as Bobo-Dioulasso, which have experienced rapid industrialization and urbanization. A study by Guipo, (2019) corroborates this trend, indicating that since the 1990s, migratory movements have frequently been directed towards major urban centers like Ouagadougou and Bobo-Dioulasso, as well as secondary cities in regions with high natural potential, such as the cotton-growing areas of the West and South.

6.1.6.2 Migration dynamics in the province of Boulkiemdé

In contrast to Comoé, Boulkiemdé experienced negative net migration throughout the period analysed. In 1985, the inflow was 22,927, but the outflow reached 80,742, resulting in a net migration of -57,805. This pattern reflects the more difficult socio-economic and environmental conditions of the Sudano-Sahelian zone of Burkina Faso. The great droughts of the 1970s and 1980s contributed to the mass exodus of people from these areas, where the climatic conditions were the worst (Niva et al., 2021; Nébié & West, 2019). These findings are consistent with Henry et al. (2004), who documented significant population losses from arid and semi-arid zones to more favourable areas. In 1996, immigration increased slightly to 27,108, while emigration increased to 83,742, resulting in a negative net migration of -56,634. This stagnation may be due to persistent challenges such as limited economic opportunities and increased rainfall variability.

In 2006, the province recorded its highest migration loss, with a net migration of -76,389. Inflows reached 31,636, but outflows rose to 108,025. This significant loss is probably due to environmental factors, in particular the frequent droughts in the Sudano-Sahelian zones, which drive the population towards more fertile agricultural areas in west (Sawadogo, 2022). Teye and Nikoi, (2022) showed that climatic shocks, especially droughts, are a major driver of migration in semi-arid regions of West Africa.

In 2019, the province of Boulkiemdé recorded a peak in inflows of 73,644 individuals, but outflows were higher at 130,420 individuals, resulting in a net migration of -56,776. This is not consistent with the increase in humidity conditions noted in the analysis of drought trends (SPEI) in the province and confirmed by Sanou et al. (2023) in the Sudano-Sahelian zone. This migration trend highlights the persistence of structural challenges, in particular high demographic pressure, land scarcity and limited economic resources (Zoma et al., 2024).

6.1.6.3 Comparison between Comoé and Boulkiemdé

Figure 6.16 clearly illustrates the dynamics of inflows and outflows for Boulkiemdé and Comoé for the years 1985, 1996, 2006 and 2019, while Figure 6.17 shows the trends in net migration for the two provinces.

