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Assessing the Impact of Climate extreme events and Conflicts on internal migration in Burkina Faso: the case of internal displacement

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DEDICATION

With the blessings of God, the supreme being, and the compassionate, I offer this research as a heartfelt tribute to my parents, whose unwavering dedication has propelled me toward success. May they discover within these pages the profound appreciation I hold for them.

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Abstract

Climate extreme events (floods, storms) and conflicts are still major problems for the sedentary life of the Sahelian populations. In recent years, floods, storms and conflicts (violent, non-violent or demonstrations) have been alarming in Burkina Faso. This study aims to assess the impact of extreme weather events and conflicts on internal displacement in Burkina Faso.

The study used monthly data on floods, storms, violent and non-violent conflicts and demonstrations from 2018 to 2022. We used the dynamic modelling approach (ARDL) to identify and model short and long run relationships. Internal displacement forecasts for 2025 were made using the ARIMA modelling method.

The results showed that, unlike storms, floods have affected all regions of Burkina Faso. Demonstrations are little known, whereas violent and non-violent conflicts are better known in the Sahel and Eastern regions and are spreading rapidly to other regions. The ARDL results showed that in the short run, the number of violent events, demonstrations and storms have a positive effect when they occur, while floods have a negative effect on the displacement of people. In the long run, violent events, storms and floods have a positive effect on the displacement of people in Burkina Faso. Forecasts show that the number of displaced people will rise to 2.6 million by early 2025.

Conflict management, therefore, needs to be taken seriously so that the number of displaced persons can be considerably reduced. In addition, climate measures and actions must be taken to reduce the effects of storms and floods on people's displacement.

Keywords: climate extreme events; conflicts; internally displaced people; environmental disasters; internal displacement forecast; Burkina Faso.

Résumé

Les événements climatiques extrêmes (inondations, tempêtes) et les conflits restent aujourd'hui un problème majeur pour la vie sédentaire des populations sahéliennes. Ces dernières années, les inondations, les tempêtes et les conflits (violents, non violents, ou manifestations) ont été alarmants au Burkina Faso. Cette étude vise à évaluer l'impact des évènements climatique extrêmes et des conflits sur les déplacements internes au Burkina Faso.

Cette étude a utilisé des données mensuelles d'inondations, de tempêtes ainsi que de conflits violentes, non violentes et de manifestations de 2018 à 2022. Nous avons utilisé l'approche de modélisation dynamique (ARDL) pour identifier et modéliser les relations de court terme et de long terme. Les prévisions des PDI pour 2025 ont été réalisées à l'aide de la méthode de modélisation ARIMA.

Les résultats ont montré que contrairement aux tempêtes, les inondations ont affecté toutes les régions du Burkina Faso. Les manifestations sont peu connues alors que les conflits violents et non violents sont plus connus dans les régions du Sahel et de l'Est et se propagent à grande vitesse vers d'autres régions. Les résultats de l'ARDL ont montré qu'à court terme, le nombre d'événements violents, de manifestations et de tempêtes ont un effet positif au moment où ils se produisent, tandis que les inondations ont un effet négatif sur le déplacement des personnes. A long terme, les événements violents, les tempêtes et les inondations ont des effets positifs sur le déplacement des populations au Burkina Faso. Pour les prévisions, on observe que le nombre de personnes déplacées augmentera jusqu'à 2,6 millions au début de l'année 2025.

Il est donc nécessaire de prendre au sérieux la gestion des conflits pour une réduction considérable du nombre de personnes déplacées. Par ailleurs, des mesures et actions climatiques doivent être prises pour réduire les effets des tempêtes et des inondations sur le déplacement interne des personnes.

Mots-clés : Les évènements climatiques extrêmes; conflits; personnes déplacées interne; catastrophes environnementales; prévisions de déplacements internes; Burkina Faso.

ACRONYMS AND ABBREVIATIONS

ACLED: Armed Conflict Location & Event Data Project

CCKP: The Climate Change Knowledge Portal

COP: Conference of Parties

ARDL: Autoregressive Distributed Lag

ARIMA: Autoregressive Integrated Moving Average

EM-DAT: International Disasters Database

GRID: Global Report on Internal Displacement

GDP: Gross Domestic Product

ICRC: International Committee of the Red Cross

IDP: Internally Displaced People

IDMC: Internal Displacement Monitoring Centre

IPCC: Intergovernmental Panel on Climate Change

IPCC-AR6: Sixth Assessment Report of the Intergovernmental Panel on Climate Change

IOM: The International Organization for Migration

OCHA: United Nations Office for the Coordination of Humanitarian Affairs

SDG: Sustainable Development Goals

SP/CONASUR : Secrétariat Permanent du Conseil National de Secours d'Urgence et de Réhabilitation

RCCC: Red Cross Red Crescent Climate Centre

RGPH : Recensement général de la population et de l'habitation

UN: United Nations

UNICEF: United Nations International Children's Emergency Fund

USAID: United States Agency for International Development

WBG: World Bank Group

WFP: World Food Programme

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Introduction

Justification and context

The concept of Migration is complex. Migration can be broadly defined as people's movement from one country or region to one another. The International Organisation for Migration (IOM) has provided insight into who can be called a migrant. According to the IOM, a migrant is a person who moves away from his or her place of usual residence, whether within a country or across an international border, temporarily or permanently, and for various reasons (United Nations, 2019). The number of migrants has considerably increased (Clemens, 2022), both in international migrations as well as in internal migrations. Generally, internal migration is more prevalent than international migration (Ersanilli, 2013). In 2005, the estimated number of internal migrants living in their own country for a duration of five years was 229.2 million. For a lifetime, 762.6 million were estimated (United Nations, 2013) while in 2009, the international migrants are estimated at 213.9 million of people for the whole world (UN, 2009). This number has increased to 281 million in 2020. It means that 3.6% of the world's people lived outside their country of birth (IOM, 2020). This implies that the state of migration is becoming worse.

In Africa, internal migration is a common and well-known fact. For the internal migration ranking in 2005, according to the estimation, Africa is the third area where internal migration is prevalent after Latin America and the Caribbean with 39.7 million (five years) and 113.5 million (lifetime). Also, in Africa, West Africa is the place where the intensity of internal migration is outstanding. This high intensity has been observed in countries like Ghana, Senegal, and Mauritania (UN, 2009).

Since 1850, each decade is considered warmer than the precious, and successively. The Changes in temperature, precipitation, wind patterns, and other measures of global climate are becoming increasingly alarming at all points on the planet. According to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC-AR6), the coming years will see more droughts, floods, and other extreme events than we have seen to date (IPCC, 2021). Although climate change is affecting the entire planet, these impacts are not evenly distributed. Some countries will be more affected than others (Jordan, 2008). However, the least developed countries

will be the most impacted (Boko et al., 2007). Indeed, all West African countries are developing countries, and these recent years (2018) the climate project of USAID shows that West Africa is most vulnerable to climate change (USAID, 2018). By 2050 climate extreme event induced internal migration will cause more than 216 million displacements of people and 86 million from Sub-Saharan Africa (World Bank, 2021).

Conflict behavior remains a surprising fact observed in countries, states, communities and societies. Often, where there is peace, the determining factors for development can be brought together. Conflicts usually cause casualties, collateral damages, and loss of property which are efforts of many years of work and a loss of men capable of building a bright future of global development. A brief example is the lesson that should be drawn from the two world wars with their exorbitant number of deaths and casualties, where just from the second world war the general estimated number of casualties was approximately between the range of 70 and 85 million people (Second World War: Deaths per Country 1939-1945 | Statista). Apart from that the ongoing situation is the one in Ukraine (Ukraine Civilian War Casualties, 2023 | Statista); conflicts destabilize people. However, when facing these types of situations leaving the conflict areas are a likely option. Thus, the number of people migrating to save their lives or fearing a destabilization of their economic situation will necessarily increase. These movements of displacement or change of environment or region can be done inside their country as well as outside. That's why, when talking about the causes of internal migration, it's very paramount to not forget the implication of conflicts in people's displacements. In 2021, the worldwide number of people displaced internally related to conflicts and violence was 59.1 million (IDMC | GRID, 2022) conflicts and violence have triggered the displacement of 11.6 million people while disasters are responsible for 2.6 million people internally. Notwithstanding, sustainable development goals (SDGs) number eleven is promoting peace which is a very important step that countries must reach to move toward development.

Problem statement

In Burkina Faso, human displacements caused by climate extreme events and conflicts have been intensely accentuated in recent years. Burkina Faso faces challenges like climate extreme events,

terrorism, political and economic problems like most of west African countries. Cities and villages are not safe. Climate change and climate extreme events in Burkina Faso should be considered. Historically, since 1975, annual average temperatures in Burkina Faso have increased. The annual average temperature has risen by roughly 0.10°C per decade (1901-2013), and it has warmed by 0.26°C during the past 30 years (USAID 2017; RCCC-ICRC,2022). In 2009, the city of Ouagadougou, which is the capital city of Burkina Faso, experienced a devasted flood that cause a lot of damage. Thousands were cleared out destitute and various homes were devastated in Burkina Faso's capital Ouagadougou because of 12 hours of rainfall (OCHA, 2009). Many other natural disaster cases can be found in the international disaster database (EM-DAT) includes vital core information on the incidence and consequences of over 22,000 catastrophic disasters that have occurred worldwide between 1900 and the present. The database is created using data from a variety of sources, including UN agencies, non-governmental organizations, insurance firms, research institutes, and press agencies.

Apart from flooding, drought has also remained one of the serious problems for the country since 1970. In Burkina Faso, sporadic rains and poor water retention in soils are concerns related to drought whereas in some Northern regions of the country, rains come two months out of the year (WBG CCKP; Climate Risk and Adaptation Country Profile Burkina Faso, 2011). According to the Ministry of Agriculture and Irrigation, approximately 2.5 million of Burkina Faso's 20 million population suffer from food shortages. As droughts reduce crop yields, which in 2018 resulted in almost half-million-tons underproduction of grain (DROUGHT IN BURKINA FASO: OUR RESPONSE, 2011). Climate change has an impact on agriculture in several ways, including soil degradation, decreased water availability and crop yields, lost harvests from drought and flooding, reduced pastures and grasslands, and livestock losses. Face all these situations, people must move and look for the best place or shelter and restart their life.

Conflicts play a big role in people's displacement in Burkina Faso. The internal conflict has intensified, spreading across all regions of the country. Armed violence has caused massive population displacements and is increasingly targeting civilians. In Burkina Faso, conflicts exist since and can fall in different categories such as riots, protests, violence against civilians or farmers conflicts (Breusers et al., 1998). Even, if they are not diffused massively in news like this recent year, they exist and have made much death. We should first know the different types of conflicts we should consider. Conflicts related to terrorism, movement after elections, conflicts between

civilians… All of these are considered as conflicts and from that people must move, flee their places, and find peace at a place where they can sleep and wake up in peace.

To showcase, in February 2022, they were 1 814 283 internally displaced persons in Burkina Faso (SP/CONASUR, 2022). The situation is alarming, and research needs to be conducted to enhance and support the activities of the government both with policy brief as well as the implementation of decision support tools to cope as quickly as possible with the problem. Therefore, this present work falls into assessing the impact of environmental disasters and conflicts on internal migration with the case study, internal displacement. We also develop a web application for monitoring conflicts and disasters as well as forecasting the number of internally displaced people. In a scientific research approach manner, this work is based on questions, hypotheses and objectives that we are going to achieve.

Research question:

The main research questions are:

How do climate extreme events and conflict affect internal displacement in Burkina Faso?

The specific research questions are:

- How has the occurrence of climate extreme events, conflicts, and internal displacement evolved in Burkina Faso?
- Do climate extreme events and conflicts contribute to an increase in internal displacement in Burkina Faso?
- What is the projected trend of internal displacement in Burkina Faso for 2025?

Research hypotheses:

The main research hypothesis:

Climate extreme events and conflicts drive internal displacement in Burkina Faso.

The specific research hypotheses are:

- There is an increasing occurrence of climate extreme events, conflicts, and internal displacement in Burkina Faso.

- Climate extreme events and conflicts play a significant role in the rise of internal displacement in Burkina Faso.
- Internal displacement is expected to experience a substantial increase in 2025.

Research objectives:

The main research objective is:

To assess the impact of climate extreme events and conflict on internal displacement in Burkina Faso.

The specific research objectives are:

- To examine the dynamics of climate extreme events, conflicts, and internal displacement in Burkina Faso.
- To investigate the influence of climate extreme events and conflicts on internal displacement in Burkina Faso.
- To develop a forecasting model for internal displacement in Burkina Faso for the year 2025.

Chapter 1:

Literature Review of climate extreme events, conflicts, and Internal displacement

This section presents the different concepts in the field of internal migration, climate extreme events and conflicts and covers the overview of relevant literature, gaps and controversies in the literature.

1.1 Definition of concepts

The aim of defining the concepts of climate change, internal Migration, forced migration, internally displaced persons and armed conflicts, climate extreme events is to give an explanation from the sources (glossary) to facilitate the understanding of each reader.

Climate change: A change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer (IPCC glossary, 2012).

Internal migration: The movement of people within a state involving the establishment of a new temporary or permanent residence (IOM glossary, 2019).

Forced migration: A migratory movement which, although the drivers can be diverse, involves force, compulsion, or coercion (IOM glossary, 2019).

Internally displaced persons: 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 (IOM glossary, 2019).

Armed conflict: A conflict in which there is a resort to armed force between States or protracted armed violence between governmental authorities and organized armed groups or between such groups within a State (IOM glossary, 2019).

Climate extreme event: is a time and place in which weather, climate, or environmental conditions such as temperature, precipitation, drought, storms or flooding rank above a threshold value near the upper or lower ends of the range of historical measurements (Chen and Sun, 2015).

Mobility: A generic term covering all the different forms of movements of persons (IOM glossary, 2019).

1.2 Climate extreme events and internal displacement

The rapid evolution of migrants is a major fact that will continue to push researchers to investigate the complex relationship between climate change and migration issues. Earlier research on migration introduced in 1880, focused on mobility (Peter Scholten, Introduction to Migration Studies). With the recent increase in the number of displaced people, the characterization of internal migration becomes important. Internal migration on its basis encompasses other specifications including displacement. Often internal displacement is described as a fact of forced

displacement (Maru, 2022). Earliest research has proven that climate change is really affecting things around human beings in its environment (Homer-Dixon, 1991). Worldwide climate change is causing extremes of precipitation (O'Gorman, 2015); diminished precipitation with the expanded hazard of dry spells in some zones (Zou et al., 2005); expanded precipitation with the expanded hazard of flooding in others (Pielke and Downton, 2000; Zou et al., 2005); and more tropical storms and other extreme weather events (Easterling et al., 2012). Long dry spells, floods, a hotter temperature and extremes of precipitation are adversely influencing rural yields (Myers et al., 2017). Thus, surveying the effect of worldwide temperature increment on the generation of these distinctive crops' wheat, rice, maize, and soybean has appeared negative temperature impacts surrender at the worldwide scale. Each degree-Celsius increment in worldwide cruel temperature would, on normal, diminish worldwide yields of wheat by 6.0%, rice by 3.2%, maize by 7.4%, and soybean by 3.1% (Zhao et al., 2017). Therefore, following the IPCC reports, the raise of the global temperature will cause environmental-related risks that are nothing but floods, drought, dry spells, sea-level rising and many others (Djalante, 2019). These are numerous reasons why environmental disasters pose such a colossal challenge for African farming (Dodson, 2004; Nanjira et al., 1991). Crops most used in African diets, such as wheat, maize, sorghum, and millet, will hardly be productive with the rising temperatures. Multifactor stress combination disasters will be more severe under warming of 2℃. Therefore, crop yields over Sub-Saharan Africa will diminish by 10 percent. Warming over the 2℃ will cause crop yields to drop by up to 20 percent. Therefore, at a raise of warming to 3℃, all present-day cropping zones for maize, millet and sorghum in Africa will get to be unproductive (IRLI, 2022). Studies show that this shortage in agricultural productivity is causing food insecurity (CLOVER, 2010), and usually cause displacement (Crush, 2013). One leading problem, for the world, is the lack of water resources due to drought (Du Plessis and du Plessis, 2019). From the 8 billion people around the globe, it has been estimated that 5 million will be living in nations encountering water stress by 2025 (United Nation, 2023). In Iran, water scarcity is seen as one of the major reasons of many people's displacement (Lehane, 2014). In fact, the lack of water needs has not only reached humans. It has also affected animals that need water for their survival (Nardone et al., 2010). In the Sahel region of Africa known as a zone for breeding, due to this water stress caused by drought, people move (Blanco, 2020). Thus, climate change and the repetitive occurrence of climate extreme events become major causes of internal

displacement (Ferris & Stark, 2012). Facing problems like land degradation, reduction in crop productivity and incomes, water scarcity and environmental disasters, internal migration such as rural-urban migration becomes an adaptation means of adaptation for the affected population. This appears in Burkina Faso within a study held on the cause of intervillage migration (Sanfo et al., 2017).

