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Weather variability and food insecurity as driving forces for out-migration, 1992-2016: a study from rural Burkina Faso

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Dedication to:

To my wife, Lydie. To our son, Galilee, and nephews Saibata and Sylvie. To my mother and father for giving me life and education. To all my brothers and sisters in the extended family.

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List of abbreviations and acronyms

ACCRONYM		SIGNIFICATION
ANAM	:	Agence Nationale de la Météorologie (National Meteorological Service of Burkina Faso)
AVV	:	Aménagement des Vallées Voltaiques
CRSN	:	Centre de Recherche en Santé de Nouna
EDS	:	Enquête Démographique et de Santé
FAO	:	Food and Agriculture Organization of the United Nations
HDSS	:	Health and Demographic Surveillance System
HIGH	:	Heidelberg Institute of Global Health
HIPH	:	Heidelberg Institute of Public Health
INDEPTH	:	International Network for the Demographic Evaluation of Populations and their Health
INSD	:	Institut National de la Statistique et de la Démographie
IOM	:	International Organization of Migrations
IRR	:	Incidence Rate Ratio
MADIMAH	:	Multisite workshop of analysis on Dynamics of migration and health
NASA	:	National Aeronautics and Space Administration
NOAA	:	National Oceanic and Atmospheric Administration
RGPH	:	Recensement Général de la Population et de l'Habitation
SD	:	Standard deviation
SE	:	Standard Error
SDG	:	Sustainable Development Goals
UN	:	United Nations
UNFCCC	:	United Nations Framework Convention on Climate Change
UNFPA	:	United Nations Population Fund

USA	:	United States of America
VA	:	Verbal Autopsy
VER	:	Vital Events Registration
WASCAL	:	West African Science Service Center on Climate Change and Adapted Land Use
WEDO	:	Women's Environment and Development Organization
WHO	:	World Health Organization

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1. Introduction

1.1 Research rational

Climate change impacts ecosystems, plant and animal species, water quality and quantity, infrastructure, human health and well-being, cultures, and the earth's heritage. Living things dependent on nature and the environment will have to cope with these impacts through adaptation and mitigation (Sorgho et al. 2020). This climatic impetus is not without consequences for the living conditions of human beings. Empirical investigations have shown that climate change is associated with crop failure and food insecurity, which are important determinants of health outcomes (Belesova et al. 2017). These health risks have been shown to be lower under 1.5°C climate warming compared to 2°C of climate warming (Belesova et al. 2017; Belesova et al. 2019; IPCC 2018).

In sub-Saharan Africa, where agriculture is mainly for subsistence, climate change has led to low crop yields (Belesova et al. 2019). In this context, low crop yields have been associated with major health impacts such as on child mortality. The effects of low crop yields in the year of childbirth are particularly crucial (Belesova et al. 2019). In rural Burkina Faso, rainfall variability, feeding patterns, and young child undernutrition are founded to be empirically and significatively associated (Mank et al., 2021). The increasing variability of rainfall and temperature influence the growth of crops (Vinke et al. 2021; Vinke et al. 2022). Moreover, the agricultural sector is highly sensitive to climate variability and this makes it more difficult to produce the additional 60 % of the food needed by 2050 to feed a growing population in the world, mainly in sub-Saharan Africa. This climate change and agriculture connection has grasped the attention of the international community. The United Nations Framework Convention on Climate Change (UNFCCC) states that climate change is a key driver of food insecurity and a risk amplifier (Sitati et al. 2021). Moreover, the Food and Agriculture Organization (FAO) of the United Nations (UN) states that the effects of climate change on food security will increase in the upcoming years. Approximately

800 million people around the world will go to bed hungry at night, most of them being small-scale farmers who depend on agriculture to earn a living and feed their families (Raleigh et al. 2008). The UN Sustainable Development Goals has placed food security at the heart of global targets, including with "Zero Hunger by 2030" and the Paris Agreement on Climate Change recognizes the need to protect vulnerable populations, including migrants (UN 2015).

Burkina Faso is located in Sub-Saharan Africa. Its climate is dry tree savanna with an average annual rainfall of 796 mm (Diboulo et al. 2012; Diboulo et al. 2016). The majority of its active population (about 80%) is composed of farmers, and the country has already been experiencing the impacts of climatic hazards such as mini-droughts, heat waves, torrential rains, and extreme weather events for nearly 40 years (Sorgho et al. 2020; SP/CONAPO 2011). These effects are not without consequences for the economy and social and environmental domains (SP/CONEDD 2011). The population itself and the national economy are highly dependent on agriculture, livestock and forestry. Indeed, agriculture occupies about 80% of the active population and this agriculture is mostly rain-fed and subsistence. The majority of people eat what they grow. Climatic aridity persists and increases over the years, resulting in the increasing precariousness of food production. The country's geographical position and climatic conditions explain the fragility of its natural environmental resources which can have an impact on human life and behavior. This situation leads to the movement of families from dry areas to wet areas in search of land suitable for agriculture (SP/CONAPO 2011). In this context of agricultural dominance, the effect of climate change on population movements are intensified because migration is closely linked to climatic conditions (Henry et al. 2004).

Climate impacts on natural resources may influence health parameters through direct or intermediate variables. First, directly, climate change could affect the frequency of extreme weather conditions, including heat, drought and heavy rainfall. Second, the impacts of climate change on health outcomes, include other more direct physical and mental health effects such as stress, anxiety, depression as well as a range of some 100 climate-sensitive diseases (Schwerdtle

et al. 2020). The effects may be strongly mediated by human systems, such as occupational impacts, undernutrition and mental stress (Field et al. 2014). Lacking enough to eat, and the loss of the expected harvest is not without consequences on the mental health of the population. The reduction in the quantity of the harvest will impact the quality of nutrition and increase the stress of life (Mank et al. 2021; Schwerdtle et al. 2020). Similarly, qualitative study on out-migration, carried out in Bourasso, a village, situated in the study area., found that a major reason for their husbands' seasonal outmigration was poor harvest (Vinke et al. 2021).

Faced with the effects of climate change, humanity is adopting behaviours accordingly to mitigate, counter, or adapt to the impacts of climate change. Among a multitude of existing strategies, some populations resort to outmigration (Schwerdtle et al. 2019). Populations will respond to poor economic, social, and political conditions by migrating in hopes of finding better living conditions (Kumari et al. 2018). In particular, populations that are highly susceptible to being trapped in areas that are highly exposed to the impacts of climate change and that have not been able to ensure food security have often no choice but to migrate, at least seasonally, i.e., in the dry, non-agricultural season. Recognizing the irreversible environmental shift from climate change, the United Nations stated that with the increasing frequency of tropical storms, hurricanes, droughts, and floods in many parts of the world, and given the devastating impact of natural disasters on the lives and livelihoods of climate-vulnerable communities, the magnitude of migration is expected to increase further (UN 2015; UNFCCC 2017). Furthermore, migration is central in the 2030 Agenda for Sustainable Development (UN 2015), and 30 of the 244 indicators defined to achieve the 169 targets related to the 17 SDGs refer to migration. Reports estimate that between 200 million and 1 billion people will be displaced by climate change over the next 40 years, pending on the degree of warming which humankind allows to happen (Laczko and Piguet 2014; Voûte et al. 2021). A recent World Bank study on climate-induced migration asserts that Sub-Saharan Africa, South Asia, and Latin America would experience about 140 million internal climate migrants by 2050 (Kumari et al. 2018).

In addition, Burkina Faso's high migration rate is due to population growth, geographic location, history, and colonial arrangements (CONAPO 2006). To date, about 3.5 million Burkinabés live and work in Côte d'Ivoire. Burkinabés are known to be a very mobile people compared to those in other West African countries (Henry et al. 2003). Burkina Faso has historically been a country of migration both within and outside its borders. Estimated at 4,349,000 in 1960-61, Burkina Faso's population reached 20.4 million in 2019. The average annual growth rate was 2.9 % between 2006 and 2019 (INSD, 2020). Burkina's population is characterized by extreme youth. The average age is 21.8 years, while the median age is 15.5 years.

The settlement of the territory has been consolidated on a background of occupation by several sedentary peoples who arrived in successive waves of migration. Thus, the ancient settlement gradually diversified with the arrival of groups, between the 13th and 18th centuries. Attached to the colony of Haut-Sénégal - Niger in 1904, the territory was made a colony in 1919 under the name of Haute Volta after the revolts of the populations of the *Boucle de la Volta Noire* in 1916. The dislocation of the territory in 1932 and the attachment of two-thirds of its surface area to the Ivory Coast and French Sudan (now Mali and Niger), was the result of the French colonial vision that placed the majority of human resources and capital at the service of the coffee and cocoa plantations of the Ivory Coast and the projects of French Sudan. Under pressure from the customary and religious chiefs, the colony of Upper Volta was re-established in 1947 within its 1932 boundaries. Indeed, because the colonization plan specialized in the movement of labour in West Africa to supply the plantations of the Ivory Coast, the French-Sudan and the projects of Senegal, many individuals fled the harshness of French colonization for the Gold Coast (current Ghana), such as requisitions, forced labor, house tax, and increasingly massive military recruitment (CONAPO 2006). On the Gold Coast, the British colonial system of Indirect Rule was more flexible, and wages were much higher than those paid in the Ivory Coast. The Gold Coast was therefore the main destination for emigration, receiving two to three times more emigrants than the Ivory Coast. The independence of Burkina Faso in 1960 did not stop or end migration

abroad, mainly to Côte d'Ivoire, just as the abolition of forced labour in 1946 did not prevent the Upper Volta from being emptied of its workforce (CONAPO 2006).

The issue of migration is very topical, with globalization, regional and sub-regional integration processes that are accompanied by high capital mobility and fluid communication.

As a societal phenomenon with multi-sectoral implications, migration in Burkina should receive greater attention, going beyond the ad hoc management of crises and tensions caused by internal and external migration (CONAPO 2006). Under these previous findings, Burkina Faso is an interesting case study for examining the contextual and methodological aspects of the tripartite link between climate change, food insecurity and emigration.

1.2 Research questions and objectives

The overarching aim of this doctoral research is to contribute to the understanding of the links between weather variability, food insecurity and emigration. With this goal, I follow the vision set by the United Nations' Sustainable Development Goal (SDG#2: "end hunger, achieve food security, nutrition and agriculture", SDG#3 "good health and well-being"), SDG #11 ("human settlements") SDG #13 ("combat climate change and its impacts").

In pursuit of this goal, the specific research questions are:

i. How does weather variability manifest itself in the Nouna research area, rural Burkina Faso, during the period 1992 - 2016? (Objective 1).
ii. Is there any change in typology and destination of migration in the Nouna research area between 1992 and 2016? (Objective 2).
iii. What is the link between weather variability, food insecurity and emigration in the research area between 1992-2016? (Objectives 3).

My central hypothesis is that the increase in both rainfall variability and food insecurity lead to increased levels of emigration.

To tackle these scientific challenges, this thesis has 3 distinct objectives.

First, to *"describe weather variability over 26 years in Nouna HDSS"*. In this objective, I am looking to answer how weather variability is manifesting in the Nouna research area.

Second, to *"describe migration's trends, typology and destination of migration in Nouna HDSS"*. This objective aims to answer whether there is any change in typology and destination of migration in the CRSN surveillance zone.

Third objective will examine the impact of rainfall variability and food insecurity on emigration. Laczko.2014 asserts that "vulnerable" households respond to changes in rainfall variability by using migration as a strategy.

1.3. Literature review

1.3.1 Definitions and classification of migration

Migration is an essential element of human history (Schwerdtle et al. 2019). There are several definitions according to scientific disciplines. This diversity of definitions calls for a certain prudence in comparing the results of migration studies.

In the demographic area, migration or migratory movement can be defined as the change of habitual place of residence for a minimum conventional duration (U.S. Census Bureau 2019). According to Louis Henry (Louis, 1981) migration is "a set of journeys that has the effect of transferring the residence of the concerned persons from a certain place of origin or place of departure to a certain place of destination or place of arrival (Louis, 1981;Sié et al. 2018).

According to the International Organization for Migration (IOM), *a migrant is "any person who is moving or has moved across an international border or within a state away from his/her habitual place of residence, regardless of (1) the person's legal status, (2) whether the movement is voluntary or involuntary; (3) what the causes for the movement are; or (4) what the length of the stay is. International migration refers to short-term, temporary or permanent outmigration* (WFP 2017).

The definition of migration considers temporal (time) and spatial (space) dimensions as key criteria.

In terms of time, it is generally considered to be at least a given duration such as four (04) or six (06) months spent in or out of the habitual place of residence. Some definitions include the intention of spending at least that conventional time in or outside of the habitual place of residence.

As for the criterion of space, it concerns the crossing of administrative boundaries (villages, communes, departments, countries, etc.).

Migration can have several classifications referring to the key dimensions of time and space.

Migration is international when it refers to changes in habitual residence between countries. It is internal when it involves the crossing of one or more administrative divisions, such as states, counties, or provinces, but it always occurs within the boundaries of a given country (U.S. Census Bureau 2019) .

According to duration, migration can be seasonal or permanent. Internationally, the interest in migration is increasing (U.S. Census Bureau 2019).

1.3.2 Definition and an overview of climate change

The National Aeronautics and Space Administration (NASA) defines ***weather*** as the current state of the temperature at any given time and location. Its dimension comprises temperature, precipitation, humidity, atmospheric pressure, albedo (solar radiation) and windspeed and direction. The *climate* is weather averaged over at least one decade. Climate change is a change in earth's climate.

"*Climate change refers to 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. Climate change may be due to natural internal processes or external forcing's such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use*" (IPCC

2018)., Climate change is “a set of changes that are attributed directly or indirectly to human activity, altering the composition of the global atmosphere and adding to the natural variability of the observed climate over comparable periods” (UNFPA & WEDO 2009). This definition also implies long-term changes in climatic conditions. The scientific consensus primarily attributes current climate change to emissions of carbon dioxide and other greenhouse gases resulting from human activity, such as unsustainable production and consumption patterns caused by the combustion of fossils fuels and deforestation (Hoffmann 2013). This results in increased global temperatures, frequency and intensity of extreme weather events accompanied by their attendant natural disasters, as well as serious consequences for the survival of ecosystems (IPCC, 2021). According to NASA Earth's temperature has gone up about one-degree Fahrenheit in the last 100 years (NASA 2017). Although this may not seem significant, small changes in Earth's temperature can have big effects. Some of the changes, already observed, include the melting of the globe’s ice caps, sea level rises. The most “visible” changes are, however, the extreme weather events, which have increased in frequency, duration and intensity in the past decades.

1.3.3 Overview of Burkina Faso climate and weather

Burkina Faso has a tropical climate of the Sudano-Sahelian type with significant rainfall variations, alternating between a long dry season from October to April and a rainy season from May to September. It is a landlocked Sahelian agricultural country located in West Africa in the river Niger Loop between 9 ° and 15 ° North Latitude, 2 ° 30 'East Longitude and 05 ° 30' West Longitude (SNAT, 2010). This is an area of about 274,200 km² with no maritime outlet.

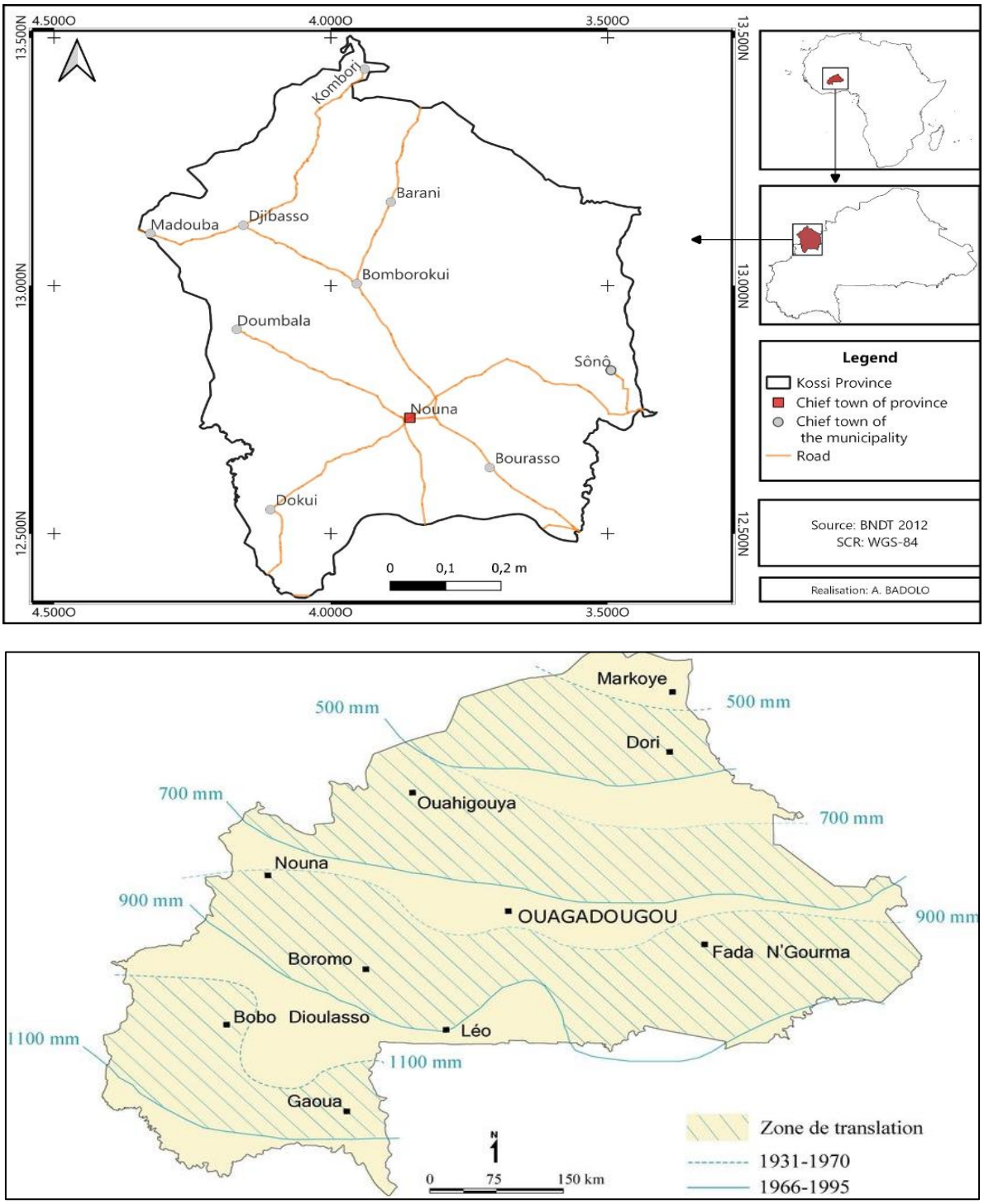


Figure 1: Climatic zones of Burkina Faso and location of Nouna in Kossi province (from Kambire et al. 2016;Tourre et al. 2019; Clavel et al. 2009)).

The average monthly temperatures vary between 12 ° and 42 °. From the north to south the country has three main climatic zones (SP/CONAPO 2011):

- The Sahelian zone in the north, where precipitation is less than 600 mm per year, with a short season, 2 to 3 months at most between July and September, and a large interannual and spatio-temporal variability of precipitation;
- The Sudano-Sahelian zone in the centre, with intermediate rainfall, is characterized by a rainy season of 4 to 5 months.
- The Sudano-Guinean zone to the south, whose rainfall exceeds 900 mm, is characterized by a rainy season of nearly 6 months.

1.3.4 Definition of food security and food insecurity

Food security means having, at all times, both physical and economic access to sufficient food to meet dietary needs for a productive and healthy life. A family is food secure when its members do not live in hunger or fear of hunger. The World Food program defines food security as "*Food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life. Household food security is the application of this concept to the family level, with individuals within households as the focus of concern*"(WFP 2010).

Researchers in the social sciences, define it in terms of availability, accessibility, stability, and quality. For Ouédraogo et al. 2007, availability refers to the domestic quantity of food produced during the year, plus the volume of available stocks at the beginning of the year and the quantities of food that can be acquired with the disposable income or imported (FAO 2001a) (Ouédraogo et al. 2007). Accessibility is the capacity of the household in terms of production and trade. The author distinguishes physical access from economic access. Physical access to available food essentially refers to places of exchange and regular supply. The affordability of available food is related to the household's purchasing power resulting from the combined effects of income levels and prices. Stability of supply refers to the regularity of food availability both spatially and temporally. Stable supplies are affected by internal factors and factors external to households.

Quality involves the nutritional aspect of foods. This includes perception, consumer preferences as well as the amount of energy and nutrients in foods.

The author argues that food security results from the interaction between the four elements just described. Food security is related to undernourishment, but undernourishment is the point when "*... caloric intake is below the minimum dietary energy requirement (MDER). The MDER is the amount of energy needed for light activity and to maintain a minimum acceptable weight for attained height. It varies by country and from year to year depending on the gender and age structure of the population. Throughout this report, the words "hunger" and "undernourishment" are used interchangeably"*(WFP 2010).

Food insecurity is often rooted in poverty and has long-term impacts on the ability of families, communities, and countries to develop (USAID 2021). *"It exists when people do not have adequate physical, social or economic access to food as defined above"*(WFP 2010). In another words, food insecurity refers to a situation where people lack secure access to sufficient amounts of safe and nutritious food for normal growth and development and active and healthy life (Napoli et al. 2011). Ouédraogo et al. (2007) referring to CILSS (2004) argue that food insecurity refers to the situation of people who are below the threshold required to eat from their production and/or annual income and who are forced to consume their savings, sometimes to sell their means of production or to solicit solidarity (CILSS, 2004).

Factors that may lead to a situation of food insecurity include non-availability of food, lack of access, improper utilization and instability over a certain period (op. cited).

1.3.5 Climate change/weather variability as a push factor for migration

This chapter aims to introduce some of the theoretical explanations of migration.

For years scientists have researched the complex and multifaceted phenomenon of migration(Arango 2000). Migration is too diverse and multifaceted to be explained by a single theory (Arango, 2000; Schwerdtle et al., 2019).

According to the *neo-classical* literature**,** the increasing internationalization of economic activity, decolonization and emergent process of economic development in the Third World brings the intensification of migration (Arango 2000). In this theory, I notice W. Arthur Lewis's *economic development* with an unlimited supply of labour in 1954. When the modern sector expands, it draws from the traditional sector, where marginal productivity is zero. Migration results from the uneven geographical distribution of labour and capital. It's the reason individuals respond to differences between countries or regions and engage in migration, according to the micro version of the neoclassical theory (Todaro, 1969, 1976) cited by Arango (2010).

The challenge of a changing reality criticizes *neoclassical theory* by rejecting the idea that economic disparity does not mean for migration flow to take place. It posits that the migration factors are much more influential than the differential wage to determine mobility or immobility. Furthermore, it argues that the selectivity of the migrants can be explained more in terms of legal entitlement, or of personal characteristics in the case of undocumented moves, than in terms of the wage differential.

According to *contemporary mosaic theory*, the contemporary volume and nature of labour demand in receiving societies lead to some changes in the way of coping with migrations. New forms of migration based upon entitlements have emerged. The restrictive migration policies have increased undocumented migrations and clandestine human traffics (Arango 2000).

The *new economics of labour migration* theory shares a variant with the neoclassical theory of migration but differs from it by focusing on the family and the household as actors who seek to enhance migration utility. Migration in its viewpoint is a family strategy to maximize income, not in the absolute sense, but in comparison to other households. It means that this theory lends attention to income distribution, contrary to the neo-classical theory. It concerns itself only with the cause of migration at the destination. The *new economy of migration* theory intervenes in the year 1990 and it is an extension of the *neo-classical theories*. It postulates that the household is a migration decision-making unit. The calculation of the costs and benefits, the probability of

success or failure must be done concerning the household. In doing so, the propensity to migrate depends on the demographic structure.

Dual labour market theory concludes that international migration is caused by permanent demand for foreign labour that stems from certain intrinsic characteristics of advanced industrial societies, which in turn result in the segmentation of their labour markets. The foreign workers are requested to fill jobs shunned by native workers because these kinds of jobs are or confer low status and prestige and promise scant upward mobility (Arango 2000).

This World system theory shares the idea that developed economies need the works of foreign labour of low wage in certain sectors. But it goes further by postulating that migration is caused by dislocations brought about by capitalist penetration in developing countries. The conceptual cornerstone of this theory is contained in the sociologist Immanuel Wallerstein 's concept: "*modern world system*". According to *life cycle or life cycle theory*, a freer person (not yet married) who does not have children enrolled in residential schools has this increased propensity to migrate. According to the *theory of human capital*, it is the level and characteristics of human capital that expose individuals to migration. Thus, a more qualified person has a greater propensity to take risks therefore migrate. According to the theory, migration depends on the difference between the current and future income of the potential migrant.

For others, Piguet, which takes up the idea of Fischer et al., 1997 in *the theory of incomplete information*, postulates that people who already have a migratory experience have an increased propensity to formulate the intention to migrate again. The lack of information can lead to a better future for potential migrants and thus formulate a favourable or positive influence on the decision to migrate. To relativize this theory, some authors think rather the information draws the migration. Through the *Migration as a risk management strategy* lens, the household spatially diversifies its risk by sending one of the members of the household to out-migrate and in doing so the latter would be able to provide relief in case of crisis. Emigration becomes insurance against climatic hazards.

The issue of migration is also examined by psychologists (*Approaches from social psychology*). Although their works have remained outside the theorization of migration, I can cite the theories of motivation, theories of expectations and values, the theories specifically developed to understand the links between attitudes and behaviors.

In the rational actor framework, migrants seek countries with hospitable political environments to maximize both their political representation in government and their access to labour market opportunities as a result of citizenship rights and social acceptance(Helms and Leblang 2019).

Migration in Burkina Faso has two major historical and cultural factors. Colonization is the triggering factor for this migration (Dabiré 2016).

First, during the conquest and occupation of the territory by the settlers, there was a need to displace the populations for the establishment of the colonial administration and infrastructures. As a result, the population fled from the invader (IOM 2016).

Second, there was the adoption in 1921 of the law on the development of the colonies. The colony of Upper Volta, now Burkina Faso, was designated as a labour provider for work in the other colonies, particularly in Côte d'Ivoire (Coulibaly et al., 1980: 84 quoted by Dabire 2016).

According to B. Dabire in the report IOM, the geographical position and other characteristics of the country are determinants of migration: first, Burkina Faso is a landlocked country without an outlet to the sea. Second, the poor quality of the soil, the very capricious rainfall, the weakness of agricultural yields that do not arrive to meet the needs of the population- third, there is high demand for work in the coffee and cocoa plantations in Côte d'Ivoire(IOM 2016).

Migration is the result of a decision process involving factors specific to the origin and/or destination areas (macro factors), and also individual and household-related determinants (micro factors)(FAO IFAD IOM WF 2018).

Some factors push individuals out of their place of origin (push factors), such as a lack of employment opportunities, famine, food insecurity, political uncertainty, violence, crime rates, conflicts and natural hazards (FAO IFAD IOM WF 2018).

1.3.6 Food insecurity as a push factor for migration

Examining migration theories, particularly the economic theory, food insecurity can influence migration. Numerous studies have quoted food insecurity among these multiples' factors driving migration (Schwerdtle et al. 2017; Sitati et al. 2021; Vinke et al. 2022). Deciding to migrate stems from micro factors and macro factors involving the characteristics of both the origin and the destination areas (FAO IFAD IOM WF 2018). In a situation of economic or nutritional stress, migration is often used by farm households to diversify income sources and hedge against income uncertainty and food insecurity risks (FAO IFAD IOM WF 2018; Vinke et al. 2021). As studies predicted the intensification of drought/rainfall variability and floods in sub-Saharan Africa (Nkegbe and Kuunibe 2014), this impact will also be reflected negatively on many other sectors such as the agricultural sector, increasing agricultural migration.

1.3.7 Climate change as a push factor for food insecurity

Food insecurity is a multi-dimensional phenomenon (Napoli et al. 2011). The World Food Summit says that stability must be present "at all times" in terms of availability, access and utilization for food security to exist. This stability can be disrupted because of climate change which can influence household's agriculture. Any phenomenon likely to influence water resources and agricultural production will inevitably have an impact on food security. Climate variability impacts household production outcomes significantly, especially agricultural income, farm revenue and ultimately household welfare (Nkegbe and Kuunibe 2014). It highlights the relationship between climate change and food security (MacroGeo, 2018). Agriculture is subject to fluctuations in production, income and employment due to climatic factors and its seasonal nature, and typically in rural areas non-farm employment opportunities are limited risks(FAO IFAD IOM WF 2018). The variation in rainfall is one of the cyclical factors of food insecurity and one of the climatic risks in Burkina Faso (Ouédraogo et al. 2007).

A study in the USA predicts a negative effect of climate change on agriculture and some consequences for food security (Hatfield et al. 2014).

Although the strong commitment of international institutions, world hunger and food insecurity still represents one of the biggest challenges (Napoli et al. 2011). The Food and Agriculture Organization of the United Nations (FAO) through the State of Food Insecurity in 2010 estimated that 1 billion people are undernourished (USAID 2021). USAID asserts that nearly 800 million people across the globe will go to bed hungry tonight, most of them smallholder farmers who depend on agriculture to make a living and feed their families. Despite an explosion in the growth of urban slums over the last decade, nearly 75 per cent of poor people in developing countries still live in rural areas. A spike in world food prices in 2008 hurt economies across the world and led to destabilizing riots in over 30 countries. To feed a population expected to grow to 9 billion by 2050, the world will have to double its current food production, all the while with less water and land.