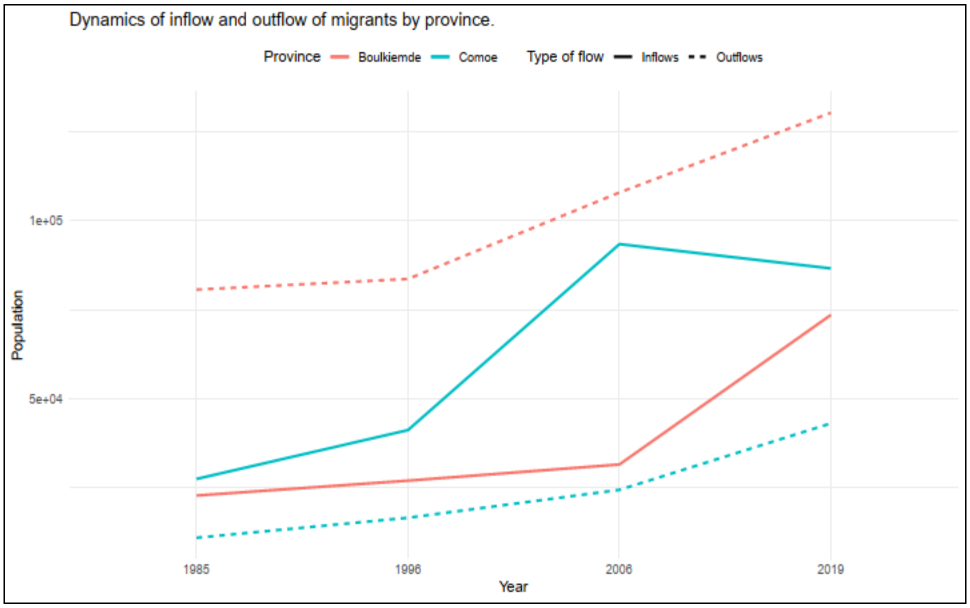

Figure 6.16: Trend of inflow and outflow of migrants in Boulkiemdé and Comoé

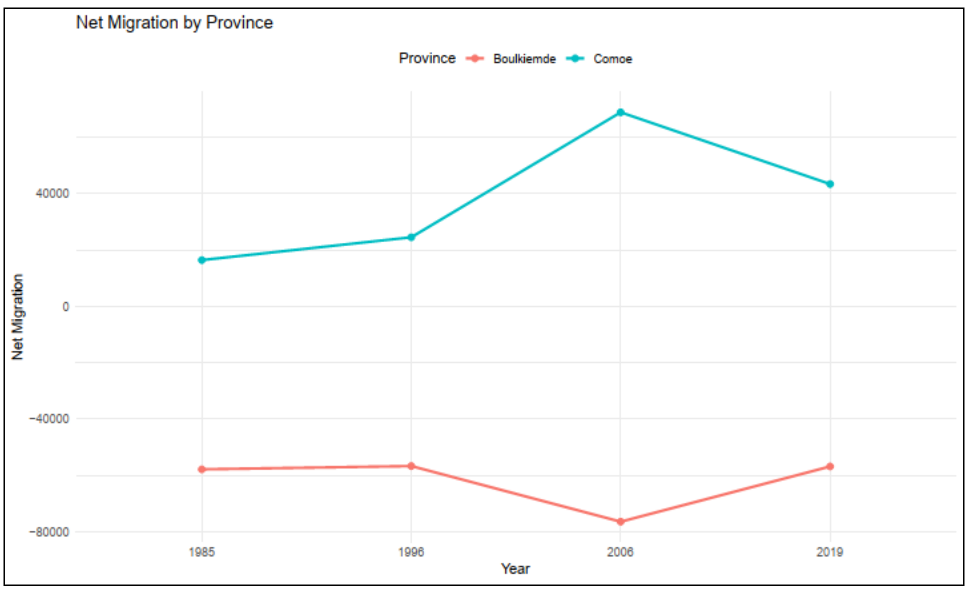

Figure 6.17: Trend in net migration in Boulkiemdé and Comoé

The province of Comoé has consistently recorded higher inflows than outflows, reflecting its continued attractiveness. In 2006, inflows peaked at 93,523, probably due to favourable economic and agricultural conditions. Although inflows declined slightly in 2019 (86,703), net migration remained positive at 43,511, confirming that the province continues to attract significant numbers of migrants. Net migration peaked in 2006 (69,012), reflecting a period of increased attractiveness. These findings are consistent with studies of migration in West Africa, which show that Sudanese regions with better climatic and economic conditions attract more migrants (Nébié & West, 2019; Sanfo et al., 2017). In contrast, the province of Boulkiemdé consistently shows lower inflows relative to outflows, resulting in a persistent negative net migration. In 2019, inflows increased significantly to 73,644, while outflows peaked at 130,420, reflecting continued population loss. This trend is attributed to socio-economic and environmental constraints, such as limited resources and adverse climatic conditions, as similarly observed by Schürmann et al. (2022) in other semi-arid and arid zones in Burkina Faso. Net migration reached a notable low in 2006 (-76,389) and improved slightly by 2019 (-56,776), possibly due to population maintenance efforts.

Migration dynamics in the provinces of Comoé and Boulkiemdé reflect divergent socio-economic and environmental contexts. Comoé stands out for its ability to attract and retain its population, largely due to favourable climatic conditions and growing economic opportunities. Conversely, Boulkiemdé experiences persistent population loss due to structural and environmental challenges. These findings are consistent with observed migration trends in Burkina Faso and West Africa, where Sudanian regions attract more migrants, while Sudano-Sahelian regions continue to lose their population (Schürmann et al., 2022;Teye & Nikoi, 2022).