1.3 Conflicts and Internal displacement

The approach of conflict was advanced by Karl Marx (1818-1883). This is related to the idea that societies are in constant conflict because of competition for limited resources. From this conception, conflicts can take different forms (Greer et al., 2008). Among the push factors that trigger internal displacement, conflicts are well represented. Many factors lead to people displacement such as interstate wars, soil conflicts, protests. While very few internally displacements of people are caused by interstate wars, the majority of conflicts that result in internal displacement involve both internal warfare and overt foreign military intervention and are most frequently connected to civil war (Brun, 2005). Around the world, the number of internally displaced has tremendously increased and is largely greater than the one of refugees, and conflicts related to wars have been greatly increased (IMDC, 2022). In exploring the transformations in security threats, their root causes, and their consequences on the issue of people's displacements in the Sahelian Zone using a case study of and Burkina Faso and Mali, it has been found that Burkina Faso and Mali are facing many problems like fighting with terrorists, a takeover of the army, violence, and bad leadership. (Okafor et al., 2023; Soumahoro, 2019). Generally, conflicts with exorbitant numbers of internal displacements are at the heart of many problems. Studies show that internally displaced people are the most vulnerable (Owoaje et al., 2016). Especially when such people are obliged to migrate within their own countries, particularly because of war (Naidu et al., 2015). It has been established that those who were internally displaced because of conflicts like war experienced health problems (Austin et al., 2008; Cantor et al., 2021). 12 million people were displaced by armed war and violence in Africa in 2015. Malnutrition in children (stunting 52% and wasting 6%), malnutrition in adult men (24%), diarrhea (62% in children and 22% in adults), and acute respiratory infections (45%) were the physical health issues and symptoms.

Depression (31%-67%) and post-traumatic stress disorder (42%-54%) were the two most common mental health issues (Owoaje et al., 2016). Conflicts do not concern only the use of weapons; conflicts are not only about the use of weapons. They are also about disturbances of public order, riots, and social problems (civil war). An example has been demonstrated in Kenya (2007-2008) with more than a thousand people displaced internally (Klopp et al., 2010). In the Sahelian zone of Africa conflicts and crime are well known. This is usually coming from extremist groups such as Al-Qaeda in the Islamist Maghreb (AQIM), Jama'a Nusrat ul-Islam wa al-Muslimin and Boko Haram. Those groups are known for actions such as violences, crimes, kidnapping and even drug smugglings (Wehrey and Boukhars, 2013). Especially in the country like Mali, Burkina Faso, and Niger, from 2012 to 2019, an abundance of armed conflicts occurred exclusively within those specific states. A total of 4,723 individuals lost their lives due to the violence perpetrated by 195 different groups. These altercations occurred in a total of 1,263 various locations (Raleigh et al., 2021). Under a such situation, people don't have a choice. To save their life migration is the only suitable choice for them and of course many of them will be from one place to one another inside the country. In 2019 the situation of violent conflicts with the extremist groups has increased and under a such situation, in 2019 up to 2022 more than 1.9 million people were displaced internally ("Burkina Faso," 2022).

1.4 Climate extreme events, conflicts and Internal displacement

The link between climate extreme events, conflict, and internal displacement, the three concepts at once has been raised a few times. The research on this topic, particularly, those that put the tree concept together has come out after the Kampala convention (2009) which was the African Union Convention for the protection and assistance of Internally displaced persons in Africa. With the increasing number of armed conflicts, and also in the extreme events, it has been predicted that more extreme events will cause damage and people will be displaced and this displacement will likely lead to an increase in armed conflicts (Nordås et al., 2015). This simple causal model assumes that climate change will be the key factor responsible for the scarcity of resources and then the migration of people and this will be the trigger for violent conflicts, will be questioned later by some researchers who will think that this problem goes beyond a simple compensation to draw a conclusion. They will propose a more complex system that considers socio-political factors

as well as societal discourses (Brzoska et al., 2016). Syria has been a hub of studies on environmental disasters, armed conflicts, and internal migration several times. One of these studies made on climatic stress, internal migration, and the Syrian civil war onset has shown that climate stress can produce instability directly as well as indirectly through internal migration. According to the authors, regions less severely affected by drought are more likely to experience events like war and protests. This is because people from areas that are experiencing drought and other climate-related hardships are more likely to migrate to other areas, looking for better opportunities. This influx of people leads to instability in the regions that receive the migrants (Ash et al, 2020). Also in Bangladesh, research conducted aimed to understand if internal migration following natural hazards increases the likelihood of protests in migrant-receiving areas. It has been found that flood hazards and loss of assets increase the likelihood of internal migration, but unlike other types of domestic mobility, hazard-related migration does not increase unemployment. This is likely since the migrants are typically in a state of vulnerability and have limited resources, and thus are less likely to have the capacity to organize protests or engage in political action (Petrova, 2021). Despite this, some researchers have had the idea to investigate individually the resources in question, which have been generally supported as the cause of armed conflicts, protests, and riots. Of these resources, water resources, which are really impacted by climate change, have been highlighted as the cause of internal displacement of populations (Levy, 2019). A relational analysis of food insecurity, environmental change, conflicts, and internal displacement in countries using the boundary test reaffirms the long-term balance between food security, environmental change, and the number of internally displaced persons (IDPs). But in the short-term economic variable are related such as incomes (Saeed et al., 2020). Further studies on the global world will show that environmental migration tends to be internal and short-term, with a low potential for conflict. However, urban, and rural demographic instability is associated with a higher risk of civil war, and low-level social conflict in times of environmental stress is common (Raleigh et al., 2008). Particularly in Africa, the Kampala conference is one that raised a lot of points. It gives many insights and glance into internal displacement such as their right in other to avoid civil war conflicts and others (Ferris et al., 2012). We should also notice the implication of the Cancun Adaptation Framework (COP 16) which was also one of the international conferences focused on internally displaced rights. In Burkina Faso, the topic of internal displacement exists but their concern was to address a particular concern like the implication of COVID-19 in internal displacement (Ozer

et al., 2022). Others are typically dealing with climate change, conflicts, and intervillage migration. Their particular concern was on a deep analysis of the cause of farmers' intervillage migration. Although they deal with conflicts, the conflicts are identified as environmental (Sanfo et al., 2017).

Chapter 2: Materials and Methods

This section presents the material and methods used. First the study area and its characteristics are presented. Second, the data-wrangling methods, the tools, materials, and techniques used. The type of data used is discussed and a list of definitions is provided for a clear understanding and readability. The data processing and different types of analysis, including the methods, techniques and software used are also discussed. Finally, we presented the framework of the web application (DSS) developments process.

2.1 Presentation of the study area

Burkina Faso is a landlocked West African country. The country lies mainly between latitudes 9° and 15° N and 6° W and 3° E. It's bordered by different countries such as Mali in the northwest, Niger in the northeast, Benin in the southeast, Togo, and Ghana in the south, and the Ivory Coast to the southwest. The country is quite large, it covers an area of 274,222 km² considered the sixth largest within the West African countries. The country has 13 regions divided into 45 provinces which are also divided into 340 communes (306 rural communes and 34 urban communes). According to the fifth general census of the population and housing of Burkina (RGPH-2019), the population is 20505155 inhabitants and according to World Bank estimations, it could have reached 22.1 million inhabitants in 2021. Its capital is Ouagadougou, which is hosting most of the population, more than 2.45 million people (RGPH-2019) . In addition to the capital, other important and attractive cities such as Bobo-Diolasso, Koudougou, and many others must be considered. The country has many ethnic groups. The largest ethnic group is the Mossi people who represent 52% of the population or over 11 million. Burkina Faso is a relatively flat country in terms of relief, with the highest peak being the Ténakourou, at 749 meters. The country is also known for its cultural diversity. Gold, manganese, marble, limestone, salt, phosphates, and pumice are among the natural resources found in Burkina Faso (Yager, 2003). More elephants are found in Burkina Faso than in many other West African nations (Lindsey et al., 2007). Leopards, lions, buffaloes, and also other small wild animals.

2.2 Climate

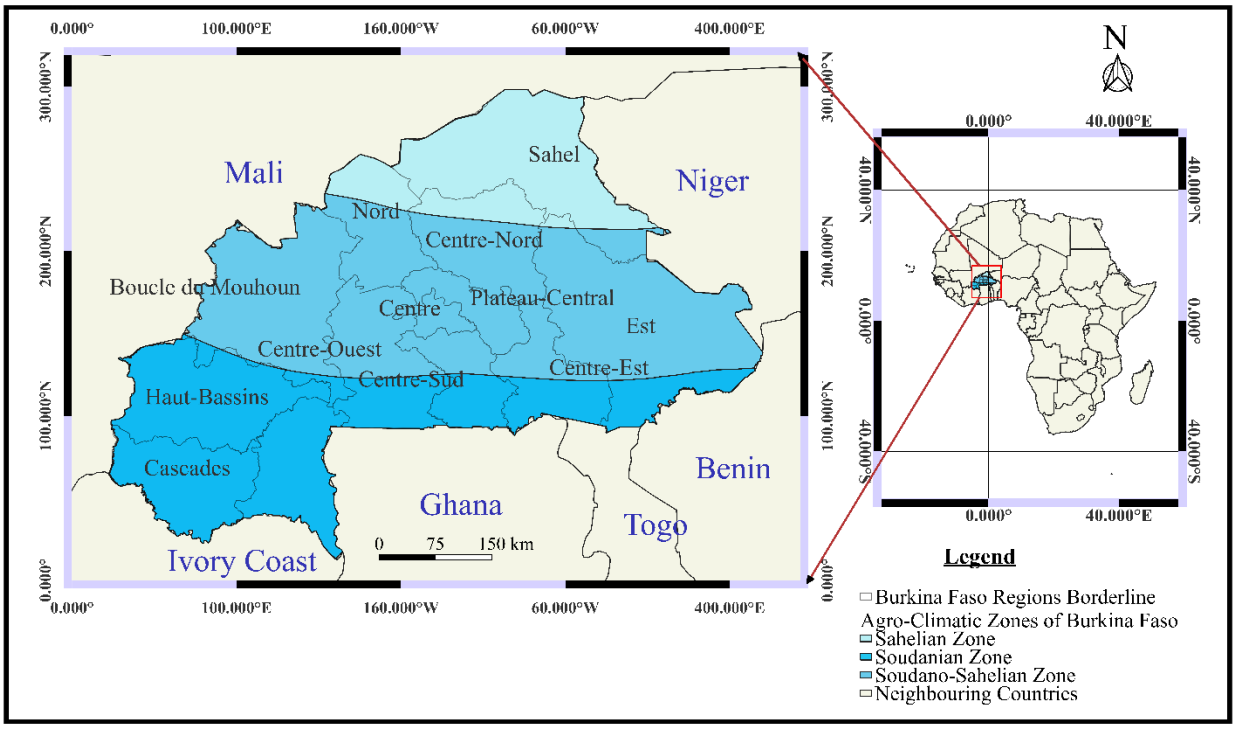
Burkina Faso has an essentially tropical climate with two distinct seasons. During the rainy season, the country receives between 600 and 900 mm (23.6 and 35.4 inches) of rainfall (Ibrahim et al., 2015). During the dry season, which is the period of the harmattan, there is heat, dryness, and wind blowing from the Sahara. The rainy season lasts about five to six months, from May/June to October/November, and is shorter in the north of the country (Sauerborn et al., 1996). Three climatic zones can be defined: the Sahel, the Sudan-Sahel, and the Sudan-Guinea. The Sahel, in the north, generally receives less than 600 mm of rainfall per year and experiences high temperatures, ranging from 5 to 47 °C (41 to 117 °F). A relatively dry tropical savannah, the Sahel extends across the borders of Burkina Faso from the horn of Africa to the Atlantic Ocean, bordering the Sahara in the north and the fertile Sudan region in the south. Located between 11°

3′ and 13° 5′ north latitude, the Sudano-Sahelian region is a transitional zone in terms of rainfall and temperature. Further, the Sudano-Guinean zone receives more than 900 mm of rainfall per year and has cooler average temperatures (Alvar-Beltrán et al., 2020).

2.3 Agriculture, Food Security, and Water

Agriculture in Burkina Faso is considered one of the pillars of development in most West African countries. It involves many people. According to the world bank (2020), One-quarter of the working population of Burkina Faso is formally employed in agriculture and it is estimated that nearly 90% of Burkina Faso's working population is employed in the agricultural sector to some degree. The agricultural sector accounts for 18% of the nation's GDP. From the hunger project (2023), 86% of the country farmers are smallholders and engaged in subsistence agriculture, and also there are many lack access to modern farming techniques. Since 2008, the agricultural population of Burkina Faso has been predominantly female. Indeed, women represent more than 50% of the agricultural population. In 2017, this rate was 51%, as in 2016, and is considered as the average value for the last five years. The proportion of women in agriculture is higher in the Centre-East and Hauts-Bassins regions (54% and 53% respectively). The main crops grown are sorghum, pearl millet, maize, groundnuts, rice, cotton, etc (Lykke et al., 2002). Despite this representative share of agriculture in the GDP and the efforts made by the government, agriculture faces many problems. Burkina Faso's climate also makes its crops vulnerable to insect attacks, including locusts and crickets, which destroy crops and further hamper food production (Pul et al., 2023). Out of these, land degradation is one of the famous problems farmers are facing. From 1992 to 2012 many of the agricultural lands were lost. In Burkina Faso, due to the drought, agricultural land is decreasing (IGB, BDOT 1992, 2002 et MERH/Projet BKF-015-IFN2 (BDOT, 2012)). From 1992 to 2012, the crop land decreased about 2 million hectares (12 568861 to 10443290).
All these problems are at the root of the increasing food security in Burkina Faso. According to the Global Hunger Index, a multidimensional tool used to measure and monitor the level of hunger in a country, Burkina Faso was ranked 65 out of 78 countries in 2013. Recent studies of WFP show Burkina Faso have reached an unprecedented level for 3.45 million people facing food security issues (GIEWS, 2022). However, access to safe drinking water has improved over the past 28 years. According to UNICEF, access to drinking water increased from 39% to 76% in rural areas

between 1990 and 2015. In the same period, access to drinking water increased from 75 to 97% in urban areas.