According to UNFCCC, climate change is a key driver of migration and food insecurity. Climate change is having far-reaching effects on agricultural productivity and food security", pushing many people to move from the rural area to cities to escape the food insecurity. Labour migration to rural and urban areas is a common component of diversified local economies. In lesser developed countries, labour migration is typically internal, temporary, and circular.

1.3.8 Health shocks as push factors for migration

Disagreements persist over which term to use when referring to individuals who migrate due to environmental factors. There is a discord between the use of terms such as "ecological migrants" versus "climate refugees (Piguet et al. 2011). Regardless of the terminology, shock is acknowledged as a leading possible push factor for migration. Investigating the relationship between shocks and migration in Malawi, Anglewicz and Myroniuk (2018) found that environmental, economic and family shocks often lead to migration (Anglewicz and Myroniuk

2018). This study finds that the migrating population presents different characteristics compared to those who do not migrate. In developing countries, most do not have structured health insurance facilities. There, health shock creates serious hardships for households (Hossain et al. 2019). Another study demonstrated that rainfall shocks have a negative association with rural out-migration and assert that migrants choose to move to communities where rainfall variability and drought probability are lower (Lewin et al. 2012). This author also finds a relationship between rainfall and migrant's consumption.

1.3.9 The contribution of weather variability

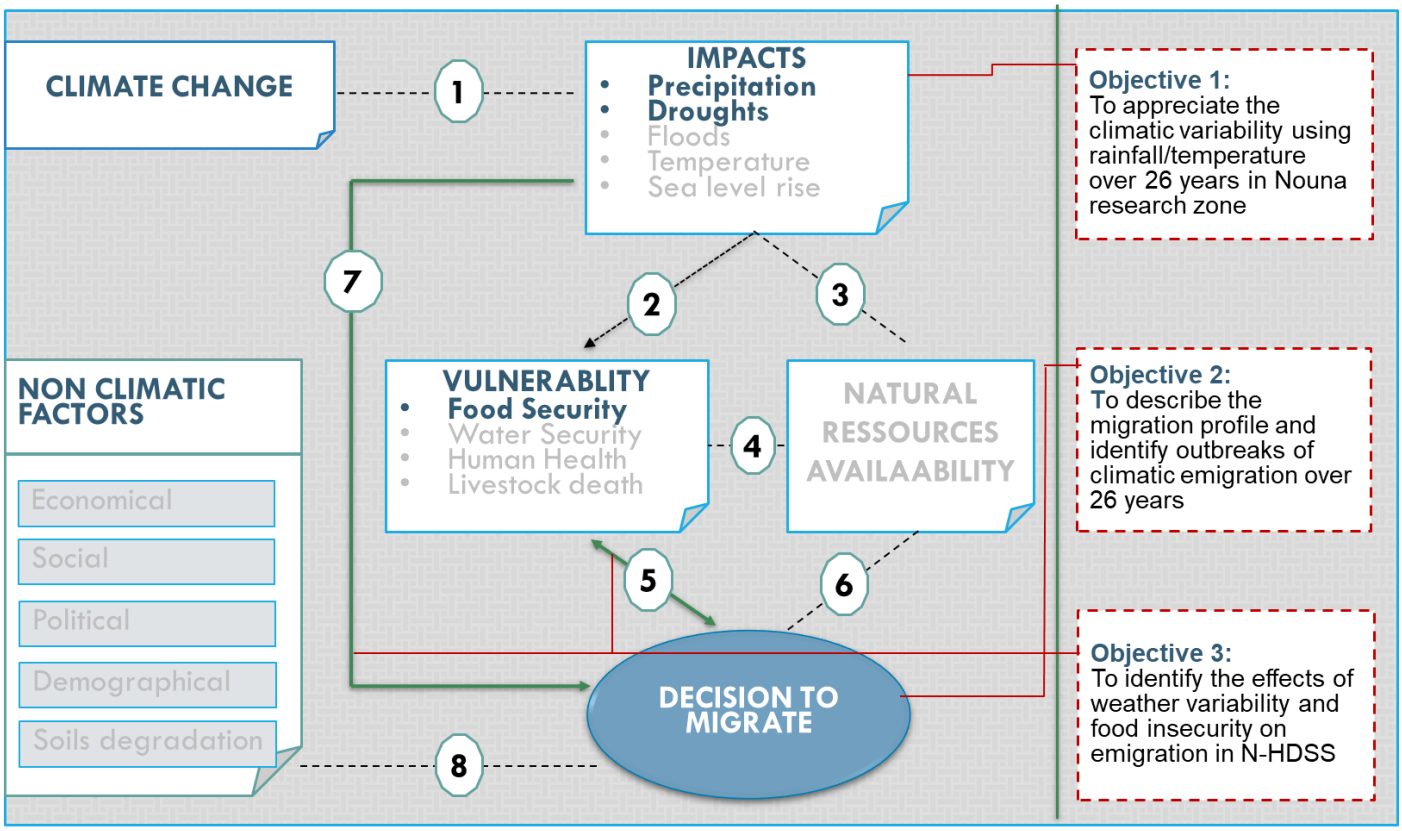
Extreme weather events and weather variability increase migration from rural areas for both men and women, regardless of their age. The effect varies with the capacity of rural households to adapt to climatic constraints (Defrance et al. 2020). Several factors, ranging from lack of opportunities, globalization, natural disaster (flood and drought) and sometimes crop failure forces villagers to migrate to cities. In a study implemented in Malawi people who experienced multiple shocks were shown to be more likely to migrate (Anglewicz and Myroniuk 2018). This study concluded that the exact relationship between shocks and migration varies by gender and the number of shocks experienced.

1.3.10 Conceptual framework

My concept, inspired by literature review particularly Diallo's concept (Diallo et al., 2013) is illustrated in figure 2 below. It is on this conceptual framework that I express how I base my thesis works. It illustrates the relationships between climate change, food insecurity and migration and summarizing the study objectives.

The relationships are materialized by lines/arrows, numbered from 1 to 8. Each number in parenthesis ((1), (2), … (8)) indicates a relationship between two concepts of the conceptual framework. The green arrows represent the relationships on which are the focused my analyses,

depending on the availability of information. The dotted lines are the relationships that exist but are not addressed in my analyses.



***Legend*:**
Each line/arrow, numbered from 1 to 8 represents a relationship between two concepts.
The green arrows represent the relationships on whom are the focus of the analysis in this thesis;
The dotted lines are the relationships that are not addressed in my analyses.

Figure 2: Conceptual framework of the relationships between climate change and migration (adapted from Diallo et al. & PNUE, 2011 "Maximalist" approach (Diallo et al. 2013)

The maximalist or "alarmist" theory is a theoretical approach who is concluding on a direct causal relationship between climate change and population migration. This approach is merging with of Malthus theory who postulates that the increase of the world population and the intensification of climate change are supposed to reduce drastically the available resources and create a high level of vulnerability in the population. The analysis of IOM concludes that any natural disasters may induce migration at least temporarily. Climate change adds new complexity to the relationship between migration and the environment (IOM 2018; Powers et al. 2018; Schwerdtle et al. 2017).

On the conceptual framework, migration is determined by both climatic and non-climatic factors. (1) Climate change will be manifest by leading to extreme variation of temperature and precipitations, rising sea level, extreme climatic events like droughts, floods, cyclones, ... (IPCC, 2018; IPCC 2007) and the destabilization of forest (Sakho 2013).

(2°) Climate change impacts will have effects on population vulnerability in terms of exposition to food/water insecurity, health risk and livestock's death; consecutive droughts in sub-Saharan Africa will lead to crops failures, water shortages, famine and death of livestock. The World Bank forecasts that climate change will mostly affect the developing world. (3°) Climate change impacts will also affect natural resource availability with environmental upheavals. The increase of atmospheric temperatures, the violent winds, the rise of the sea level will also impact the natural resources and scarcity of drinking water resources...

Looking at the relationship between (2) and (3), the climate impacts are leading to an increased intensity, frequency and duration of vulnerability and resources availability. (4) There is an interaction between resources availability and population vulnerability. Food security and livestock are positively influenced when there is an important natural resource.

A reciprocal relationship exists between population vulnerability and migration (5). Many theories argue that people decide to out-migrate when there is a difference of livelihood between their current living place and their intended destination (Ginsburg et al. 2016; Arango, 2000). The livelihood stress will influence the decision to migrate and people who are stressed can out-migrate, explaining the double head of the arrows. Migrating in terms of responses to climate variability, climate change and environmental degradation include voluntary migration, planned relocation, and forced displacement. In the same way, a mutual relationship (6) exists between natural resources availability and migration.

(7) It may also happen that after drought and floods, drawing on their experience, individuals begin to search for solutions to the predicted unfavourable results and effects of the drought and flood. This search for solutions includes emigration and looking for support or assistance.

(8) It is important to notice that climate impacts do not act in isolation in driving migration, they intersect with and amplify other ‘macro drivers of migration (e.g., economic, social, demographic, political, environmental). Climate differentially impacts individuals, households, and communities, depending on the characteristics of vulnerability and resilience and the context of economic development. That interaction makes it difficult to quantify exclusively the climate-related migration level. According to IOM, the relationship between climate change and migration is often complicated by the multifaceted associations with other factors, such as population growth, poverty, governance, human security, and conflict.

2 Study Population and Methods

2.1 Study population and research area

2.1.1 The Kossi province

Burkina Faso as well Kossi province is characterized by a sub-Saharan climate with one dry and one rainy season. It is limited to the north and west by Mali, to the east by the provinces of Sourou and Nayala, to the southeast by the province of Mouhoun, to the southwest by the province of Banwa. Nouna is the chief town (Kossi Monograph, 2014).

The population of the Kossi province was 278,546 inhabitants according to the 2006 census. Projections from the same source, estimate that the population stands at 368,395 in 2017, with a growth rate of 2.7 %. The spatial distribution of the said population is 40 inhabitants per km^2. The sex structure shows a population numerically dominated by women who make up 50.6% of the total population. The distribution by age suggests a young population across Burkina Faso. Those under 20 accounted for 61.5% of the country's total population. The ethnic composition of this population is in descending order, Marka, Bwaba, Peulh, Dogon, Mossi and Samo.

The province of Kossi as a result of its border with the Republic of Mali is a hub of trade with the market pools of Djibasso, Doumbala, Sono and Barani. The main activity of producing financial resources in these markets is the livestock trade. The breeding is of traditional form and there is a strong transhumance activity explained by the scarcity of pastures and water points. That characteristic rhymes with seasonal migration.

The Nouna area is a dry orchard savannah, populated almost exclusively with subsistence farmers of various ethnic groups. The area has a sub-Saharan climate, with a mean annual rainfall of 796 mm (range 483–1083 mm) over the past five decades and an average high daily minimum (20-28.1°C) and maximum temperature (29.5-37.2°C) throughout the year.

Religions practiced include Islam, Catholicism, Protestantism and Animism, with Islam being the most widespread. The national illiteracy rate is high, at approximately 80%.

The main activity of the area is agriculture, with harvests lasting from November to January. A large part of food produced is for household consumption. Wells are the main source of water for household use. Nouna city has had electricity since 1998.

The predominant activities are agriculture and livestock which occupies 90% of the population. Fishing and handicraft activities are also practiced throughout the province (Kossi monograph, 2014). The main food crops are millet, maize, sorghum, fonio, rice and peanuts. Other crops are also found: vegetable crops such as tomatoes and onions. Cash crops such as cotton and sesame are becoming increasingly important. Since fertile soils cover only 32 % of the arable land, cereal production is often insufficient to cover the population's cereal needs. As for herding, there is a diversity of animal species cattle, sheep, goats, pigs, insects, horses, poultry are commonly herded in the area.

Like Balés, Banwa, Mouhoun, Nayala and Sourou, the province of Kossi falls under the governorate of Boucle du Mouhoun whose main town is Dédougou; it has 284 villages grouped in communes.

In addition to the urban community of Nouna, it includes the rural communes of Barani, Bomborokuy, Bourasso, Djibasso, Dokuy, Doumbala, Kombori, Madouba, and Sono.

The health situation in Kossi Province is subject to high morbidity due to acute illness. Malaria is holo-endemic and is known for its seasonal recrudescence during the rainy season, at which time it accounts for the main cause of fever and mortality in the district. (Würthwein et al, 2001, Stich et al, 2006, Becher et al, 2008). During the dry season, in February and March, lower respiratory infections are the main cause of morbidity, due to the relatively cool temperatures and strong winds, which bring up dust and dirt.

The mortality rate due to Malaria among children under five years ranged from 15 % to 8 % between 2000 -2012. The morbid prevalence related to all-cause acute illnesses was 170.7 ‰ for the whole population from February to April 2011. Among children under 5 years of age, this indicator was higher at 325.0 ‰ in the same reference period of February to April 2011. Similarly,

this segment of the population is particularly vulnerable to nutritional deficiencies with a malnutrition rate of 14% (Belesova et al, 2017). Nutritional deficiency diseases are common and related to food shortages.

General mortality in Kossi province, although declining since 1994, remains high and is consistent with statistics at the national level with a general mortality rate of 11.2 ‰ (INSD 2007). According to the 2015 report of CRSN, this general mortality rate decreased from 16.4% in 1994 to 8.0% in 2015, with an average annual decrease of 0.39 points over the 21 years.

Mortality in childhood has high rates and is characteristic of mortality in developing countries. At the national level, the under-five mortality rate increased from 193 ‰ to 129 ‰ between 1993 and 2010 (DHS 2010). Within the HDSS borders, infant and child mortality rates are 39‰ and 88‰, respectively (Sié et al. 2018).

According to the epidemiological table in Nouna HDSS from 2000 to 2014, malaria is the leading cause of death in the entire population with a maximum proportion of 40% in 2010 and a minimum weight of 20.1% in 2014. Malaria is followed by diarrheal diseases, whose proportions varied between 11 and 10%. But from 2007 until 2014, diarrheal diseases have given way to acute respiratory infections whose proportions have oscillated between 10 and 14%. HIV / AIDS ranks last since 2005 and accounted for 1.9% of deaths diagnosed in 2014. All these causes show a declining trend, except for acute respiratory infections and diarrheal diseases, which increased between 2013 and 2014. The proportions of communicable diseases occupy the largest proportions and varied between 55% and 70% over the period 2000-2014(Sié et al. 2018). The weight of noncommunicable diseases (NCD) has increased between 20 and 40% for all pathologies.

2.1.2 Data source: Health and Demographic surveillance system-HDSS

Health and Demographic surveillance system (HDSS) consists of a series of field activities and computer procedures aimed at managing the longitudinal follow-up of well-defined entities or subjects that are mainly individuals, households and residential units in a clearly defined

geographical area (INDEPTH 2003) . HDSS has a very clear and delimited borders. It is usually starting with an initial census that defines and records the reference population and collects data at specific intervals (monitoring rounds) to identify new inhabitants, households and residential units, to update key variables and indicators. The figure 2 is displaying the Nouna HDSS borders.

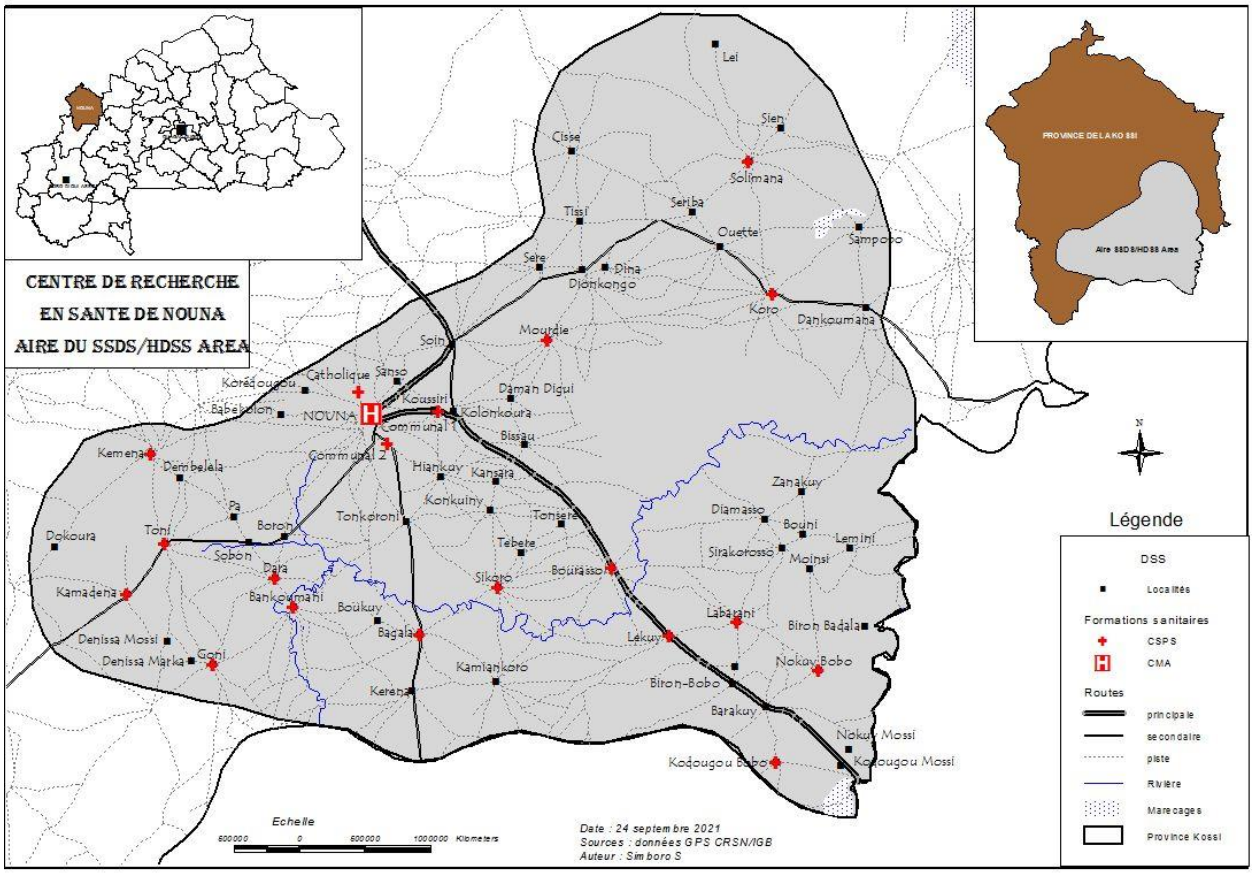


Figure 3: The N-HDSS villages geographical distribution (From CRSN,2022)

The N-HDSS started with a baseline census in 1992 who has determined the population under surveillance. From this initial population, a continuous rounds of surveillance are been allowing the follow up of dynamic cohort as shown on the following figure 4.

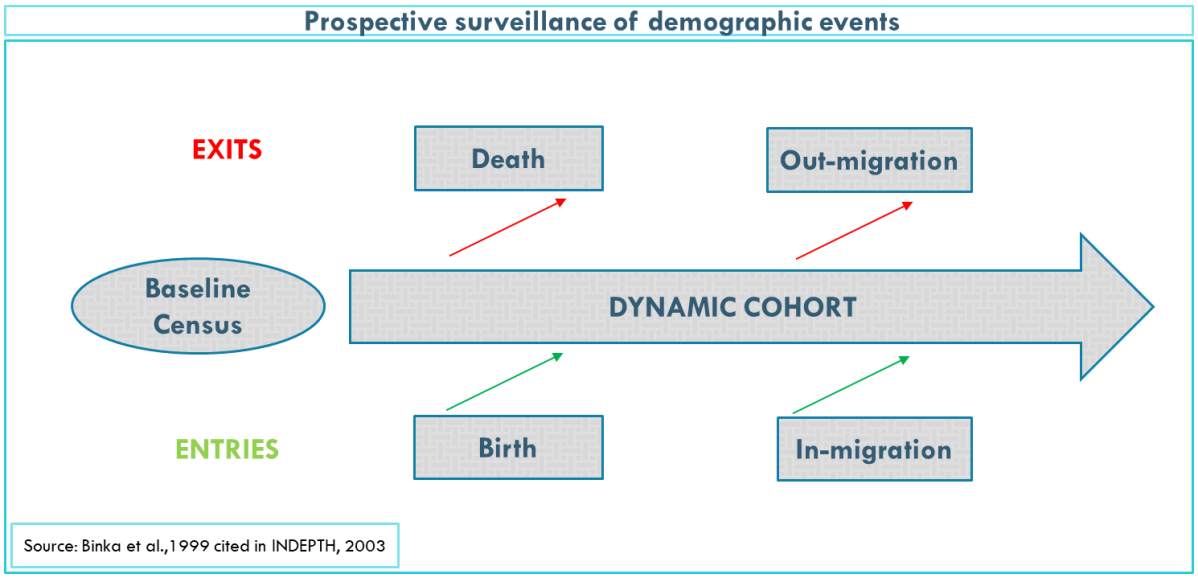


Figure 4: Prospective surveillance of demographic event in an HDSS (from Binka et al. 1999 cited in INDEPT, 2003)

The HDSS monitors population dynamics through routine collection, so called round of surveillance. The round is a door-to-door visits of the HDSS households to record information on vital events such as births, deaths, and migrations which are the only demographic events leading to any change in the initial size of the resident population. In the HDSS, beside the demographic variables, others specific variables, accordingly to the interest of the research Centre, are collected. The HDSS provides important social and economic information on the population and health dynamics, including household formation and dissolution, acquisition and loss of economic assets, and the socioeconomic status (SES).

The HDSS can also be used as a sampling frame or as a platform for other studies in the same geographical area.

The Nouna Demographic and Health Surveillance System (N-HDSS) was established in 1992. Its first census took place in the same year and covered 26,000 individuals. The HDSS has undergone four expansions in 2000, 2004, 2006, and 2018 respectively. The Nouna HDSS was chosen as a recruitment site by the Ministry of Health to evaluate the performance and results of newly organized rural health services in Burkina Faso.

What has been measured and how have the HDSS databases been constructed?

Three times a year, fourteen field workers have been visiting every household (14 000 households in total at the end of our period of analysis) for conducting interviews. In each household they have been directly administering the questions to the Household head preferably, but in case he is absent, any adult member of the household can respond to the questions regarding vitals events registration (VER). Their access to the villages and household is facilitated by 58 key informers based in the villages. All information collected by every field worker is checked and validated by 4 supervisors before transferring the data to the informatics service. To reduce errors, interviewers use questionnaires, based on the information of the previous round of data collection. Quality assurance of data collection is achieved in the field through the review of a sample of 5-10% of entire questionnaires by the field supervisors to check for consistency of data gathered. Other field check includes several blind-control interviews conducted by the supervisors, during which data is collected and compared to the data collected by the interviewers. In addition, regular field interview observations are done followed by feedback at the end. At the central office, the supervisors read and correct each questionnaire before sending it to the archivists. From the archivist, the questionnaires are sent to the data-entry team.

During data entry, questionnaires with missing or unclear information are sent back to the field supervisors and if necessary, to the interviewers for correction.

Checking data consistency is done in two steps:

Controlling data entry: The data-entry program was developed to prevent errors, including user data-entry masks, with easy-to-enter codes, two data-entry modes (read-only and modify), and automatic attribution of individual IDs. It also has automatic validation and verification of household and individual IDs, using message boxes for warnings.

Manual supervision: As data are entered into several computers, the data entry supervisor merges all the files into one single database. After the merging, specified variables are reviewed by listing and verifying all the households and individuals entered (check for completeness) and by searching

all variables for invalid values. This includes syntactic tests to check whether entered values are allowed and semantic tests to compare two variables with some logic relation. Further validation is carried out through duplicate data entry of 5% of all questionnaires by the data-entry supervisor.

Data eliciting process

Since 1992 to 2016, corresponding to our period of analysis, the N-HDSS has been using a self-developed database, based on MS Access. The database can register longitudinal information and check for data consistency. It includes information from the censuses and the vital events registration.

The main information collected in the migration questionnaires are presented at the following table 1 but my analysis is focused on the emigration questionnaire.

Table 1: The key variables on the immigration and emigration questionnaire in the N-HDSS

Object table	Event table
Subject	Information
Location	Location ID, and number of households
Household	Household ID, household head ID, household head name
Demographic variables	Individual ID, names, sex, date of birth (DoB), ethnic group, religion, education level, literacy, main occupation, marital status and relationship with the household head.
In-migration	In-migrant identification (names, ID, sex, date of birth (DoB), . . .), date of migration, origin of migration episode, type of migration (internal, regional, national, international), reason for migration and previous residence within the HDSS.
Out-migration	Out-migrant identification (names, ID, sex, date of birth (DoB),...), date of migration, destination of migration episode, reason for migration.

Control censuses

Periodically, full door-to-door control censuses were conducted in 1994, 1998 and 2009 and lastly in 2019 in the N-HDSS. It allows cross-checking the quality, integrity, and completeness of data collected during the last or the current round of data collection and as a cross-sectional survey. It, therefore, provides a snapshot of the population over a specific period.

Control censuses are planned for every 5 years to supplement the vital-events registration and produce a clear picture of the study population at certain fixed points in time.

Vital-events registrations have been collecting data every 4 months from all households of the HDSS area since January 2000. As part of the VER, field agents verify the presence of household members. This leads them to record new events as pregnancies, births, deaths, immigrants and emigrants... For migration, an individual who was absent at the previous visit and has been present in the household for at least 6 months or has a clear intention to stay for at least 6 months is considered an immigrant.

Similarly, an individual who was present in the household at the previous visit and has been absent for at least 6 months or has a clear intention to be absent for at least 6 months is considered an emigrant.

For each new event registered, a special form is filled in. Thus, for both types of migration, an immigration or emigration form is filled in. On these forms the demographic characteristics of the migrant plus the date of migration, the destination or the origin are recorded. For migration, the HDSS uses a method called "migration history" to collect data on migrants. It is a permanent method of documenting people's previous places of residence and the dates of their immigration or emigration. Special forms on immigration and emigration are used to identify migrants.

The 6 months duration was adopted by many of the HDSS by reference to the IOM definition. This duration is a limitation for my analyses as I would expect to capture migration due to pluviometry hazards, which can occur in short periods between rainy and dry seasons.

For each death recorded, a kind of interview, so call “Verbal autopsy (VA)” is conducted within two months after the event. VA’s are an indirect method used to establish the causes of death by addressing relatives of the deceased. In practice, the interviewers make an appointment with the bereaved families. They conduct interviews with those present to find out what happened during the hours, days or months that preceded the death.(Byass et al., 2012, Sié et al., 2018;INDEPTH, 2003; Soleman et al.,2006).

For each death, a VA is conducted. Information such as name, age, gender, occupation, and other risk factors are usually collected, in addition to an unstructured account of events leading to death, previously diagnosed medical conditions, and symptoms that appeared before death.

Subsequently, the probable cause of death is inferred from the sequence and combination of symptoms and facts. Two experienced local physicians review the questionnaire to interpret the given information and to determine independently the most probable cause of death. In case of disagreement, a third physician is consulted as a referee. In case of disagreement with the third physician, a team of physicians made up of the three coders tries to find an agreement upon the most probable cause of death. An adapted version of WHO ICD10 was used to categorize diseases and deaths like in the other INDEPTH HDSS sites to harmonize the coding procedures. Verbal autopsies have been recorded since 1993 in the N-HDSS area, but data is considered only since 1999 when active vital event registration was implemented. Despite their acknowledged limitations, verbal autopsies are still considered the best possible method to get cause-of-death estimates in areas where vital events registration systems are not available.

In parallel to physician's diagnosis, N-HDSS is using automated Bayesian models to assign the most likely causes of death, and this method is called Inter-VA.

Nouna HDSS Population

In 1992, the catchment area was for the N-HDSS covered 39 villages with a population of about 26 000 inhabitants. In the year 2000, it was extended to include the semi-urban town of Nouna and 02 additional villages. Since 2004, 17 villages were added bringing the catchment area to 58 villages plus Nouna town till today. To date, the N-HDSS covers about 14,500 households for 106,601 inhabitants(Sié et al. 2018). With a total population of 106,601 individuals in 2015, the gender composition is almost balanced, with women holding 50.6%. This composition gives a sex ratio of 98%. This indicator is almost identical to that of the province of Kossi (97.5% according to projections by the INSD).