6.1.7 Linking migration and drought in Comoé and Boulkiemdé Provinces

The Comoé in the Soudanian zone and the Boulkiemdé in the Soudanian-Sahelian zone provide contrasting contexts in which to explore possible links between drought conditions, as measured by the SPI and SPEI indices, and the dynamics of migration. The Pearson correlation matrix is used to quantify the links between these climatic indices and migratory flows - specifically inflows, outflows and net migration. A province-by-province analysis highlights the unique characteristics of migratory dynamics in each province, while also exploring similarities and differences in how climatic conditions affect these flows.

6.1.7.1 Migration and drought dynamics in the province of Comoé

Table 6.2, showed Pearson correlation matrix between SPI/SPEI and migration variables in Comoé.

In 1985, the province of Comoé experienced slightly humid climatic conditions, characterised by positive SPI and SPEI indices, although both remained below 1. The Pearson correlation between the SPEI6 and inflows was 0.81, and the correlation with net migration was similarly high at 0.8.

These values underline the strong influence of medium-term wet conditions on migration dynamics in the province. During this period, inflows represented 15.44% of the population, while outflows were 6.19%, resulting in a positive net migration rate of 9.25%. These findings are consistent with Hassan and Tularam, (2018), who showed that favourable climatic conditions promote rural retention and even attract migrants to agriculturally productive regions in Burkina Faso and Senegal.

By 2006, the province had become slightly more humid. Inflows increased significantly to 22.95%, while outflows decreased slightly to 9.01%, resulting in a net migration rate of 16.93%. Correlations showed a very strong relationship between SPI6 and net migration, with a correlation value of 0.88, highlighting the positive impact of medium-term wet conditions on migration attractiveness. These findings are in line with Van der Land et al. (2018), who noted that improved precipitation seasons facilitate internal migration in West Africa, especially in areas with stable agricultural conditions.

In 2019, despite favourable climatic conditions as indicated by positive SPI and SPEI indices, migration flows declined compared to 2006. Inflows represented only 13.70% of the population, while outflows increased slightly to 6.83%, resulting in a lower net migration rate of 6.88%. Nevertheless, correlations showed a strong relationship between climate indices and migration flows, with the SPI12 showing a positive correlation of 0.87 with net migration. These results suggest that although climatic conditions were favourable, other factors such as land saturation and declining economic opportunities played a key role in limiting migration to the province. This is in line with the conclusions of Piguet et al. (2011), who highlighted the predominant influence of socio-economic factors in climate-related migration.

Table 6.2: Pearson correlation matrix between SPI/SPEI and migration variables in Comoé

Year	**1985**			**1996**			**2006**			**2019**		
Variable	**Inflows**	**Outflows**	**Net Migration**	**Inflows**	**Outflows**	**Net Migration**	**Inflows**	**Outflows**	**Net Migration**	**Inflows**	**Outflows**	**Net Migration**
SPI3 Comoé	0.63	-0.48	0.71	-0.49	0.41	-0.56	0.77	-0.62	0.84	0.58	-0.44	0.65
SPI6 Comoé	0.75	-0.42	0.78	-0.63	0.38	-0.67	0.82	-0.67	0.88	0.49	-0.37	0.57
SPI12 Comoé	0.02	-0.37	0.29	-0.68	0.32	-0.72	0.29	-0.41	0.55	0.81	-0.63	0.87
SPEI3 Comoé	0.68	-0.51	0.77	-0.52	0.42	-0.61	0.53	-0.48	0.69	0.23	-0.17	0.35
SPEI6 Comoé	0.81	-0.43	0.8	-0.51	0.35	-0.59	0.61	-0.49	0.74	0.33	-0.19	0.41
SPEI12 Comoé	0.33	-0.28	0.58	-0.47	0.31	-0.53	0.15	-0.22	0.32	0.72	-0.56	0.83

$|r|<0.3$: Low correlation; **$0.3 \leq |r|<0.7$:** Moderate correlation, **$|r| \geq 0.7$** : Strong correlation

Source: Authors computation

6.1.7.2 Migration and drought dynamics in the province of Comoé

Table 6.3 showed the Pearson correlation matrix between SPI/SPEI and migration variables in Boulkiemdé.