Source: ANAM (climatology 1991-2020) Date: June 2023 Author: ADZAVON K. D. D

Figure 1 : Map of the study area (Burkina Faso in West Africa and agroclimatic zones)

2.4 The Data

2.4.1 The Data collection

The data used in this study came from several sources (Table 1). In order to achieve our objectives specific data was used such as the climate extreme events dataset, conflicts dataset, and also internal displacement dataset, all concerning Burkina Faso. We have downloaded some of these data from online open-source data platforms and others collected from the public administration. The table below explains the categories of datasets collected and the duration covered by each one.

Table 1 : Data collected

Datasets	Data sources	Duration
Climate extreme events	SP/CONASUR Burkina Faso	07-2018 – 12-2022
	FIRE SERVICE of Burkina Faso	
	EM-DAT	
Conflicts	ACLED	
Internal Displaced Data	SP/CONASUR Burkina Faso	

2.4.1.1 Internal Displaced Data

The internally displaced data were collected from the Permanent Secretariat of the National Council for Emergency Relief and Rehabilitation (SP/CONASUR). The data covered a time range of July 2018 to December 2022. The data contains the registrations of the number of people considered displaced. This has been structured in terms of the date of each registration, the regions, province, and commune of the displaced persons. The data is collected in the camps for displaced persons and also from families that host them for a duration. The Data gathered, was in Excel Workbook (XLSX).

2.4.1.2 Climate extreme event Data

Climate extreme events data were generated from different sources. Disaster events were focused on floods and storms. Thus, we gathered our first data from EM-DAT, the international disasters database. But with the lack of data, we go for other sources where we can also access data to complete this lack. We collected data from SP/CONASUR and from the FIRE SERVICE Burkina Faso. From the SP/CONASUR the data were gathered in an Excel Workbook (XLSX) format and from the FIRE SERVICE the data were gathered on paper given hand by hand and later sent by email in portable document format(pdf).

2.4.1.3 The Conflicts Data

We gathered conflict data from the Armed Conflict Location and Event Data (ACLED) which is an online database for conflicts. To be able to download the data, we registered and got an API key usable once per year. The data contains a lot of conflict data information for different countries where we just extracted the concerns. From that source, different types of conflicts are categorized. We, therefore, have battles, explosions, and remote violence, violence against civilians, strategic developments, protests, riots. For more understanding of what each type of conflict means, we provide a broad explanation according to their definitions (ACLED, 2019).

Table 2 : Explanation of the different types of conflicts

General category	Type of conflicts	Definition
Violent events	Battle	Battles are violent clashes between at least two armed groups. Battle types are distinguished by whether control of a location is unchanged because of the event; whether a non-state group has assumed control of a location, or whether a government has resumed control of that location. (Armed crash, Government regains territory, non-state actor overtakes territory)
	Explosions and remote violence	Explosions/Remote violence refers to events where an explosion, bomb, or other explosive device was used to engage in conflict. (Chemical weapons, Air/drone strikes, Suicide bombs, grenades, missile attacks, remote explosives)
	Violence against civilians	Violence against civilians involves violent attacks on unarmed civilians. (Sexual violence, civilians attacks, Abduction/ forced disappearances)

Non-violent actions	strategic developments	Strategic developments include incidences of looting, peace talks, high-profile arrests, non-violent transfers of territory, recruitment into non-state groups, changes to group/activity, disrupted weapon use, and agreements.
Demonstrations	Protests	Protests are non-violent demonstrations, involving typically unorganized action by members of society. (Peaceful protests, protests with interventions)
	Riots	Riots are violent demonstrations, often involving spontaneous action by unorganized, unaffiliated members of society. (Mob violence)

Source: ACLED data

2.4.2 Data processing and analysis

Two programming languages has been used for the analysis (R and Python) and EViews software for the ARDL modelling. The data were cleaned using Python programming language. This required the use of many packages that helps in data cleaning and wrangling. We imported packages like Pandas, Numpy, and Datetime to process the time series data. Daily data were aggregated to monthly data. We have chosen to aggregate the data by months to avoid having a huge amount of missing information as weekly information is not available. Furthermore, missing data has been handled by many processes. In our dataset, we got many missing values. By, questioning the data providers, we were able to understand how to solve them. For the conflict dataset, we didn't get any missing data. For the climate extreme events data, we saw that some months don't have records because there was no event registered. We just filled them by zero. Also, for the internal displaced data, we filled the missing data with the rolling averages. Some data for the period of May to August 2022, were not available. In fact, SP/CONASUR realized that there is duplication in people registration, and they wanted to solve those issues before continuing the registration. The institution was not able to collect new field data for four months. To help fill the gap, we applied a linear interpolation technique to recover the missing data because from the period of May to August 2022, there were still people within the county that fled their

places due to reasons of terrorism and other conflicts, floods and storms.

The generated data are used to develop an interactive web application for visualization and manipulation with the dash framework (version 2.3.0). It's built on top of Flask, Plotly.js (for an interactive plots), and React.js (for creating a user interface based on components). It contains libraries that contain HTML and CSS components.

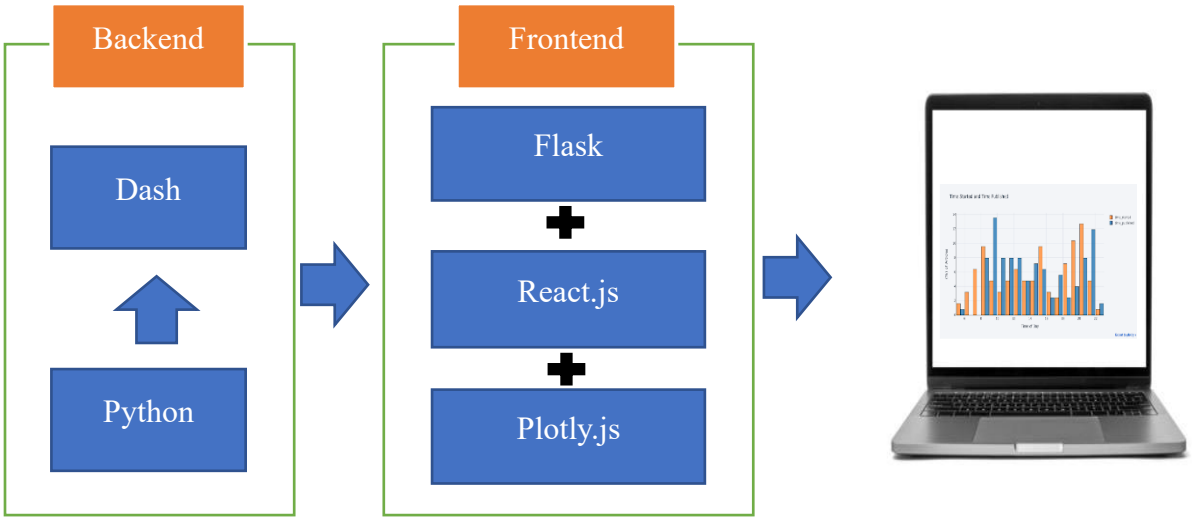


Figure 2 : Conceptual web app system

2.5 Methods for econometrical modeling

2.5.1 Theoretical model

A model is a systematic description of an object or phenomenon that shares important characteristics with its real-world counterpart and supports its detailed investigation. Therefore, many types of models can be distinguished. Among them, Quantitative models express units of

analyses, their interrelations and dynamics using properties susceptible of measurement (Börner et al., 2012).

The relationship between climate extreme events, conflicts and internal displacement is complex. Many models have been used to understand this complex relationship. Usually, this relationship can be explained in the short run as well as in the long run. The ARDL (Autoregressive Distributed Lag) model, first introduced by the econometrician S. O. Akaike in 1969, and further developed and popularized by the economists C. W. J. Granger and Paul Newbold in their influential 1974 paper titled "Spurious regressions in econometrics", has become a widely used approach in econometrics for analyzing short run as well as in the long run relationships between variables. ARDL models are dynamic that combine the autoregressive models but also distributed lag models.

- Autoregressive models (AR) are dynamic models in which we can have the explanatory variables and the pass values (lag) of the independent variables. In general, they are presented in this format:

$$y_t = f(Y_{t-p}, X_t) \quad (1)$$

Y_t = The dependent variable

Y_{t-p} = The lags of the dependent variable

X_t = The independent variable

p = optimal lag order associated with the dependent variable

- Distributed lag models (DL) are also dynamic models in which the lag values of the independent variables are included. Their general format is:

$$y_t = f(X_t, X_{t-q}) \quad (2)$$

X_{t-q} = The lags of the independent variables

q = optimal lag order associated with the independent variable

Through that combination, AR and the DL models abounds the pass value of the explanatory variables but also the lags of the dependent variables. The model can be expressed as follows:

$$y_t = f(Y_{t-p}, X_t, X_{t-q}) \quad (3)$$

Usually, dynamic models are models that suffer from multicollinearity and autocorrelation of the error. This makes the estimate complex and difficult with the ordinary least square estimation

methods. Therefore, robust estimation methods are often used to avoid those problems. The variables in the models should be stationary to avoid spurious regressions. The general equation for an ARDL model is below:

$$Y_t = \varphi + \sum_{i=1}^{p} a_i Y_{t-i} + \sum_{j=0}^{q} b_j X_{t-j} + e_t \quad (4)$$

Or in a simplest way:

$$Y_t = \varphi + a_1 Y_t + \cdots + a_p Y_{t-p} + b_0 X_t + \cdots + b_q X_{t-q} + e_t \quad (4)$$

Where:

φ = The vector of the unknow parameters

e_t = The error terms

$e_t \sim iid(0,\ \sigma^2)$

In this equation, "b_0" is the short-run effect of the independent variable on the dependent variable. The long-run effect of the independent variable on the dependent variable "λ" can be expressed by this equation:

$$Y_t = k + \lambda X_t + u \quad (5)$$

Then the long-run effect "λ" is:

$$\lambda = {\sum b_j}\Big/{(1 - \sum a_i)}$$

2.5.2 Process for pre-estimation tests

The pre-estimation tests refer to different tests that must be done before the ARDL modeling. They are considered like the steps to follow. It allows us to also know which estimation method to adopt. Those steps are:

- Unit root checking test
- Optimal lag selection
- Bound test

2.5.2.1 Unit root checking on the data

When conducting time series analysis, stationarity and non-stationarity should be one of the beginning steps before choosing the model to estimate. Stationarity data in the simplest way means that the data is taking constant mean and variance while its contrary is non-stationary data. Also, non-stationary data means that the data has a unit root that can cause spurious estimation results. To address those issues, we can differentiate the data to make it stationary. Many methods have been used so far such as the test of Augmented Dickey-Fuller(ADF), the test of Phillippe-Perron(PP), Kwiatkowski–Phillips–Schmidt–Shin (KPSS)… where The ADF test is effective in the presence of error autocorrelation, the PP test is recommended in the presence of heteroscedastic errors, and the KPSS test decomposes a series into three components (deterministic part, random part, white noise) with the null hypothesis of stationarity (Jonas Kibala, 2018).

2.5.2.2 Optimal lag selection for the Model

As for all dynamic models, the optimal lag selection is based on information criteria. Therefore, we have the Akaike Information criteria (AIC), the Schwarz Information criteria (SIC) and the one of Hannan Quin (HQ). To determine the optimal lag (p*, q*), we select the minimum value given among the result of the criteria. Those result are computed using the following formula:

$$AIC(p) = log\left|\tilde{\Sigma}\right| + \frac{2}{T}n^2p \qquad (6)$$

$$SIC(p) = log\left|\tilde{\Sigma}\right| + \frac{logT}{T}n^2p \qquad (7)$$

$$HQ(p) = log\left|\tilde{\Sigma}\right| + \frac{2logT}{T}n^2p \qquad (8)$$

$\tilde{\Sigma}$ = estimated covariance matrix

n = number of the freely estimated parameter

T = number of observations

2.5.2.3 The bounds test or co-integration test

ARDL model is a model that statistically handles a small amount of data and is significantly significant. Also, the ARDL model can be applied when the regressors are integrated at a mixed (level I(0) and integrated at the first differenced level I(1) (Pahlavani et al., 2005). The Bounds test is guided by the assumption of stationary variables at the level I(0), at the first difference I(1), and never at the second difference I(2) (Giles, 2013). The Pesaran et al (2001) cointegration test, called the "bounds test to cointegration", originally developed by Pesaran and Shin (1999) can be used. We use Pesaran's cointegration test to verify the existence of one or more cointegrating relationships between the variables. Co-integration between series implies the existence of one or more long-run equilibrium relationships between them, which can be combined with the short-run dynamics of these series in an error correction (vector) model.

The test procedure is such that the Fisher values obtained should be compared with the critical values (bounds) simulated for several cases and different thresholds. The upper bound includes the values for which the variables are integrated of order 1 I(1) and the lower bound concerns the variables I(0). Thus:

If Fisher calculated > upper bound: there's co-integration.

If Fisher calculated < lower bound: there's no co-integration.

If lower bound < Fisher calculated < upper bound: No conclusion.

Cointegration is an econometric concept that mimics the existence of a long-run equilibrium over time. Thus, cointegration establishes a stronger statistical and economic basis for the empirical error correction model, which brings together short and long-run information in modeling variables. Testing for cointegration is a necessary step to establish if a model empirically exhibits meaningful long-run relationships. If it failed to establish the co-integration among underlying variables, it becomes imperative to continue to work with variables in differences instead. However, the long-run information will be missing (Nkoro & Uko, 2016). If there is no co-integration, the ARDL (p, q) models will be specified as:

$$\Delta Y_t = \varphi + \sum_{i=1}^{p} a_i \Delta Y_{t-i} + \sum_{j=0}^{q} b_j \Delta X_{t-j} + e_t \qquad (9)$$

If there is co-integration, the error correction model (ECM) representation is specified as:

$$\Delta Y_t = \varphi + \sum_{i=1}^{p} a_i \Delta Y_{t-i} + \sum_{j=0}^{q} b_j \Delta X_{t-j} + \rho ECT_{t-1} + e_t \qquad (10)$$

2.5.3 Process for post-estimation tests

Post-estimation tests are statistical procedures used to evaluate the results of a statistical model after it has been estimated. These tests are used to assess the goodness of fit of the model, the validity of the assumptions underlying the model, and the statistical significance of the estimated parameters.

2.5.3.1 Autocorrelation Test

Autocorrelation, also known as serial correlation, occurs when the errors or residuals in a regression model are correlated with each other over time. Autocorrelation violates one of the key assumptions of linear regression, namely that the errors are independent of each other.
To test for autocorrelation in a regression model, there are several methods, including the Durbin-Watson test, the Ljung-Box test, and the Breusch-Godfrey test.

2.5.3.2 Heteroscedasticity Test

Heteroscedasticity is a statistical term used to describe the unequal variances of a dependent variable across the range of values of an independent variable. In simpler terms, it means that the variance of the errors in a regression model is not constant. Popular test for heteroscedasticity is the Breusch-Pagan test or the White test. The Breusch-Pagan test involves regressing the squared residuals from a regression model on the independent variables and testing the null hypothesis that the variance of the residuals is constant. The White test is similar, but it also includes additional terms for the cross-products of the independent variables to account for potential heteroscedasticity due to interaction effects.