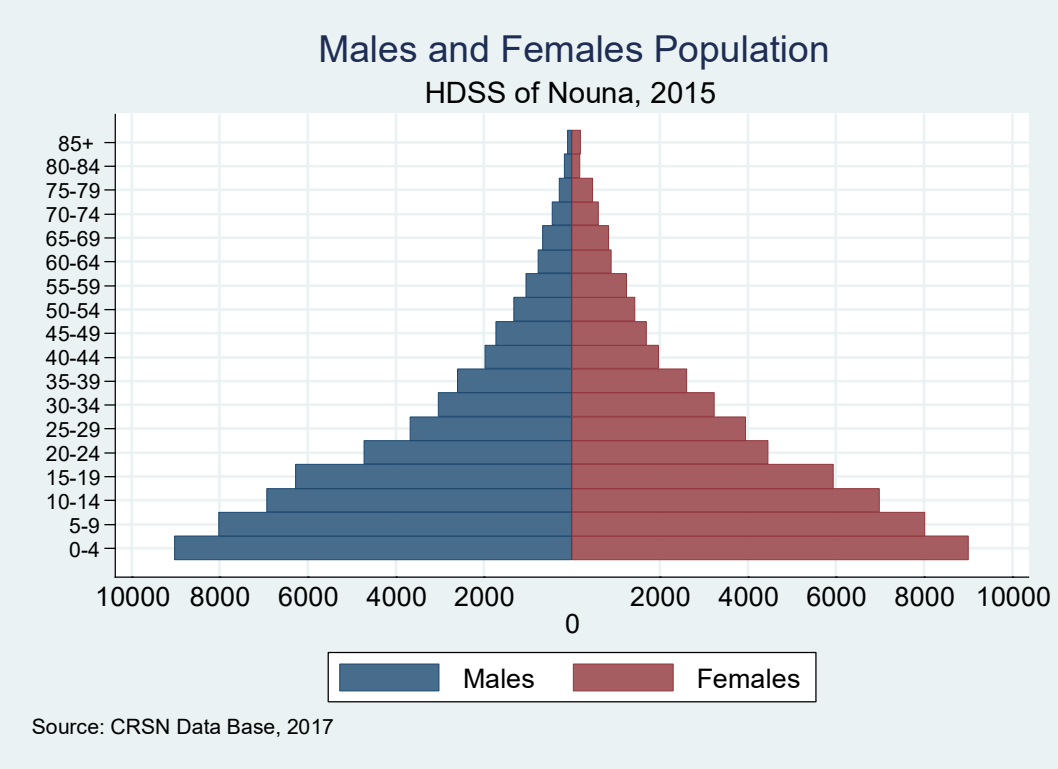


Figure 5: Age and sex structure of Nouna HDSS population in 2015 (constructed by author)

The structure by age and sex as illustrated by the pyramid above (Figure 5) is indicative of the structure of the population of African countries. N-HDSS is characterized by the young population. The population under 15 represents 46% of the total population against 50% and 4% for respectively the age groups 15-64 and 65 and over. This predominance of the young population is due to the high level of fertility (Total Fertility Rate=5,2) (Sié et al. 2018), a common characteristic of developing countries.

The progressive narrowing of the pyramid to a sharp peak indicates a high and even accentuated adult mortality. This narrowing is more pronounced from 50 years for men compared to women. Excess mortality of men is noted in the N-HDSS. In a population subject to the unique effects of demographic phenomena of birth and death, it means that without a disturbing phenomenon such as wars and epidemics, mortality is thereby more pronounced in men (ref. figure 5).

Migration data is collected using two questionnaires called respectively “fiche emigration” for out-migration and “fiche immigration” for in-migration and displayed at appendix 9.2. These

questionnaires are used in Nouna HDSS to register migration information between 1992 to 2016. Events of emigration and immigration, destination and provenance of migration are collected with the dates of reference.

2.1.3 Other data sources

Sources of daily meteorological variables

The meteorological data comes from several data sources. To compare climate characterization, I used two sources of data. The first is NASA station data. Data are downloaded for free from the NCDC site web "ncdc.noaa.gov" using the Central Coordinates of the HDSS area. To find this data, visit ncdc.noaa.gov, click on "Search by Map," and navigate to the location of interest. To investigate a station of interest, you have to click on the "i" button on the top left and then on the station. You will get information about the station name and available period on record. You can then click on the station name to submit a data request. Once the file is ready it will be e-mailed to you directly from NCDC.

The file can be opened in any program like Excel or Stata. It is a simple "txt" file. The data can be merged the data into another file that has a "full calendar," as this file only includes days with available data. This can be done in Excel using a "SUMIF".

The second is the National Agency of Meteorology from Dédougou, encompassing Nouna, situated 57 km from Dédougou. From both sources, daily data was downloaded and transformed accordingly.

Rainfall and weather data were used to achieve the second and third objectives which are to describe climate variability in the study area and identify the empiric relationship between Climate change and out-migration.

Sources for data on harvested food and cash crops

This data source was the household survey. This survey is used to collect socio-economic and health data. The principal information is on households' access to water and sanitation, agriculture, lives stock, morbidity, mortality data, household's revenue, and expenditures. The survey comprises about 1000 households, randomly selected from the HDSS as source population. The

main objective is to settle an evaluation and surveillance system on the HDSS households' socio-economic and health situation to understand morbidity and mortality patterns (Souarès et al. 2010). Information on agricultural production was collected from those aged 15 and over. If a household report having practiced agriculture, crop type, quantities, measuring tools are recorded. I am interested in crops that are known to be sensitive to climate variability and food security, therefore cash crops (cotton and sesame) and cereals (maize, pearl millet, sorghum, beans, *fonio*, *poids de terre*, groundnut) were selected.

2.2 Study Methods

2.2.1 Migration and other demographic variables

Any definition of migration considers temporal and spatial dimensions. This diversity makes suggests being careful in comparing the results of migration studies (Sié et al. 2018).

In general, migration can be defined as the change of habitual place of residence for a minimum conventional duration. According to Louis Henry (1981; 105), migration is *"a set of journeys that has the effect of transferring the residence of the concerned persons from a certain place of origin or place of departure to a certain place of destination or place of arrival ... "* Generally the definition of migration considers two key criteria that are time and space. In terms of time, it is generally considered to be at least six months in duration or to spend at least six months outside of one's locality of habitual residence.

As for the criterion of space, it concerns the crossing of administrative boundaries (villages, communes, departments, countries, etc.).

Operationally, I have adopted two definitions of migration in this thesis. On one hand, I have looked at migration in the entire HDSS, considering the HDSS like, a unique zone. Here, an emigration is defined as any move of an individual from inside the HDSS area to outside the HDSS area for a minimum duration of six months or with the clear intention to stay outside for a minimum

of six months. Conversely, in-migration is a move of an individual from outside the HDSS areas to inside the HDSS area for a minimum of six months or with the intention to reside there.

The second definition keeps the same parameter of time/duration but changes borders. The crossing border is no longer the HDSS border, but the border of each village. Therefore, emigration is any movement from a village to another village within the HDSS area for a minimum duration of six months or with the intention to reside outside for a minimum of six months.

The demographic database was cleaned and put into the Event History Analysis (EHA) format following the methodology of the INDEPTH network. For a recall, the EHA is a collection of statistical methods for the analysis of longitudinal data on the occurrence and timing of events. This format of data fits with the linear or logistic regression analysis, except that the dependent variable is a measure of the likelihood or speed of event occurrence. As with other regression methods, EHA is often used to develop causal or predictive models for the occurrence of events (Encyclopedia Sociology 2001).

Data consistency and quality checks were conducted, and data were transformed into a biographical "residency episode" structure. This structure implies that in- and out-migration events for individuals are recorded sequentially and in a continuous-time (Ginsburg et al. 2016).

The EHA is an appropriate approach to examine repeated events like migration. An individual can make more than one migration.

The levels and trends of migration are measured using rates.

Calculation of rates and descriptive tabulations

In- and out-migration rates are computed by stratified by age quinquennial group (0-4, 5-9, …, 80-85) and sex. Rates are expressed as the number of events (in- or out-migrations) divided by the person-time of the population at risk (person-years at risk) (Donatien B., Bocquier P., 2010).

The typology of migration is described as follows: “permanent” migration when an individual leaves the study area for more than six months and has not yet returned (emigrated only). This assumes that this individual had been resident and moved out for at least six months but not yet returned.

Migration is considered “returning” when an individual leaves the study area for at least six months and come back (out-migration followed by in-migration).

For return migration, duration of migration is calculated to get the difference between those who emigrate and return within 1 year, 1-3 years and those who out-migrate permanently (more than 3 years). It is considered circular migration when the individual did at least 2 returning migrations.

According to duration

Calculating the duration of out-migration, two types of migrations are identified: short term and long-time migration.

Migration can also be defined according to the destination: “internal migration”, “national migration” “regional migration” and “international migration”.

Internal migration is referring to migrations within the study area (from one village of the HDSS to another village of the HDSS). National migration is when moving from the HDSS toward other zones of Burkina Faso. Regional migration is referring to migration between the study area and another country in West Africa. International migration is operating between the study area and continents outside of Africa. The destination of migration has been documented over 26 years to examine the main destination of Burkina’s migrants.

2.2.2 Meteorological/climatic variables and indices

Operationalizing weather variability statistically

De Longville, Markov and Sivakumar (Longueville et al. 2016; Ouedraogo 2013; Fodé and Adamou 1993) methods are complementary used to compute climate variability categorization using rainfall occurrence.

The aim is to determine the occurrence of droughts on a daily scale and the variation of precipitations.

According to the Markov property of order 1, the state of the day *t* depends only on the state of the day *t-1*. In the same order, the state of the day *t* will depend on *t-1* and *t-2* according to the 2nd order Markov chain.

Consider a sequence of *n* consecutive days: Let x_i $(i = 1,2,3, \ldots\ldots, n)$ be a series of *n* random variables taking the values $x_i = d$ (dry=sec) and $x_i = w$ (wet=humide). So, for example $x_2 = d$ means that the second day of the sequence is dry and $x_5 = w$ means that the 5th day is wet.

Let $P(x_1;\ x_2; \ldots\ldots\ldots; x_n)$ be the probability that the sequence $(x_1;\ x_2; \ldots\ldots\ldots; x_n)$ occurs, i.e., that $P(x_1)$ is the probability that the event of day $n-1$ of the sequence occurs and so on until order *n*.

Applying the Markov property to order 2 leads to the following writing:

$$P(x_1;\ x_2; \ldots\ldots\ldots; x_n) = P(x_1) \times P(x_2/x_1) \times P(x_3/x_2, x_1) \times \ldots \times P(x_n/x_{n-2}, x_{n-1})$$

This equation makes it possible to calculate the different probabilities of combinations contained in the sequence. So, to determine the state (rainy or dry) of a given day, I will refer to the state of the two previous days. In order 3, logically the state of the three previous days will allow us to predict the state of the day in question.

The 2nd order Markov chain will require the determination of the number of dry sequences of length greater than or equal to two days. As announced above, a dry sequence is automatically a time without precipitation or even with precipitation that does not reach the threshold set for the study. This scoring will be used throughout the rest of this thesis. in the rest of the reasoning of the study.

In my study, I set 20mm as a threshold of rainfall quantity per day according to the option of Longville.

(wd) defined as a dry day to precede a rainy day and its probability will be noted P_{wd}.

Thus, the expression which will allow us to have the probability of having two dry days surrounded by rain is as follows:

$$P_{wddw} = P(d/dw) \times P(w/dd)$$

With $P(d/dw)$ = a probability of having a dry day knowing that the day before it was dry and the day before wet; $P(w/dd)$ = The probability of having a rainy day knowing that the two days before were dry. $P_{wddw} = P_{wdd} \times P_{ddw}$, it will be noted q_2.

The probabilities of having 3 days and 4 dry days surrounded by rain are respectively q_3 and q_4 and are given by the following expressions:

$$q_3 = P_{wdddw} = P(d/dw) \times P(d/dd) \times P(w/dd) = P_{wdd} \times P_{ddd} \times P_{ddw}$$

$$q_4 = P_{wddddw} = P(d/dw) \times P(d/dd) \times P(d/dd) \times P(w/dd) = P_{wdd} \times P_{ddd}^2 \times P_{ddw}$$

When generalizing, considering for *n* dry days, I get:

P_{wdd} corresponds to the probability of having a dry day knowing that the day before and the day before were dry and rainy, respectively. Since this is a conditional probability, the additional event would therefore be to have a rainy day with the same initial state, namely a dry day preceded by a rainy day. In other words, the events "*having two dry days after a rainy day*" and "*having a dry day framed by two rainy days"* are complementary events, the sum of their probability is equal to 1.

So, $P_{wdd} = 1 - P_{wdw}$.

P_{ddd} is the probability of having a dry day after two dry days and since according to Markov chains of order 2, the state of a given day only depends on those of the two preceding days, the events (ddd) and $(wddd)$ are equivalent so $P_{ddd} = P_{wddd}$. Yet $(wddd)$ is the complementary event of $(wddw)$. So, $P_{wddd} = P_{ddd} = 1 - P_{wddw}$.

$P_{ddw} = P_{wddw}$ because according to the same logic of 2nd order Markov chains, the state of a given day depends only on those of the two preceding days. In conclusion, for 2nd order Markov chains, the probability that a dry sequence lasts *n* days is given by the relation:

$$q_n = (1 - P_{wdw})(1 - P_{wddw})^{n-2}(P_{wddw})$$

For 3-order Markov chains:

$$q_n = (1 - P_{wddw})(1 - P_{wdddw})^{n-3}(P_{wdddw})$$

The different probabilities contained in the expression of the second and third-order Markov chains are calculated empirically:

$$P_{wdw} = \frac{Number\ of\ sequences\ wdw}{Number\ of\ sequences\ wd\ \ldots}$$

$$P_{wddw} = \frac{Number\ of\ sequences\ wddw}{Number\ of\ sequences\ wdd\ \ldots}$$

Thus, for the empirical probabilities, the probability that a dry sequence lasts n days is given by:

$$P_{wdddw} = \frac{Number\ of\ sequences\ wdddw}{Number\ of\ sequences\ wddd\ \ldots}$$

The approach consisted of identifying the dry sequences according to the criteria established above and running calculations with the goal of displaying the distribution of the probabilities.

$$q_n = \frac{Number\ of\ sequences\ of\ n\ dry\ days}{\sum_{i=1}^{30} Number\ of\ sequence\ \underbrace{wd\ldots..dw}_{i\ times}}$$

Household status regarding food insecurity will be drawn up using a compilation of crops in the households.

2.2.3 Operationalizing Food insecurity

Food insecurity exists when people do not have adequate physical, social or economic access to food as defined above (WFP, 2010). Food insecurity exists when people lack secure access to sufficient amounts of safe and nutritious food for normal growth and development and active and healthy life (Napoli et al., 2011). Ouédraogo et al.2007 referring to CILSS 2004 argue that food insecurity refers to the situation of people who are below the threshold required to eat from their production and/or annual income and who are forced to consume their savings, sometimes to sell their means of production or to solicit solidarity (CILSS, 2004).

In my study, I build food insecurity on the crop's quantity gained by the household. The sufficiency of that quantity is dependent on the number of household members.

All the crop types cultivated by the household have been harmonized and converted into kilograms. To appreciate if the house has enough food, I divided the total amount of crops by household size. The quantities were aggregated at the household level to provide figures on the quantity of food crops (cereals) and cash crops per household. This information facilitated the calculation of the quantity of harvest per individual per year for each household.

2.3 Regression model used to identify migration and weather relationship

2.3.1 Rainfall variability

To answer the question" Is there any association between climate change and out-migration in the N-HDSS", I used *Poisson Regression Analysis for Count Data* developed by Karen Grace-Martin. According to Karen Grace-Martin, many dependent variables cannot be laded to be normally distributed. The most common are count variables–the variable that measures the count or rate of some event in a sample. Here, instead of a place of migration rate, I count the number of events (out-migrations) that can be more than one per individual. This method allows us to describe the time variation of rainfall (changes related to climate) and the occurrence of events (out-migration). The Event History Analysis (EHA) data of migration and weather data is transformed for events counting. I calculated rainfall quantity by month and merged it with the migration data using dates

of events. The numbers for emigration are counted by month. After that data preparation, I use Stata *tsset* & *tsline* commands for describing graphically at the same time the rainfall variability and the number of monthly emigrations. I observe yearly/monthly dissemblance and similitudes between tendency of rainfall and emigrations.

Explanative analysis using Poisson regression (event counting) were performed by months and analyzed, observing the effects of rainfall variation with 4-6 months lags on the number of events of migrations. In another terms, what effect of rainfall variability is observed in 4-6 months later.

Poisson model of monthly emigration

Out-migration $_t$ – Poisson (μ_t)

$\mu_t = \beta_0 + \beta_1 X_t + S(time)$

Mean Out-migration at $t=0$:	$\exp(\beta_0)$
Mean Out-migration at $t = t_1$:	$\exp(\beta_0 + S(time= t_1))$
Out-migration at $t = t_1$ for $X=x_1$:	$\exp(\beta_0 + S(time= t_1) + \beta_1 X_t = x_1)$.

Relative Risks

- RR= $\exp(\beta_1)$
- 95% CI = $\exp(\beta_1 \pm 1.96*se)$
- If RR <1 decreasing Out-migration with increasing x (equal to coefficient <0)
- If RR = 1 no effect (equal to coefficient = 0)
- If RR > 1 increasing Out-migration with increasing x (equal to coefficient >0)

Multiplicative scale

Combined relative risk for $X=x_1$ *and* $Y=y_1$:

$\exp(\beta_1 X_t=1 + \beta_2 Y_t=1) = \exp(\beta_1 + \beta_2) = RR1*RR2$

A 10 unit change in X results in:

$\exp(\beta_1 X_t=10) = exp(10\beta 1) = exp(\beta_1)^{10} = RR_1^{10}$

2.3.2 Meteorological indices of rainfall variability

The retained indices of climate variability are summarized in table 2 below: where TOTR is the Total annual rainfall (TOTR); SDII is the Average rainfall by wet day (SDII); SDWS is the Starting day of the wet season (SDWS); EDWS is the Ending Day of the wet season (EDWS); CDDWS is the Maximum number of consecutive dry days; and CWD is the Maximum number of consecutive wet days.

Table 2: Rainfall indices with their definitions and units.

ID	DEFINITION	UNIT
TOTR	Total annual rainfall	mm
SDII	Average rainfall by a wet day	mm/day
CDD	Maximum number of consecutive dry days (rainfall <20mm)	days
CWD	Maximum number of consecutive wet days (rainfall ≥20mm)	days
R10MM	The annual number of days when rainfall≥10mm	days
R20MM	The annual number of days when rainfall≥20mm	days
RX1DAY	Annual maximum 1-day rainfall	mm
RX5DAY	Annual maximum 5-days rainfall	mm
LWS	Length of the wet season	days
SDWS	Starting day of the wet season	day
EDWS	Ending day of the wet season	day
CDDWS	Maximum number of consecutive dry days (RR <20mm) during the wet season	days

Source : F. de Longueville et al.2016

The first day of the wet season (beginning of rainy season) is the date X at which a quantity of 20mm of rains will have been collected in 3 consecutive days after the 1st of May without dry period greater than 7 days within 30 days.

Ending day of the wet season (end of rainy season) refers to a date Y, the day when, after September 1st, there is no more rain for at least 20 days.

A number of consecutive dry days (pockets of drought): *n* consecutive days without rainfall. It can be 1,2,3…15 consecutive days without rainfall.

The length of the wet season is the number of days between the first rainfall and the last rainfall of the wet season.

2.4 Presentation of the study main variables

2.4.1 Presentation of the operational variables

The operational variables are displayed in the table 3. Some of them are individuals when others are constructed using a combination of several individuals variables.

Table 3: Operational variables

Variable	Nature	Data source	Evolution over	Level	Type

Individual ID	Demographic	HDSS data		Individual	independent
Migratory status	Demographic	HDSS data	Continuous	Individual	dependent
Age	Demographic	HDSS data	Continuous	Individual	independent
Sex	Demographic	HDSS data	Static	Individual	independent
Observation year	Demographic	HDSS data	Continuous	Individual	independent
In-migration	Demographic	HDSS data	Continuous	Individual	dependent
Out-migration	Demographic	HDSS data	Continuous	Individual	dependent
Ethnic	Socio-	HDSS data	Static	Individual	independent
Religion	Socio-	HDSS data	Static	Individual	independent
Place of residence	Socio-	HDSS data	Static	Individual	independent
Total annual rainfall	Climatic	NASA/ANAM	Continuous	Contextual	independent
Daily quantity of rainfall		NASA/ANAM	Continuous	Contextual	independent
Longville indicators					
Average rainfall by a wet day	Climatic	NASA/ANAM	Continuous	Contextual	independent
Maximum number of consecutive dry days (RR<20mm)	Climatic	NASA/ANAM	Continuous	Contextual	independent
Maximum number of consecutive wet days (RR20mm)	Climatic	NASA/ANAM	Continuous	Contextual	independent
The annual number of days when rainfall≥10mm	Climatic	NASA/ANAM	Continuous	Contextual	independent
The annual number of days when rainfall≥20mm	Climatic	NASA/ANAM	Continuous	Contextual	independent
Annual maximum 1-day rainfall	Climatic	NASA/ANAM	Continuous	Contextual	independent
Annual maximum 5-day rainfall	Climatic	NASA/ANAM	Continuous	Contextual	independent
Length of the wet season	Climatic	NASA/ANAM	Continuous	Contextual	independent
Starting day of the wet season	Climatic	NASA/ANAM	Continuous	Contextual	independent
Ending day of the wet season	Climatic	NASA/ANAM	Continuous	Contextual	independent
Maximum number of consecutive dry days (RR <20mm) during the wet season	Climatic	NASA/ANAM	Continuous	Contextual	independent
Number of Household members	Demographic	HDSS data	Continuous	Household	independent
Household ID	Demographic	HDSS data	Continuous	Household	independent
Agricultural Production	Socio-economical	HDSS data	Continuous	Household	independent
Total Household production	Socio-economical	HDSS data	Continuous	Household	independent
Ratio Production/Individual		HDSS data	Continuous	Household	Dependent

2.4.2 Variable and method of construction/calculation

All indicators/variables are summarized in the table below.

Table 4: Indicators/variables

VARIABLES/INDICATORS	CALCULATION METHOD	TYPE OF VARIABLE
Number of emigrations of the household any destination	Counted number of emigration events out of N-HDSS in the HH	Outcome variable
The average number of emigrations per household toward Burkina neighbouring countries	Number of emigration events toward Burkina Faso neighbouring countries divided by the HH size	Outcome variable
Total household harvest quantity in Kg	Summed of any kind of crops in the HH- or Quantity of crops of the HH (cash + cereals) without distinction	Independent but / Intermediaries (at the second phase)
Quantity of crops (cash crop) of the household in Kg	Total quantity of crops in cash (cotton, beans, peanut)	Independent but / Intermediaries (at the second phase)
Quantity of crops (cereals) of the household in Kg	Total amount of crops destinated for eating(cereals) of the HH	Independent but / Intermediaries (at the second phase)
Total quantity of crops per head of individuals in the household	Quantity of harvest (cash + cereals) / Household size	Independent but / Intermediaries (at the second phase)
Quantity of crops (cash crop) per head of household in Kg	Quantity of harvest (cash crops) / Household size	Independent but / Intermediaries (at the second phase)
Quantity of crops (cereals) per head of individuals in the household in Kg	Quantity of harvest (cereals) / Household size	Independent but / Intermediaries (at the second phase)
Household size	Number of individuals in the HH	Independent
Household labor force (demographic)	Number of individuals aged 15-64	Independent
Number of men in the household	Number of males in the HH	Independent
Number of women in the household	Number of female members in the HH	Independent
Number of children under 15 in the household	Number of children under 15 in the household	Independent

3. Results

3.1 Summary of migration and rainfall variability indicators

The table 5 shows a summary of the studied populations accordingly to the specific objectives. The weather datasets contain a total of 20,962.2 mm and 19,990.2 mm according respectively the NASA and ANAM registration on the 25 years. The other parameter like temperature and number of pockets of drought are summarized on this table with the monthly maximum, minimum and average.

For migration trends and levels, the dataset contained 2,193,065 observations in terms of person-years. Let me clarify that because the dataset is in the Event History Analysis (EHA) format, as noted earlier in the methodology section, each observation represents one individual for each year over 25 years. This means that an individual will be recorded multiple times based on the number of years it has been tracked in the study area. With respect to emigration, a total of 70,382 emigration events were recorded in the HDSS between 1992 and 2016. This number includes 31,890 males' emigrations and 38,472 females' emigrations. Over the whole study period, the Nouna HDSS registered an average of 237 out migrations per month with a minimum of 5 and a maximum of 761 emigrations per month.

The distribution of number of emigrations by sex and age group also is displayed on this table.

A total of 7,311 households were interviewed for agricultural farming from 2004 to 2009. Each year, between 900 to 1600 households were interviewed. The smallest number of households were interviewed in 2006 and the biggest number in 2009 (Table 5).

Table 5: Summary statistics from transforming the database in counting events and distribution of household interviewed for insecurity

	EVENTS	SEX		AGE						AREA	
Statistics	Number of out-migrations	Male	Female	0-9yr	10-19yr	20-34yr	35-49yr	50-64yr	65yr+	urban	rural
sum	70362	31890	38472	16042	27842	20006	4187	1560	725	24987	45375
mean	236,9	107,4	129,5	54,0	93,7	67,4	14,1	5,3	2,4	84,1	152,8
min	5	0	3	1	1	0	0	0	0	0	5
max	761	404	396	175	328	204	51	32	12	405	655

	PRECIPITATIONS			TEMPERATURE				DROUGHT			
Stats	Rain_CRSN	Rain_ANAM	Rain_NASA	Temp_nna	T°Moy.NASA	T°Min.NASA	T°Max.NASA	Nb. Consecutive 1 day without rainfall	Nb. Consecutive 7 days without rainfall	Nb. Consecutive 10 days without rainfall	Nb. Consecutive 15 days without rainfall
sum	4161,6	20962,2	19990,2	-	-	-	-	973	65	346	6
mean	14,0	70,6	67,3	27,7	28,3	21,9	35,5	3,3	0,2	1,2	0,0
min	0	0	0,0	20,9	20,6	12,9	29,1	0	0	0	0
max	352,9	417,1	340,2	33,5	34,8	28,5	42,3	11	2	5	1

YEAR	**NUMBER HOUSEHOLDS**	**PER CENT**
2004	992	13.57
2005	1,092	14.94
2006	902	12.34
2007	1,208	16.52
2008	1,594	21.80
2009	1,523	20.83
Total	7,311	100.00

Legnd :

Rain_CRSN: Rainfall amount from the station of Centre de recherche en santé de Nouna
Rain_ANAM: Rainfall amount from the station of National agency of meteorology,
Rain_NASA: Rainfall amount from the station of National Aeronautics and Space Administration
Temp_CRSN
T°Moy.NASA : National Aeronautics and Space Administration
T°Min.NASA : National Aeronautics and Space Administration
T°Max.NASA : National Aeronautics and Space Administration

3.2 Climate variability over 25 years in Nouna HDSS area

3.2.1 Cumulative annual rainfall during 1992-2016

In this section, figure 6 displays the quantity of rainfall for the period of investigation (1992 to 2016) according to the nearby (50 km) official Burkinian wheather station in Dédougou. Accordingly, there is an irregular variability in the yearly quantity of rainfall; According to the data provided by *the Agence Nationale de la Météorologie de Burkina Faso* (National Meteorological Service of Burkina Faso; ANAM, Dédougou station) the area registered a mean of 834 mm of rainfall as shown by the red straight line in figure 6 below. All the years with a total rainfall below this line were considered as a dry rainfall season, while the rainfall of the years above reflects high total annual rainfall. For the entire period, in 2000 the lowest cumulative rainfall (600mm) was measured, while in 1994 and 2015 the highest quantity of rain fell (≈ 1150 mm).