In 1985, negative SPI and SPEI indices indicated prolonged droughts, resulting in high emigration of 22.11% of the population and limited immigration of 6.28%, leading to a highly negative net migration rate of -15.83%. Pearson correlations revealed a strong relationship between prolonged droughts and migration flows, with SPI12 showing a highly negative correlation of -0.912 with net migration. SPI3 also showed a moderate negative correlation of -0.612 with inflows and a strong positive correlation of 0.743 with outflows. These results are in line with Bruning & Piguet, (2018), who showed that droughts exacerbate outflows in vulnerable agricultural regions.

In 1996, when climatic conditions remained dry, slight improvements were observed. Outflows decreased to 19.88%, while inflows increased slightly to 6.43%, resulting in a less negative net migration rate of -13.44%. The SPI12 continued to show a strong negative correlation with inflows (-0.837) and a moderate positive correlation with outflows (0.629), confirming the impact of prolonged droughts. These findings are consistent with Van der Land et al. (2018), who found that environmental conditions affect migration, but are moderated by economic and social factors. Azumah and Ahmed, (2023) similarly, found that in addition to climate factors, migration decision of maize famers in Ghana is influenced by socio-economic factors such as household size, farming experience, access to credit, training in climate-smart farming, access to extension services and information provided by extension agents.

In 2006, the intensification of prolonged droughts exacerbated migration dynamics. Outflows increased to 21.69%, while inflows decreased slightly to 6.35%, resulting in a net migration rate of -15.34%. The SPI12 again showed a strong negative correlation of -0.912 with net migration, confirming the negative impact of prolonged droughts on migration. The SPI3 also showed a moderate negative correlation with inflows (-0.612) and a strong positive correlation with outflows (0.743), reflecting the significant impact of adverse climatic conditions on migration flows.

By 2019, significant improvements in rainfall, indicated by positive SPI and SPEI indices, led to an increase in inflows of 10.69% and a decrease in outflows of 18.92%. This reduced the negative net migration rate to -8.24%. The SPI12 showed a very strong positive correlation with net migration (0.974) and a strong negative correlation with outflows (-0.862), suggesting that prolonged periods of wetness favoured increased inflows and reduced outflows. These findings are consistent with Diallo, (2024a), who observed that improved precipitation stabilises migration flows in regions affected by climate variability in Senegal.

Table 6.3: Pearson correlation matrix between SPI/SPEI and migration variables in Boulkiemdé

Year	1985			1996			2006			2019		
Variable	**Inflows**	**Outflows**	**Net Migration**	**Inflows**	**Outflows**	**Net Migration**	**Inflows**	**Outflows**	**Net Migration**	**Inflows**	**Outflows**	**Net Migration**
SPI3 Boulk.	-0.612	0.743	-0.889	0.345	-0.471	0.558	0.611	-0.719	0.842	0.611	-0.719	0.842
SPI6 Boulk.	-0.531	0.648	-0.805	0.218	-0.318	0.419	0.715	-0.805	0.891	0.715	-0.805	0.891
SPI12 Boulk.	-0.837	0.629	-0.912	0.104	-0.205	0.291	0.928	-0.862	0.974	0.928	-0.862	0.974
SPEI3 Boulk.	-0.047	0.283	-0.355	-0.278	0.341	-0.473	0.354	-0.405	0.489	0.354	-0.405	0.489
SPEI6 Boulk.	0.221	-0.195	0.109	-0.381	0.508	-0.641	-0.189	0.232	-0.289	-0.189	0.232	-0.289
SPEI12 Boulk.	-0.341	0.524	-0.602	-0.469	0.612	-0.769	-0.356	0.495	-0.623	-0.356	0.495	-0.623

6.1.7.3 Comparative analysis between Comoé and Boulkiemdé

Comparing the provinces of Comoé and Boulkiemdé, it is clear that climatic conditions, as measured by the SPI and SPEI indices, have a significant impact on migration dynamics. However, the impact of droughts is more pronounced in Boulkiemdé, where they consistently lead to negative net migration rates, while in Comoé wet periods generally support positive migration dynamics. This difference can be attributed to factors such as the level of socio-economic development, the availability of arable land and economic opportunities, which determine how populations respond to climatic conditions. These observations are consistent with the findings of Fernández et al. (2024), which emphasise that while climate is a key driver of migration, its effects need to be examined within a broader framework of socio-economic and structural dynamics.