2.5.3.3 Normality Test for Residuals (Histogram and Jarque-Bera Test)

A normality test for residuals is used to check whether the errors in a regression model are normally

distributed. One way to check for the normality of residuals is to create a histogram of the residuals and visually inspect it for a normal distribution. If the histogram is bell-shaped and symmetric around the mean, it suggests that the residuals are approximately normally distributed. However, if the histogram is skewed, multi-modal, or has heavy tails, it indicates that the residuals may not be normally distributed. The Jarque-Bera test calculates a test statistic that follows a chi-square distribution with two degrees of freedom. The critical values of the test statistic depend on the significance level and the sample size. Typically, a p-value less than 0.05 indicates that the null hypothesis of normality is rejected, and the residuals are not normally distributed.

2.5.3.4 Parameter Stability Test (CUSUM Graph)

The cumulative sum (CUSUM) of the residuals and the cumulative sum of square (CUSUMQ) of the residuals are tests used to access the parameter stability. The CUSUM test identifies systematic changes in the regression coefficients and the CUSUMQ test is used to detect sudden changes from the constancy of the regression coefficient (Adenomon & Ojo, 2020). This fall under the hypothesis of:

H0: parameters are stable (desirable),

H1: parameters are not stable (undesirable).

If the CUSUM plot and CUSUMQ plot fall within the upper and lower lines, which are typically chosen to represent a specified level of significance, then we accept the null hypothesis and conclude that the parameters are stable. If, however, the plot exceeds these lines, we reject the null hypothesis and conclude that the parameters are not stable.

2.5.4 Empirical model specification

In the case of this study, our concern is to capture the impact of environmental disasters and conflicts on people's displacement. This led to the use of the study's variables as the number of floods, storms, demonstrations, non-violent conflicts, violent conflicts, and the number of internally displaced people by month in Burkina Faso to write the equation. To avoid problems of variance stabilization and non-normalization of the distribution, we applied a natural logarithm on

all variables and also, we replaced the values 0 by a very small values 0.001 (Khedive, 2014) so that we can avoid infinite (log (0)). Then the internally displaced people function can be written mathematically as follows:

$$lnIdp = f(lnVe, lnNve, lnDm, lnFl, lnSt)$$

$lnIdp$ = logarithm of the number of internally displaced people

$lnVe$ = logarithm of the number of Violent events

$lnNve$ = logarithm of the number of Non-violent events

$lnDm$ = logarithm of the number of Demonstration

$lnNve$ = logarithm of the number of Floods

$lnNve$ = logarithm of the number of Storms

Hence, the linear relationship can be written as followed:

$$ln(Idp) = a + a_1\, ln(Ve_{it}) + a_2\, ln(Nve_{it}) + a_3\, ln(Dm_{it}) + a_4\, ln(Fl_{it}) + a_5\, ln(St_{it}) + \varepsilon_t \qquad (11)$$

a_1 = Coefficient of violent event

a_2 = Coefficient of non-violent event

a_3 = Coefficient of demonstration

a_4 = Coefficient of floods

a_5 = Coefficient of storms

In case of no-cointegration, the ARDL $(p, q_1, q_2, q_3, q_4, q_5)$ model will be specified as:

$$\Delta lnIdp_t = a + \sum_{i=1}^{p} a_{1i}\, \Delta lnIdp_{t-i} + \sum_{i=0}^{q_1} a_{2i}\, \Delta lnVe_{t-i} + \sum_{i=0}^{q_2} a_{2i}\, \Delta lnNve_{t-i} + \sum_{i=0}^{q_3} a_{3i}\, \Delta lnDm_{t-i} + \sum_{i=0}^{q_4} a_{2i}\, \Delta lnFl_{t-i} + \sum_{i=0}^{q_5} a_{2i}\, \Delta lnSt_{t-i} + \varepsilon_t$$

In case there is co-integration, the Error correction model (ECM) representation will be specified

as:

$$\Delta lnIdp_t = a + \sum_{i=1}^{p} a_{1i}\,\Delta lnIdp_{t-i} + \sum_{i=0}^{q_1} a_{2i}\,\Delta lnVe_{t-i} + \sum_{i=0}^{q_2} a_{2i}\,\Delta lnNve_{t-i} + \sum_{i=0}^{q_3} a_{3i}\,\Delta lnDm_{t-i} + \sum_{i=0}^{q_4} a_{2i}\,\Delta lnFl_{t-i} + \sum_{i=0}^{q_5} a_{2i}\,\Delta lnSt_{t-i} + \rho ECT_{t-1}\,\varepsilon_t$$

With:

ρ = The speed of adjustment parameter with a negative sign which shows convergence in the long-run else the model is explosive

ECT = The error correction term, the ordinary least squares (OLS) residuals series from the long-run co-integration.

$a_{1i}, a_{2i}, a_{3i}, a_{4i}, a_{5i}$ = The short-run coefficient of the model's adjustment long-run equilibrium.

The differences (Δ), captures the short-run and the ECT, captures the long-run. The short-run causal effect is represented by the statistical significance of the t-statistic or (P-values < 0.05) on the explanatory variables (short-run coefficients). If the t-statistic of the coefficients $a_{1i}, a_{2i}, a_{3i}, a_{4i}, a_{5i}$ is significant, then we can know the direction of causality from the regressor to the dependent variable (Nkoro & Uko, 2016). The long-run causal effect is captured by the significance of the ρ, which is the parameter for the error correction term (ECT). If ρ is significant then it tells us that there is a long-run causality among the variables.

2.6 Methodology used for the forecast (ARIMA)

ARIMA stands for Autoregressive integrated Moving Average and is also called Box-Jenkins method. It's a modeling technique that uses econometric and statistical methods to measure events that occur over time. In a series, the model is used to interpret previous data or forecast future data in order to better take decisions. It can be used for univariate forecasting as well as in multivariate forecasting. In this thesis, we are very interested in what will be the future of Internal displacement in Burkina Faso. Although we are using the ARIMA modeling method, it needs some processes to

follow such as the stationarity, the selection of the best parameter to include in our model.

2.6.1 Unit root test or Data stationarity

The stationarity of the data is very important in the process of ARIMA modelling. Stationary data tells us that the mean, the variance, and the autocorrelation do not change over time. To check the stationarity of the data, we use the Augmented Dickey-Fuller test (ADF). The formula of the calculation is the same as in the ARDL model. In this concern, non-stationary data can be differentiated so that it could be stationary. The order at which our data is stationary is going to be a core parameter we include in the model building process. The differencing process is as follow:

$$y'_t = y_t - y_{t-1} \quad (11)$$

Where:

y'_t = The differenced series of the first order

y_t = The actual series

y_{t-1} = The past series

2.6.2 Autocorrelation and partial autocorrelation

Autocorrelation and partial autocorrelation are measurements of relationship between current and previous series values that reveal which previous series values are most beneficial in forecasting future values. This method gives information to identify the order of processes in an ARIMA model. To be more specific, ACF stands for autocorrelation function. This is the correlation between series values that are k intervals apart at lag k. PACF stands for partial autocorrelation function. This is the correlation between series values that are k intervals apart at lag k, taking into consideration the values of the intervals between.

2.6.3 Optimal lag selection

Optimal lag selection is very important in ARIMA modeling. The optimal lag selection can be done automatically, manually or using the autocorrelation and partial autocorrelation. The

automatically selection can be done using the minimum of the Akaike Information criterion (AIC) computed. Manually, we can select the optimum lag by using many combinations of the AR order, I order and MA order. However as stated in the autocorrelation and partial autocorrelation the order of can also be detected.

2.6.4 Forecast equation (ARIMA)

An ARIMA model is characterized by three 3 terms such as the Autoregressive (AR) order p, the Differentiation (I) order d, and the Moving Average (MA) order q. The ARIMA model is a combination of different single models. The Autoregressive model (AR) is the model that depends on its own lag. Then, the equation can be written in this form:

$$y_t = \alpha + \beta_1 y_{t-1} + \beta_2 y_{t-2} + \cdots + \beta_p y_{t-p} + \varepsilon_1 \qquad (12)$$

Where:

y_t = The predicted value of our series

y_{t-1} = The first lag of the series

β_1 = The coefficient of the first lag of the series

α = The intercept

As the Autoregressive model, we have the moving average model which is also depending on the lagged forecast errors. The equation can be written as follow:

$$y_t = \alpha + \varepsilon_t + \emptyset_1 \varepsilon_{t-1} + \emptyset_2 \varepsilon_{t-2} + \cdots + \emptyset_q \varepsilon_{t-q} \qquad (13)$$

Where:

The error terms are the errors of the autoregressive model of the respective lags.

Therefore, our ARIMA model can be developed by combining the AR model and the MA model. The model equation can be written as follow:

$$y'_t = \alpha + \beta_1 y'_{t-1} + \beta_2 y'_{t-2} + \cdots + \beta_p y'_{t-p} + \emptyset_1 \varepsilon_{t-1} + \emptyset_2 \varepsilon_{t-2} + \cdots + \emptyset_q \varepsilon_{t-q} + \varepsilon_t \qquad (14)$$

Where:

y'_t = The forecasted series

2.6.5 Model Evaluation

After forecasting the model evaluation is very important to check the performance of the model. It helps to accept the model build or to reject the model. For this purpose, many metrics have been developed for evaluating a model. Each metric has its strengths and weakness. That's why the choice of the metric should be made and be justified so that it can be acceptable. In our case we choose to use two metrics to evaluate the performance of the ARIMA model. The mean square error (MAE) is one of the strongest metrics. It helps to measure the average magnitude of the errors in our dataset of forecasts, without considering their direction.

$$MAE = \frac{1}{n}\sum |y - y'| \qquad (15)$$

Where:

y' = The forecasted series

y = The actual series

n = The length of the dataset

Moreover, the mean absolute percentage error is a metric that defines the accuracy of the forecasting method. It represents the average of the absolute percentage error of each entry in our dataset to calculate how accurate the forecast series were in comparison with the actual series.

$$MAPE = \frac{100\%}{n}\sum |\frac{y-y'}{y}| \qquad (16)$$

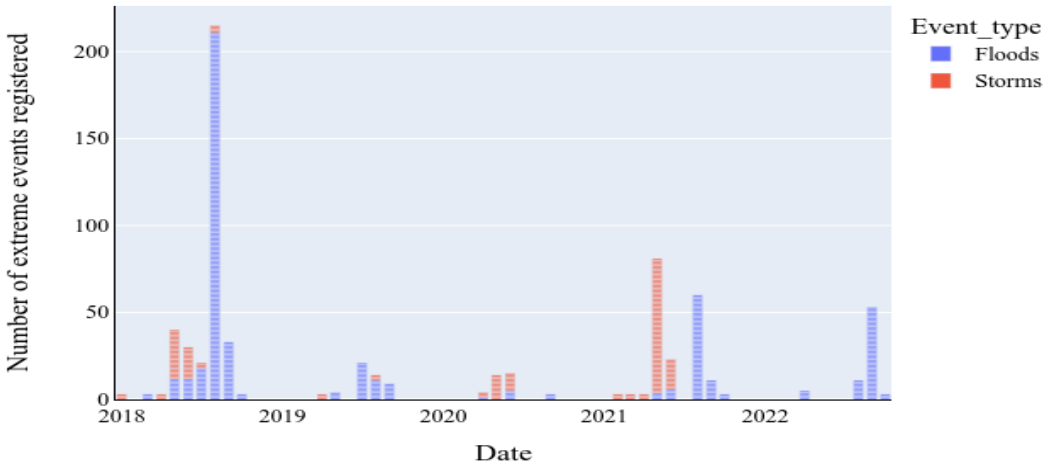
Chapter 3: Results and Discussions

This chapter presents and discusses the results, the tables, and figures are also presented and discussed.

3.1 Exploring the historical variability of climate extreme events, conflict, and Internal displacement in Burkina Faso.

3.1.1 Climate extreme events analysis over the time in Burkina Faso

The climate extreme events are over the time occurring in Burkina Faso. Generally, floods are events that could happen in rainy seasons, and storms in rainy season as well as in dry season. Thus, the below figure shows the variability in floods and storms occurrence in Burkina Faso from a period of 2018 to 2022.



Source: SP/CONASUR, Fire Service

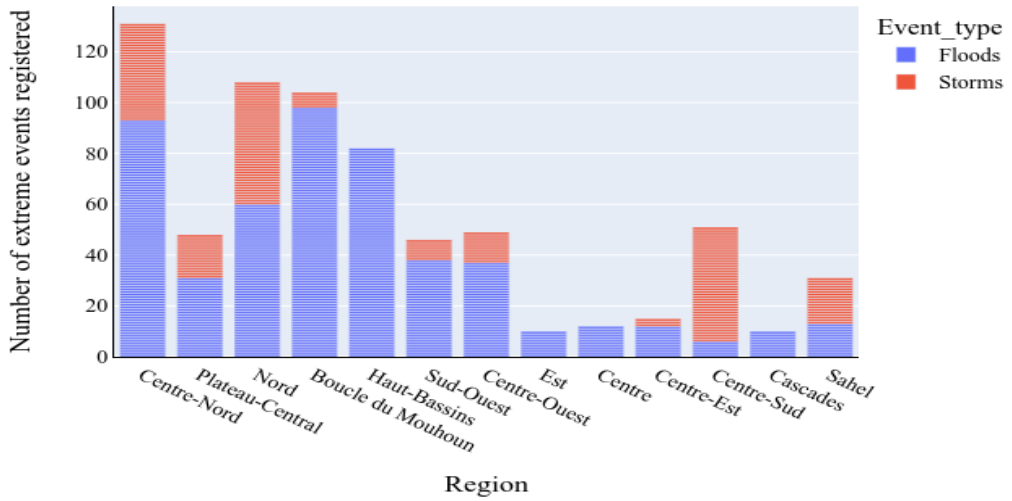
Figure 3 : Climate extreme events 2018 to 2022

This figure above depicts the periodicity in floods events in Burkina Faso. Usually, floods events are highly registered in the month of July to October. During the period of the study, the highest floods occurred each August. August 2018 has the highest case of floods with a level of 211 cases. Based on the figure above, storms events happen in the first semester of each year. This graph gives the easiest understanding of storms occurrences. Following its evolution, the year 2021 had the highest storms events with close to 100 cases registered.

3.1.2 Analysis of environmental disasters

An insight on the climate extreme events occurrence previously done, lead to more deepen of where those events are happening. The below figure depicts the number of the occurrence of each type of extreme events by region in other to see the most affected. During 2018 to 2022, we can see that all the regions have been impacted by floods. The most affected regions are the Boucle du Mouhoun, the Centre-Nord and the Haut-Bassins. These regions have more than 80 cases of floods during the time of the study. And the less affected are the region of Centre, the Est, the Cascade, Centre-Est, and the Centre-Sud. These regions have less than 20 cases of floods during the five years period while in the other regions the number of floods is over 20 cases but less than 60 cases of floods. Over time, all the regions are not affected by storms. The storms are more present in the

northern regions of the country (Sahel, Nord, Centre-Nord) but also in some regions in the center and the south (Centre-Sud, Plateau Central). We also observe that some of the regions had a very low case of storms. This is the case of the region of Boucle du Mouhoun, of the Sud-Ouest, the Centre-Est but also in Centre-Ouest. The other regions didn't have storms during the study period. Those regions are the Est, the Centre, the Cascade region, and Boucle du Mouhoun.