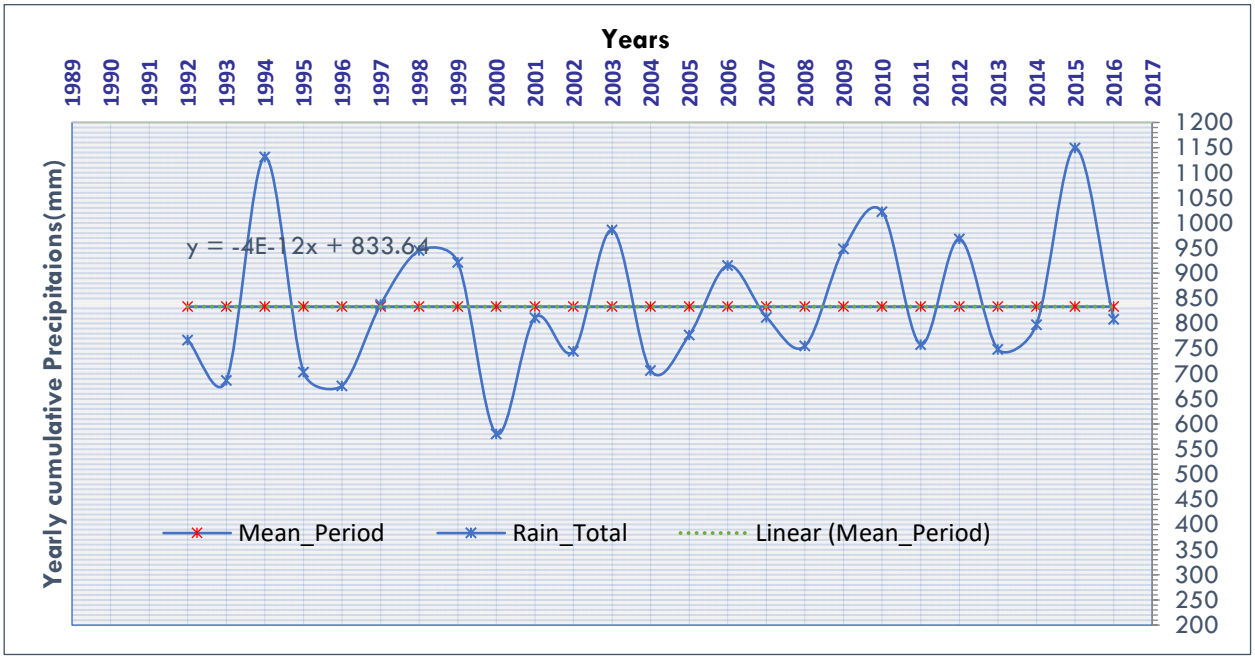


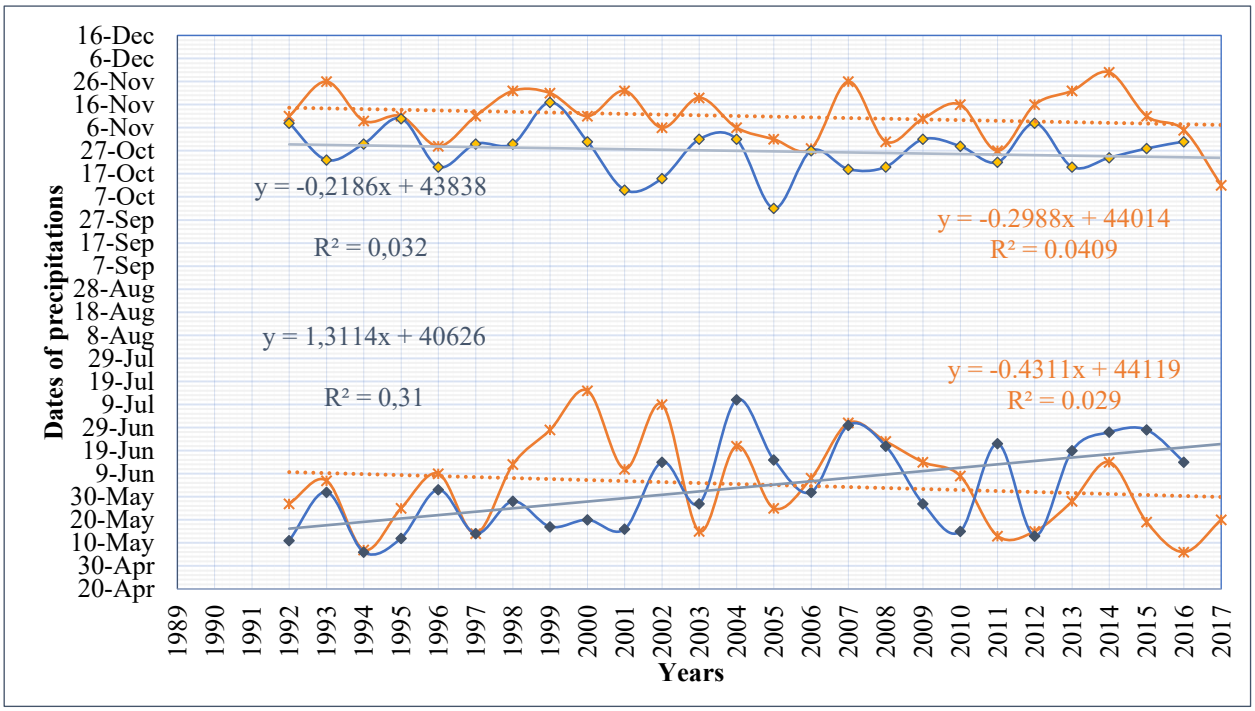
Figure 6: Yearly cumulative rainfall from 1992 to2016 (constructed using ANAM data)

3.2.2 Evolution of the starting and the ending days of the rainy season between 1990 and 2016

In this section, the dates of the start and end of the rainy season were investigated. I observed that the rainfall season is starting later and ending early since a few years. Figure 7 displays those dates as well as the overall change of the length of the wet season (dark blue line). To verify the findings, two different data sources were used to retrieve rainfall data for area, namely from NASA and ANAM. Thus, figure 7 also displays the difference in rainfall data from these two sources. The blue colour refers to data retrieved from ANAM data based on Dédougou station and the orange color refers to NASA data.

Accordingly, based on the ANAM data, for example, for 1990, the rainfall season started on May 30th and ended on October 30th. In the same year, based on the NASA data the rainfall season started only on June 29th and ended on November 16th. Comparing both data sources, the difference in the start of the rainy season is approx. 30 days, while the difference of the end of the rainy season is about 17 days. However, the overall length of the rainy season is similar across both data sets as the ANAM data measured an earlier start and earlier ending, while the NASA data showed a later start and so later ending.

Observing the change over the entire period from 1992 to 2016, in the 1990s, the rainy season lasted from May to late October/ early November. Since 2000, the rain starts falling later about a month (namely from mid-May to mid-June), but ends at about the same time in late October. Subsequently, independent of the data set used, the data shows that the rainy season starts overall later and ends earlier.



Legend: Data from ANAM is shown in blue and data from NASA is shown in orange

Figure 7: Evolution of the first and last day of rainfall by year from 1990 to 2016 Nouna HDSS area (constructed using ANAM & NASA data)

3.2.3 Evolution of the length of the rainy season

The length of the rainy season is characterized by the number of days between the starting and ending date of the wet season. Figure 8 combines figure 6 and figure 7 to show the length (dark barre) of the rainy season and the cumulative yearly rainfall (blue curve).

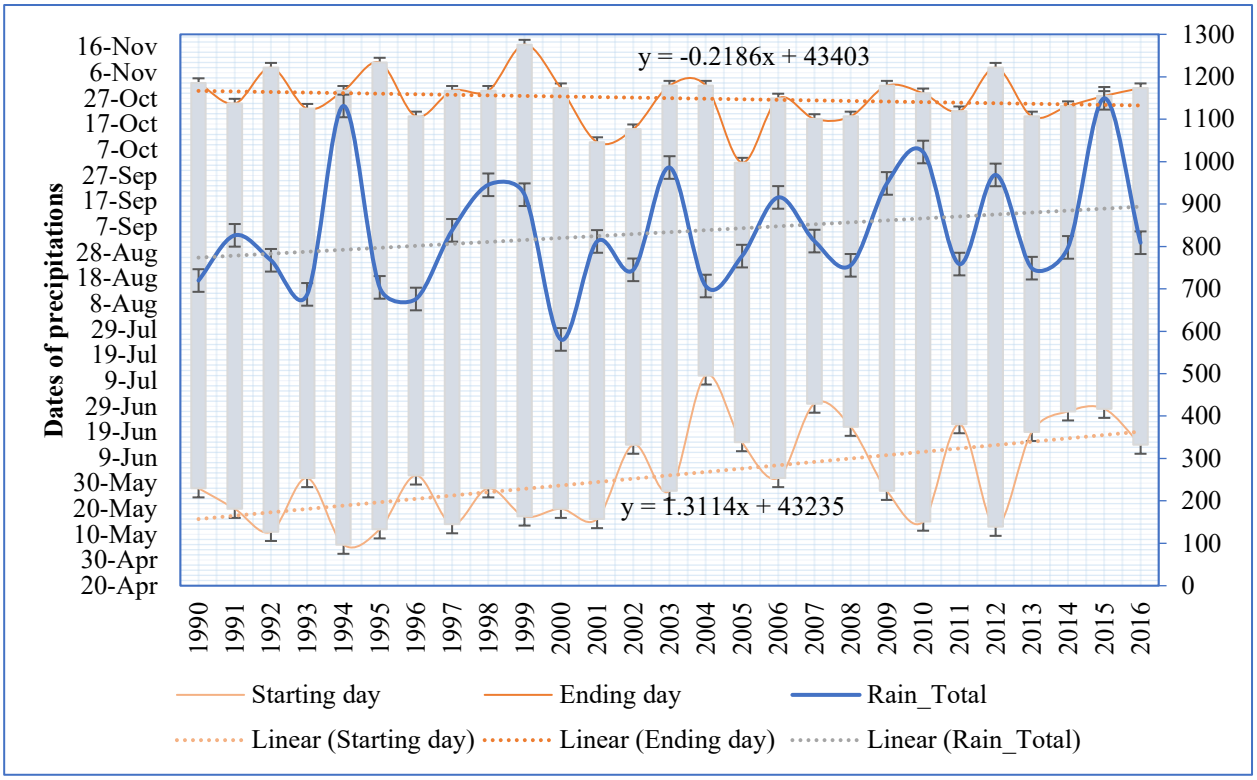


Figure 8: Evolution of length of the rainy season between 1990 and 2016 (constructed using ANAM data)

The data does not provide a specific pattern, but rather a strong variability in yearly total rainfall and length of the rainy season. Accordingly, in 1999, 1995,1992 and 2012 the longest rainy seasons were experienced with 184, 182, 181 and 179 days respectively. While the shortest rainy seasons were in 2005, 2007 and 2004 with only 109, 111, 113 and days long respectively. On average between 1990 and 2016, the rainy season was 147 days long.

Comparing the years, the longest rainy season is not necessarily the one that recorded the highest quantity of rainfall as a display by figure 9 below.

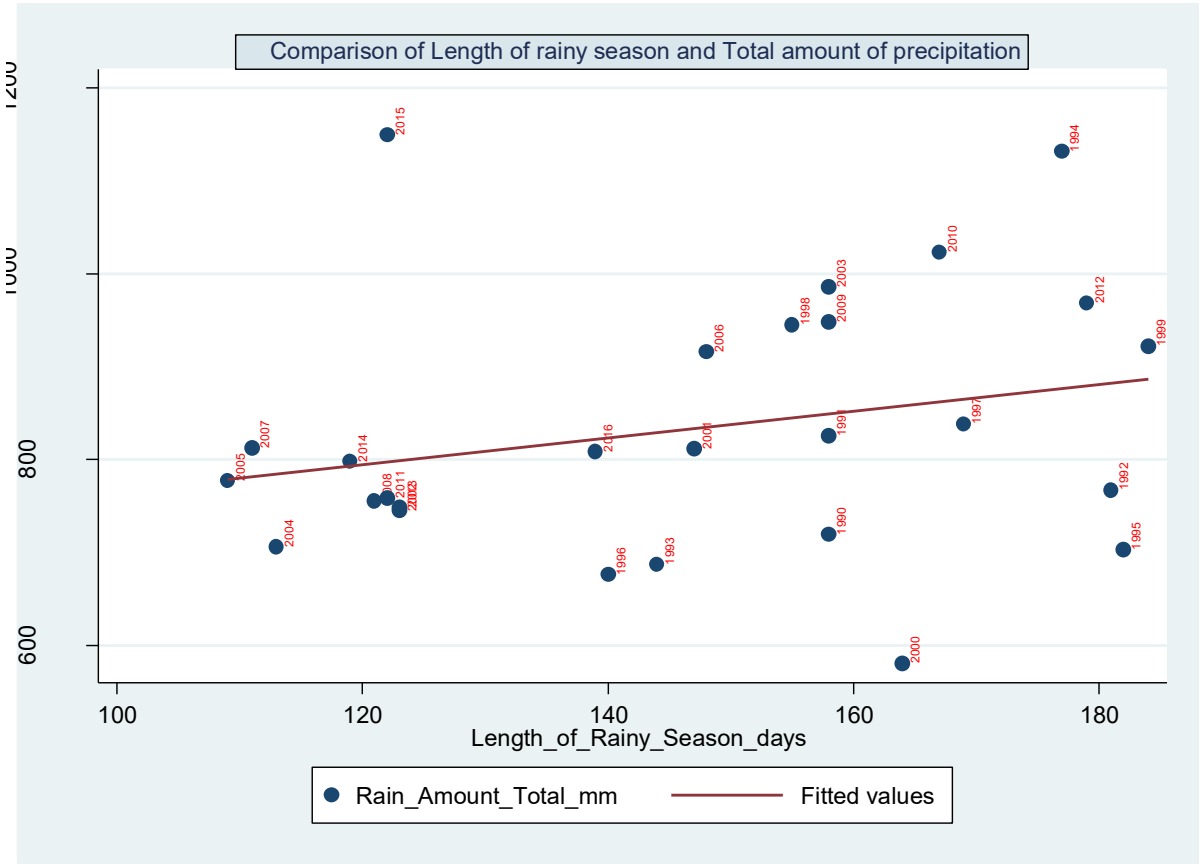


Figure 9: Comparison of the years regarding the length of the rainy and cumulative rainfall (using ANAM & NASA data)

In 1994 and 2015 the highest amount of rain fell. However, the rainy season was 177 and 122 days long, respectively. Therefore, it can be assumed that more rain fell over a shorter period. On the contrary, in 2000 the lowest amount of rainfall was measured (581 mm) despite a rainy season of 167 days. This might be an indication of mini-droughts and thus, a high number of consecutive dry days during the rainy season, which will be shown in the next Chapter.

The rainy season may be a little shorter, but the amount of rainfall is higher. This situation may express a bad temporal distribution of the rains. The consequences are floods that can destroy buildings and housing, but especially fields and crops.

Overall, the data shows a decrease in the length of the rainy season since 1990, but an increase in the total annual rainfall.

3.2.4 Occurrence of number of consecutive dry days between 1990 and 2016

This section has investigated the variability in the number of consecutive dry days during the wet season. For comparison, the data set was divided into two parts: 1992-2005 and 2006-2016.

The distribution of the number of consecutive dry days is presented in figure 10. Accordingly, the number of consecutive dry days during the wet season ranged from 1 to 15 days. The most common consecutive dry days are those lasting between 1 to 7 days, their probability ranges from 2 % to 42 %, respectively.

From 2006 to 2016, the data showed a higher number of consecutive dry days with a length of 1 to 5 days compared to the data from 1990 to 2005. On the other hand, the older period (blue curve) showed more dry periods of 5 to 10 days compared to the recent period. The two sub-periods have the same probability of having droughts of 10 to 15 consecutive dry days. The overall difference between the two periods is yet marginal.

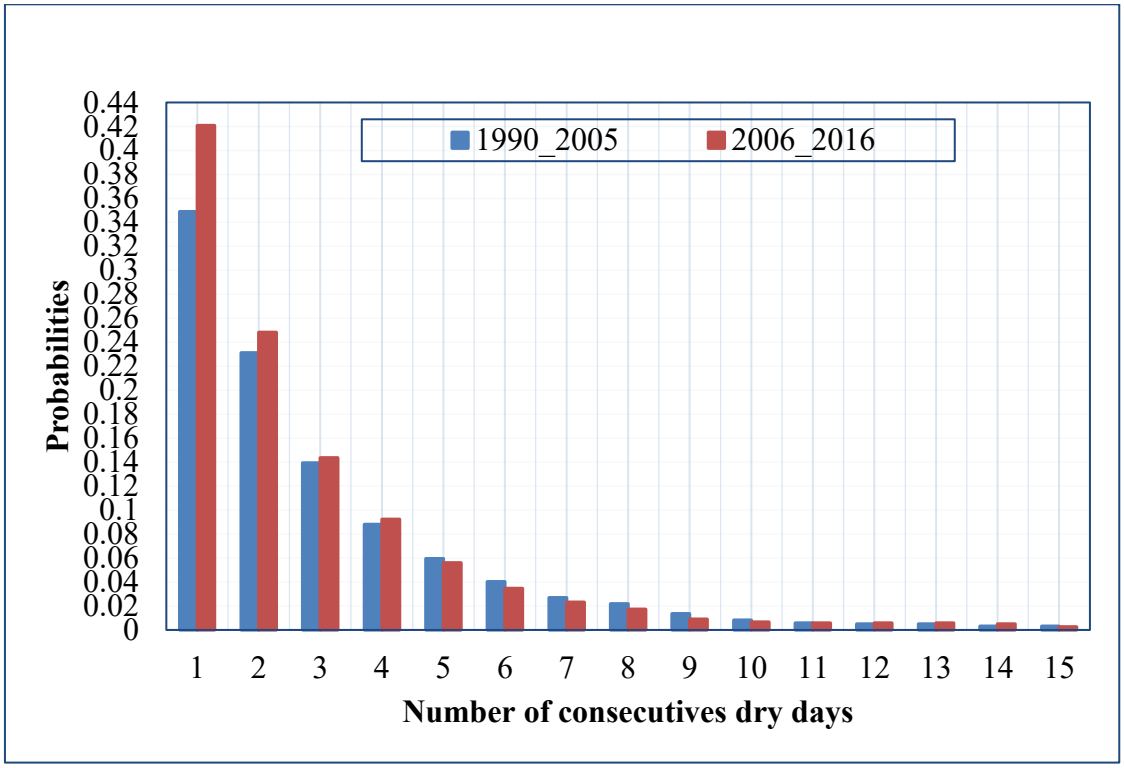


Figure 10: Evolution of probabilities of having a dry period of *n* consecutive dry days between 1990-2016 (constructed using ANAM/ Dédougou Station data)

3.3 Migration levels and patterns in the Nouna Health and Demographic Surveillance System

3.3.1 Immigration and emigration patterns of the population in the Nouna HDSS area

The population of the Nouna HDSS was found to be emigrating as shown by the emigration rates. Accordingly, movements between villages within the Nouna HDSS area, within Burkina Faso (internal migration) and to other countries (external migration) were observed. For the entire study period, the data showed a negative migratory balance (-2,2 ‰). This means that between 1992 and 2016, the area recorded more events of out-migration than immigrations. A negative net migration demonstrates that the Nouna HDSS area is not attractive. In other terms, there are more outgoings than entries.

Immigration level in the Nouna HDSS

In the study area, during the entire period, 29 individuals are immigrating among 1000 inhabitants in a year (immigration rate 29,3 ‰) between 1992 and 2016.

Some disparities can be observed with regard to age groups, sex and study years. Respectively, young people between 10 to 19 years of age were found to migrate the most in the Nouna HDSS compared to other age groups, regardless of the study years or place of residence (Figure 11). A high proportion of migrants were also found among the youngest age group (10-35 years of age). The 15-19 women migration could be understood, most likely because of early marriage, and the migration of the 20-24 men use to leave to look for jobs or to study outside the area.

The results has shown also that a high number of children under 10 of age were found to be migrants.

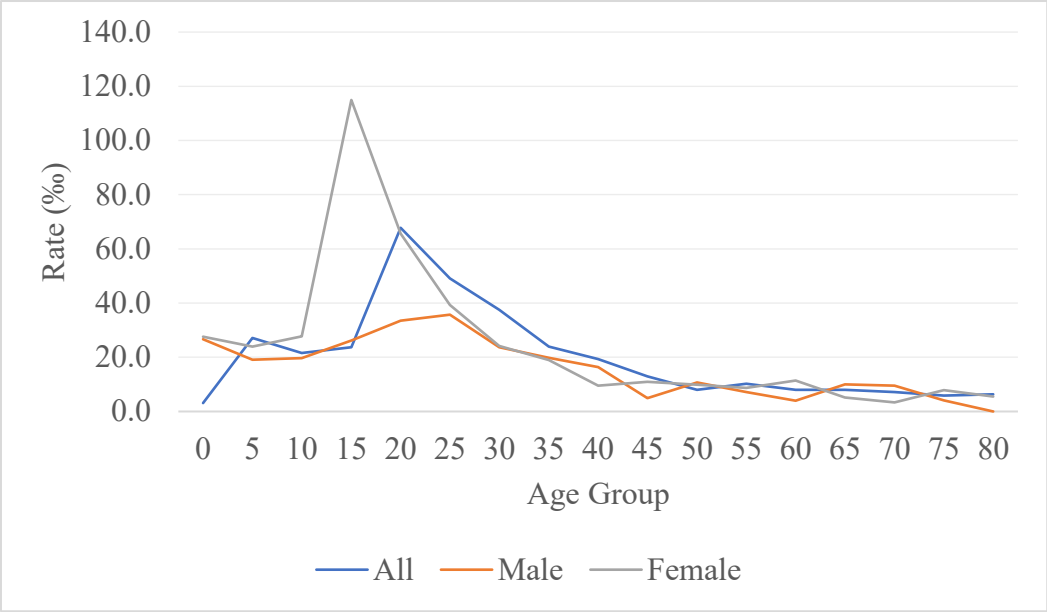


Figure 11: Age specifics in-migration rate by age-group and Sex

Emigration level in the Nouna HDSS

The emigration rate of the period 1992-2016 in the area is 31,5‰, corresponding to 32 out of 1000 individuals per year. A look at the migration trends shows a higher rate of emigration between 2000- 2006 compared to the other parts of the study period.

As shown in figures 11 and 12, regardless of the type of migration, women were more likely to move compared to men.

Due to marriage, women in the Nouna HDSS either move to the Nouna HDSS from other localities outside the area, or they were in the Nouna HDSS area and emigrated to search for paid jobs to prepare for their marriage.

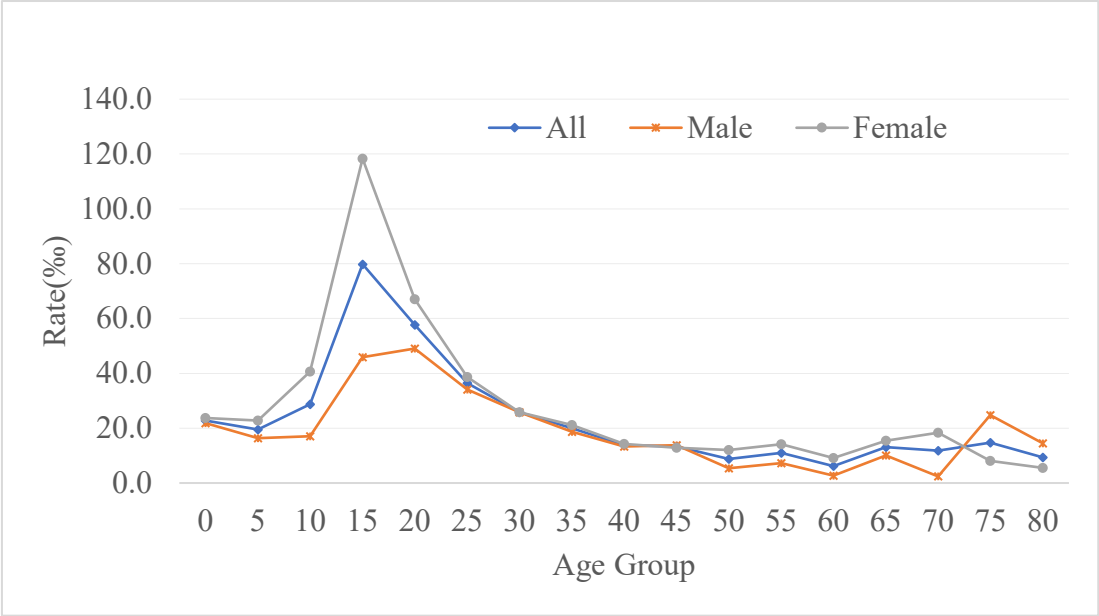


Figure 12: Age specifics Out-migration rate by Sex in Nouna HDSS (from CRSN Database, 2018)

The figure 13 below displays the age groups rate of emigration from the Nouna HDSS to others parts of the country even if out of Burkina Faso. Accordingly, adolescence between 10 to 19 years of age showed the highest migration rate during the entire period of the study. Regardless of sex, the figure highlights three major observations: (i) Before 1999 migration was relatively low; (ii) the period 1999-2006 shows the highest level of emigration, and (iii) the migration level declined again between 2006 and 2016.

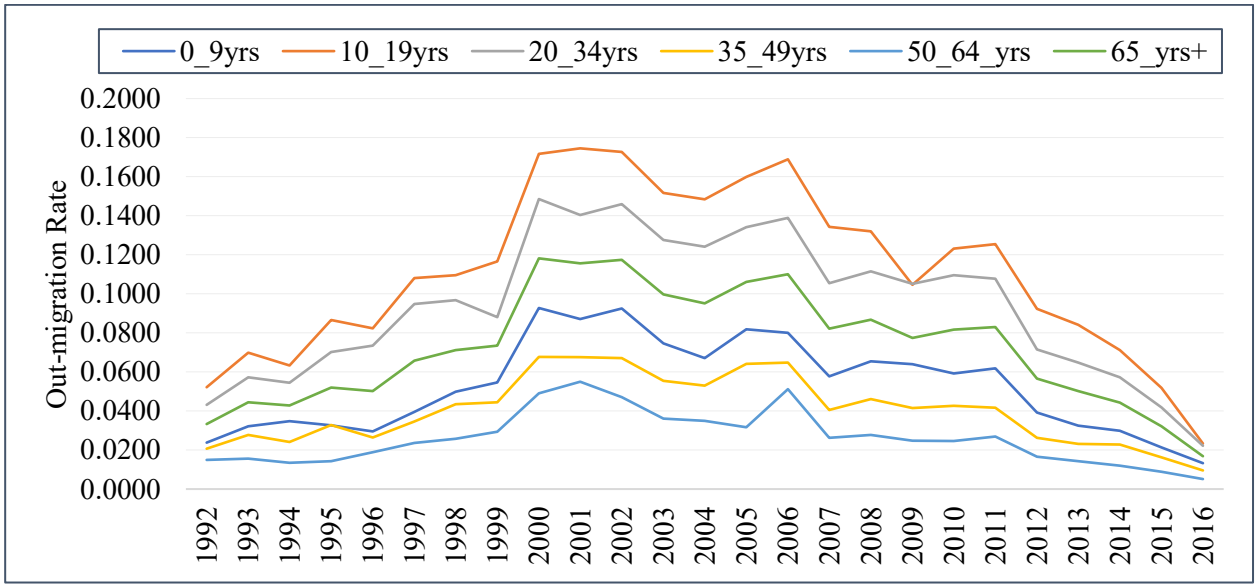


Figure 13: Trend of emigration rate by age-group in the Nouna HDSS from 1992-2016 (CRSN Database, 2018)

3.3.2 Migration in the Nouna HDSS area due to climate change

In this section, the focus is on migration movements of the Nouna HDSS population due to climate change impacts. Precisely, the aim was to investigate migration trends over the past 25 years (1992-2016), destinations, motives, and specifically determinants that led to migration.

Emigration rates of urban and rural area

Figure 14 shows the emigration rate by place of residence or place of origin according to age. In other term, it is comparing the sub-urban (Nouna city only) migration's level to the rural (the 58 villages). Regardless of age, the sub-urban population showed the highest migration rate compared to the rural population. The data confirms also the previous observations made concerning migration differences between youngers and elders: the youngest and here younger from the sub-urban were found to migrate more often than elders. This observation is independent of the type of migration (in- and out-migration).

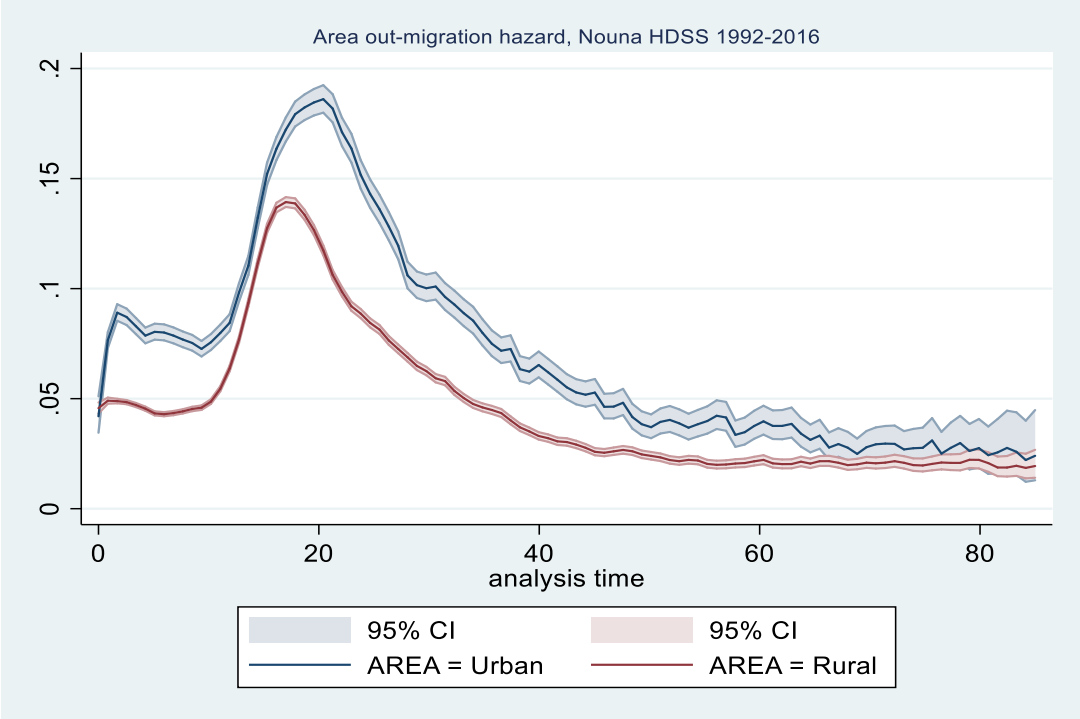


Figure 14: Age-specific emigration rate by place of residence -Urban vs Rural (from CRSN Database, 2018)

The urban area comprises here Nouna town (approx. 30,000 inhabitants), where mainly educated people, students, and employed inhabitants are living. Nouna is the headquarter of the Kossi province and so, a stepping stone for rural people, who in a first step migrate to Nouna and then elsewhere.

Migration's rates by village

Emigration rates were found to be different between as well as within the Nouna HDSS villages. And for each village, the rates are varying over the years. Figure 15 shows the emigration rates per village from 2012 to 2016. In 2012 and 2013 an overall higher level of emigration was observed and this regardless of the village. In 2012, for example, the emigration rate was very high in Zanakui (140 ‰), a little village of 278 inhabitants located in the Est part of the Nouna HDSS, while in 2013, migration movements were highest in the seven sectors of Nouna town (123 ‰).