6.2 Conclusion

The analysis of drought dynamics in the provinces of Comoé and Boulkiemdé, based on SPI and SPEI indices, reveals significant differences in climate trends and their impacts on migration. Comoé, located in the Sudanian zone, experiences less frequent but more intense droughts, with a maximum intensity of -4.1 (SPI3) for extreme meteorological droughts and extreme hydrological droughts lasting up to 43 months (SPEI12). In contrast, Boulkiemdé, situated in the Sudano-Sahelian zone, is affected by prolonged and severe droughts, particularly in the long term, with extreme hydrological droughts lasting up to 119 months (SPEI12). The integration of evapotranspiration in the SPEI index underscores the growing impact of rising temperatures, particularly in Comoé, where hydrological degradation is reflected in a statistically significant negative trend in SPEI12 (Sen's slope = -0.001, p-value = 0.0).

The assessment of drought intensity across different timescales indicates that more intense droughts are observed in Comoé**,** particularly in the long term, as reflected by SPI12 and SPEI12 values. However, Boulkiemdé shows resilience through occasional localized hydrological recovery, with SPEI indices indicating slight positive trends over time (e.g., SPEI6 Sen's slope = +0.001, p-value = 0.0). Agricultural and hydrological droughts exhibit increasing severity in both regions, as evidenced by SPEI6 and SPEI12, reinforcing the need for targeted water resource management strategies.

The results confirm that prolonged droughts significantly influence migration trends. Comoé consistently attracts more migrants due to its relatively favorable climatic and socio-economic conditions, with a peak net migration of 69,012 in 2006, driven by high inflows (93,523) and limited outflows (24,511). Conversely, Boulkiemdé faces consistent population loss due to severe drought conditions and socio-economic constraints, exemplified by a net migration low of -76,389 in 2006, with outflows reaching 108,025.

The correlation between drought conditions and migration dynamics is evident. In Comoé, periods of increased precipitation and hydrological stability correspond to higher inflows and positive net migration, with SPEI6 showing a strong positive correlation ($r = 0.81$) with net migration. Conversely, in Boulkiemdé, drought conditions drive significant outmigration, with strong negative correlations between SPI12 and net migration ($r = -0.912$). These findings highlight the critical role of climate variability in shaping migration patterns and the need for adaptive strategies tailored to each region's distinct climatic and socio-economic contexts. Based on these results, the government, municipalities, and NGOs should promote climate-resilient farming practices, such as adopting drought-resistant crops and improving water infrastructure, including reservoirs, to mitigate drought impacts. Migration policies must align with climate adaptation strategies, addressing environmental drivers and supporting vulnerable regions. Additionally, targeted measures should focus on preventing land grabbing and strengthening vocational training to enhance local resilience and reduce migration pressures.

CHAPTER 7 : CONCLUSION AND RECOMMENDATIONS

7.1 Conclusions

This study provides a comprehensive analysis of internal migration in Burkina Faso, structured around three key objectives: analyzing internal migration dynamic from the perspective of local stakeholders, examining drivers and impacts of climate-induced internal migration on welfare, and assessing the relationship between drought dynamics and migration trends in selected provinces.

The analysis of internal migration by local stakeholders showed that it is influenced primarily by environmental factors, with spatial specificities. In the provinces of departure, Boulkiemdé and Oubritenga, migration is primarily driven by economic hardship and environmental degradation. The interplay of these two factors is the main catalyst for out-migration. Conversely, in the destination provinces, Comoé and Ziro, migration is largely influenced by environmental factors, due to the fact that most migrants are farmers, so particularly responsive to favorable climatique conditions. Future migration trends from Oubritenga are likely to be shaped by persistent drought and insufficient policy interventions, while in Boulkiemdé, land scarcity and a lack of access to quality education and vocational training will be key drivers of migration. In destination areas, future arrivals of internal migrants will likely be influenced by environmental and economic factors specific to each region. In Comoé province, adequate rainfall plays a key role in ensuring favorable agricultural conditions, while gold mining represents a major economic opportunity likely to attract new arrivals. Regarding Ziro province, future migration is expected to be primarily determined by the availability of arable land and adequate rainfall.