Source: SP/CONASUR, Fire Service

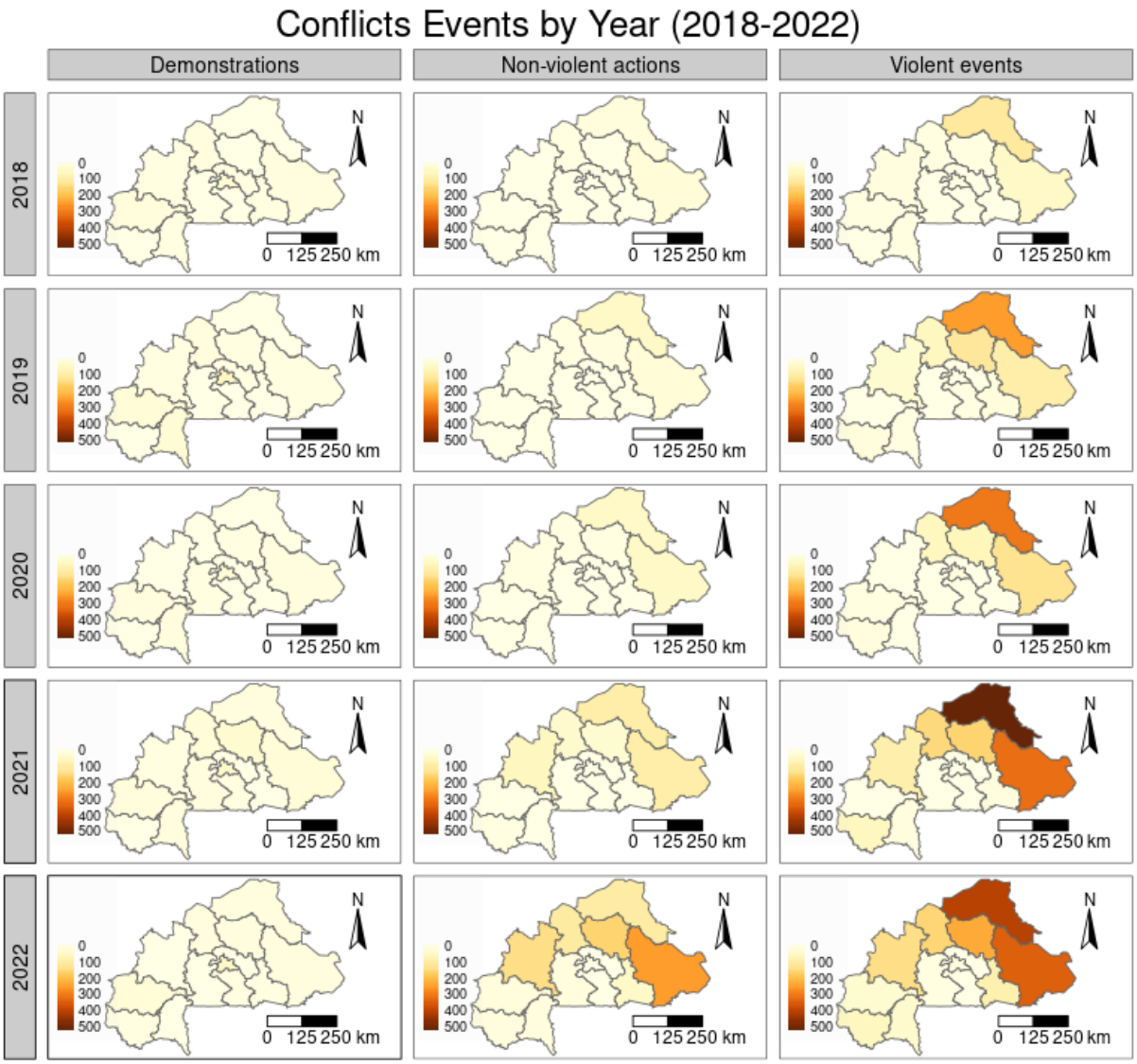
Figure 4 : Climate extreme events by region

3.1.3 Conflicts analysis

In chapter 2, we discussed the different types of conflicts. Those conflicts are all occurring in Burkina Faso. The analysis shown that the demonstration are the conflicts that are very low in Burkina Faso. The results show no changes (Figure5). This mean that the demonstrations are almost the same in Burkina Faso, but they are a little bite higher in the region of the Center and in the Haut-Bassins than the other regions.

Apart from Demonstration, non-violent conflicts are also a type of conflicts that usually happen in Burkina Faso. This conflict is the one that is growing now in the country. In the year 2018 up to the year 2020, we can see that this conflict is not so high in the country. Then, in the year 2021, it has becoming high in the year 2021 and more in 2022. In 2021, non-violent conflicts were more known in the Sahel and East regions than in the Boucle de Mouhoun, Nord and in the Centre-Nord regions. In the year 2022, the non-violent conflict has undergone a great evolution more in the

region of Est than the others. These non-violent conflicts evolved in the north and in the east while the regions of the center and the southern region are less affected. The violent conflicts have more occurrence. In 2018, the violent conflicts were important in the region of the Sahel and Est. In 2019 and 2020, it has evolved more in the Sahel but the changes in the region of Est was not so high as it was in 2018. In the year 2021, violent conflict was very high in the Sahel region. This can be close to 500 cases of conflicts in the region and is considered the highest, considering the duration of the study. Also, in the Est region this conflict has evolution and has started to reach more other regions. In 2022, violent conflict, has decreased in the Sahel region but the region was still the most affected. It has been followed by the Est region in which the conflicts have more occurrence than the previous year. After those regions, the map showed that violent conflicts were becoming more present in the region of the Centre-Est, the region of Cascade, in the Haut-Bassins and in the Sud-Est where the rate of these conflicts was very low. Despite the changes in the violent conflicts observed throughout the regions, we do not see a very important change in the number of conflicts in some regions. This is the case in the region of Centre, Centre-Sud, Centre-Ouest but also in the region of Plateau Central. Considering the type of conflict that is most affecting the country during the year, we can see that each year violent conflicts and non-violent conflicts are growing and are reaching new regions. In 2018, the only type of conflicts that was very denoted is the violent conflicts while others are still low. This have grown in 2019 and 2020 in the same regions in the country. After 2020, things have changed, and non-violent conflicts also have started to be very important in the country. We can also pull out from the map that these conflicts have started in the northern and eastern region and from there are spreading to other areas of the country.



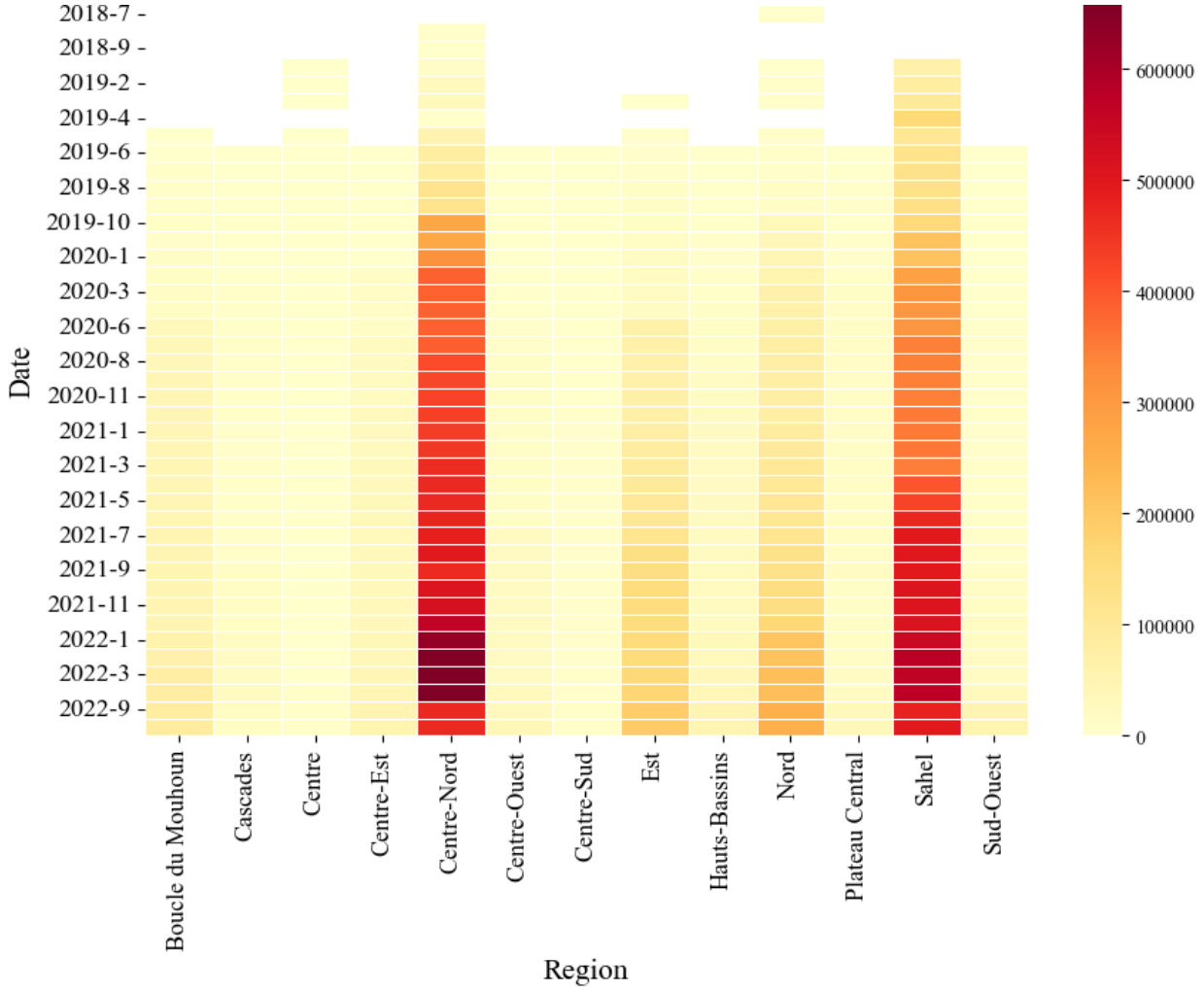
Source: ACLED data

Figure 5 : Conflicts events by year (2018-2022)

3.1.4 Internal Displacement analysis

The Internal displacement in Burkina Faso is a phenomenon well known in Burkina Faso. The changes in the colors of the plot show the number of internally displaced persons over time but

also the place where they are coming from. During the period of July 2018 to December 2022, we can see that the internal displacement was not very important in all regions. In July 2018, just a few internally displaced people have been registered in the country. It was only in the region of the Nord.



Source: SP/CONASUR

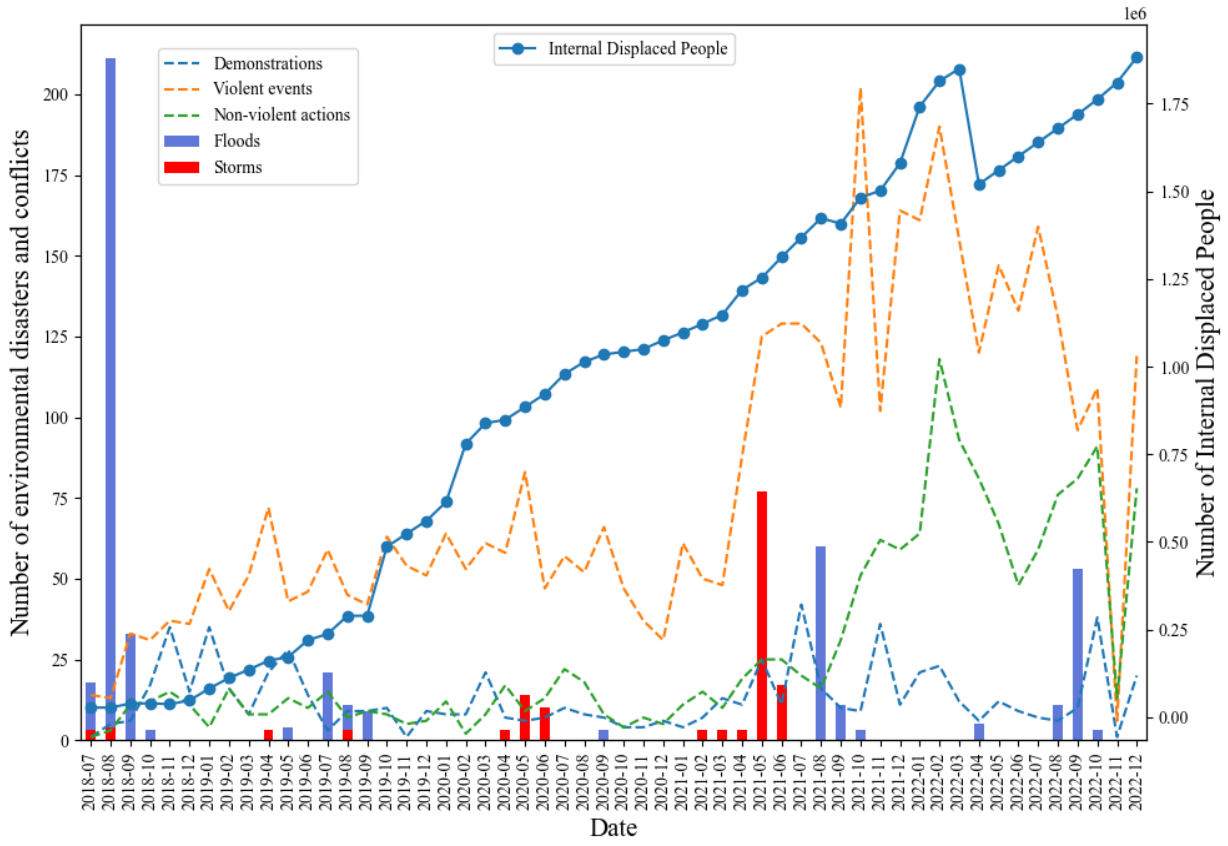
Figure 6 : Internal displaced people by month

After July 2018 up to the end of April 2019, it has started in some other region such as in the Sahel, Centre-Nord, Centre and in the Est. After July the Internal displaced have been recorded in the other region and up to December 2022, internal displaced people are now from each region. The

evolution of internally displaced persons is very strange in Burkina Faso. Right now, the country has more than 1.8 million internally displaced people. Looking at the below plot, two regions are the place where the displaced people are coming from. Especially in the region of the Centre-Nord and in the region of the Sahel. The displacement has started early in the two regions and intensifies over time. We can see that the number of internally displaced is also coming up from the region of the Nord, Boucle du Mouhoun and in the Est since June 2020 and is growing over time. The new region from where the internally displaced people is coming is the region of the Centre-Est and the Sud-Ouest. In the other regions, people are displaced but the number is less than 50000 people.

3.1.5 Analysis of Internal Displaced People, climate extreme events, and conflicts

Timeseries plots are one of the most used in data analysis when trying to capture information over time but also understand phenomenon by visualization. The plot we did in this section is putting together the evolution of extreme events, conflicts and the number of people recorded as displaced persons. Getting a look at it, we can try to compare each event to internal displaced people. Thus, in this comparison, we can see that the in 2018, when having the highest number of floods, the number of internal displaced people was very low while for the highest registration of storm in May 2021, the number of internally displaced people was very high. For conflicts, the Demonstration has a very low occurrence during the study period. Non-violent conflicts are very low at the beginning with small variabilities but in August 2022, they have started to be very a high. Comparing this with the internal displaced people number, we see that it has also a light evolution. For the violent conflicts, at the beginning of the study period, that were very important with also several internal displaced people growing. In March 2021, they had a very high evolution and also the number of internal displaced has grown in the country. Also, the light decrease of the violent conflict in July 2021 to September 2021 has been also followed by a light decrease of the number of internal displaced persons in October to November 2021. This was the case for the non-violent conflict.