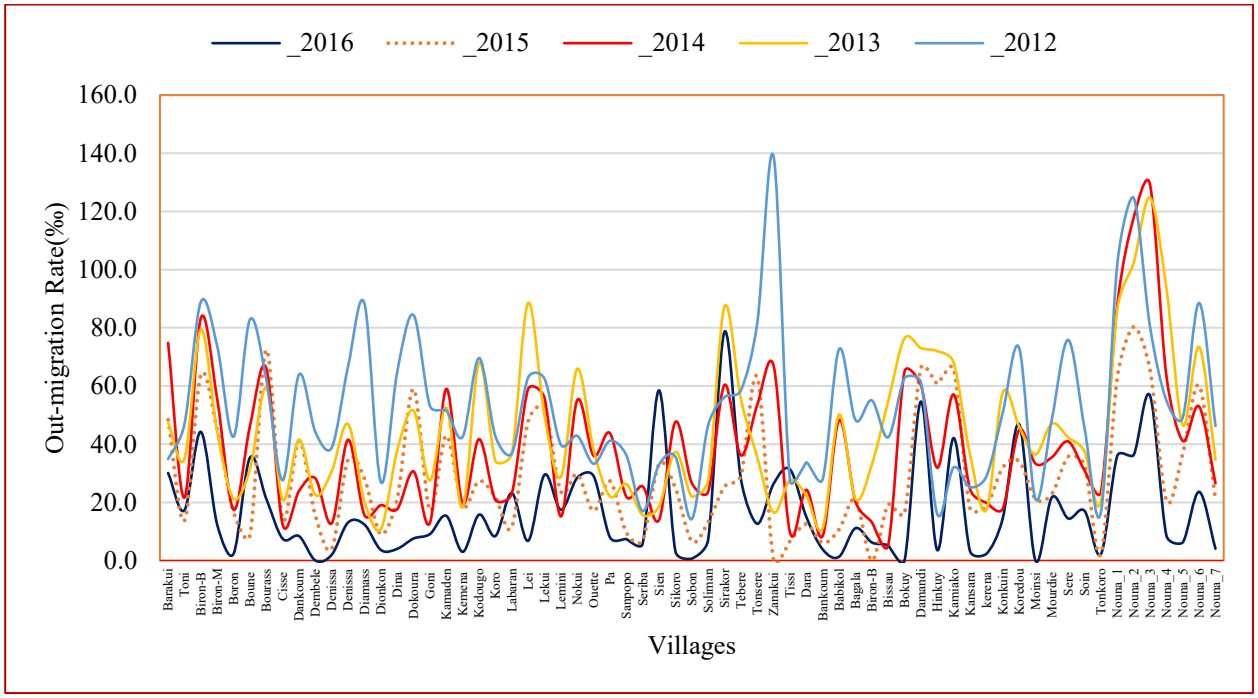


Figure 15: Evolution of the emigration rate by Nouna HDSS village from 2012 to 2016(from CRSN Database, 2018)

The emigration rates vary strongly both spatially (from village to village) and temporally (from year to year.

3.3.3 Destination of migration

In this section, for comparison purposes, I put the villages in 3 sub-groups:

a- Sub-group 1: Villages that were part of the Nouna HDSS since 1992 (N = 41 villages) (figure 16).

b- Sub-group 2: Villages that were added to the Nouna HDSS in 2000 (N = 1 village = Nouna town) (figure 17).

c- Sub-group 3: All villages that were part of the Nouna HDSS in 2004 (N = 58 villages+ Nouna town) (figure 18).

Figure 16 shows the destinations of 41 villages located within the Nouna HDSS area from 1992 to 2016. Accordingly, the highest migration movements take place between rural villages rather than urban areas within Burkina Faso or other countries.

The most important destination for external migration was the Ivory Coast.

Notably, the importance of that country as a destination started declining in 1996 and fell to almost 0 % between 2002 and 2003. This could be explained by the civil unrest in Côte d'Ivoire at that time. The proportion climbed a little bit between 2003 and 2011. The proportions climbed up from 9% to 15% between 2011 to 2012 and is climbing down again since 2012 when the political crisis was solved. However, movements to the Ivory Coast after the political crisis remain overall low until the end of the study period compared to the pre-conflict years (pre-2000).

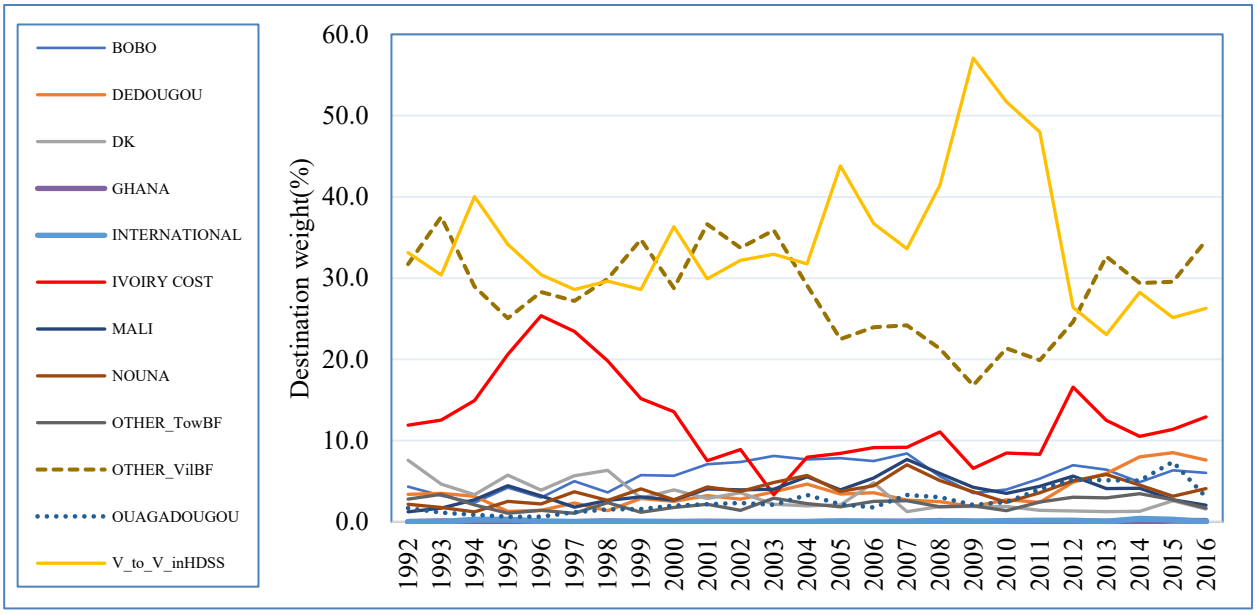


Figure 16: Destination of emigration of 41 Nouna HDSS villages between 1992-2016 (from CRSN Database, 2018)

Furthermore, considering emigration from Nouna, as illustrated by Figure 17, other villages of the Nouna HDSS also remained an important destination for the population for over 25 years. Migration movements to the capital city Ouagadougou increased from the lowest in 2012 of 8 % to 15 % in 2014.

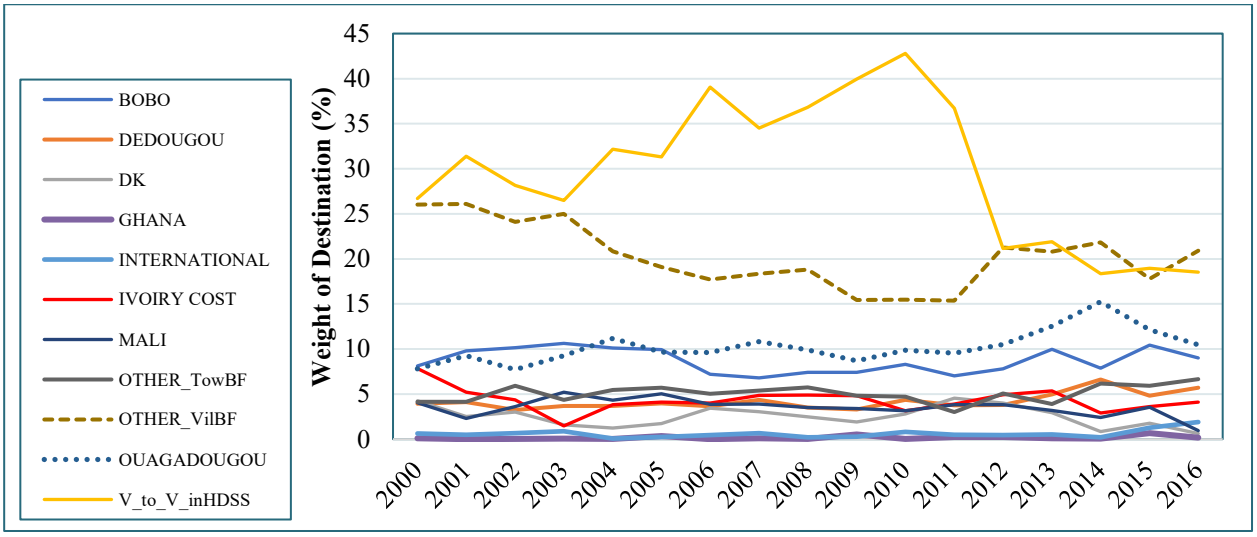


Figure 17: Destination of emigration from Nouna town between 2000-2016 (from CRSN Database, 2018)

Figure 18 shows the emigration data of all Nouna HDSS villages (58 villages plus Nouna town) between 2004 and 2016. The previous observations do also apply here: proportion of migration

between villages inside the Nouna HDSS goes from 31 % in 2004 to the highest in 2009 (50 %). Since 2009, the proportion of migration between villages was getting down until 2016 (23%). The population movements toward other villages of Burkina Faso were holding the second position after migration between villages inside Nouna HDSS. The movement toward other villages out of the HDSS but toward other villages of Burkina Faso evolved from 25.4 % in 2004 to 17.5 % in 2011. From this date, this weight of migration toward other villages of Burkina Faso was getting more and more. Rising from 17.5 % in 2011 to 28 % in 2016, where it was the highest among the destination of the population movements. The highest migration trend can, thus, be confirmed for movements between rural villages from 2000 to 2016. Nevertheless, a deep drop in movements between villages within the Nouna HDSS occurred between 2010 and 2012, which is contrary to a slight rise in movements to Ouagadougou during the same period. The migration level to the Ivory Coast stayed between 6 % and 10.4 % and was relatively stable from 2000 to 2016.

The international migration as a destination stayed lower than 1 % and remained stable from 2000 to 2016.

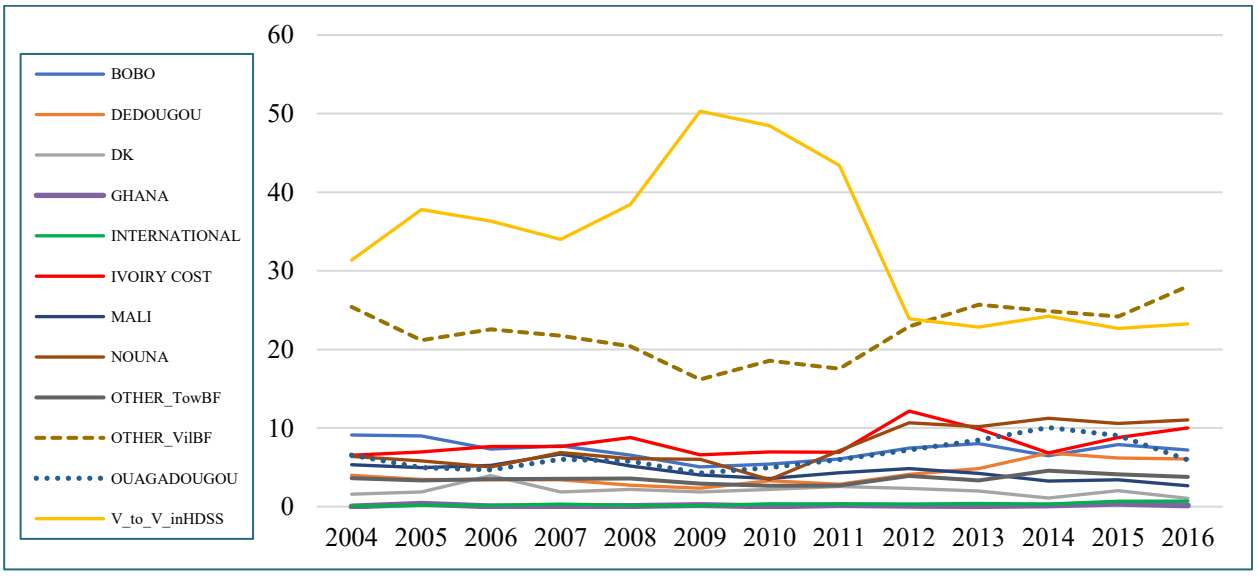


Figure 18: Destination of emigration combining data from all villages plus Nouna town between 2004-2016 (from CRSN Database, 2018)

Figure 19 displays and compares national and international movements. Regardless of the year, the movement toward other localities of Burkina Faso consistently occupied between 80 to 90%

of proportion, compared to the international direction who always remain below 20 % of the proportion. This is also the case for emigration levels to other neighboring countries such as Mali or Ghana.

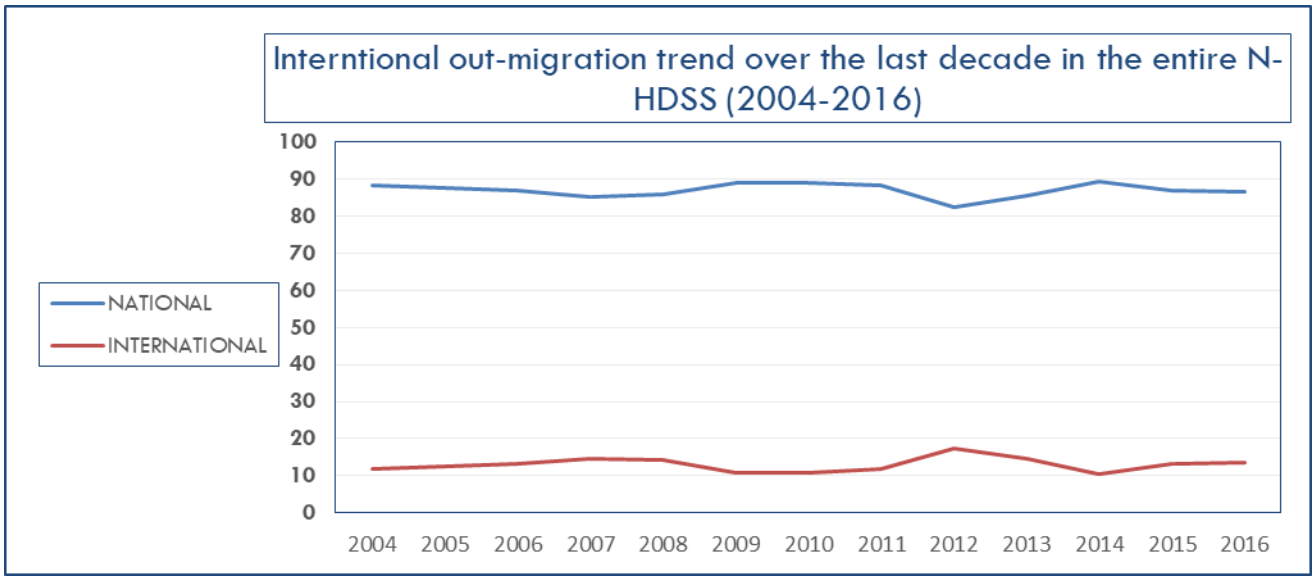


Figure 19: Weight of international emigration between 2004-2016 (from CRSN Database, 2018)

3.3.4 Typology of migration

According to our definition of typology of migration at the methodology section, two types of migration were identified: circular and permanent migration. Because the Nouna HDSS has been recording migration based on the definition of migration as a displacement of at least six months duration, this database did not allow analyzing circular or seasonal migration, which takes place usually within 3 to 12 months. However, the record of episodes allowed to investigate the movements regardless of the duration. Some people repeatedly left their village and came back, while others left forever or at least until the end of the study period (1992 to 2016). Regardless of the duration, these population groups are called circular and permanent migrants, respectively. As shown in the results (e.g., figure 20), some individuals out-migrated even 1, 2, or 3 times over during their life as sown on figure 20. Accordingly, the data showed that most people (80 %) migrated one time during the period 1992-2016 and did not yet come back, while others left and

returned two to four times or even more. Circular migration has representing between 10% and 20% of the total emigration over the study years (red color + green color).

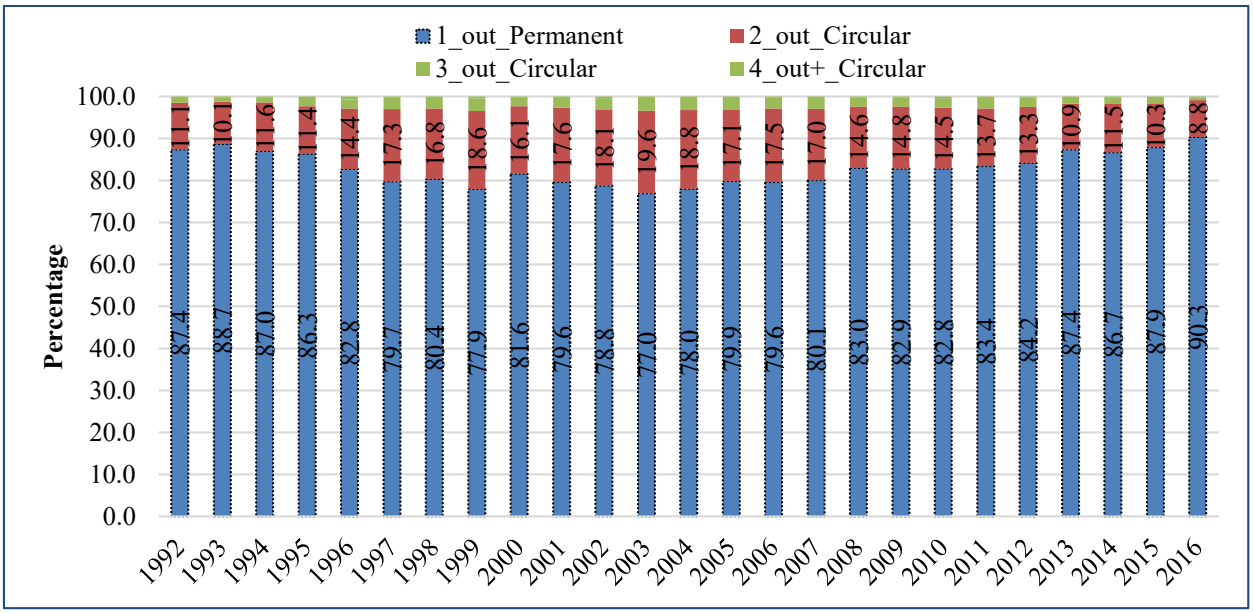


Figure 20: Evolution of the proportion of circular migration comparatively to permanent migration (from CRSN Database, 2018)

3.3.5 Motives for migration

In the Nouna HDSS area, several motives were identified that led to emigration over the 25 years of observation. Those range from following parents, work/ job, divorce or marriage, studies or health related. The data showed that most people left their village regardless of destination, primarily for work, followed by a group who followed their relatives. These two groups always occupied between 15 % to 35 % of motives between 1992 and 2016. Out-migrating motives linked to cultivation or pasture and health problems may be linked to climate change and climate-related impacts, but the proportion remains low. The number of people migrating for marriage or those who returned home showed an upward trend in 2016.

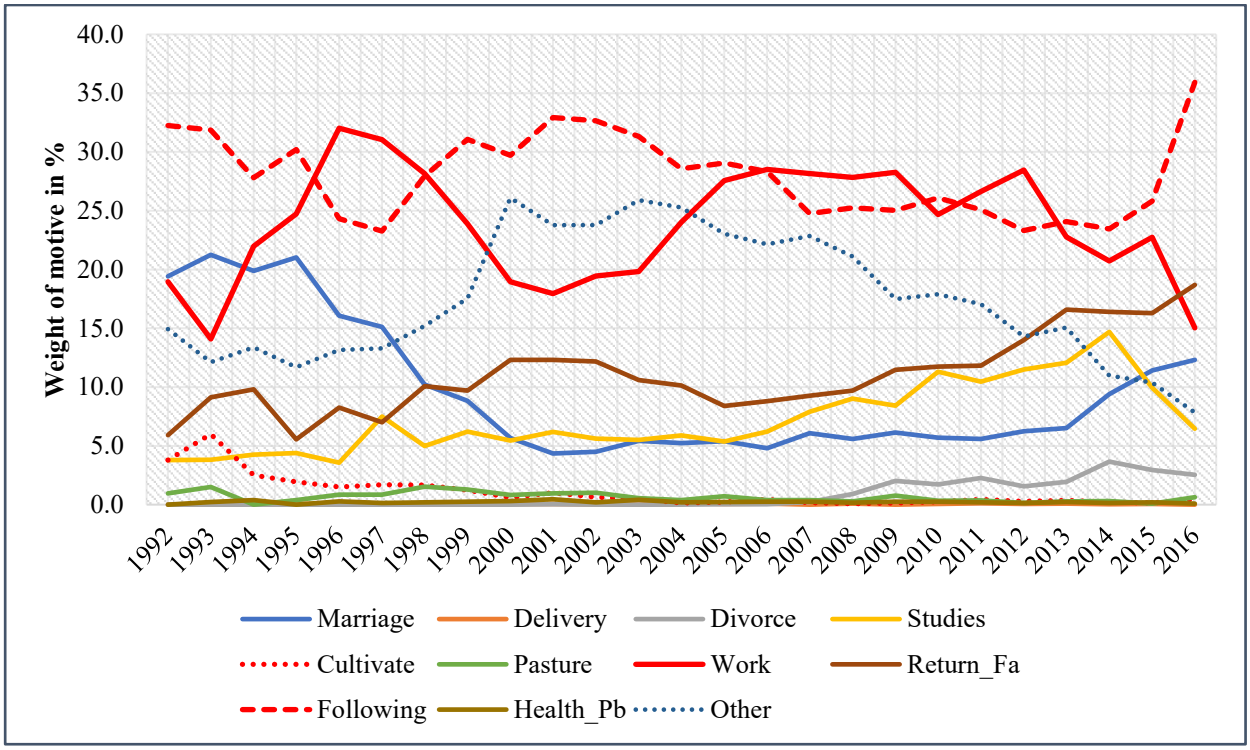


Figure 21: Evolution of the motives for emigration between 1992 and 2016 (from CRSN Database, 2018)

3.3.6 Destinations according to motives for migration

Based on the motives for migration, figure 22 combines migration motives and destinations. Accordingly, 29% of those who reported having left for work-related reasons left the Nouna HDSS to the Ivory Coast. 20%, who reported to have gone to Ouagadougou, stated as their primary reason study-related motives. For people who are leaving the village for a purpose of study, their main destination is either Ouagadougou or an Internal village. And for the motives “pasture, marriage and cultivate, people use to move from a village to another village inside the Nouna HDSS are.

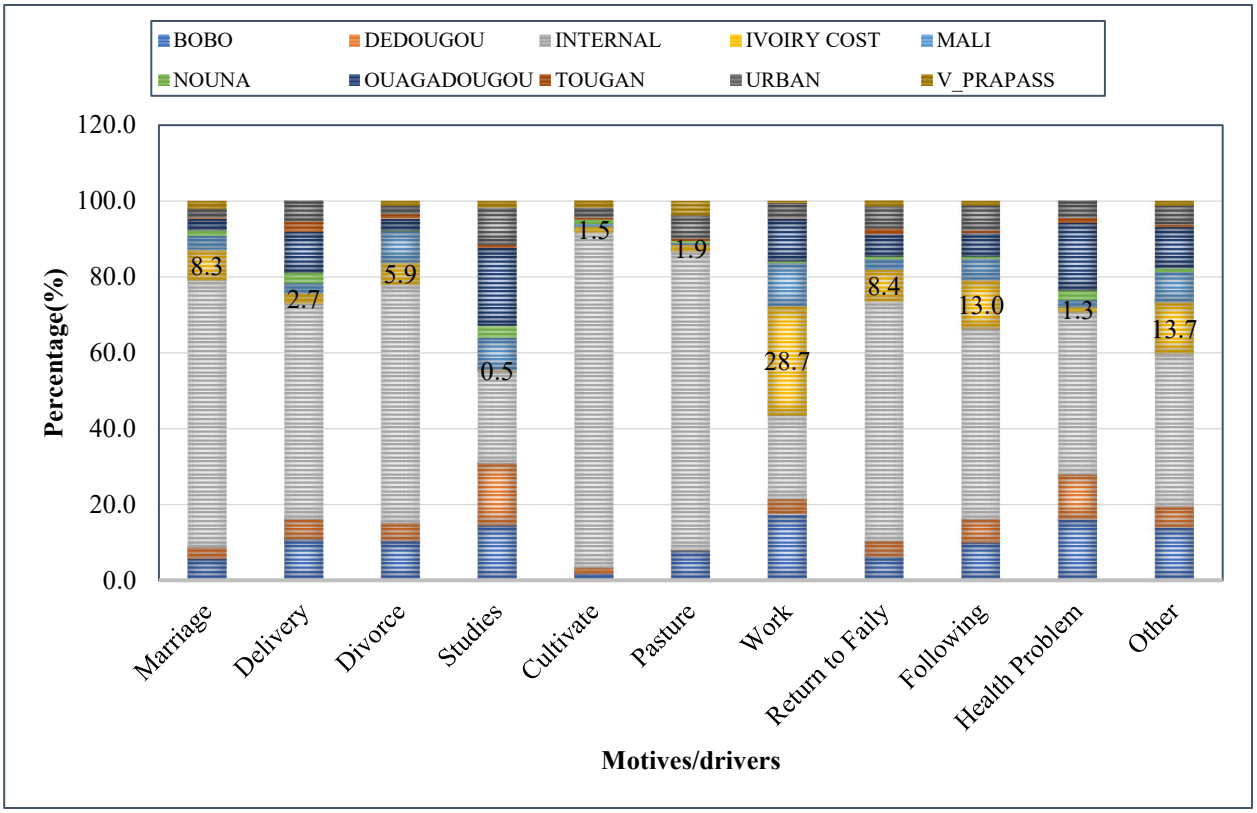


Figure 22: Evolution of the destination according to emigration motives between 1992 – 2016 (from CRSN Database, 2018)

3.4 Characteristics of the study population linked to emigration likelihood in the Nouna HDSS area

Table 6 contains the results of the regression analyses to determine specific characteristics that enhance the likelihood of migration among the Nouna HDSS population. All variables applied in the regression were found to be statistically significant, namely sex, education, occupation, religion, ethnicity, and place of residence.

Specifically, the data showed that people, who work as religious leaders were found to be 2 times more likely to migrate compared to those working in the agricultural sector. (HZR 2.15, CI :1.81 - 2.54; p<0.000). The same applies to those employed and having salary (HZR 2.47; CI: (HZR 2.30 - 2.65); p<0.000), they have 2.47 times more risk to emigrate compared to those who work in agricultures. According to ethnic groups, the Mossi were found to have a higher likelihood to emigrate compared to the Dafing/Marka (HZR 1.26; CI (1.24 - 1.29; p<0.000). Likewise, women

and those without formal education have a higher likelihood to migrate compared to men and those having primary level education, respectively.