The Marginal Treatment Effect model results showed that climate-induced internal migration is primarily driven by environmental factors such as inadequate rainfall, soil degradation, and persistent droughts, which severely affect agricultural productivity. Its confirms that internal migration is an important adaptation strategy for households in regions facing climate variability, particularly for those heavily reliant on agriculture. Migrants generally accumulate more assets than non-migrants, indicating that migration can be a means to secure better livelihoods and enhance household wealth. However, this opportunity is not accessible to all, as extreme environmental degradation in some areas limits people's ability to migrate, trapping them in poverty. The findings highlight the complex interplay between environmental stress, socio-economic factors, and migration decisions, and underscore the importance of understanding these dynamics for more effective policy interventions.

The analysis of drought dynamics using SPI and SPEI indices in Comoé and Boulkiemdé reveals significant regional disparities in climate trends and their impacts on migration. Surprisingly, SPEI indicates that Comoé, the wettest province, is experiencing a slight but significant trend towards drought, while Boulkiemdé, located in a drier area, is showing a slight but significant trend towards increased wetness. In both provinces, SPI generally measures higher drought intensities, especially for extreme events. SPEI, by integrating evapotranspiration, moderates these intensities but detects a greater number of mild and moderate droughts. In Comoé, periods of increased precipitation and hydrological stability in 1985 correspond to higher inflows and positive net migration, with SPEI6 showing a strong positive correlation with inflows ($r = 0.81$) and net migration ($r = 0.80$). Conversely, in Boulkiemdé, drought conditions in 1985 coincide with significant outmigration, with strong negative correlations between SPI12 and outflows ($r = 0.83$) and net migration ($r = -0.91$). These findings highlight the critical role of climate variability in shaping migration patterns. While drought conditions influence migration trends, they do not act in isolation. In Comoé, despite a moderately negative correlation (-0.68) between SPEI12 and inflows in 1996, migration data showed an unexpected increase in inflows from 15.44% in 1985 to 17.11%. Similarly, in Boulkiemdé in 2019, although SPI12 exhibited a strong positive correlation (0.92) with inflows, inward migration declined from 22.94% in 2006 to 10.69%. These inconsistencies highlight the complex interplay between environmental constraints and socio-economic factors in shaping migration trends, reinforcing the need for a multi-dimensional approach to climate-induced migration analysis.

This study, while providing valuable insights into internal migration, presents some limitations that must be considered when interpreting the findings.

The analysis of migration from the perspective of local actors was conducted in four provinces of Burkina Faso. However, the results indicate that migration patterns and influencing factors vary significantly across different regions. This geographical limitation prevents the formulation of general conclusions at the national level and restricts the applicability of the findings for comprehensive migration management planning in the context of climate change.

The econometric analysis of migration's impact on well-being primarily focused on objective measures (total asset and remittances), excluding subjective well-being indicators. As a result, the study partially evaluates the overall impact of migration on well-being, overlooking psychological and social dimensions that could provide a more comprehensive understanding of migrants' quality of life.

The analysis of the relationship between drought and migration relied on a linear regression approach using Pearson correlation matrices. This methodological choice was driven by the limited availability of migration data. However, given the complexity of migration dynamics, this approach may not fully capture the intricate relationship between climate variability and population movements, potentially limiting the depth of the findings.

Despite these limitations, the study provides a solid foundation for understanding the interactions between climate change and internal migration in Burkina Faso.