Source: SP/CONASUR, Fire Service, ACLED data

Figure 7 : Evolution of climate extreme events, conflicts, and Internal displacement from 2018 to 2022

3.2 The role of environmental disasters and conflict on internal displacement in Burkina Faso.

Based on the methodology used in chapter 2, the investigation has been focused on the autoregressive distributed lag model (ARDL). This is a dynamic model that considers the lag values of the regressor but also for the lagged value of the dependent variable.

3.2.1 Unit root test for each variable

These unit root tests are the results after application of the Augmented Dickey Fuller test (ADF). The result can be seen in the table below where we have the ADF t-statistic, and the probability value (Prob.*) which is also called the P-values (MacKinnon P-values). However, the conclusion of this test is given by the start sign showing the significance level of the results at 1%, 2.5% and 5%. We can derive from the table that our variables are integrated at level I(0) or at the first difference I(1). This respects the condition of ARDL modeling. So, it implies that ARDL model can perfectly be used, and further analysis can be done.

Table 3 :Summary of the unit root test

Variables	Intercept				Intercept and Trend			
	ADF t-statistics	Prob.*	5% critical values	Order of Integration	ADF t-statistics	Prob.*	5% critical values	Order of Integration
LnIdp	-6.748638	0.0000	-2.918778	I(1)***	-6.681241	0.0001	-3.498692	I(1)***
LnVe	-13.24094	0.0000	-2.918778	I(1)***	-13.26188	0.0000	-3.498692	I(1)***
LnNve	-9.854916	0.0000	-2.918778	I(1)***	-3.637180	0.036	-3.496960	I(0)**
LnDm	-6.470125	0.0000	-2.917650	I(0)***	-6.406800	0.0000	-3.496960	I(0)***
LnFl	-5.989995	0.0000	-2.917650	I(0)***	-6.115303	0.0000	-3.496960	I(0)***
LnSt	-5.698434	0.0000	-2.917650	I(0)***	-5.650491	0.0001	-3.496960	I(0)***

3.2.2 Optimum Lag selection

In the second chapter, we discussed the lag selections methods. We demonstrated that several methods could help us to have the best lag for our model. We were focused on AIC, BIC/SC, and the HQ criteria. From our results, we find that the AIC criteria is the best for us. Choosing AIC is

not done though comparisons with the other criteria. Through comparison, we can find that the AIC criteria is the lowest among all the other criteria and the sixth lag has more selection than the others. By choosing this criterion in the right way, we are avoiding many misspecification problems such as including too few lags may result in omitted variable bias, while including too many lags may result in overfitting and decreased model efficiency. A model with the appropriate number of lags can help improve the model's predictive ability.

Table 4 : summary result of the optimum lag selection

VAR lag Order Selection Criteria

Endogenous variables: Idp, Ve, Nve, Dm, Fl, St

Exogenous variables: C

Date: 04/23/23 Time: 17:20

Sample 2018M07 2022M12

Included observation: 48

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-1684.729	NA	1.58e+23	70.44705	70.68095	70.53545
1	-155.035	223.2701	3.10e+21	66.50144	68.13874*	67.12018
2	-1508.530	66.36061	2.24e+21	66.10542	69.14613	67.25451
3	-1436.090	87.53210	5.94e+20	64.58708	69.03116	66.26651
4	-1408.968	25.99143	1.29e+21	64.95701	70.80452	67.16679
5	-1349.427	42.17546	1.06e+21	63.97610	71.22701	66.71623
6	-1217.186	60.61015*	9.10e+19*	59.96609*	68.62040	63.23656*

* Indicates lag order selected by the criterion

LR: sequential model LR test statistic (each test at 5% level)

FPE: Final prediction error

AIC: Akaike information criterion

SC: Schwarz information criterion

HQ: Hannan-Quinn information criterion

This is because the model is better able to capture the underlying relationships between the variables being analyzed. Also, by selecting this appropriate number of lags, our ARDL model is better able to identify the causal relationships between the variables and reduce the risk of spurious results.

3.2.3 Bound test

The bound test is the last test in the test to be carried out for the pre-estimation process. It reveals if the analysis should be done in the short run or in the long run. The acceptance or the rejection of the hypothesis has been stated in the second chapter. The result of the test shows that the value of the F-statistic (26.09468) is greater than the value of the upper band I(1) at 5% level of significance(3.79) and even at the other significance level (1% : I(1) = 4.68 ; 2.5% : I(1)= 4.18 ; 10%: I(1) = 3.35) . This means that we should reject the hypothesis of non-co-cointegration and accept the hypothesis of cointegration. The acceptance of this hypothesis implies that there is a long-term relationship that we should estimate.

Table 5 : summary of the bound test

Test Statistic	Value	Signif.	I(0)	I(1)
F-statistic	26.09468	10%	2.26	3.35
k	5	5%	2.62	3.79
		2.5%	2.96	4.18
		1%	3.41	4.68

3.2.4 Empirical results of the ARDL estimation

For the estimation of the short run ARDL model, we use AIC criterion. This criterion was the best

criteria among the other (BIC/SC) and HQ. For the model to estimate, we follow the instruction given by the pre-estimation process, especially the maximum lag selection. This model uses a maximum lag of 6 for the regressors and five for the dependent variable. For the dependent variable lag selection, we do not have a process for it, so it has been a choice made from our end. We choose the option of automatic selection. This has been made so that we can have the 20 top best orders. Then from these 20 top models we are estimating the ARDL (1,6,0,5,5,6) because it's the minimum among the all the best.

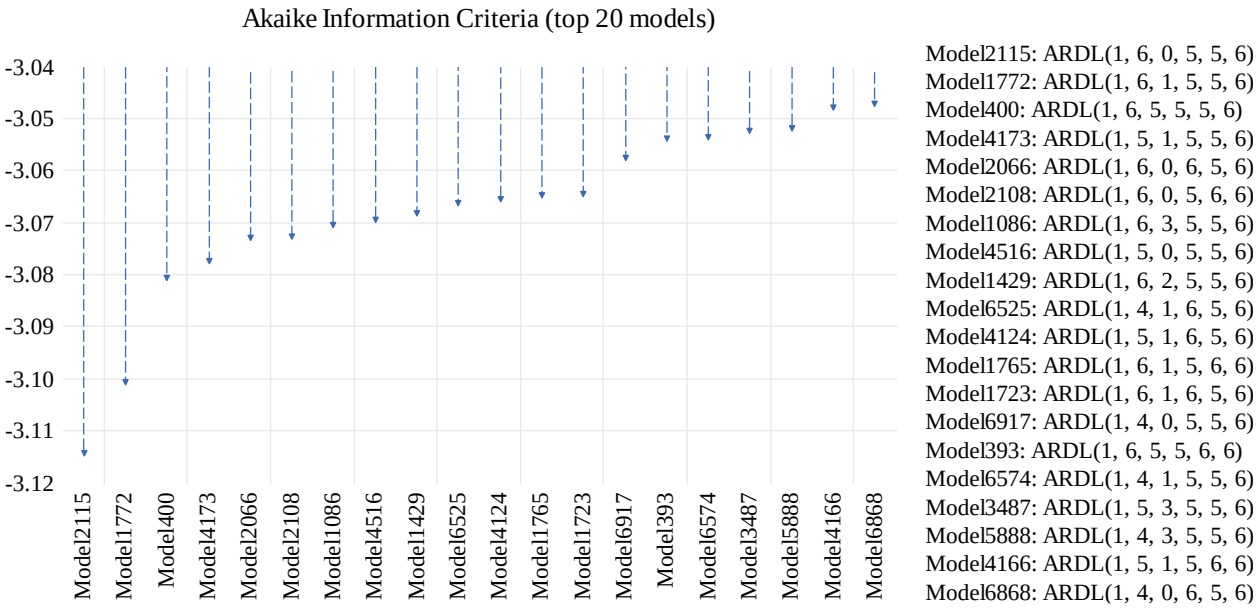


Figure 8: Summary of the best model selection with the ARDL approach

3.2.5 ARDL estimation

3.2.5.1 The Short run relation

The results of the short-run Auto-regressive distributed lag ARDL (1,6,0,5,5,6) model shows the relationship between the number of internal displaced people (LnIdp), and different other variables representing different events like violent events (LnVe), non-violent events (LnNve), demonstrations (LnDm), floods (LnFl) and Storms (LnSt). The coefficients in the model represent

the estimated effect of each independent variable on the dependent variable. The t-statistic and the probability value indicate the level of significance of each coefficient with lower probability value indicating higher significance.

The results show that, the lagged difference of the violent event has a positive coefficient of 0.057385, which imply that an increase in the number of violent events in one percent in the current period leads to an increase of (0.06%) in the number of internally displaced people in the same period. The past negative coefficient of the lagged differences of LnVe(-1) to LnVe(-5) indicate that the past violent events also have an adverse impact on internal displacement in Burkina Faso. The lagged difference of the demonstrations has a positive coefficient of 0.006275, suggesting that an increase in percentage in the demonstration can lead to a modest rise in percentage in the number of internally displaced people in the same periods. The positive coefficients of the lagged differences of LnDm(-1) to LnDm(-4) suggest that the demonstration also have a positive impact on people displacement in Burkina Faso. From the results, we can see that floods have a negative coefficient in its first lagged difference but also in the past difference. Which means that when floods increase it doesn't affect positively an increase in the number of internally displaced people. Which means that floods reduce the number of internally displaced people in Burkina Faso. There are some scenarios where floods can potentially reduce the number of internally displaced people. One such scenario is when an area has been experiencing prolonged drought or water scarcity, and a flood event replenishes the water sources in the region. This can reduce the pressure on communities to migrate in search of water and can prevent displacement due to water scarcity. Another scenario is when floodwaters provide nutrients to crops and improve agricultural yields. This can improve food security in the area, reduce the need for people to migrate in search of food and livelihood opportunities, and ultimately prevent displacement. For the case of Storm, we see that the coefficient of the lagged difference has a positive coefficient (-0.005192) implying that an increase in the severity of storms leads to one percent increase of the number of internally displaced people in the same periods. The negative coefficients of the lagged differences of LnSt(-1) to LnSt(-5) indicate that past storms also have an adverse impact on lnIdp.

Which means that in the short run, the occurrence of any violent event such as terrorism, sexual violence and any other in the same period are drivers of the internally displacement in Burkina Faso. The past event of conflicts doesn't really affect to the rise the number of internal displaced people in Burkina Faso in the short run. Also, in the short run, the intensification of demonstration

has significant effect on displacement in Burkina Faso whether in the present or whether in the past. Usually, those people are people protesting for a change in their conditions or any other reasons. When the government doesn't hear them, they must leave their place for a better life at any place in the country. The results show that when storms occur in the current period it leads to people migration in the same periods while the past events of storms don't affect positively to an increase of the internal displacement.

The model shows a positive value of the intercept, and this value is significant. A simple explanation of this coefficient is that we have many other variables that are driving the internal migration in Burkina Faso.

The R-squared value of the 0.947756 suggest that the model explain 94.8% of the variance in the LnIdp and the Adjusted R-squared of 0.897689 indicates that the model's explanatory power is reliable even after adjusting for the number of explanatory variables. The Error correction term (CointEq(-1)) has a negative coefficient of the -0.211888 indicating that the deviation of the short run results from the long-run equilibrium relationship between the variables converge backs towards the equilibrium at the speed of 21.19%.

Table 6 : Estimated Short-Run Coefficients Using: ARDL (1,6,0,5,5,6) model

ECM Regression Case 3: Unrestricted Constant and No Trend				
Variable	Coefficient	Std. Error	t-Statistic	Prob
C	2.193451	0.151970	14.43340	0.0000
D(LnVe)	0.057385	0.016104	3.563430	0.0021
D(LnVe(-1))	-0.293875	0.030770	-9.550675	0.0000
D(LnVe(-2))	-0.313353	0.037030	-8.462229	0.0000
D(LnVe(-3))	-0.216528	0.038695	-5.595762	0.0000
D(LnVe(-4))	-0.110131	0.037074	-2.970590	0.0079
D(LnVe(-5))	-0.056173	0.028528	-1.969019	0.0637
D(LnDm)	0.006275	0.009580	0.655033	0.5203
D(LnDm(-1))	0.152581	0.016363	9.324712	0.0000

D(LnDm(-2))	0.131063	0.015395	8.513367	0.0000
D(LnDm(-3))	0.093809	0.014812	6.333272	0.0000
D(LnDm(-4))	0.034412	0.010876	3.163975	0.0051
D(LnFl)	-0.005192	0.001594	-3256690	0.0042
D(LnFl(-1))	-0.011157	0.001816	-6.142617	0.0000
D(LnFl(-2))	-0.011838	0.001667	-7.101921	0.0000
D(LnFl(-3))	-0.009081	0.001701	-5.337867	0.0000
D(LnFl(-4))	-0.009172	0.001625	-5.644097	0.0000
D(LnSt)	0.006656	0.002529	2.631979	0.0164
D(LnSt(-1))	-0.018497	0.002724	-6.791005	0.0000
D(LnSt(-2))	-0.006240	0.002669	-2.338520	0.0304
D(LnSt(-3))	-0.007891	0.002317	-3.405400	0.0030
D(LnSt(-4))	-0.003928	0.002181	-1.800978	0.0876
D(LnSt(-5))	-0.008816	0.002094	-4210718	0.0005
CointEq(-1)*	-0.211888	0.015067	-14.06308	0.0000

R-squared	0.947756	Mean dependent var	0.076515
Adjusted R-squared	0.897689	S.D dependent var	0.123225
S.E. of regression	0.039415	Akaike info criterion	-3.322501
Sum squared resid	0.037285	Schwarz criterion	-2.386901
Log Likelihood	103.7400	Hannan-Quinn criterion	-2.968937
F-statistic	18.92977	Durbin-Watson Stat	2.257840
Prob(F-statistic)	0.000000		

3.2.5.2 Long run relationship results

The ARDL model is a powerful tool for analyzing the long run relationship between the variables. The model was specified as ARDL (1,6,0,5,5,6). This result was estimated from the result of the short run and the long run result of the previous model. The result of the model showed that the violent event has a significant and positive effect on the number of internal displaced people this

indicates that as the number of violent event increases in Burkina Faso the number of internally displaced people also increases. This finding is consistent with the information provided in the earlier results in the short run, which indicated that Burkina Faso has been experiencing a significant increase in violent event such as battles, explosions, violence against civilians and other forms of armed conflicts. Usually when there are conflicts, mainly armed conflicts, people run away from the affected areas by just fearing the conflicts. Conflicts from observation and intuition are a very high drivers of people displacement. Therefore, this finding is not surprising, given that Burkina Faso has been experiencing a surge in violent conflicts during the time covered by this research study. Particularly in the northern and the eastern regions of the country where the internally displaced people are coming from armed groups, including jihadist groups, have been responsible for much of the violence, which has led to displacement and a humanitarian crisis. We also have the negative coefficient of the non-violent event (-0.158877), which means that one increase in percentage of non-violent event lead to a decrease in percentage of (-0.158877) number of the internally displaced people. Also, this coefficient is not significative. Which means that we could draw a conclusion on that because the result is not so reliable for decision making. For the demonstration, the result of the estimation gives in the long run a negative coefficient (-0.556042). This result let us understand that demonstration encourage to a decrease of internally displaced people in Burkina Faso. From that we can say that an increase in one percent of demonstration reduces internal displacement to -0.556042%. This result of the estimation is statistically significant (0.0063) because the probability value is less than 5%. The demonstrations events are usually events that include protest and riots. In the case of Burkina Faso, protest happen such as non-violent protest which itself include peaceful demonstration and sit-in. They are often seen as an important form of political expression and can help to raise awareness about social and political issues. From our knowledge, protests can have both negative and positive effects on democratic participation. On one hand, protests can help to mobilize and empower citizens and can serve as a mechanism for holding political leaders. Protests can help build social networks and coalitions that can lead to greater engagement and participation and on the other hand, protest can lead to polarization and social fragmentation. So, from our case the result we got gives a fact that in Burkina Faso demonstration events are done for claiming an improvement. If these claims are from the government, we can conclude that the government understands the needs of the protesters and helps to solve improve their life or any type of issue that have been raised. That is a fact for which

we say that demonstration vents are tools used by Burkina Faso people to raise their voice and reach their needs. For the case of floods, from the result it has been shown that flood event has a positive coefficient (0.049344). In the context of Burkina Faso, floods can have an impact on the population and the economy, leading to displacement, loss of property and damages to infrastructure. This indicates that floods are drivers of the internal displacement, but the result is insignificant (0.1782). This insignificance of floods indicates that the relationship between floods and internally displaced people in the long run may not be robust and we can't base on this take a reliable decision. According to the estimated coefficients of the model, Storms have a significant positive long run effect on the number of internally displacement in Burkina Faso. Its coefficient (0.137757), specify that, one percent increase in the number of storms event in Burkina Faso is associated with a 0.137757 percent increase in the number of internally displaced people holding another factor constant. Storms cause significant damage to infrastructure, homes, and crops, leading to displacement and migration of people. In Burkina Faso, for example, storms in recent years have caused significant damages to housing, agriculture, resulting in displacement of people from their homes. Moreover, Storms can also exacerbate existing conflicts and violence in a region. For instance, competition over scare resources such as water and land can be heightened during times of drought or flooding, leading to increased tensions among committees. Hence, the statistically significant positive long-run effect of storms on the number of internally displaced people highlights the importance of understanding the role of climate extreme events in causing displacement and migration, particularly in vulnerable regions such as Burkina Faso. It also emphasizes the need for effective disaster risk reduction and management strategies to mitigate the impact of storms and floods on vulnerable populations.