Table 6: Results of Cox Proportional Hazards Regression on determinants of emigration

VARIABLES		HAZARD RATIO
OCCUPATION	Farmers(ref.)	1.00
	Inactive	1.60***(1.57 - 1.64)
	Pasture	0.95(0.89 - 1.01)
	Trader	1.17***(1.11 - 1.24)
	Salary	2.47***(2.30 - 2.65)
	Artisan	1.49***(1.43 - 1.55)
	Other	1.46***(1.38 - 1.55)
	Religious leader	2.15***(1.81 - 2.54)
	Housewife	2.85***(2.76 - 2.94)
ETHNIC	Dafing/Marka(ref.)	1.00
	Bwaba	1.09***(1.07 - 1.12)
	Mossi	1.26***(1.24 - 1.29)
	Fulani	1.15***(1.12 - 1.18)
	Samo	1.10***(1.07 - 1.13)
	Other	1.78***(1.72 - 1.85)
RELIGION	Muslim(ref.)	1.00
	Catholic	1.13***(1.11 - 1.15)
	Protestant	1.24***(1.20 - 1.29)
	Tradition	1.18***(1.14 - 1.22)
AREA OF RESIDENCE	Rural	1.00
	Urban	1.58***(1.55 - 1.60)
MARITAL STATUS	Not married	1.00
	Under-age15	0.98(0.96 - 1.00)
	Union	0.32***(0.31 - 0.33)
	Speared/divorced	1.02(0.94 - 1.10)
	widow/er	0.45***(0.42 - 0.48)
SEX	Male(ref.)	1.00
	Female	1.19***(1.17 - 1.21)
EDUCATION	Primary	1.00
	No formal education	2.01***(1.97 - 2.06)
	Secondary	1.12***(1.09 - 1.16)
	Higher school	1.95***(1.71 - 2.22)
Observations		1,671,034
Wald Chi-square		23377
Log Lik		-833464
Subjects		190842
Time at risk		1.477e+06
Failures		82093

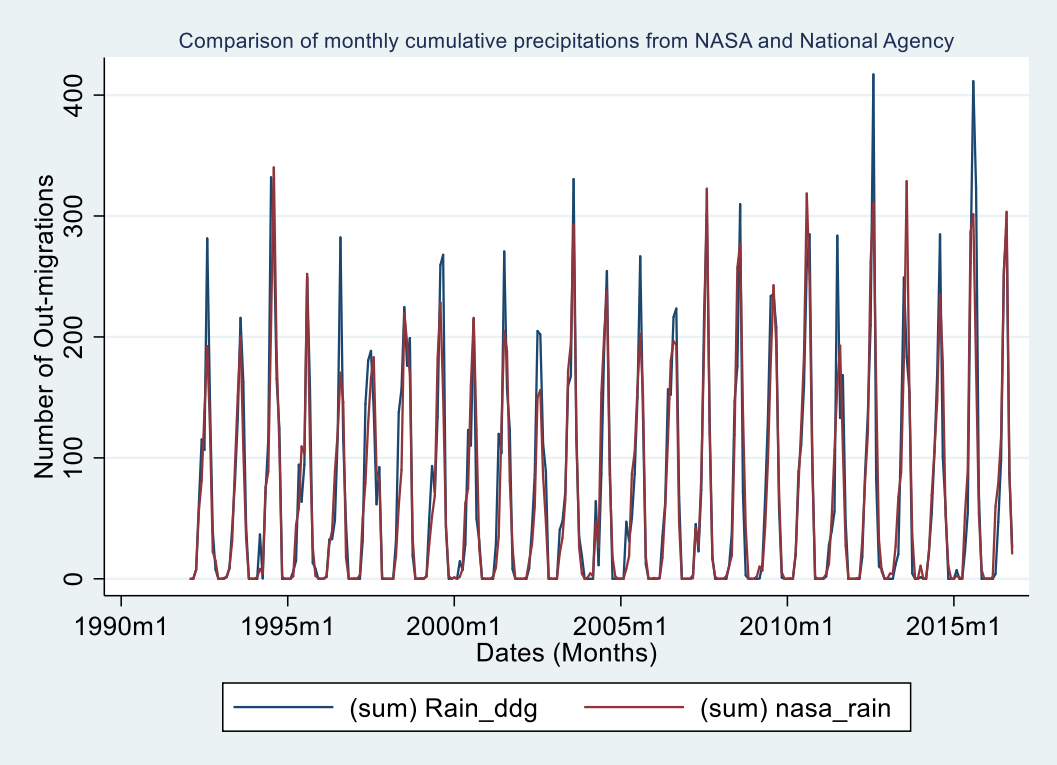
3.5 Explicative aggregated analysis of the link between rainfall variability and migration level

The following chapter builds up on the findings made above and additionally integrates climate variability indicators.

3.5.1 The impact of weather variability on migration in the Nouna HDSS area

Comparison of precipitation variability data from the National Agency of Meteorology and NASA

Figure 18 illustrates the distribution and evolution of precipitations over months on the Nouna HDSS. There is a quasi-equality of rainfall quantity and distribution according to the two data sources. That differences are negligible and that henceforth I take only one source of meteorological data. In another word, because of this similarity, I continued the analysis using one data source only, the ANAM data.



Legend: m1 = month 1

Figure 23: Comparison of the rainfall data from NASA and ANAM by year

Combining rainfall and migration patterns from 1992 to 2016

Figure 24 illustrates the monthly sum of emigrations as events and the monthly precipitation data. Visualizing both types of data graphically offer a good overview.

Here it is shown that each year, the highest number of emigrations is achieved just after the highest level of the month's rainfall, which also coincides with the harvest season. The peak of the precipitation curve is always preceding the peak of the migration curve. One of the results which clearly suggest a link between weather/season and out migration. This observation is particularly strong from 1992 to 2000 and slightly levels off the years after. From 2000 to 2008, migration and rainfall flatten slightly and become less consistent. For the most recent years (2008 to 2016), emigration patterns even seem to be homogeneous over the whole year. Nevertheless, the peak of emigration remains just after the rainy season, although not as strong as in earlier years.

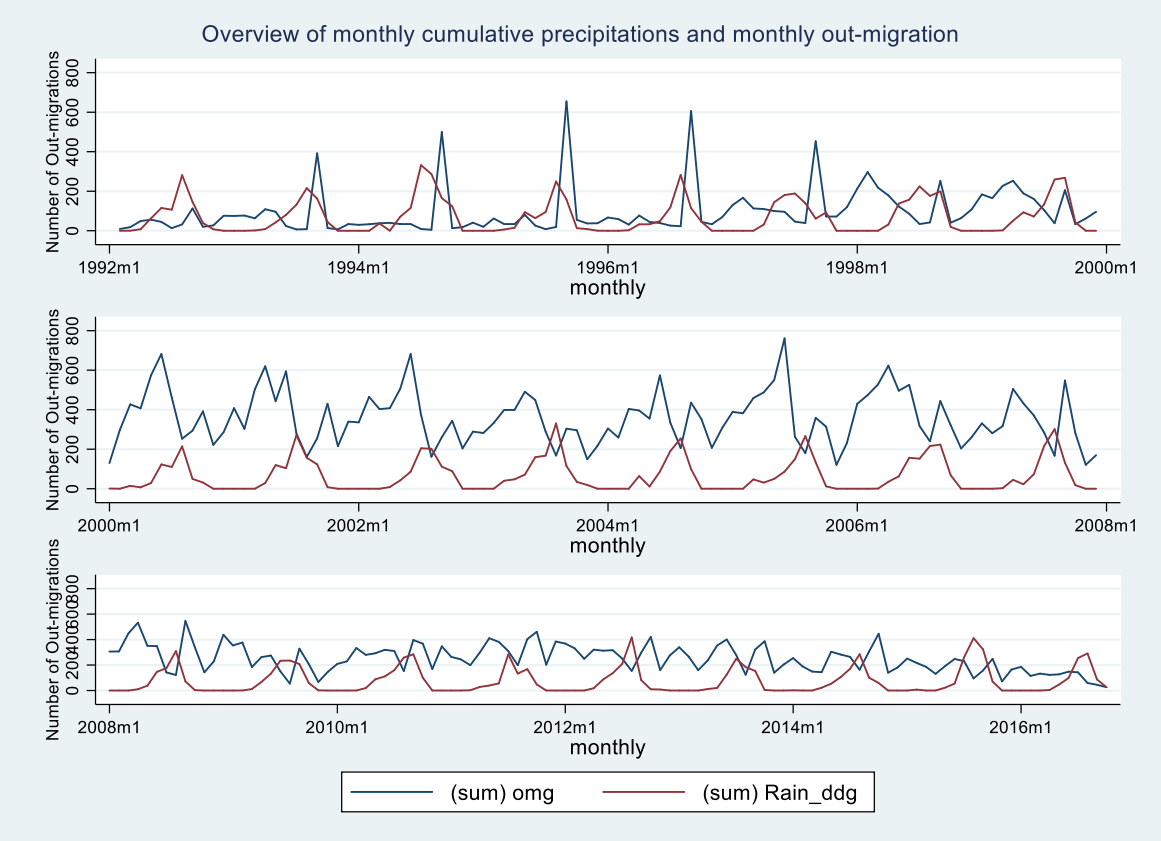


Figure 24: Comparison of the quantity and distribution of cumulative rainfall of ANAM data sources (constructed using CRSN Database, 2018)

Another important observation is that the emigration number went up within two consecutive years when rainfall levels decreased and vice-versa. A good example is the reduction in cumulative rainfall from 1994 to 1995, which is followed by an increase in the number of migrations. On the contrary, from 1997 to 1998, monthly rainfall increased while the number of migrations decreased.

3.5.2 Influence of rainfall variability on emigration using Poisson regression for counting data

Table 7 below contains the incidence risk ratio (IRR) of yearly emigration for 25 years of observation. The year 1992 is the reference. Between 1994 and 1995, this IRR is below 1 (0.72 and 0.95, respectively). This means that there was less rainfall-induced emigration in these years compared to 1992. An overview of the entire period shows that the IRR is increasing progressively since the beginning of the study period (excepted 1994-1995) until 2006 when the risk for emigration due to rainfall increased by the factor 9.7. From this date onwards, the risk decreases until 2016. This evolution of the IRR is similar to the evolution of emigration rates as shown earlier. These results are statistically significant at 0.01 for all years except for 1995.

For monthly risk estimations, the reference month is January. Although rainfall is rare to zero in January, migration still occurs in any month. Therefore, the analysis was performed over all the months. Excepted February and October, all results were found to be statistically significant at 0.01. The IRR was below 1 in July and August compared to January. This result was expected because these dates correspond to the intensive agricultural activities during the rainy season. People tend to out-migrate following those months as shown earlier.

Table 7: Results of the Poisson regression: Differential impact dates (years and months) on emigration

	Emigrations	IRR*	Std. Err.	z	P>z	[95% Conf.	Interval]
YEAR	1992 (Ref.)	1.00					
	1993	1.88	0.11	10.97	0.000	1.68	2.10
	1994	0.73	0.06	-3.88	0.000	0.62	0.86
	1995	0.96	0.07	0.62	0.538	0.83	1.10
	1996	2.51	0.14	16.37	0.000	2.25	2.80
	1997	2.54	0.15	16.25	0.000	2.27	2.84
	1998	5.18	0.30	28.05	0.000	4.62	5.81
	1999	3.68	0.21	23.11	0.000	3.30	4.11
	2000	9.02	0.44	44.62	0.000	8.19	9.93
	2001	9.10	0.45	45.04	0.000	8.27	10.02
	2002	9.52	0.47	45.45	0.000	8.64	10.50
	2003	7.58	0.38	40.82	0.000	6.87	8.35
	2004	8.13	0.40	42.08	0.000	7.37	8.96
	2005	9.29	0.46	45.22	0.000	8.43	10.23
	2006	9.73	0.48	46.53	0.000	8.84	10.70
	2007	7.32	0.37	39.85	0.000	6.63	8.07
	2008	7.96	0.39	41.84	0.000	7.22	8.77
	2009	5.96	0.30	35.23	0.000	5.40	6.58
	2010	6.82	0.34	38.56	0.000	6.18	7.52
	2011	7.64	0.38	40.79	0.000	6.92	8.42
	2012	6.91	0.34	38.74	0.000	6.26	7.62
	2013	6.46	0.32	37.23	0.000	5.85	7.12
	2014	5.62	0.29	33.96	0.000	5.08	6.21
	2015	4.57	0.24	28.99	0.000	4.12	5.06
	2016	2.45	0.14	15.86	0.000	2.20	2.74
MONTH	January (Ref.)	1.00					
	February	1.00	0.02	-0.04	0.969	0.96	1.04
	March	1.08	0.02	4.27	0.000	1.04	1.12
	April	1.19	0.02	9.77	0.000	1.15	1.24
	May	1.22	0.02	11.02	0.000	1.18	1.26
	June	1.37	0.02	17.79	0.000	1.32	1.42
	July	0.91	0.02	-4.71	0.000	0.88	0.95
	August	0.51	0.01	-26.51	0.000	0.49	0.54
	September	1.29	0.02	13.91	0.000	1.25	1.34
	October	1.02	0.02	1.23	0.217	0.99	1.06
	November	0.50	0.01	-28.94	0.000	0.48	0.53
	December	0.79	0.02	-11.14	0.000	0.76	0.82
	Constant	42.03	2.05	76.78	0.000	38.20	46.24

*IRR= incidence rate ratio

3.5.3 Effects of previous 2-3 months lag rainfall on emigration number

The following chapter looks at the impact of rainfall 3 months and 6 months before the date of emigration. The impact of the previous 6 months on emigration was not found to be significant as shown in the results of table 8). Thus, table 8 shows only the relationship between total rainfall of the previous 3 months on emigration using NASA rainfall data. The previous 3 months rainfall showed to have a significant impact on emigration in the Nouna HDSS area. The increase of one unit of rainfall three months early should multiply by 0.99(<1) the risk of having an emigration event. This implies that an increasing rainfall quantity is reducing the risk for emigration.

Table 8: Results of Poisson regression: effects of preceding rainfall, lagged by 2-3 months lag on emigration

Emigrations	IRR	Std. Err.	z	P>z	[95% Conf.	Interval]
Male	1.007	0.002	3.51	0.000	1.003	1.011
Female	1.013	0.002	6.52	0.000	1.009	1.017
Rural	0.999	0.000	-13.07	0.000	0.999	0.999
0-9yr	0.993	0.002	-3.64	0.000	0.989	0.997
10-19yr	0.994	0.002	-3.18	0.001	0.990	0.998
20-34yr	0.997	0.002	-1.42	0.156	0.993	1.001
35-49yr	0.996	0.002	-1.96	0.050	0.991	1.000
50-64yr	0.987	0.002	-5.36	0.000	0.982	0.992
Rain ddg avr2-3*	1.000	0.000	-8.31	0.000	0.999	1.000
Constant	75.558	0.764	427.90	0.000	74.076	77.070

**Rainfall 2-3 months before the outmigration date;* IRR: incidence rate ratio

3.5.4 Impact of interannual variation (current amount of rain compared to the previous year) on the number of emigration events

Table 9 shows the results of the regression analysis for emigration events by the previous yearly quantity of rainfall. Accordingly, variation of rainfall quantity was not statistically significant in the crude model (individual regression rainfall x emigration), but when controlled for confounding variables. Those were sex and location. This means that other parameters could play a role when migration decisions were made. Among these parameters, rainfall distribution by locality was most relevant for the rural areas, where most of the people depend on yield production for their livelihood.

Table 9: Results of Poisson regression: impact of the decrease in the amount of the previous year on the number of emigration events

Emigrations	IRR	Std. Err.	z	P>z	[95% Conf.	Interval]
Male	1.0	0.0	-6.5	0.000	1.0	1.0
Female	1.0	0.0	33.1	0.000	1.0	1.0
Rural	1.0	0.0	3.4	0.001	1.0	1.0
Decru DDG	1.0	0.0	-1.2	0.246	1.0	1.0
Cons.	633.7	11.8	347.5	0.000	611.0	657.2

**Rainfall 2-3 months before the outmigration date;*
IRR: incidence rate ratio
Decru DDG= Diminution of rainfall quantity between two consecutive years (Dédougou station)

3.5.5 Influence of the maximum number of consecutive dry days

Table 10 shows the effect of the maximum number of consecutive dry days on emigration. The maximum number of 1, 2, 3 …15 consecutive dry days during the rainy season was calculated. And the regression shows a significant relationship between this variable and emigration. Except for the maximum number of 7 and 10 dry days, all other variables are statistically significant but overall weak. But the coefficient of correlation (R2) of the model is strong 0.97.

Theoretically, when the rainfall is badly distributed, this will negatively impact the agricultural sector and thus could increase the risk for migration.

Table 10: Results of Poisson regression: impact of the maximum number of consecutive *n* dry days on the number of emigration events 2-3 month later

Emigrations	IRR*	Std. Err.	z	P>z	[95% Conf.	Interval]
Male	1.00	0.00	-3.46	0.001	1.00	1.00
Female	1.00	0.00	26.53	0.000	1.00	1.00
rural	1.00	0.00	1.58	0.113	1.00	1.00
Lag* Dry2	1.01	0.00	2.80	0.005	1.00	1.01
lag Dry3	1.01	0.00	3.43	0.001	1.01	1.02
lag Dry7	1.01	0.01	1.68	0.094	1.00	1.02
lag Dry10	0.98	0.01	-2.11	0.035	0.96	1.00
lag Dry15	0.95	0.01	-4.29	0.000	0.93	0.97
Constant	498.27	33.79	91.59	0.000	436.26	569.11

* Lag of 2,3,7,10,15 dry days occurred *2-3 months before the emigration date;* IRR: incidence rate ratio;

3.5.6 Global Model in Poisson regression

To control the effects of the previous variables, I put all of them in a global model. The results are presented in Table 10. Accordingly, the maximum number of consecutive dry days, the cumulative quantity of rain of the previous year, the decreasing quantity of the precedent year, the cumulative quantity of rainfall and the lag of 3-month early rainfall were associated with the number of emigrations in the Nouna HDSS between 1992 and 2016.

Table 11: Controlling effects of the determinants of emigration

Emigration	IRR*	Std. Err.	z	P>z	[95% Conf.	Interval]
Male	1.000	0.000	1.080	0.281	1.000	1.000
Female	1.001	0.000	14.920	0.000	1.001	1.001
Rural	1.000	0.000	0.410	0.680	1.000	1.000
Lag mount of rainfall	1.000	0.000	1.560	0.120	1.000	1.000
Decru DDG	0.975	0.018	-1.420	0.154	0.941	1.010
lag Dry1	1.008	0.002	3.720	0.000	1.004	1.012
lag Dry2	0.996	0.003	-1.200	0.231	0.991	1.002
lag Dry3	1.046	0.007	6.850	0.000	1.032	1.059
lag Dry7	0.991	0.007	-1.370	0.170	0.978	1.004
lag Dry10	0.996	0.010	-0.350	0.727	0.976	1.017
lag Dry15	0.984	0.015	-1.010	0.311	0.954	1.015
Constant	221.864	28.716	41.740	0.000	172.154	285.929

**Rainfall 2-3 months before the outmigration date;*
**IRR: incidence rate ratio*
Lag of 2,3,7,10,15 dry days occurred 2-3 months before the emigration date
Decru DDG= Diminution of rainfall quantity between two consecutive years (Dédougou station)

3.6 Climate change and food insecurity in Nouna HDSS, Burkina Faso

3.6.1 Migration level by village of the household survey sample

Figure 25 illustrates the different patterns of emigration within the Nouna HDSS's villages. The pattern shows a great variation between the villages. Thus, the villages Lemini, Boune, Ouette and Dankoumana experience strong emigration as shown by the highest rates of around 0.8 (8 members within 10), compared to the other villages. This means that in these villages, 80% of the household members experienced emigration during the relevant year. This high migration number could be explained by the geographical position of these villages. Boune and Lemini are situated around the Mouhoun river, which is a favourite agricultural and pastoralist zone. In contrast, the villages of Cisse, Diamasso, Bourasso and Tonseré come last with rates below 0.2(2 members over 10). Cisse is characterized by its very conservative character, which might explain the small number of emigrations. In the theory of social change, modernity is known to be a factor of change. Cisse is a refractor to change. For example, in this village people did not like using health facilities for family planning. The character of a conservator in this village may keep it sedentary compared to others.

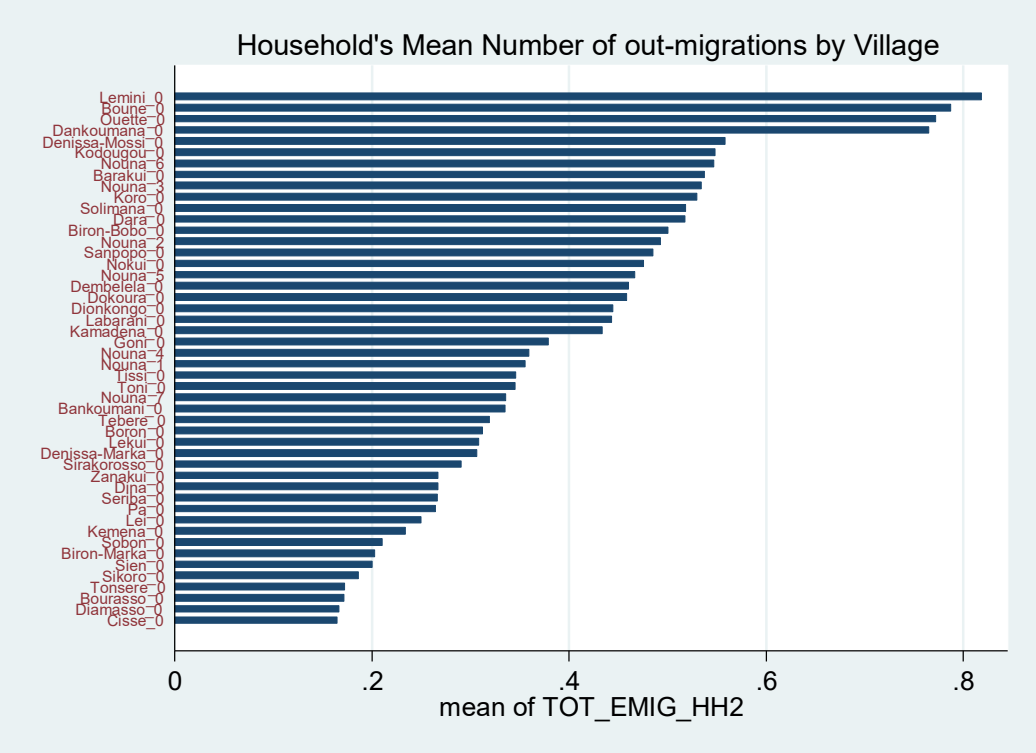


Figure 25: Household mean number of out-migrants by village in the Nouna HDSS (constructed using CRSN database, 2018)

3.6.2 Migration patterns by year in the household survey sample

Considering the evolution of migration across years, emigration per household shows an irregular trend. Between 2004 and 2005 migration movements decreased but increased again between 2005 and 2006. The year 2006 also had the highest record (0.6) of emigration levels compared to the other years. The year 2009 has the lowest (0.3) emigration level, corresponding to 30 % of the household members in this village use to migrated during the relevant year. The low level of emigration in the most recent years was noted in the previous chapter on the evolution of the migration level. This is explained by the decrease in agricultural migration which most often involves the displacement of all members of the household from one place to another area deemed to have the richest cultivable land. In summary, many policies that were impelling migration diminished over the years because of the higher cost of the interventions(Fauré 1997). For a recall, the colonial period of Burkina Faso (1932-1960) organized or push emigration toward neighbouring countries like Ivory Coast, Mali, and Ghana. Also, in the post-colonial period,

mainly with the *Amenagement des vallées voltaiques* (AVV) policy, the Government organized people to move from the very hard part(North) of the country toward South-Center(Fauré 1997).

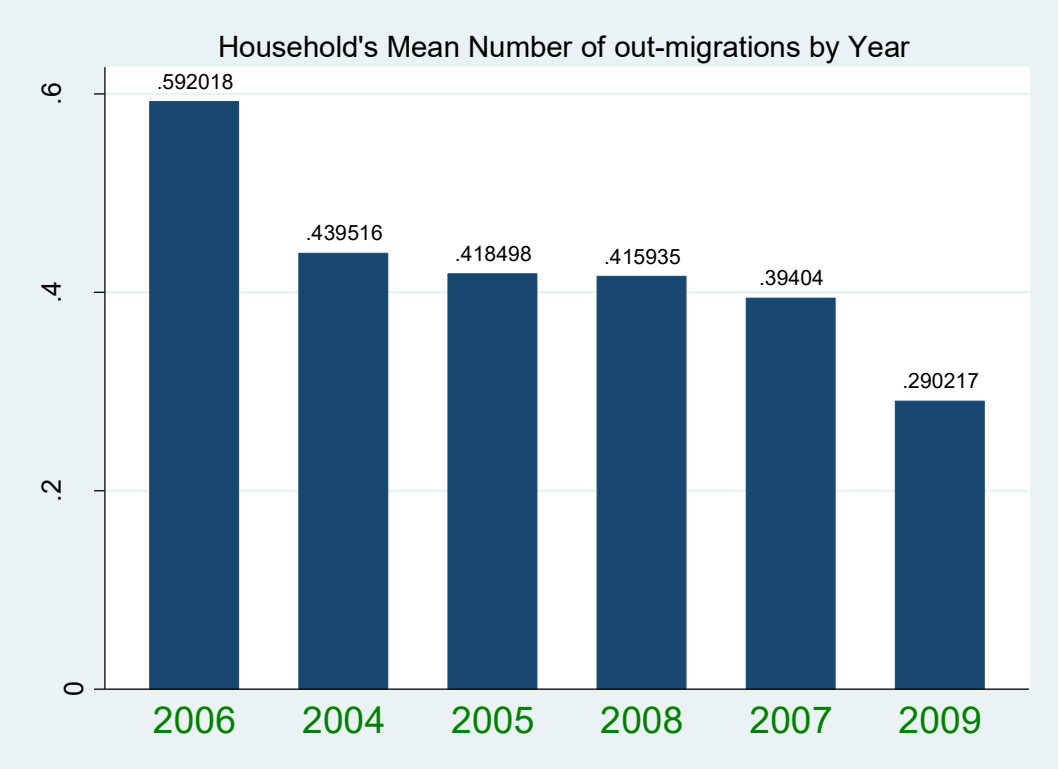


Figure 26: Mean number of emigrations in the households in the Nouna HDSS area by study year (constructed using CRSN Database, 2018)

3.6.4 The impact of household crop quantity on emigration

For a recall, I associated emigration with household crops quantity using the Poisson regression model for counting data. The predictor's variables are the Total household harvest amount, the Quantity of crops (cash crop), the Quantity of crops (cereals), the Total amount of crops per head of individuals in the household, the Quantity of crops (cash) per head in the household, the Quantity of crops (cereals) per head in the household, plus the household characteristics (Household size, Household labour force (demographic), Number of men in the household, Number of women in the household, Number of children under 15 years in the household).

A general interpretation of the regressions' coefficients is as follows: for a one-unit changed in the dependent variable, the difference in the logs of expected counts is expected to change by the respective regression coefficient, given the other predictor variables in the model are held constant. To facilitate and avoid interpreting a very small coefficient I have preferred adding the option IRR in the regression command to have "Incidence Rate Ratio" **(**IRR). They are obtained by exponentiating the Poisson regression coefficients.

The effect of Quantity of household crop harvest on emigration

The table 11 above contains the Incidence Rate Ratio (IRR) of the simple regression model.

For a one-unit changed in the *ratio of crop quantity for an individual in the household (RRIND_PRODUCTION_HH)*, the difference in the logs of number of emigrations is expected to be multiplied by the 1.003967, given the other predictor variables in the model are held constant. In another words, if a Household were to increase its *ratio of crop quantity for an individual in the household* by one kilogram, its rate ratio for emigration would be expected to be multiplied by 1.003967, while holding all other variables in the model constant.

For *ratio of crop quantity for an individual in the household*, it's 95% sure that the predicted IRR will be comprised between [1.002333-1.005604].

Quantity of cash crops harvested per individual in the Household (RRIND RENTE F) – If a Household were to increase his *Quantity of cash crops harvested per individual in the Household* by one Kilogram, his rate ratio for emigration would be expected to decrease by a factor of 0. 9960642 [0.9944404 - 0.9976906], while holding all other variables in the model constant.

Quantity of cereal harvested per individual in the Household (RRIND CEREAL F): If a Household were to increase its *Quantity of cereal per individual* by one Kg, its rate ratio for *emigration* would be expected to decrease by a factor of 0. 9945043 [0. 9927677- 0. 9962439] while holding all other variables in the model constant.

Number of elders aged 65 years and above in the Household (NB 65 ANSO TOT) – This is the estimated rate ratio for a one-unit increase in *Number of elders aged 65 years and above in the*

Household, given the other variables are held constant in the model. Increasing the number of elder's individuals in a Household by one individual will multiply the rate ratio for *emigration* by 1.123193 [1.099344- 1.147559] while holding all other variables in the model constant.

Table 11: Impact of crop quantity on Household's members' emigration

Total number of emigrations in the household	IRR*	std. err.	z	p>z	[95% conf.	interval]
Ratio of crop quantity for an individual in the household	1.004	0.001	4.76	0.000	1.002	1.006
Quantity of cash crops harvested per individual in the Household	0.996	0.001	-4.74	0.000	0.994	0.998
Quantity of cereal harvested per individual in the Household	0.995	0.001	-6.18	0.000	0.993	0.996
Number of elders aged 65 years and above in the Household	1.123	0.012	10.61	0.000	1.099	1.148
Constant.	0.402	0.012	-31.3	0.000	0.380	0.425

***** *IRR: incidence rate ratio*

3.6.5 The impact of household crop quantity on emigration tacking into account household characteristics

Table 12 presents the regression results of crop production on household characteristics. All predictor variables were included in the model as presented in table 3 in the Methods chapter.

Table 12: Effect of household crop productions and household characteristics on emigration

Total number of emigrations in the household	IRR*	Std. Err.	z	P>z	[95% Conf.	Interval]
Ratio of crop quantity per capita and household	1.00	0.00	3.26	0.001	1.00	1.00
Quantity of cash crops harvested per individual in the Household d	1.00	0.00	-3.25	0.001	1.00	1.00
Quantity of cereal harvested per individual in the Household	1.00	0.00	-5.11	0.000	0.99	1.00
Total number of male people in the household	0.87	0.04	-3.30	0.001	0.80	0.94
Total number of female people in the household	0.88	0.04	-3.06	0.002	0.81	0.95
Total number of individual aged 0-14 years	1.17	0.05	3.74	0.000	1.08	1.27
Total number of individual aged 15-64 years	1.19	0.05	4.00	0.000	1.09	1.29
Total number of individual aged 65 years and over	1.13	0.05	2.73	0.006	1.03	1.23
Constant	0.26	0.01	-38.76	0.000	0.25	0.28

***IRR: incidence rate ratio**

The data shows that the relationship between household crop quantity and household emigration is statistically significant.

The ratio of crops per individual in the household (RRIND PRODUCTION HH)– If a Household were to increase its *ratio of crops per individual* by one kilogram, his rate *ratio for emigration* would be expected to be multiplied by 1.002898 [1.001156 - 1.004644], while holding all other variables in the model constant.

The coefficient relating to the *quantity of cash crops harvested per individual in the Household* (RRIND RENTE F) is the estimated rate ratio for a one-unit increased in cash crops per individual in the Household, given the other variables, are held constant in the model. If a household were to

increase his *cash Crops quantity* by one Kg, his rate ratio for emigration would be expected to decrease by a factor of 0. 9971156 [0. 9953804 - 0. 9988539] while holding all other variables in the model constant.