7.2 Recommendations

7.2.1 Recommendations for Policy

Policymakers should implement urgent measures to prevent land grabbing in Boulkiemdé by ensuring local communities have access to and control over arable land. Vocational training programs tailored to local economic opportunities should be expanded in high-emigration areas to reduce migration pressures. Additionally, best practices in Soil and Water Conservation/Soil Defence and Restoration (SWC/SDR) should be promoted to combat land degradation and improve agricultural productivity, particularly in the departure zones.

Climate-resilient agricultural technologies, including improved irrigation systems, drought-resistant crops, and soil conservation and restoration techniques, should be adopted to stabilize agricultural productivity and mitigate migration drivers. Water scarcity should be addressed through improved water storage, rainwater harvesting, and policies promoting efficient water use. Furthermore, migration should be integrated into climate change adaptation strategies to ensure a coordinated response to climate-induced displacement.

The government, municipalities, and NGOs should prioritize climate-resilient farming practices by promoting drought-resistant crops and investing in water infrastructure such as reservoirs.

Migration policies should align with climate adaptation strategies to address environmental migration drivers while supporting vulnerable communities. Additionally, policies should focus on preventing land grabbing and expanding vocational training programs to enhance local resilience and reduce migration pressures in climate-affected regions.

7.2.2 Recommendations for Future Research

Comprehensive national-level studies should be conducted to analyze internal migration patterns and their driving factors from the perspective of local stakeholders. This approach would facilitate evidence-based local planning by integrating precise, context-specific data rather than relying on generalised information.

Future research should incorporate both objective and subjective indicators of well-being to provide a holistic assessment of migration's impact on individuals and households. This could involve capturing migrants' perceptions of their quality of life, social integration, and overall life satisfaction, complementing quantitative analyses with qualitative insights

Future research should expand migration data collection to enable more advanced analytical approaches beyond linear regression, such as non-linear models better suited to capturing the complexity of migration dynamics. A more comprehensive dataset would allow for more robust investigations into the relationship between migration and climate variables like drought.

7.2.3 Contribution to Knowledge

This research advances the study of internal migration, climate change adaptation, and migration policy by integrating diverse methods, stakeholder perspectives, and systematic empirical assessment. By incorporating insights from migrants, policymakers, and affected communities, it refines push-pull migration models and identifies key migration drivers through participatory workshops. This approach enhances the contextual accuracy of migration studies and informs policy development.

A major contribution of this study is its examination of climate-induced migration and its effects on household welfare. Using rigorous econometric methods, particularly the Marginal Treatment Effect (MTE) framework, it provides robust statistical insights into migration decision-making and its socioeconomic consequences. The findings challenge conventional assumptions by showing that while migration enhances household asset accumulation, it does not necessarily result in sustained financial support (remittances) for non-migrant households. These insights are crucial for policymakers and development organizations designing targeted interventions in climate-vulnerable regions.

Empirical analysis of climate migration patterns employs climate indices (SPI & SPEI), statistical correlation analysis, and regional assessment. A long-term evaluation of drought severity and migration flows in Burkina Faso reveals a moderate to strong statistical link between climate variability and internal migration, with regional disparities. Boulkiemdé (Sudano-Sahelian zone) experiences persistent outmigration due to prolonged droughts, while Comoé (Sudanian zone) attracts migrants due to more stable climatic and economic conditions.

Methodologically, this research advances climate migration studies by demonstrating that SPEI more effectively captures evapotranspiration effects on drought severity and migration in Burkina Faso compared to SPI. It also introduces return level analysis to estimate the probability of extreme drought events and their migration impacts, while correlation matrices between drought indices and migration variables offer new quantitative insights into climate-induced displacement in West Africa.

Beyond theoretical and methodological contributions, this study has practical policy implications. The findings highlight the need for climate-resilient agricultural practices, improved water management, and livelihood diversification to mitigate migration pressures. Additionally, they underscore the importance of migration support programs to facilitate the integration of climate migrants into host communities.

In summary, this study makes a significant contribution to migration studies, climate adaptation research, and development policy by integrating econometric modeling, climate science, and participatory research methods. It offers new theoretical insights, methodological advancements, and policy recommendations for addressing climate-induced migration in Burkina Faso and the broader Sahel region.

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APPENDICES