Table 7 : Estimated Long-Run Coefficients Using: ARDL (1,6,0,5,5,6) model

Dependent Variable : LnIdp

Variable	Coefficient	Std.Error	t-Statistic	Prob.
LnVe	1.465514	0.214997	6.816443	0.0000
lnNve	-0.158877	0.129106	-1.230591	0.2335
lnDm	-0.556042	0.181122	-3.069985	0.0063
lnFl	0.049344	0.035296	1.398034	0.1782
lnSt	0.137757	0.036721	3.751449	0.0014
C	10.35195	0.768770	13.46560	0.0000

3.2.6 Post-estimation Tests

3.2.6.1 Autocorrelation Test

For the autocorrelation test, Breusch-Godfrey is one of the most powerful among many we know. This test uses the residues of the model. This is based on a hypothesis of which there is no serial correlation of any order up to p. the results of our test shows that we should accept this hypothesis and reject the alternative hypothesis which state that the model is suffering from serial correlation.

Table 8 :summary result of the autocorrelation test

Breush-Godfrey Serial Correlation LM Test: Null hypothesis: No serial correlation at up to 2 lags			
F-Statistic	0.298288	Prob.F(2,17)	0.7459
Obs*R-squared	1.627340	Prob.Chi-Squared (2)	0.4432

3.2.6.2 The Heteroscedasticity Test

Objective for which we are conducting this test is to determine whether the variance of the residuals is constant or not. For this we have two assumptions. The first is called homoscedasticity (when the variance of the residual is constant) and the second is called heteroscedasticity (when the variance of the residual is not constant). It's preferable to have homoscedasticity rather than heteroscedasticity.

The hypothesis for the heteroscedasticity test can be created as follows:

Ho: Residual variance is constant (homoscedasticity)

H1: Residual variance is not constant (heteroscedasticity)

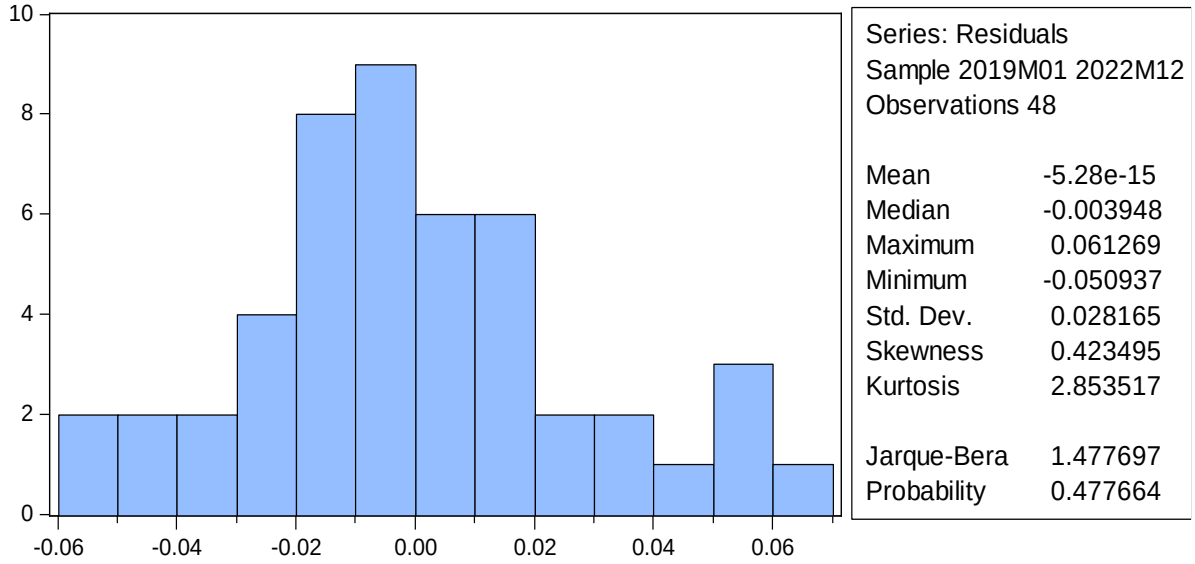
In our case if the P-value > 0.05: Ho is accepted and if P-value ≤ 0.05: Ho is rejected (H1 is accepted). Our result shows that the variance in the residuals for this model is homoscedastic. Then our model is free from heteroscedasticity.

Table 9 : Summary of the Heteroscedasticity test

Heteroskedasticity Test: Breusch-Pagan-Godfrey Null hypothesis: Homoskedasticity			
F-Statistic	0.491684	Prob.F(28,19)	0.9572
Obs*R-squared	20.16725	Prob.Chi-Squared (28)	0.8583
Scaled expalained SS	2.928451	Prob.Chi-Squared (28)	1.0000

3.2.6.3 Normality Test for Residuals (Histogram and Jarque-Bera Test)

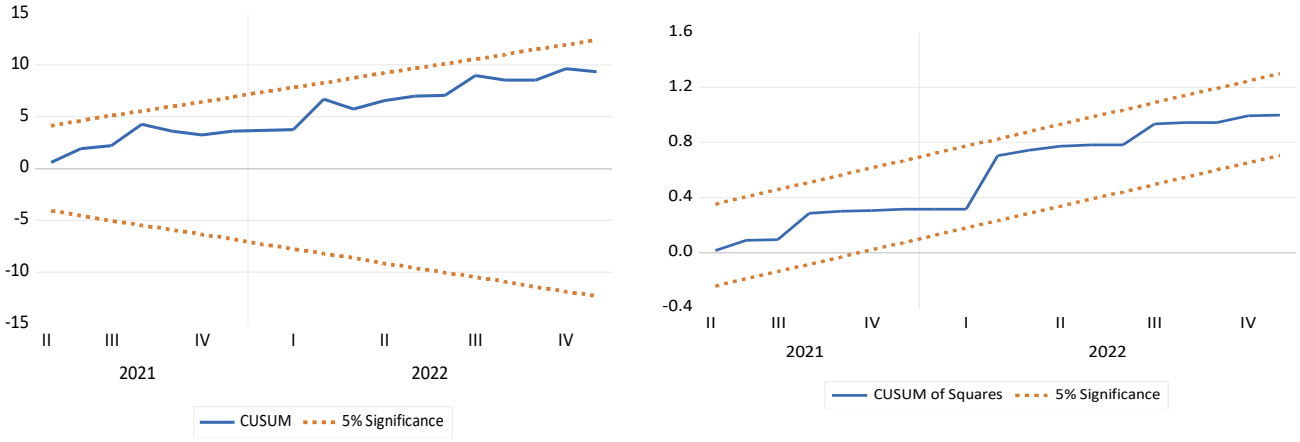
The Jarque-Bera test for normality is one of the tests that measures if sample data has skewness and kurtosis that are like a normal distribution. The Jarque-Bera test statistic is always positive, and if it is not close to zero, it shows that the sample data do not have a normal distribution.



Source: Author computation from EViews

Figure 9 : Histogram of the ARDL residual distribution

3.2.6.4 Parameter Stability Test (CUSUM Graph)



Source: Author computation from EViews

Figure 10: CUSUM and the CUSUM of the squares plot

The parameter stability test is based on the cumulative sum of recursive residuals and plot the cumulative sum with 95% confidence bands. In the previous section, which is the chapter on the

methodology we define the assumptions. The result shows that the model parameters are stable because our CUSUM plot and the CUSUM of the square falls between that upper and the lower band.

3.3 A forecasting model for internal displacement in Burkina Faso for the year 2025.

3.3.1 Results of the ARIMA forecasting model

3.3.1.1 Determination of the Best order

The determination of the best order for an ARIMA model is very important. Three methods can be found. The first is the automatic method by using the minimum Akaike information criteria (AIC). The second is the ACF and the PACF plot methods to determine the best order. The third and last method is a manual method by trying many combinations to get the best order parameter. These methods are used to help calibrate the model.

In our case the result of the automatic determination using the AIC shows that using 0 lag, differencing twice our data, and using 1 as parameter of the moving average (0,2,1) is the best order for our model.

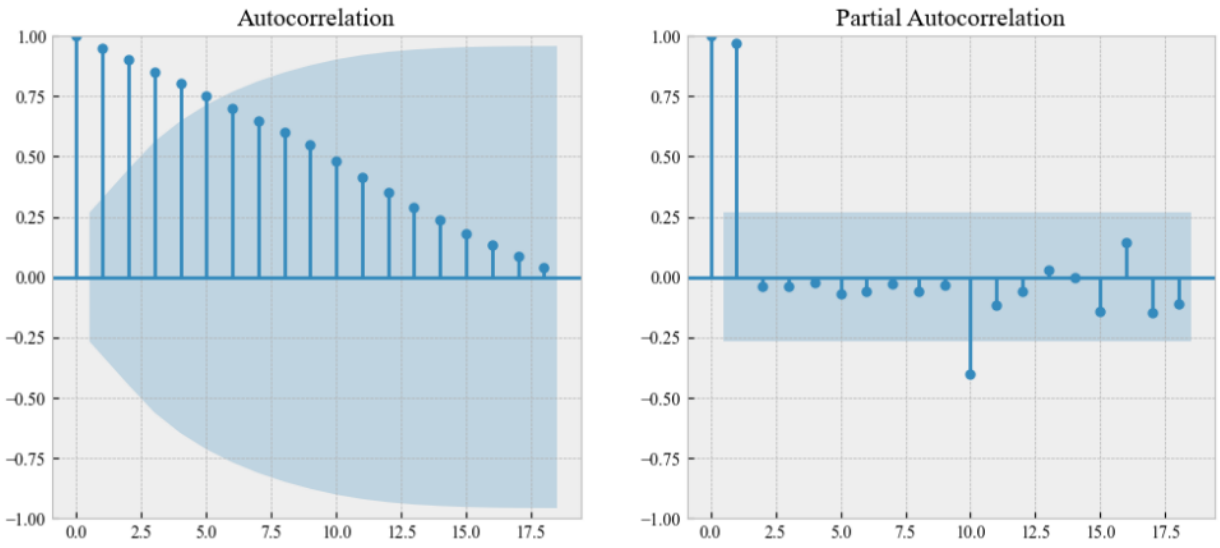
Table 10 : summary of the best model with ARIMA forecast model

Best first Model	AIC
ARIMA (1,2,1)(0,0,0)[0] intercept	1146.248
ARIMA (0,2,0) (0,0,0)[0] intercept	1163.562
ARIMA (1,2,0) (0,0,0)[0] intercept	1148.127
ARIMA (0,2,1) (0,0,0)[0] intercept	1144.545
ARIMA (0,2,0) (0,0,0)[0]	1161.609

ARIMA (0,2,2) (0,0,0)[0] intercept	1145.002
ARIMA (1,2,2) (0,0,0)[0] intercept	1146.524
ARIMA (0,2,1) (0,0,0)[0]	1139.731
ARIMA (1,2,1) (0,0,0)[0]	1141.245
ARIMA (0,2,2) (0,0,0)[0]	1142.592
ARIMA (1,2,0) (0,0,0)[0]	1146.282
ARIMA (1,2,2) (0,0,0)[0]	1143.500

3.3.1.2 Autocorrelation and partial autocorrelation result

In other hand, the manual determination shows that a good forecast result can be also obtained by using the (5,2,2) combination. Using the Partial correlation plot, we can also see that in the ACF from the first to the six lag are significant and can be used as parameter for the autoregressive model, and from the PACF plot, we can derive that including three lags in our model for the as parameter for the moving average model is good.



Source: Author computation from Python

Figure 11 : Autocorrelation and partial autocorrelation

3.3.1.3 ARIMA forecast model evaluation

Our concern is to be able to forecast the future internal displacement number for the short term in Burkina Faso. This comes to split our model in to train and test set. One of the widely methodologies used is to use 80% of our data for train the model and the 20% remaining for testing the model and evaluate the model and judge the model based of the difference metric we calculated. For that end, we use the Mean Absolute Error (MAE) and the Mean Absolute Percentage Error (MAPE) to evaluate the model. In our model evaluation table below, we can see that our models are given a very close result. This means that all the models are acceptable with a qualification of high accurate forecasting (Montaño Moreno et al., 2013). But by comparing them, we see that the model (0,2,1) gives the least MAPE followed by the manually determined order (5,2,2). This is also the case for the MAE. However, the model order determines through the PACF and the ACF plot whether MAE or MAPE gives the highest result which means that we could reject it comparatively the two first.