In the same sense, the coefficient relating to the *quantity of cereal per individual in the household (*RRIND CEREAL F) is the estimated rate ratio for a one-unit increased in *quantity of cereal per individual in the household*, given the other variables are held constant in the model. If a household were to increase its Quantity of cereal per individual by one Kg, its rate ratio for emigration would be expected to decrease by a factor of 0.9951238 [0. 9932585- 0.9440232] while holding all other variables in the model constant.

Now comes the household characteristics *(Household size, Household labour force (demographic), Number of men in the household (*NB MALE TOT*), Number of women in the household (*NB FEMAL TOT*), Number of children under 15 years in the household (*NB 0 14ans TOT*), the Number of people 15-64-years-old (*NB 15 64ans TOT*), the number of individuals of 65years and more (*NB 65 ans O TOT*)*.

A test of multicollinearity revealed collinearity between household size and the other variables of household characteristics. For this reason, I excluded the household size in the final model.

All these variables related to household characteristics are significantly linked to emigration. In contrasted, the *Number of men (*NB MALE TOT*)* and the *Number of women in the household (*NB FEMAL TOT) has a reducing effect on household emigration. But the number of people under 15 years, 15-65 years and 65 years and above has a positive relationship with the household emigration.

The coefficient related to number of elders aged 65 years and above in the Household (NB 65 ANSO TOT) correspond to the estimated rate ratio for a one-unit increase in Number of elders aged 65 years and above in the Household, given the other variables are held constant in the model. Increasing the number of elder's individuals in a Household by one individual will multiply the

rate ratio for emigration by 1.123193 [1.099344 - 1.147559] while holding all other variables in the model constant.

3.6.6 The impact of crop quantity on international outmigration

The same model as above was applied to determine the relationship between crop quantity and only international emigration (emigration toward others countries than Burkina Faso).

Table 13 shows that the quantity of the crop for an individual in the household (RRIND PRODUCTION HH), cash crops per individual in the Household (RRIND RENTE F), the quantity of cereals per individual in the Household (RRIND CEREAL F) are still significantly affecting the level of emigration toward international countries.

Table 13: Impact of crop quantity on international outmigration

Total number of emigrations in the household	IRR*	Std. Err.	z	P>z	[95% Conf.	Interval]
Ratio of crop quantity per capita and household	1.01	0.00	9.44	0.000	1.01	1.01
Cash crops quantity per individual in the household	0.99	0.00	-9.20	0.000	0.99	0.99
Quantity of cereal per individual in the household	0.99	0.00	-8.75	0.000	0.99	0.99
Total number of male people in the household	1.40	0.24	1.95	0.051	1.00	1.97
Total number of male people in the household	1.49	0.26	2.30	0.022	1.06	2.08
Total number of individuals aged 0-14 years	0.72	0.12	-1.91	0.056	0.51	1.01
Total number of individuals aged 15-64 years	0.72	0.12	-1.90	0.057	0.51	1.01
Total number of individuals aged 65 years and over	0.67	0.12	-2.27	0.023	0.48	0.95
Constant.	0.04	0.00	-49.50	0.000	0.04	0.05

IRR: incidence rate ratio

The quantity of harvested crop is statistically associated with household emigration. An enough crops harvest by the household has a reducing effect on household emigration. It is the same for the quantity of cash crop that the household use to sell for a purpose of getting cash money. By separating the type of crops in the analysis, the result clearer as expected in theory.

4. Discussion

4.1 Description and typologies of migration

Refereeing to objective one (see pages 18/19), this section discusses the levels, typology and the evolution of migration.

4.1.1 Nouna -HDSS as a zone of higher migration level

Nouna HDSS area is characterized by higher population movements compared to the neighboring countries of West Africa (IOM 2016). This could be explained by the geographical position of this land-locked country. Specifically, women, adolescents and young adults (aged 10-34years) tend to be more likely to migrate compared to men and older age groups, respectively. This result is in line with other studies from West Africa as well as Burkina Faso confirming regular emigration (IOM 2016;CONAPO, 2006). This dynamic was enhanced for some decades due to colonization as the settlers from the foreign countries moved many people to the Ivory Coast to work on the plantations. Specifically, the population of Burkina Faso were encouraged to migrate to neighboring countries such as the Ivory Coast, Mali, Gabon, or Ghana between 1932 and 1960. Equally, during the post-colonial period (Burkina Faso gained independence in 1960), the Government pushed the population to move from the North of the country towards the Southern part due to a succession of droughts and improperness of cultivable soils (Fauré 1997). Since then, out-migrating became a cultural practice among certain ethnic groups mainly in the East and North part, inhabited by Mossi. Among this ethnic group, travelling abroad was culturally expected as part of an initiation process (IOM 2016). Accordingly, for a Mossi to become a “man”, which is considered equal to becoming “responsible”, he had to stay abroad for some time before coming back. So, out-migrating had a high cultural acceptance among the Mossi population.

4.1.2 The diminution of emigration levels

We showed that the migration’s level in rural Burkina Faso is decreasing between 1992 and 2016. This might be explained by two important factors. On the one hand, the increasing political

problems in the Ivory Coast between 2002 and 2011 made the country less stable to move to, despite it being the main destination for migrations from Burkina Faso for such a long time. Among those political problems were the global economic crisis, the draconian conditions imposed on migrants and the increasingly violent and deadly conflicts in the country (IOM 2016). The general emigration and in-migration levels decreased considerably these last years since 2011. The bad experiences during the armed conflict that took place in the Ivory Coast caused many return migrations to Burkina Faso , which discouraged those where intending to emigrate from Burkina Faso (Zongo 2003).

The second major reason for the declination of migration levels may be that the population experienced what sociologists called "social change". This concept refers to the transformation of societies over time under the impulsion of modernity and capitalism. More and more, people tend to settle and cultivate and invest in their own land, which they do not want to leave behind. Out-migrating to abandon these investments in a capitalist context is irrational. The *social change* that is empowering the importance of land ownership should reorient emigration, notably for rural people. In fact, rural people, in majority uninstructed could not be comfortable with the new dynamic requirement of international migration conditions. Besides, the Government gave up the politic of AVV since 1979. AVV means in French, "*Amenagement des vallées voltaiques*" and it was a national policy consisting to organize population displacement inside the country to valorize the new cultivable soils, gained from the eradication of onchocerciasis in some parts of the country (North-Center, South-Center…). In this policy, the population was recruited from the hard zones of the country to be settled in some new land conquered from fighting against onchocercid diseases (Fauré 1997). An evaluation of this migration policy before 1980 demonstrated it is very expensive and the process was postponed until to date.

4.1.3 Women were the largest migrant population

We reported a high propensity of women to out-migrate, compared to men. These results are in good line with the finding of the MADIMAH[1] study (Ginsburg et al. 2016), which was identifying internal migration's effects on mortality in Africa using health and demographic surveillance systems of the INDEPTH Network (Ginsburg et al. 2016). The predominance of female emigration is explained by either marriage or an outing to seek paid work in the city to prepare for marriage (Barry et al. 2021; Vause et al. 2015).Furthermore, many women entered the Nouna HDSS area by marriage. Either they were from other localities outside the Nouna HDSS and enter for the first time, or they were in the Nouna HDSS and had emigrated to search for paid jobs for a purpose of preparing their imminent marriage.

As far as men are concerned, it is known that men in some localities of the Nouna HDSS make seasonal emigration to look for paid employment. Most of males aged 20-25 migrate just before the end of the field works. The new married return at the beginning of the rainy season, unlike singles who stay longer in emigration (Barry et al. 2021; Sié et al. 2018).

The net-outmigration out of the Nouna area could be explained by the fact, the area is surrounded by areas with fertile and cultivable lands. This result is not at odds with a recent study commissioned by IOM in 2016 that, which listed "*Boucle du Mouhoun*", a region that is encompassing the Nouna-HDSS zone, among the attractive regions of Burkina Faso the least being the North and the Sahel (IOM 2016; Néya 2016).

4.1.4 Emigration for other work purposes is increasing but emigrating for cultivating purposes especially is decreasing

The individuals out-migrating for work (other works, excluding farming) purposes are increasing particularly since 2013, but migrating for farming/cultivating purposes is decreasing. This is an unexpected result in the context of climate change that the motives for cultivating and for doing pasture are diminishing. Likewise, emigration for pasture remained low over the period of the

[1] MADIMAH: Multisite workshop of analysis on Dynamics of migration and health

investigation. This was unexpected in the context of climate change-induced migration. As our results show the degradation of rainy season, it was expected to observed more emigrations in purpose of looking for cultivable lands. However CONAPO (2006) find the main reason for internal migration between rural areas is the search for cultivated land and the intensity of internal migration was increasing since the 1980s (CONAPO 2006). But questioning climate change, and observing climate variability, it was expected to see increasing the importance of these motives. Returning to one's father home is constantly getting important. Starting with less than 7% at the beginning of the period, this motive at the end of the period occupied 19% of the motives. In the Nouna HDSS area, many children are taken care of by other relatives instead of their biological parents. By that time, they could be going back to their father home. *Social change* with the reducing family size is taking place even in the villages.

4.1.5 Lower level of international migration compared to domestic (or in-country) migration

Another change seen in the migration patterns is the weight of international migrations and their destinations. In the Nouna HDSS area, migration is dominated by internal (within the Burkina borders) migration between the villages of the HDSS or between this and the other villages of the rest of the country. This result is different from those shown by CONAPO studies who find that the Burkina migration is predominated by the international migration at 53 to 70 % between 1974 and 1996 (CONAPO 2006). In the Nouna HDSS area, international migration represented less than 20% of total moves (between 10 – 19%) over the last decade 2004-2016.

4.1.6 Migration destination has changed

Likewise, migration destination has changed. Ivory Coast remained the main destination of emigration from the N-HDSS as well found by previous studies (IOM, 2016;CONAPO 2006; Néya 2016; Vause et al. 2015). While 70% of international migrations have been toward Ivory Coast

according to previous studies, in the Nouna HDSS area, migration toward this country is diminishing over time. Then, migration toward Mali and Ghana has almost disappeared.

A new dynamic of internal migration is the movement towards the other villages of the country, toward Bobo Dioulasso and Ouagadougou and other international parts.

4.2 Characteristics of weather variability in the Nouna HDSS

4.2.1 Displacement at the end and the start of the rainy season

When appreciating weather variability, the results show some key changes in the Nouna-HDSS area. There is the displacement of the end and the start of rainfalls over the period 1990-2016. In the decades 1990, the rainfall was starting in May and ending later October-November. At the end of the period of my investigation, rainfalls are starting in June and ending in October. In other terms, more and more, the wet season is starting late and ending early.

4.2.2 A slight increase in annual cumulative rainfall over the period but irregular evolution of the yearly quantity of rainfall

Another change observed in the climate variability is the irregular evolution of the yearly cumulative rainfall over the period, but the evolution of the total annual precipitation trend shows a slight increase in annual rainfall. This result is contradicting the finding of de Longueville 2016 who conclude the significant decrease of this indicator (De Longueville et al. 2016; Sitati et al. 2021; Sorgho et al. 2020; Voûte et al. 2021). In fact, the same quantity of rainfall could differ from their results on crops impact according to the distribution of this quantity along the months of the rainy season. So, it is common to observe floods because of a bad spatial and temporal distribution of the number and quantity of rainfalls in August or September in Burkina Faso. This led a catastrophic flood in September 2009, notably in the capital city, Ouagadougou.

4.2.3 A shortening of the wet season

Third, there has been an irregular evolution of the length of the rainy season, but the tendencies have been a shortening of the length of wet seasons. This result is sustained by the change in the

Ending and *Starting* of the wet season. The investigations on the rainfall season's quality show more frequencies of having pockets of drought lasting 1 to 5 days during the recent period (2006-2016) compared to the period 1992-2005. In other terms, during the recent period (2006-2016) the rainfall season has the highest probability of having pockets of drought lasting 1 to 5 days. In short, within the Nouna HDSS, the period between 1992 -2016 is marked by a degradation of the quality of the wet seasons. This result is in line with the finding of De Longueville when investigating the conjugation of rainfall, maximum consecutive dry days. He concluded on a certitude of changes in the pattern of rainfall (De Longueville et al. 2016). Henry et al. also argued that Burkina Faso's rainfall is characterized by a high degree of seasonal and annual variability (Henry et al., 2004). This could be explained the geographical position of Burkina Faso, a landlock country, without access to the sea. Such phenomenon can impact negatively agricultural production (Hatfield et al. 2014; Schwerdtle et al. 2017; Voûte et al. 2021) which is one of the migration's determinants.

4.3 The impact of climate variability on emigration

4.3.1 Climate variability increases emigration

Monthly cumulative rainfall had a significant association with the monthly number of emigration events. And the incidence risks ratios were regularly increasing over the years from 1992 to 2006 before starting to decrease from this year until the end of our investigation period. This result is in line with Tacoli finding (Tacoli 2009). This author investigated on the entire country of Burkina Faso and concluded that a decrease in rainfall amount increases rural-rural temporary migration.

We reported that the maximum number of consecutive dry days, the cumulative quantity of rain of the previous year, the decreasing cumulative quantity of rain of the precedent year, the cumulative quantity of rainfall and the lag of 3 months early rainfall were all significantly associated with emigration. It is plausible that climate-induced greater weather variability with alternating dry spells and torrential rainfalls have a negative impact on crops. Another study implemented in Northwestern Algeria using scenarios of projection for the 21st century predicted

more expositions to extreme events like droughts and floods (Bouabdelli et al. 2020). This author mainly points out a future exacerbation of hydrological drought in this region who will negatively impact food production and provision via water resources rarefication.

4.3.2 Food insecurity induces emigration

The fourth objective of this study was to see, if food insecurity can lead to emigration. We showed that food insecurity expressed for the purpose of our study as the quantity of food crops harvested by the household was a factor associated with migration. Total quantity of crops in cash (cotton, beans, peanut), Total amount of crops destined for eating(cereals) of the HH, Quantity of harvest (rent + cereals) per individual in the Household are significantly associated with the household members' emigration in the Nouna HDSS.

These results fit with other studies that find strong empirical evidence between household income shocks and emigration. In fact, Kosec and Song (2018) concluded that negative household income shocks induced by agricultural price fluctuations, significantly increased the likelihood of emigration, especially for men. The authors suggested that migration could be seen as a potentially beneficial strategy to adapt to bad harvest from climate change and help provide livelihood support to those who remain behind (Kosec and Song 2018). This, however was contradicted by Vinke et al. (2022) in a village in the Nouna HDSS area (Bourasso). The authors, investigating in Burkina Faso has concluded that migration is not an effective adaptation tool only. other factors like structures of like the perceptions of migrants, their relatives, their personal experience and costs, as well as fears and expectations, adverse effects on health, and pressures on households who stayed behind could impede migration effectiveness(Vinke et al. 2022)

These findings confirm the hypothesis of this thesis according to which the increase in both climate variability and food insecurity leads to increasing the levels of emigration. Nevertheless, for some studies the impact of both climate variability and food insecurity on emigration could be relativized. It's not systematically but depending to other parameters.

A non-negligible proportion of children under 10 years of age were also found to be migrants. So-called juvenile migration deserves further investigation, which is yet not the aim of this study due to its focus on climate-related migration. In fact, in a brief thought, juvenile migration might be explained by the migration of the entire household, and/ or mothers with children of this age group. They are then also referred to as “followers”. In another way, the decision to emigrate is not made by these young, but by the household head.

4.4 Conclusions and recommendations

4.4.1 Conclusion

This thesis intended to (1) describe climate variability over 25 years in Nouna HDSS, to (2) describe migration’s trends, typology and destination in the Nouna HDSS and to (3) examine the effects of climate variability and food insecurity on emigration.

The research question about the typology and evolution of migration is answered as the results of the investigations shown the Nouna HDSS is a very dynamic zone in terms of population movement. Also, climate variability, operationalized by the amount of rainfall, has manifested itself in a degradation of the quality of the rainy season through delays in the start and precocity in the end of the rainy season, with a higher probability of having pockets of drought. Finally, the explanatory analyses confirmed the existence of links between rainfall variability, food insecurity and emigration in rural Burkina Faso.

The overarching hypothesis of the thesis is confirmed as the results of analysis has shown that the increase in both levels of climate variability and food insecurity leads to increasing the levels of emigration in rural Burkina Faso between 1992 and 2016.

These results imply the ongoing international debate on global warming. The recent COP27 decided to maintain the objective of 1.5°C and reiterated the commitment to support the most vulnerable countries through a first contribution on loss and damage. This resolution could certainly contribute to reduce climate migration in sub-Saharan Africa, including Burkina Faso.

Beyond these commitments, the international committee should not procrastinate on the measures defined in relation to the major emitters in order to progressively reduce fossil fuels, nor on the new commitments on climate mitigation. Burkina Faso's context would benefit if these international resolutions are observed. It is clear that the increasing momentum of climate variability cannot be ignored by a country where about 80% of the working population are subsistence farmers. The eventual effects would be an increased climate migration in search of rich, cultivable soils. This projection implies to align with the IOM vision on the need to organize internal migration.

4.4.2 Recommendations

In the following, I propose first my recommendation for future research and consider then those for policy.

For future research

Many studies concluded on the interlinkages between weather variability and migration and that relationship pass by agricultural productivity and food insecurity. But only few studies were able to quantify that relationship. Our retrospective longitudinal study had the benefit of covering almost three decades of weather variability and migration events. The backdrop inherent in such retrospective studies is that not all variables of interest can be captured, as the HDSS was not designed to give detailed answers to the nature and trends of migration with respect to weather variability changes. I therefore recommended to investigate in this way to refine the link between crops insufficiency and emigration. Such studies should explicitly collect prospective and longitudinal data on the specific reasons of emigrate by an individual or household. Harvested quantities of the households, food purchases and sales of the household should be simultaneously measured. It may also be interesting to measure child undernutrition as an indicator of lack of food availability within the household. In this way, it could be possible to quantify the part of migration due to climate variability induced crops shocks.

Furthermore, meteorological data should be measured as close to the population as possible, given the high spatial variability of rainfall. This is currently being installed over the Nouna HDSS area starting with 5 automated weather stations.

For policy-makers

One way to respond to increased harvest driven emigration would be for the country and the international donor community to invest in climate resilient agricultural practices and food crop cultivars.

First, to promote and improve modern water irrigation systems plus intensive agriculture to allow cultivators to be able to grow seeds during the post-wet-season period. By doing this, in case of insufficient rainfall or crops fail, households could try their chance during the dry season and avoid emigrating for complementary crops or revenue supply.

Another policy would aim to spread the risk of bad harvest, as not all households are likely to be affected in the same way, such a policy is currently in fact piloted in Burkina and tested in the study area of Nouna.

Finally early warning systems with a high resolution such at the household or at least the village level, could enable the government to organize targeted supply of grains to the worst affected villages or households respectively. Such early warning systems should link highly resolved meteorological data with satellite-based harvest predictions (Karst et el. 2020).

Limitations

We analyzed retrospective, i.e., already collected data. Invariably this meant that not all co-variates had been collected, as the HDSS data were not primarily designed to study the topic of this thesis. Due to this fact, the investigation lacks some other variables that may refine the sense of the relationship between climate change and migration. Another limitation is that climate or weather change has not been explicitly coded as one of the reasons for emigration. A similar variable which was not part of the HDSS was the collection or measurement of harvested food crops. In addition, the episodes of migration happening between 0-6 months were missed. In fact, referring to IOM definition, several HDSS including Nouna HDSS were registering migration whom the duration exceeds at least six months. This rule in the HDSS data collection constituted a limitation for me to have seasonal and short-term migration whom are relating to climate induced migration.

To finish, the study was limited by the shortest of the period of available data for the three meteorological, migration and crops data. Climate change is concerning at least thirty years of data but our available longitudinal data are between ten to twenty-five years. That is why I was using climate variability instead of climate change.

5. Summaries

5.1 Summary

Climate variability is a common phenomenon experienced world-wide. These impacts are more perceptible in sub-Saharan Africa. In Burkina Faso, a landlocked country in Western Africa, about 80% of the population depend on their own crops for living. As a result, the Burkinabè population has adopted a variety of adaptation strategies, including migration with the goal of finding alternative best conditions of life elsewhere. The current thesis determines the relationship between climate change, food insecurity and migration for the first time in the Nouna Health and Demographic Surveillance System which covers about 100,000 inhabitants in rural Burkina Faso. My central hypothesis is that an increase in both climate variability and food insecurity leads to a rising level of migration in rural Burkina Faso.

To characterize climate variability in the Nouna Health and Demographic Surveillance System area, I used weather data from the *National Aeronautics and Space Administration* on Burkina Faso, and the *Burkina National Meteorological Agency* data, as well as De Longueville and Sivakumar indicators. In terms of analyses, I draw on quantitative methods most used in population health and epidemiology. Specifically, I proceeded in the following three steps. First, event history analysis methods were employed to compute rates and proportions of migration for the population in the Nouna Health and Demographic Surveillance System area in Burkina Faso. Second, Cox proportional-hazards models were used for counting data to identify the link between rainfall variation and emigration. Third, I used logistic regression models to determine the link between household food insecurity and emigration in the study area. I assessed heterogeneity in the relationship by socio-demographic factors.

The study found that the Nouna Health and Demographic Surveillance System area is a very dynamic zone with regard to population movement with a general migration balance of -2.2 ‰ over the period of the study. The study villages showed different levels of migration by age. Women and the younger population (10-34years) were more likely to migrate compared to men

and other age groups. Internal migration, mainly between villages, occurred more often than international migration. The weather data showed that the study region is perceptible to climate variability, operationalized by the amount of rainfall, has manifested itself in a degradation of the quality of the rainy season. There are delays in the start and precocity in the end of the rainy season, with a higher probability of having pockets of drought during the period 1992-2016. The relationship between weather variability and emigration was statistically significant. Precisely, the maximum number of consecutive dry days, the cumulative quantity of rain of the previous year, the interannual variation of rainfall, the cumulative quantity of rainfall and a lag of 3-months early rainfall were significantly associated with emigration in the Nouna Health and Demographic Surveillance System area between 1992 and 2016. Food insecurity, operationalized by households' crops failure, had a positive association with household members emigration.

In terms of implications, a key policy relevance of the study lies in the demonstration that climate change contributes to emigration, whether seasonal or permanent emigration, in the context of rural Burkina Faso. Moreover, the current thesis proposes concrete strategies to mitigate the impacts of climate change, such as by making agriculture more climate resilient and retain populations. I suggest to corroborate the findings through a prospective cohort study designed to capture a wider range of non-climatic drivers of migration and appropriate confounding variables. Climate events may induce important demographic changes with considerable implications for the broader development of the region.

5.2 Zusammenfassung

Klimaschwankungen sind ein weltweites Phänomen. In den afrikanischen Ländern südlich der Sahara sind die Auswirkungen noch deutlicher spürbar. In Burkina Faso, einem Binnenstaat in Westafrika, leben etwa 80 % der Bevölkerung von ihren eigenen Ernten. Infolgedessen hat die burkinische Bevölkerung eine Reihe von Anpassungsstrategien entwickelt, darunter die Migration mit dem Ziel, anderswo bessere Lebensbedingungen zu finden. In der vorliegenden Arbeit wird zum ersten Mal der Zusammenhang zwischen Klimawandel, Ernährungsunsicherheit und Migration im Gebiet des Nouna Health and Demographic Surveillance System (HDSS) untersucht, dass etwa 100.000 Einwohner im ländlichen Burkina Faso umfasst. Meine zentrale Hypothese ist, dass eine Zunahme der Klimaschwankungen und der Ernährungsunsicherheit zu einem Anstieg der Migration im ländlichen Burkina Faso führt.

Um die Klimaschwankungen im Gebiet des Nouna HDSS zu beschreiben, habe ich Wetterdaten der National Aeronautics and Space Administration von Burkina Faso und Daten der Nationalen Meteorologischen Agentur von Burkina Faso sowie Klimaindikatoren von De Longueville und Sivakumar verwendet. Bei der Analyse habe ich mich auf quantitative Methoden gestützt, die in der Bevölkerungsgesundheit und Epidemiologie am häufigsten verwendet werden. Im Einzelnen bin ich in den folgenden drei Schritten vorgegangen. Zunächst wurden Methoden der Ereignisverlaufsanalyse eingesetzt, um die Migrationsraten und -anteile für die Bevölkerung im Gebiet des Nouna HDSS in Burkina Faso zu berechnen. Zweitens wurden Cox-Proportional-Hazards-Modelle für Zähldaten verwendet, um den Zusammenhang zwischen Niederschlagsschwankungen und Abwanderung zu ermitteln. Drittens verwendete ich logistische Regressionsmodelle, um den Zusammenhang zwischen der Ernährungsunsicherheit der Haushalte und der Abwanderung im Untersuchungsgebiet zu ermitteln. Dabei habe ich die Heterogenität der Beziehung nach soziodemografischen Faktoren bewertet.

Die Studie ergab, dass das Gebiet des Nouna HDSS ein sehr dynamisches Gebiet in Bezug auf die Bevölkerungsbewegung ist, mit einem allgemeinen Wanderungssaldo von -2.2 ‰ im Untersuchungszeitraum. In den untersuchten Dörfern war die Abwanderung je nach Alter unterschiedlich stark ausgeprägt. Frauen und die jüngere Bevölkerung (10-34 Jahre) wanderten häufiger ab als Männer und andere Altersgruppen. Interne Wanderungen, hauptsächlich zwischen Dörfern, waren häufiger als internationale Wanderungen. Die Wetterdaten zeigten, dass die Untersuchungsregion für Klimaschwankungen anfällig ist, die sich in der Niederschlagsmenge niederschlagen und sich in einer Verschlechterung der Qualität der Regenzeit manifestieren. Der Beginn der Regenzeit verzögert sich und das Ende der Regenzeit verfrüht sich, wobei die Wahrscheinlichkeit von Dürreperioden im Zeitraum 1992-2016 gestiegen ist. Der Zusammenhang zwischen Wettervariabilität und Auswanderung war statistisch signifikant. Genauer gesagt waren die maximale Anzahl an aufeinanderfolgenden Trockentagen, die kumulierte Regenmenge des Vorjahres, die interannuelle Variation der Niederschläge, die kumulierte Regenmenge und eine Verzögerung von 3 Monaten bei den ersten Regenfällen signifikant mit der Abwanderung im Gebiet des Nouna HDSS zwischen 1992 und 2016 verbunden. Ernährungsunsicherheit, operationalisiert durch Ernteausfälle der Haushalte, stand in einem positiven Zusammenhang mit der Abwanderung von Haushaltsmitgliedern.

Eine wichtige politische Bedeutung der Studie liegt darin, dass der Klimawandel im ländlichen Burkina Faso zur saisonalen oder dauerhaften Abwanderung beiträgt. Darüber hinaus werden in der vorliegenden Arbeit konkrete Strategien vorgeschlagen, um die Auswirkungen des Klimawandels abzumildern, etwa indem die Landwirtschaft klimaresistenter gemacht und die Bevölkerung zurückgehalten wird. Ich empfehle, meine Ergebnisse durch eine prospektive Kohortenstudie zu untermauern, die so angelegt ist, dass sie ein breiteres Spektrum an nicht klimabedingten Faktoren und geeignete Störvariablen für die Migration erfasst. Klimaereignisse können wichtige demografische Veränderungen auslösen, die erhebliche Auswirkungen auf die allgemeine Entwicklung der Region haben.

5.3 Résumé

La variabilité du climat est un phénomène courant dans le monde entier. Ces impacts sont plus perceptibles en Afrique sub-saharienne. Au Burkina Faso, pays enclavé d'Afrique occidentale où environ 80 % de la population dépend de ses propres cultures pour vivre. En conséquence, la population burkinabè a adopté une variété de stratégies d'adaptation, y compris la migration dans le but de trouver les meilleures conditions de vie ailleurs. La présente thèse détermine pour la première fois la relation entre le changement climatique, l'insécurité alimentaire et la migration dans la zone du Système de Surveillance Sanitaire et Démographique de Nouna (SSDS) en milieu rural burkinabè. Le SSDS qui couvre environ 100 000 habitants à ce jour, après 25 ans de suivi (1992-2016) est localisé dans le district sanitaire de Nouna. Mon hypothèse centrale est qu'une augmentation à la fois de la variabilité climatique et de l'insécurité alimentaire entraîne une hausse du niveau de migration dans les zones rurales du Burkina Faso. Pour caractériser la variabilité climatique dans la zone du Système de Surveillance Sanitaire et Démographique de Nouna, j'ai utilisé les données météorologiques de *National Aeronautics and Space Administration* sur le Burkina Faso et les données de *l'Agence Nationale de Météorologie* du Burkina, ainsi que les indicateurs de De Longueville et Sivakumar. En termes d'analyses, je m'appuie sur les méthodes quantitatives les plus utilisées en santé des populations et en épidémiologie. Plus précisément, j'ai procédé en trois étapes. Premièrement, des méthodes d'analyse de l'histoire des événements ont été utilisées pour calculer les taux et les proportions de migration de la population de la zone du Système de surveillance démographique et de santé. Deuxièmement, des modèles de risques proportionnels de comptage des données de Cox ont été utilisés afin d'identifier les liens entre la variation des précipitations et l'émigration. Troisièmement, j'ai utilisé des modèles de régression logistique pour déterminer le lien entre l'insécurité alimentaire des ménages et l'émigration dans la zone d'étude. J'ai évalué l'hétérogénéité de la relation en fonction des facteurs socio-démographiques. L'étude a révélé que la zone du SSDS est une zone très dynamique en ce qui concerne les mouvements de population avec un solde migratoire général négatif de -2,2 ‰ sur

la période de l'étude. Les villages étudiés ont montré différents niveaux de migration par âge. Les femmes et la population plus jeune (10-34 ans) étaient plus susceptibles de migrer que les hommes et les autres groupes d'âge. La migration interne, principalement entre les villages, était plus fréquente que la migration internationale. Les données météorologiques ont montré que la région d'étude est perceptible à la variabilité climatique, opérationnalisée par la quantité de précipitations, s'est manifestée par une dégradation de la qualité de la saison des pluies. Il y a des retards dans le début et la précocité dans la fin de la saison des pluies, avec une plus grande probabilité d'avoir des poches de sécheresse au cours de la période 1992-2016. La relation entre la variabilité météorologique et l'émigration est statistiquement significative. Précisément, le nombre maximum de jours secs consécutifs, la quantité cumulée de pluie de l'année précédente, la variation interannuelle de la pluviométrie, la quantité cumulée de pluie et les pluies des 3 mois précédents ont été significativement associés à l'émigration dans la zone du SSDS entre 1992 et 2016. L'insécurité alimentaire, opérationnalisée par les mauvaises récoltes des ménages, avait une association positive avec l'émigration des membres du ménage.