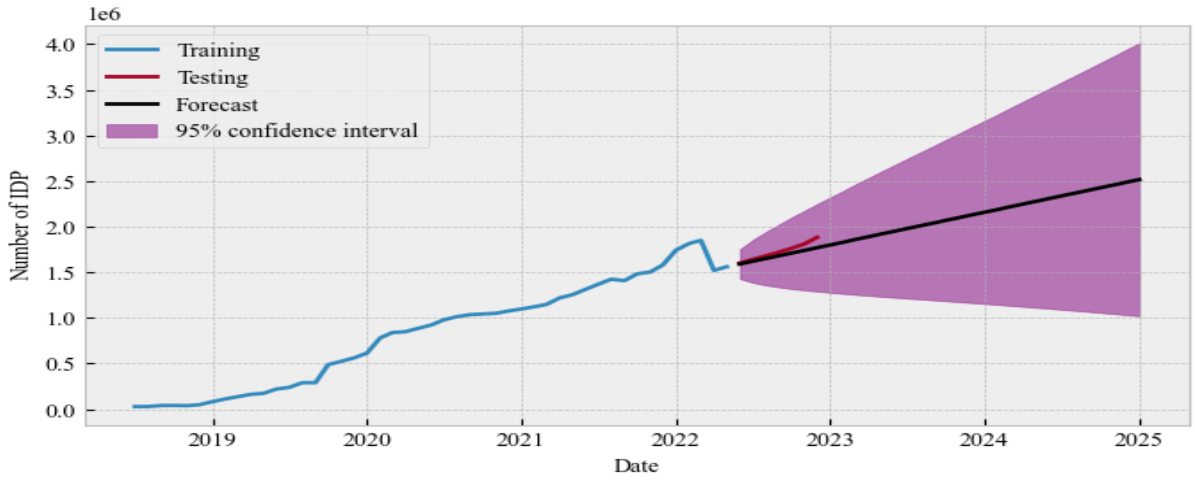
Table 11 : summary of the different ARIMA model evaluation

Forecast model order	MAE	MAPE
(5,2,2)	49107.65	2.916
(0,2,1)	48205.61	2.7
(6,2,3)	52158.31	3.07

3.3.1.4 Model selection Based on reality

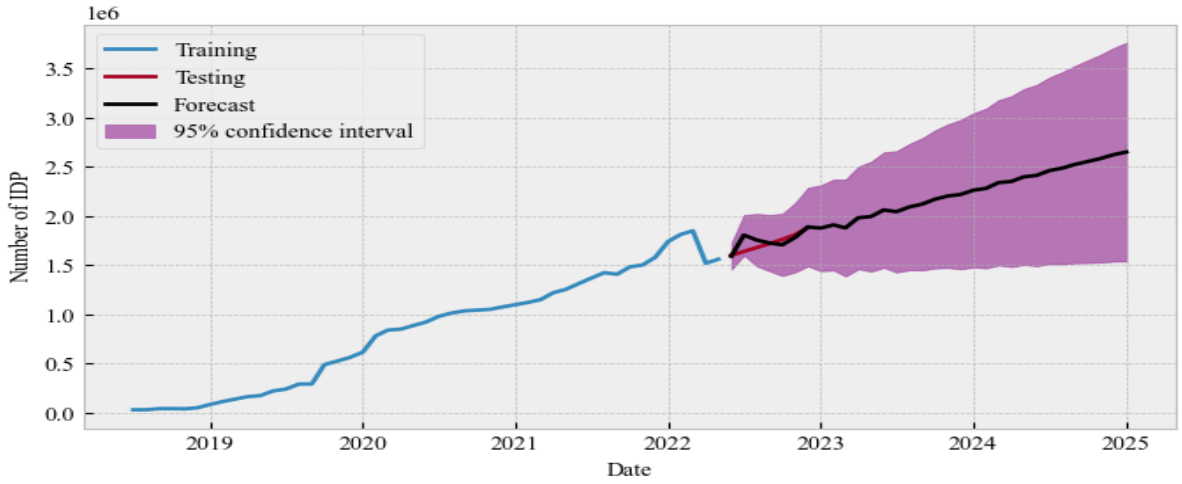
Theoretically, the three models are acceptable. If we follow the order of ranking, we can choose first the (0,2,1) and the (5,2,2) and at the end the (6,2,3). However, the reality has proven that it's better to choose the (5,2,2) rather than the others. We base this selection by using different analytics and the field recent realities such as the evolution in attacks or insecurity and inflation (SIRY and TRAORE, 2023). Further points that need the selection of that model is the IPCC report which states an increase in the number of extreme events. The plots below give the view on our

forecast result of IDP number up to 2025.



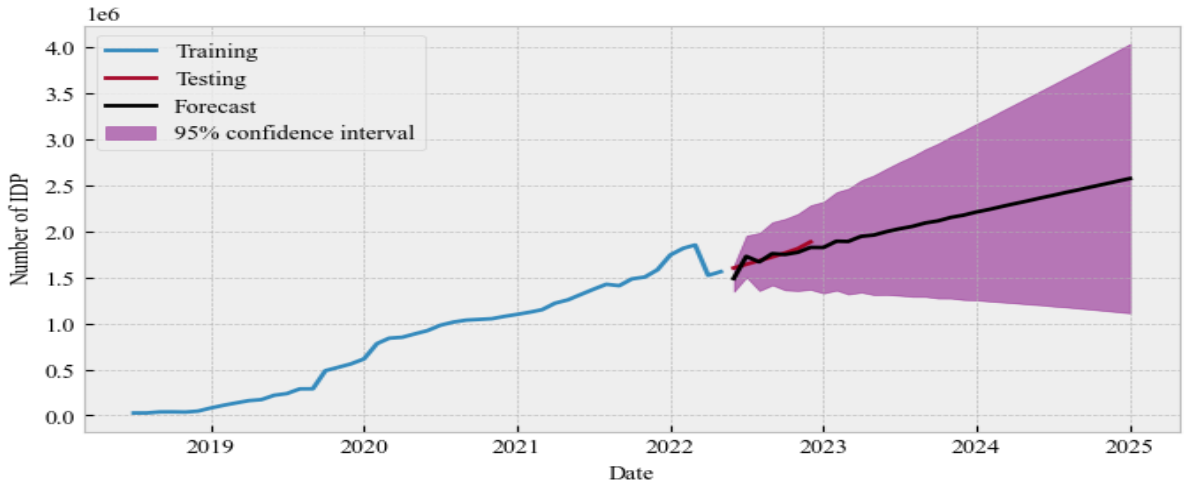
Source: Author computation with Python

Figure 12 : Internal displacement forecast for 2025, ARIMA (0,2,1)



Source: Author computation with Python

Figure 13 : Internal displacement forecast for 2025, ARIMA (5,2,2)



Source: Author computation with Python

Figure 14 :Internal displacement forecast for 2025, ARIMA (6,2,3)

3.4 Discussions

In this work, based on the three questions we have, three hypotheses have been drawn. We hypothesized that climate extreme events, conflict and Internal displacements are all going to be increase in Burkina Faso. This hypothesis has been set based on the IPCC reports, current conflicts observed and human security issues we observed in different regions in the country. However, the result shows that the number of internally displaced people are increasing as well as conflicts, mainly violent and non-violent, which are spreading toward regions in the country. This hypothesis falls in the case of the increasing number of extreme events because for that case, we observe variability. For instance, the year 2018 was very troubling with floods events while in the year 2021 many cases of storms have been registered. It has been found that those conflicts are from manly two group such as the Islamic State in the Greater Sahara (ISGS) and the Al Qaeda-affiliated Jama'at Nusrat Al Islam Wal Muslimin (JNIM) (ACLED, 2021). For the case of internally displaced people, we also find that many displaced are from the conflicts area which is something normal and meaningful because in the presence of the war or conflicts, people must flee their house

to save their life. Then this is confirming the result of the IDMC's Global Report on Internal Displacement in 2022 where many displacements are due conflicts and few from disasters (GRID, 2022). In our second objective, we were interested in deep-thinking on the relation and the contribution of each variable on the increasing number of internally displaced people. This leads us hypothesizing that climate extreme events and conflicts are contributing to an increase of internal displacement in Burkina Faso. From our result, we see that using the ARDL approach as modeling tools was very useful. It helps to capture the short run and the long run dynamics or relationship between the variables. We see that those violent conflicts have a positive coefficient at the period "t" but not the lagged period in the short run. From this we also see that many of these coefficients are highly significant. This means that violent conflicts that have happened in the last month or two and more do not encourage an increase in the number internal displacement but rather help to reduce it. This is a normal effect because when these events happen within a month people will flee. In fact, in the first month people will leave their homes and seek shelter but in the following months the fear and frustration created will diminish and some internally displaced people will certainly return to their homes. However, for the demonstration we observe that the occurrence of a demonstration event in a month "t" increases internal displacement in the short run. This is also the case for its lagged period. From an explanation of the component of the variable, we notice that demonstration encompasses protest and riots. Those events are usually about people that are fighting or claiming their rights. In the case of Burkina Faso, those protesters are students, and people raising their voice for social changes and changes in their economic conditions and even political changes. In the short run this leads to an internal displacement because protests are more peaceful while riots are not. This usually causes social troubles and people live by just fearing and avoiding risks. In the case of floods in the short run, we found that it reduces the number of displaced people in Burkina Faso. To give more detail on these results, from the work done at the University of Sussex which aim to assess the impact of climate change on migration and conflict in 2008 by Lisa Jordan and its collaborators, it has been found that in the near future, Burkina Faso is expected to be a place where drought will be more known than floods (Jordan, 2008) this is also confirming our finding. Therefore, from a long period of drought, people will leave their area because of the lack of rain, and the unproductiveness of the agriculture. From the first rains people will start to go back to their farms but in fact in case of floods they do not migrate because the duration of the floods is not too long to significantly destroy their crops.

Also, we can say that they manage traditionally or technically floods situation even if it may happen sometime that floods can affect their crops. In the short run also, we see that the occurrence of storms in a month have a positive effect as a contributor to a rise in the number of internal displaced people this result is significant which means that is not a fact of hazard. However more time past the previous storms event do not affect positively the number of internal displaced people. This, because of course after the storm's events, people perhaps may lose the roofs of their houses, the roots of trees that damage people's property. All of this will lead people to seek refuge elsewhere temporarily in order to seek funds and repair the material damage. Therefore, we see that usually in the second month up to the six month they usually come back to their place. This is a case of temporary displacements. Thus, we see that the Error correction term indicates that the deviation of the short run results from the long-run equilibrium relationship between the variables converge backs towards the equilibrium. This implies that the short run result we obtained will convergence to the long run result in the long term. In the long run we have seen that from the different variables we use only three are significant (Violent events, Storms, and Demonstrations). We see from the result that violent events will be a positive driver of internal migration as the country is currently experiencing extreme violence from different jihadist groups. Also, storms are going to be in the long run a positive driver to the raise of the number of internally displaced people. This is because according to the IPCC sixth assessment report, extreme events are going to be more severe. Thus, in this study the result shows that storms are going to be cause more displacement rather than floods in Burkina Faso. We also obtained from the results that in the long run the demonstration will be helpful in reducing the number of internally displaced people. Generally, the people have understood that the more they protest for their needs the more the government will be tired and will have no choice apart from serving them for national peace. In many cases in the world, demonstration is seen as a tool for democracy. This is also the case of Indonesia and in the Philippines where people use demonstrations to express their opinion and disagreement towards the government and is considered as a tool for a democracy system (Mamangkey, 2022). Concerning our forecast, from the chosen model, we see that the number of the internally displaced people is going to be increase in this short run which is the earlier 2025. Our result has been also confirmed by the Danish Refugees Council (DRC) which also find that the number of IDP will increase in Burkina up to 2.61 million of people by the end of 2024 (Council, 2023). In other hand, if we consider the upper bound and the lower bound for our

forecast, we see that the forecast of the UNHCR falls between or forecasted value and the upper band (Burkina Faso, 2023). Moreover, the results also show in the short run as well as in the long run that the Intercept of our model is positive and significant this implies that there are other factors which are contributing positively to a raise in the number of internally displaced people in Burkina Faso. For instance, in this research work drought were not included while some work evidently cites Burkina Faso to be the place where drought will be very severe in the near future (Jordan, 2008).

Conclusion and perspectives

Conclusion

The comprehension of migration is still broad. In fact, it encompasses many other concepts including internal migration well debated in this thesis. Internal migration itself is very large and contains many other aspects. This thesis investigated the case of internal displacement which can be caused by many factors such as climate related events, social conflicts, attacks of violent groups and terrorism or from many other factors. The results, from analysis of the historical data showed that many regions were flooded, and the flood cases were more intense in some regions than others. Many storm cases also were observed in different regions but were mostly registered in the northern regions and eastern regions than the others. In fact, many displaced people in Burkina Faso are mainly from the north and east regions. In terms of different conflicts, we explored demonstration events, non-violent events, and violent events. Non-violent events started since, but they were not intense. They have started to be more known in 2021 in the north and the eastern region while in 2022 they were higher in the east and other northern region. For the Violent events, the Sahel region has been very touched from 2018 up to 2022 and spread in other northern and eastern regions. Putting together the violent events and the non-violent event we can also derive that the non-violent event which concern people arrest and many other events can be related to violent event. The terrorist groups are well installed in the Sahel region. Therefore, they pursue attacks in the eastern region where the government also turns its arrests on. The contribution in the short and long run of the different variables to the increase of the number of internally displaced people are also investigated. In the short run, violent events, demonstrations, and storms are the contributors to an increase in the number of IDPs and in the long run, Violent events, storms, and Floods contribute to an increase in the number of IDPs. The results of the forecast for the number of internally displaced showed good performance and accuracy. The percentage of error was very low, which means that the forecast is very highly accurate. However, the confidence interval of the ARIMA (5,2,2) forecast model, was not very large but can be used for decision making. The accuracy was 97% which means that the model can predict and simulate future decisions. In general, from the findings, actions should be taken from the end of the government as well as from the population. From the end of the government, Internal displacement can be seen as an

opportunity in such a way that the government can invest in the training of the IDPs so that they can join other sectors of activity. Also, by putting in a place a sophisticated method of preventing climate extreme events, many damages can be avoided. Because once people have received the information, they can take the necessary measures to reduce the impact of these extreme events. Government can put in place quick and strategic management of extreme events so that their effects won't affect for long duration the people usually affected. For or the conflict events we congratulate the government on its efforts. We also encourage the government to add the use of artificial intelligence in the management of conflicts as well as prediction of extreme events. Monitoring, but also prediction of conflicts is mandatory and can be done. From the end of the population who are people that are facing these problems, we encourage them to help the government in the fight against terrorism and be collaborative so that the conflicts can be stopped in a very short duration. Also, the population can save themself by putting in place some traditional way of flood management. Tree planting can also be an action they can take to reduce the effect of storms on their crops and habitats. Those actions must contribute to the reduction of internal displacement in Burkina Faso. The government could continue to arrest people if they find it useful in reducing the number of internal displaced people. Concerning our hypothesis, the first and second hypothesis of the study were partially confirmed but the third was fully confirmed. At the end this work is also an added value to research. First, we can say in term of Burkina Faso that, this is a first time such axis of research is conducted on the whole country. The thesis contributes to show the dynamic nexus between displacement, conflicts and extreme events. The work shows that violent events and climate extreme such as floods and storms are some majors drivers of displacement in Burkina Faso. This thesis helps also in understanding the historical variability of each event. The thesis will help the government in where to take action in case they would like to take action on reducing the effect of floods and storms. With the forecast, the government can have an idea on what can be the future of internal displacement and put the best politics in place.

Perspectives

The results of the modeling sections have shown that in the short run, violent conflicts, storms and demonstrations are significantly explaining the internal displacement and in the long run Violent events, floods and storms drive displacement in Burkina Faso. The current study therefore calls

for other research studies in the same field to investigate other drivers of internal displacement in Burkina Faso. Some studies can be focused on linking internal displacement and inflation, internal displacement and food security, internal displacement and the government policies or internal displacement and people's health. The constant was very significant, which implies that many factors are still missing. However future research can also be focused on the causes of floods. For the lack of infrastructure, it may happen that floods occur just because there's no way for the rainwater to flow. Therefore, we can also investigate in this area so that improvements can be done. Also, further research can be done on the willingness of the IDPs to be trained and later we can propose to the government a policy brief on the management of the IDPs.

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development and management of lake oursi forage production and stockpiling of feed for livestock managing natural resources and forests country overview overview. (2016). www.worldclim.org/current

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