En termes d'implications, une pertinence politique clé de l'étude réside dans la démonstration que le changement climatique contribue à l'émigration, qu'elle soit saisonnière ou permanente, dans le contexte du Burkina Faso rural. En outre, la présente thèse propose des stratégies concrètes pour atténuer les impacts du changement climatique, par exemple en rendant l'agriculture plus résiliente au climat et en retenant les populations. Je suggère de corroborer les résultats par une étude de cohorte prospective conçue pour capturer un plus large éventail de facteurs non climatiques de la migration et des variables confondantes appropriées. Les événements climatiques peuvent induire des changements démographiques importants avec des implications considérables pour le développement plus large de la région.

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Useful link

https://www.researchgate.net/publication/227370634 Do rainfall Conditions Push or Pull Rural Migrants Evidence from Malawi

https://unfccc.int/news/climate-change-is-a-key-driver-of-migration-and-food-insecurity

https://unfccc.int/news/climate-change-is-a-key-driver-of-migration-and-food-insecurity

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7. List of Publications

Own Publications and presentations emanating from the thesis work

Zabre, S. P., Traoré, I., Sié, A., Sauerborn, R. (2022). **La Côte d'ivoire demeure-t-elle la destination privilégiée des migrations de l'Observatoire de population de Nouna au Burkina Faso** ? Revue de Géographie de l'Université de Ouagadougou (RGO), Burkina Faso ; 2 (11), 22-51. (Published)

Zabre, S. P., Barteit, S., Traoré, I., Sié, A., Mank, I., Sorgho, R., Derra, K., Lankouande, B., Schwerdtle, P., Tientega, V., Danqah I., Garenne, M. and Sauerborn, R. (2022).
Does climate variability influence out-migration in sub-Saharan Africa? A case study from the Nouna Health and Demographic Surveillance System Site (HDSS) in Burkina Faso from 1992 to 2016. (In preparation for publication).

Vinke, K., Rottmann, S., Gornott, C., **Zabre, P.,** Nayna Schwerdtle, P., Sauerborn, R**.** (2022).
Ismigration an effective adaptation to climate-related agricultural distress in sub-Saharan Africa? Popul. Environ. 43, 319–345, https://doi.org/10.1007/s11111-021-00393-7

Posters and Presentations

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Zabre S. Pascal., Sandra Barteit., I. Traoré, Lankouande B., Sié A, Derra K., Isabel M., Raissa S, Schwerdtle P; Tientega V., Ina Danqah, Garenne M., Sauerborn R
« La variabilité climatique influence-t-elle l'émigration en Afrique subsaharienne ? Une étude de cas du site du Système de surveillance démographique et de santé de Nouna au Burkina Faso de 1992 à 2016 ». Présentation orale- 21ème Journées des Sciences de la Santé de Bobo-Dioulasso, Burkina Faso, 12 au 15 Décembre 2022.

List of publications not emanating from the thesis work

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9. Appendix

9.1. Supplementary tables and figures

Table 14 Distribution of the household according to outmigration number per year

Number of outmigrations Events	1	2	3	4	5	6	7	8	9	11	12	14	17	19	Total HH of the year
2004	149	43	24	6	8	3	0	1	0	2	0	0	1	0	237
2005	174	63	24	5	5	2	1	0	1	0	1	0	0	0	276
2006	163	52	26	1	2	4	3	3	1	0	0	1	0	1	273
2007	222	53	29	3	1	3	1	1	0	1	0	0	0	0	314
2008	257	87	21	1	1	4	1	0	1	0	1	0	0	0	398
2009	205	46	23	4	3	3	1	1	0	0	1	0	0	0	287
Total	1,17	34	14	4	3	1	7	6	3	3	3	1	1	1	1,785

Table 15: Number of sequences of days without rainfall

	Number of Pockets of *n* consecutive dry days (pockets of drought)														
year	dry 1 days	dry 2 days	dry 3 days	dry 4 days	dry 5 days	dry 6 days	dry 7 days	dry 8 days	dry 9 days	dry 10 days	dry 11 days	dry 12 days	dry 13 days	dry 14 days	dry 15 days
1990	42	29	15	8	5	5	3	3	1	1	1	1	1	1	1
1991	41	31	18	8	5	2	0	0	0	0	0	0	0	0	0
1992	42	21	15	11	7	3	3	3	2	2	1	0	0	0	0
1993	34	21	12	9	5	4	3	3	2	1	1	1	1	1	1
1994	41	21	14	9	6	4	3	3	3	1	0	0	0	0	0
1995	46	27	15	9	7	4	3	2	2	2	2	2	2	0	0
1996	39	25	16	9	6	4	2	1	0	0	0	0	0	0	0
1997	40	27	16	10	5	5	5	4	2	1	0	0	0	0	0
1998	43	22	15	8	7	4	4	3	1	1	0	0	0	0	0
1999	34	21	13	8	6	4	4	4	3	1	1	1	1	1	1
2000	37	25	15	12	8	8	4	2	2	1	1	1	1	1	1
2001	31	20	13	7	7	5	3	1	1	1	1	1	1	0	0
2002	37	27	16	12	8	5	2	2	1	0	0	0	0	0	0
2003	39	26	12	10	6	2	1	1	0	0	0	0	0	0	0
2004	33	19	13	8	5	4	2	2	1	1	1	1	1	1	1
2005	31	23	13	10	6	5	3	2	1	1	0	0	0	0	0
2006	45	26	12	7	1	0	0	0	0	0	0	0	0	0	0
2007	39	22	13	12	9	5	3	2	0	0	0	0	0	0	0
2008	35	19	17	10	7	6	5	3	1	1	1	1	1	1	0
2009	45	27	12	10	5	2	0	0	0	0	0	0	0	0	0
2010	40	24	12	7	5	3	2	1	1	1	1	1	1	1	0
2011	45	26	14	8	4	3	1	0	0	0	0	0	0	0	0
2012	39	20	12	7	4	3	3	3	2	2	2	2	2	1	1
2013	40	25	14	6	3	2	1	1	0	0	0	0	0	0	0
2014	41	26	16	10	6	2	1	1	1	0	0	0	0	0	0
2015	39	20	15	10	7	4	4	3	1	0	0	0	0	0	0
2016	38	24	11	7	6	3	3	3	3	2	2	2	2	2	1
	1056	644	379	242	156	101	68	53	31	20	15	14	14	10	7
Proba.	0.376	0.229	0.135	0.086	0.056	0.036	0.024	0.019	0.011	0.007	0.005	0.005	0.005	0.004	0.002

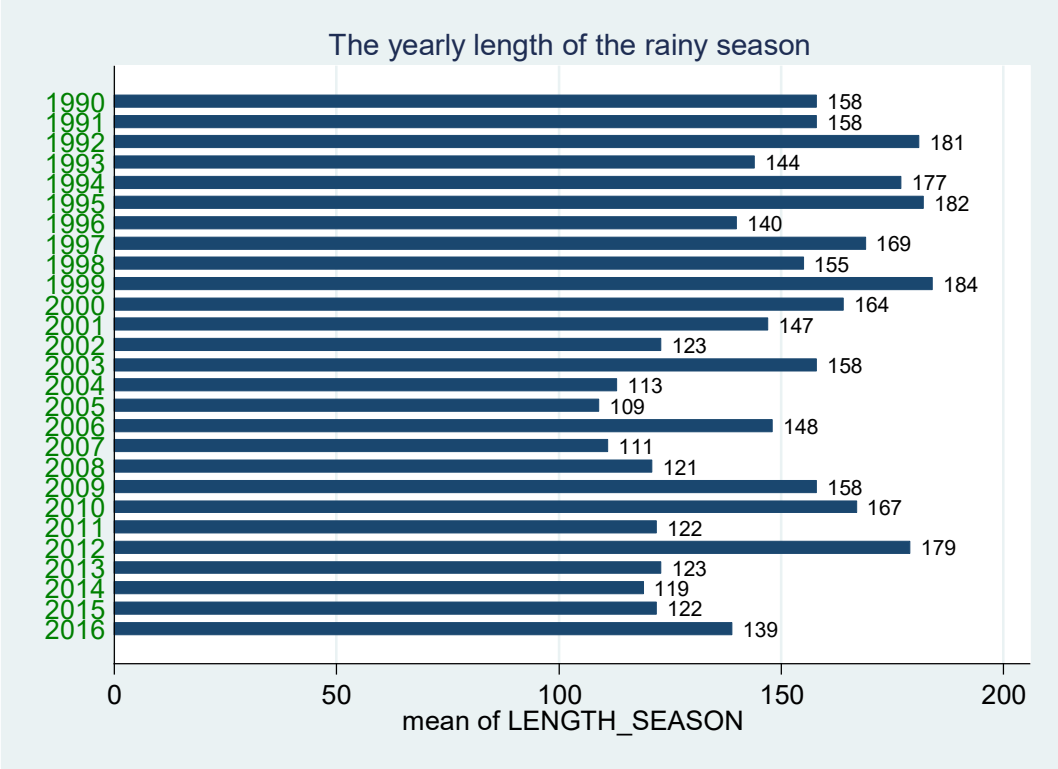

Figure 27: The yearly length of the rainy season

9.2 Questionnaires used for HDSS, Census, vital events registration, and verbal autopsy

Out-migration questionnaire

Fiche N° ☐☐☐

Enregistrement des Evènements Vitaux
Fiche d'enregistrements des émigrations

1 – Informations de base NEEV ☐☐☐

Village/Code ☐☐☐☐☐☐☐☐☐☐ ☐☐

Année Enquêteur ☐☐☐☐☐☐☐☐☐☐ ☐☐☐ Date visite *Jour* ☐☐ *Mois* ☐☐ ☐☐

IDMénage ☐☐ ☐☐☐ ☐☐

Chef de ménage ☐☐☐☐☐☐☐☐☐☐

Nom du répondant ☐☐☐☐☐☐☐☐☐☐

2 – Informations de base sur l'émigrant

S'agit-il d'une émigration interne ? OUI ☐ NON ☐

IDindividu ☐☐☐ ☐☐☐ ☐☐☐

Nom Prénom(s) ☐☐☐☐☐☐☐☐☐☐ Rang ☐☐

Date de l'émigration *Jour* ☐☐ *Mois* ☐☐ *Année* ☐☐☐☐ *Précision* ☐

Sexe ☐☐☐ Date de naissance *Jour* ☐☐ *Mois* ☐☐ *Année* ☐☐☐☐ *Précision* ☐

3 – Destination

Lieu 1- Dans la zone de recherche ☐ 2- Au Burkina Faso ☐ 3- Hors Burkina Faso ☐

IDConcession (Si 1-) ☐☐ ☐☐☐ ☐☐

Village (si1-) ☐☐☐☐☐☐☐☐☐☐

Raison de la migration 1- Mariage ☐ 2- Cultiver ☐ 3- Autres : ..... ☐

4 – Certification des informations

Superviseur ☐☐☐☐☐☐☐☐☐☐ ☐☐☐

Date de la certification ☐☐ ☐☐ ☐☐☐☐ Signature :

Observations particulières :

In-migration questionnaire

Fiche N° ☐☐☐

Enregistrement des Evènements Vitaux
Fiche d'enregistrements des immigrations

1 – Informations de base NEEV ☐☐☐

Village/Code ☐☐☐☐☐☐☐☐☐☐ ☐☐

Année ☐☐☐☐ Enquêteur ☐☐☐☐☐☐☐☐☐☐ Date visite *Jour* ☐☐ *Mois* ☐☐ ☐☐

IDMénage ☐☐ ☐☐☐ ☐☐ ☐☐

Chef de ménage ☐☐☐☐☐☐☐☐☐☐

Nom du répondant ☐☐☐☐☐☐☐☐☐☐

2 – Informations de base sur l'immigrant

S'agit-il d'une migration interne ? OUI ☐ NON ☐

L'individu a-t-il déjà été enregistré ? OUI ☐ NON ☐

IDindividu, si oui ☐☐☐ ☐☐☐ ☐☐☐

Nom Prénom(s) ☐☐☐☐☐☐☐☐☐☐

Date de l'immigration *Jour* ☐☐ *Mois* ☐☐ *Année* ☐☐☐☐ *Précision* ☐

Sexe ☐☐☐ Date de naissance *Jour* ☐☐ *Mois* ☐☐ *Année* ☐☐☐☐ *Précision* ☐

Ethnie ☐☐☐ Religion ☐☐☐

3 – Provenance

Lieu 1- Dans la zone de recherche ☐ 2- Au Burkina Faso ☐ 3- Hors Burkina Faso ☐

IDConcession (Si 1-) ☐☐ ☐☐☐ ☐☐

Village (si 1-) ☐☐☐☐☐☐☐☐☐☐

Raison de la migration 1- Mariage ☐ 2- Cultiver ☐ 3- Autres :..... ☐

4 – Certification des informations

Superviseur ☐☐☐☐☐☐☐☐☐☐ ☐☐☐

Date de la certification ☐☐ ☐☐ ☐☐☐☐ Signature :

Observations particulières :

Questionnaires of seasonal migration

Fiche N° ☐☐☐

Enregistrement des Evènements Vitaux

Fiche d'enregistrements des émigrations/ déplacements saisonniers

A – Informations de base NEEV ☐☐☐

Village/Code ☐ ☐☐

Enquêteur ☐ ☐☐☐ Date visite *Jour* ☐☐ *Mois* ☐☐ *Année* ☐☐☐☐

ID Ménage ☐☐ ☐☐☐ ☐☐

Chef de ménage ☐

Nom du répondant ☐

B – Informations de base sur l'émigration ou déplacement saisonnier

S'agit-il d'une migration interne ? ☐ *1.Oui 2.Non*

A-t-il/elle émigré et est revenu(e) en moins de 6 mois ? ☐ *1.Oui 2.Non*

A-t-il/elle émigré et a l'intention de revenir en moins de 6 mois ? ☐ *1.Oui 2.Non*

IDindividu ☐☐☐ ☐☐☐ ☐☐☐

Nom Prénom(s) ☐ Rang ☐☐

Date d'émigration *Jour* ☐☐ *Mois* ☐☐ *Année* ☐☐☐☐ *Précision* ☐

Date(ou date prévue) d'immigration(Retour) ☐☐ ☐☐ ☐☐☐☐ ☐

Sexe ☐☐☐ Date de naissance *Jour* ☐☐ *Mois* ☐☐ *Année* ☐☐☐☐ *Précision* ☐

C – Destination

Lieu ☐ 1- Intérieur SSDS 2- Au Burkina Faso 3- Hors Burkina Faso

Village (si1-) ☐

Nom du Lieu si différent de(1) : ☐ *1-Ouaga 2-Bobo 3-Dedougou 4-Nouna 5-CIV 6-Mali 7-Autre en Afrique 8-Amérique 9-Asie 10-Europe 11-Australie*

Raison/Objet de la migration ☐ *1- Mariage 2-Accoucher 3-Cultiver 4-Travail rémunéré en ville 5-Affectation/obtention d emploi 6-Travail minier 7- Travail dans les plantations 8-Autre travail 9-Paturage 10- Autres : ……..*

Causes de la migration ☐ *1- Récoltes insuffisantes 2- Saison pluvieuse catastrophique 3- Recherche de terres cultivable 4-Besoin quelconque d'argent 5- Affectation/obtention d'emploi 6-autres ……..*

D – Certification des informations

Superviseur ☐ ☐☐☐

Date de la certification ☐☐ ☐☐ ☐☐☐☐ Signature :

Observations particulières :

Socio-economic : Module- Agricultural production

Section 1.2. Revenus du ménage

1.2.1. Production agricole pendant la campagne passée (2010/2011)

Demandez à chaque membre du ménage âgé de 15 ans et plus si il a cultivé l'un des produits agricoles énoncés (lire la liste) au cours de la campagne passée. Si oui, notez le nom du produit, la quantité et son unité de mesure.

Rang	Nom, prénom, ID de l'individu	A cultivé ? Oui / Non	Nom du produit	Quantité	Unité de mesure
1	2	3	4	5	6
|__|__|		|__|__|__|	|__|__|__|	|__|__|__|	|__|__|__|
|__|__|		|__|__|__|	|__|__|__|	|__|__|__|	|__|__|__|
|__|__|		|__|__|__|	|__|__|__|	|__|__|__|	|__|__|__|
|__|__|		|__|__|__|	|__|__|__|	|__|__|__|	|__|__|__|
|__|__|		|__|__|__|	|__|__|__|	|__|__|__|	|__|__|__|
|__|__|		|__|__|__|	|__|__|__|	|__|__|__|	|__|__|__|
|__|__|		|__|__|__|	|__|__|__|	|__|__|__|	|__|__|__|
|__|__|		|__|__|__|	|__|__|__|	|__|__|__|	|__|__|__|
|__|__|		|__|__|__|	|__|__|__|	|__|__|__|	|__|__|__|
|__|__|		|__|__|__|	|__|__|__|	|__|__|__|	|__|__|__|
|__|__|		|__|__|__|	|__|__|__|	|__|__|__|	|__|__|__|
|__|__|		|__|__|__|	|__|__|__|	|__|__|__|	|__|__|__|
|__|__|		|__|__|__|	|__|__|__|	|__|__|__|	|__|__|__|

Codes « Produits Agricoles » (Col.4)

ARA = Arachides et sous produits
CAL = Calebasses (entières)
CHU = Chou
COT = Coton et sous produits
FON = Fonio
FRU = Cultures fruitières
IGN = Igname
MAI = Mais et sous produits
MIL = Mil/ sorgho et sous produits
NIE = Niébé et sous produits
OIG = Oignon
OSE = Oseille et sous produits
PAS = Pastèque
PAT = Pomme de terre
PEP = Pois de terre et sous produits
RIZ = Riz et sous produits
SES = Sésame
PAD = Patate douce
TAB = Tabac
TOM = Tomate
SAL = Salade
AUB = Aubergine
COU = Courgette
COM = Comcombre
AUC = Autres cultures
NAP = Non applicable

Codes « Quantité » (Col. 5)

Notez le nombre
997 = Non Applicable
994 = Néant
999 = Ne sait pas

Codes « Unité de mesure » (Col.6)

BOI = Boîte
TIN = Tine
SAC = Sac
KIL = Kilogramme
NOM = Nombre
TON = Tonne
NEA = Néant
NAP = Non applicable

Table 16: N-HDSS database framework

Object table	*Event table*
Household, Individual, member, residence, source-individual…	Births, Deaths, Pregnancies, In-migration, Out-migration, education, vaccination, marriage…
The information collected at each of the different levels is presented as follow:	
Subject	Information
Location	Location ID, and number of households
Household	Household ID, household head ID, household head name, household asset (television/video/radio/telephone/mobile devices, computers, laptops, cars, motorcycles, bicycles, refrigerator, etc.), housing characteristic (major source of drinking water, type of toilet facility, electricity, main material of the floor, main material of the walls, main material of the roof, number of rooms used for sleeping in the household and type of cooking fuel), alimentary security and reproduction, and malaria and health (malaria drug, bednet, etc.)
Individuals	Individual ID, names, sex, date of birth (DoB), ethnic group, religion, education level, literacy, main occupation, marital status and relationship with the household head.
Residents	Update of residency status (resident, died, out-migrated) and location.
Births	Newborn identification (Names, ID, Sex, . . .), mother's and father's identification. Date of birth (DoB), place of birth, birth weight, multiple births (if so, how many), survival status of the newborn, medical attendance at birth, and child, relationship with the household head.
Deaths	Death identification (names, ID, sex, DoB, . . .), date of death, place of death, sick and verbal autopsy.
In-migration	In-migrant identification (names, ID, sex, DoB, . . .), date of migration, origin of migration episode, type of migration (internal, regional, national, international), reason for migration and previous residence within the HDSS.
Out-migration	Out-migrant identification (names, ID, sex, DoB, . . .), date of migration, destination of migration episode, reason for migration.
Pregnancy	Pregnant women identification (names, ID, DoB . . .), current pregnancy (pregnancy age).
Vaccination	For children aged < 3 years: names, ID, birth date, sex, mother's education level and vaccination status of the child for all vaccines.
morbidity	Inventory of chronic and acute illnesses, symptoms, duration, care, degree of severity, direct and indirect costs

Curriculum Vitae

CURRICULIUM VITAE

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S. Pascal Zabré received a master's degree in demography in 2008 from the Institut de formation et de recherche démographiques (IFORD) in Yaoundé, Cameroon, and a bachelor's degree in sociology from the University of Ouagadougou, Burkina Faso. He is currently working on his PhD in global health with a focus on climate change, food insecurity and migration. Employed as a demographer since 2012 by the Nouna Health Research Center (CRSN), he has since headed the Department of Demographic Surveillance and Surveys and the Nouna Demographic and Health Surveillance System (HDSS). His professional experience ranges from organizing and coordinating data collection, to analyzing data and designing new collection tools.

EDUCATION

Heidelberg University, Heidelberg Germany
Institute of Global Health, Doctoral/PhD Program — ***Present***

Institut de formation et de recherche démographiques (IFORD), University of Yaoundé II, Cameroon — *2006-2008*
Master in Demography

University of Ouagadougou, Burkina Faso — *2001-2005*
Bachelor in Sociology

Ouagadougou
Last Class of Secondary School (Terminal D): Baccalaureate (D) of natural sciences and mathematics — ***July 2001***

QUALIFICATIONS

2009 to date

- **Data collection**: Coordination of specific surveys and Management of the Nouna Health and demographic surveillance system-HDSS.
- **Data analysis**: longitudinal data clearing and analysis.
- **Writing the study reports** and HDSS annual reports (HDSS reports :2012-2013, 2014-2015, 2016-2021 at CRSN) and national report on the state of population.
- **Computer and softwares:** Treatment of Text: Word, PPT data softwars: CSPro, EPI Data Excel, SPSS, Stata, R, ODK, Survey Solution, Sphinx
- **Demography and Global health (E**ducation - migration, mortality, migration, fertility of adolescents, demographic dividend, climate change and food insecurity).

PROFESSIONAL EXPERIENCES

2009 to date

Permanent Secretariat of the National Population Council

- 3 years of service in Demography and development: national reports 2008, 2009, 2010 on the state of the population, CIPD + 15 report of Burkina Faso
- Good knowledge of national and international development indicators (PNDES, MDG / ODD, CIPD, WHO, etc.)

Nouna Health Research Center (CRSN

- ¬ 10 years in coordinating data collection in a Health and demographic surveillance system (HDSS)
- ¬ Regional coordinator (Northern Region) of the National measle / Rubella vaccination coverage Survey in 2016, CRSN consultancy with WHO
- ¬ Regional coordinator (Boucle du Mouhoun region) of the survey on health human resources motivation, consultancy of the CRSN with the WHO 2017;
- ¬ Coordinator of the baseline Census of the Kossi province in 2018.
- ¬ Since 2013 to date, participation to data analysis workshops and scientic visit in Senegal, Ghana, Kenya, South Africa, Germany, Belgium and France

RESEACH EXPERIENCES ***2009 - 2022***

Management of the Health and Demographic Surveillance System - Analyzing longitudinal data

- ¬ Updating data collection tools (questionnaires, manuals ...)
- ¬ Coordinating the training and deployment of field workers on the field
- ¬ Cleaning the longitudinal databases
- ¬ Writing the annual reports of the HDSS based on the collected data in the HDSS
- ¬ Analyzing annually the given thematic data with CRSN institutional partners (Education with MENA, ISSP, INESS, Migration with INDEPTH(MADIMAH), Fertility with INDEPTH / MADIMAH, Mortality with ISSP, INSD, INDEPTH / MADIMAH) and writing the reports
- ¬ Helping CRSN researchers in their methodology of research and sampling.

Population and Development - development of programmatic documents and reports on the state of the population

- ¬ 2011: In charge of the folder and co-author of the National report 2010 on the State of the population, "*Population and Environment: gender and climate change u Burkina Faso*"
- ¬ 2010 Folder Manager and Co-author of the National report 2009 on the state of the population, *"education, vocational training and employment of young people in Burkina Faso"*
- ¬ 2009, 2010, 2011: Trainer of national officials on population and development respectively in Koudougou, Manga, and Tenkodogo.
- ¬ Participation in the revision of the national population policy

Civil status in the population observatories (ECOP) in Burkina Faso: completeness of acts, factors of non-recourse, access and quality of services

- ¬ Principal investigator at CRSN
- ¬ Design of the research protocol
- ¬ The conception of the methodology
- ¬ Design of collection tools
- ¬ Recruitment field workers agents
- ¬ Training of investigating officers
- ¬ Supervision of data collection
- ¬ Data cleaning and analysis
- ¬ Drafting of the supervision report
- ¬ Preparation of the report of the ETUDE

Community monitoring of the spread of the CO VID 19 epidemic and Evaluation of the action of the monitoring system in the Nouna demographic and health surveillance system - SUCPRO-COVID-19

- ¬ Writing the research protocol
- ¬ The conception of the methodology
- ¬ Design of collection tools

- ¬ Supervision of data collection
- ¬ Data analysis
- ¬ Drafting of the study report

Evaluation of the coverage vaccine: post-campaign measles/rubeola and immunization routine in Burkina Faso

- ¬ Design of the methodology
- ¬ Country mapping via Google Map
- ¬ Training of field workers in the North region
- ¬ Coordination of data collection
- ¬ Writing the report of the field coordination
- ¬ Participation in the data analysis
- ¬ Participation in the drafting of the study report

Study on the strategies of deployment/redeployment of human resources in health BURKINA Faso

- ¬ Training of field workers in Nouna
- ¬ Coordination of data collection in the *Boucle du Mouhoun* Region (Dédougou, Boromo)
- ¬ Participation in the data analysis
- ¬ Participation in the study report writing

Wrote the report " Education issues in the Nouna HDSS " since 2014

- ¬ To clean education databases;
- ¬ Clearance of HDSS databases;
- ¬ Production of indicators on access s and performance in education in the form of tables and graphs
- ¬ Writing of the MENA report

SCIENTIFIC AND NETWORK AFFILIATION

2009- to date

- ¬ International Union for the Scientific Study of Population (IUSSP)
- ¬ Union for African Population Studies (UAPS)
- ¬ ABDem: Burkina Association of Demographers
- ¬ Search Workshop on Education in Burkina Faso - AREB

LANGUAGE	**Reading**	**Speaking**	**Writing**
French	1	1	1
English	2	2	2
Deutsch	5	4	5
Date of Birth			*01.01.1976*
Place and date of Birth			*Manga-Est, Burkina Faso*
Nationality			*Burkinabe*
Marital Status:			*Married*

PRESENT POSITION	• Demographer, Head of Nouna Health and demographic surveillance system-HDSS, CRSN, Burkina Faso. • Head of the INSP's Research Program "*Information system*", Burkina Faso • PhD Candidate at Heidelberg Institute of Global Health, University of Heidelberg, Germany

Ouagadougou, January 17 th, 2023  **Zabre S. Pascal**

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Affidavit/ Eidesstattliche Versicherung

EIDESSTATTLICHE VERSICHERUNG

1. Bei der eingereichten Dissertation zu dem Thema

“Weather variability and food insecurity as driving forces for out-migration, 1992-2016: a study from rural Burkina Faso”

handelt es sich um meine eigenständig erbrachte Leistung.

2. Ich habe nur die angegebenen Quellen und Hilfsmittel benutzt und mich keiner unzulässigen Hilfe Dritter bedient. Insbesondere habe ich wörtlich oder sinngemäß aus anderen Werken übernommene Inhalte als solche kenntlich gemacht.

3. Die Arbeit oder Teile davon habe ich bislang nicht an einer Hochschule des In- oder Auslands als Bestandteil einer Prüfungs- oder Qualifikationsleistung vorgelegt. *

4. Die Richtigkeit der vorstehenden Erklärungen bestätige ich.

5. Die Bedeutung der eidesstattlichen Versicherung und die strafrechtlichen Folgen einer unrichtigen oder unvollständigen eidesstattlichen Versicherung sind mir bekannt. Ich versichere an Eides statt, dass ich nach bestem Wissen die reine Wahrheit erklärt und nichts verschwiegen habe.

Ort und Datum *Unterschrift*

-- 17.01.2023 -- ……