Master's thesis

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Department of Geography

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The Connection Between Climate Change and Conflict

A GIS Approach to the Present Conflicts in Nigeria

Master's thesis in Globalisation and Sustainable Development
Supervisor: Jan Ketil Rød
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Abstract

During the recent years and in the shadows of the much-noticed activities of the terrorist group Boko Haram, clashes between Fulani herdsmen and farmers of various other ethnic groups have spiraled into a violent conflict in Nigeria, escalating in 2015 with four-digit death tolls in approximately 200 incidents. Research has so far addressed a wide range of hypotheses on the causes for this dispute, ranging from climate change to ethnic and religious confrontations as the consequence of a Muslim attempt to reach dominance over the Christian majority in the Nigerian Middle-Belt.

By using geoinformatics (GIS) as a set of tools, this master thesis aims at analyzing the causes of the conflict with a focus on climate change. Therefore, a spatio-temporal analytical framework is applied for the comparison of land cover changes in Ghana and Nigeria between 1992 and 2019 as well as of changes in temperatures, precipitation, and wet days for the period of 1971 to 2020. As the second step of the analysis, other factors without a connection to climate change are operationalized for the use in a regression analysis in ArcGIS in order to elaborate on the most important factors contributing to the herdsmen-farmers conflict. These factors include population growth, urbanization, access to water and the natural resources of petroleum and diamonds, ethnic dominance, road density, literacy, poverty, and terrain roughness on the second-order administrative level of Nigeria.

Consequently, this thesis finds that considerable areas of grass- and shrublands, which are suitable areas for cattle herding, are transformed into mostly rainfed agricultural farmlands and urban areas for the period until 2015. In the following years, an increased conversion from agricultural areas to other land types is observable. However, neither the land cover changes nor the moderate increase in temperatures, decrease in wet days, and the hardly identifiable change in precipitation differ considerably between Nigeria and Ghana. Nevertheless, the regression analysis identifies a statistical significance of temperature, precipitation, and wet days change for the conflict between herdsmen and farmers, along with the non-climate change-related factors population growth, poverty and literacy rates, as well as urban areas.

Acknowledgements

Dedicated to my father.

I want to thank all the people who assisted me in the process of writing and editing this master thesis. A special thanks to my supervisor Jan Ketil Rød, whose comments, hints, and suggestions always proved helpful in structuring and improving this thesis, while also putting the focus on the central aspects of the thesis.

I also have to thank everyone from my reading room, who created a phantastic work atmosphere that made it much easier to focus on the work and to make progress, while also always allowing for great conversations, which made it possible to laugh, think about something else than just the topic of the thesis, and who thereby reduced the pressure and stress level whenever it tended to get too high.

Last, but not least, I want to thank my family for their support throughout all the past years with all the good and bad times, and hopefully also during all the years to come.

Lukas Murau

Trondheim, May 2021

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List of Abbreviations

AICc	Akaike Information Criterion
AMO	Atlantic Multidecadal Oscillation
C3S	Copernicus Climate Change Service
CCI	ESA Climate Change Initiative
CDS	C3S Climate Data Store
CFR	Council on Foreign Relations
CRU TS	Climatic Research Unit gridded Time Series
ENSO	El Niño Southern Oscillation
ESA	European Space Agency
GLR	Generalized Linear Regression
GDP	Gross Domestic Product
GIS	Geographic Information System/s / Science
ICG	International Crisis Group
ICON	International Committee on Nigeria
IPCC	Intergovernmental Panel on Climate Change
LGA	Local Government Area (Nigerian second-level administrative divisions)
NGO	Non-Governmental Organization
OCHA	United Nations Office for the Coordination of Humanitarian Affairs
PSJ	International Organisation for Peace-building & Social Justice
RCP	Representative Concentration Pathway

ROWCA	OCHA Regional Office West and Central Africa
UCDP	Uppsala Conflict Data Program
UNFCCC	United Nations Framework Convention on Climate Change

1 Introduction

“Nigeria’s pastoral conflict ‘six times deadlier’ than Boko Haram in 2018” is the headline of an article by the American news channel CNN (Adebayo, 2018) addressing the violent conflict between the Fulani people of Nigeria and various other ethnic groups. While stating this, the article refers to a publication by the non-governmental organization (NGO) International Crisis Group (ICG). Their report argues that more than 1,300 people have been killed in an escalating conflict between herdsmen and farmers in Nigeria’s Middle Belt only between January and June 2018 compared to approximately 200 fatalities in relation to the attacks by the Nigerian terrorist group Boko Haram (ICG, 2018, p. 1).

As will become visible in chapter 1.1, the first half of 2018 was rather an overly violent period of a long ongoing conflict. Nevertheless, the magazine Foreign Affairs published by the Council on Foreign Relations (CFR), a U.S. nonprofit think tank specializing in foreign policy, dubs this conflict the “deadliest conflict you [i.e. the magazine’s readers] have never heard of”, since Boko Haram often overshadows the other conflicts in Nigeria and therefore causes that also the conflict between the herdsmen and farmers hardly experiences any representation in the media and among scholars (Ilo et al., 2019).

Chiluwa and Chiluwa make a similar observation. According to them, foreign media seldom cover the conflict, resulting in a lack of awareness about the conflict among the international community. Furthermore, the conflict is often perceived in a wrong and overly simplistic way by reducing it to a religious and ethnic cause with the mostly Muslim Fulani herdsmen as the aggressors (Chiluwa & Chiluwa, 2020, pp. 17–18).

As opposed to this, evidence suggests that there is more to it than just a violent fight over religion or ethnicity. For instance, Nnoko-Mewanu, a women’s rights researcher at Human Rights Watch, identifies other reasons such as insufficient community land rights, commercialization of farming and herding, and land pressure due to an increasing aridity and desertification in the Sahel region as causes for a general rise in violent conflicts about land resources in Western and Central Africa (Nnoko-Mewanu, 2018). Also, Buhaug argues that climate change might have an impact on armed conflict in general, often in a way, where climate change interacts or conjuncts with other potential drivers of conflict such as land use, the affected people's vulnerability and their coping capacity as well as the state's response, resulting in a struggle for resources (Buhaug, 2016, pp. 333–334).

In contrast, it is not only resource scarcity, but also resource abundance or resource intensity, which can be a factor for conflict. As Sachs and Warner outline, this "resource curse", also referred to as "the paradox of plenty", leading to a stagnation in economic growth is especially evident in mineral-intensive countries with a high share of natural resources (Sachs & Warner, 2001). Therefore, when talking about degrading land resources as a consequence of climate change, the ways of resource distribution have also to be addressed. In this regard, globalization has had a large impact on the scale of distribution as well as on the actors that distribute and share resources. This is especially challenging for local rural communities that get rapidly included into the global economic sphere. A change from a nonmonetized to a monetized transaction system can already be an issue, since resources are no longer used for subsistence, but for financial reasons, while, simultaneously other, more powerful foreign actors get access to the local resources (Stern et al., 2010, pp. 475–477).

Taking these considerations into account, the violent conflict in Nigeria between the herders and farmers is likely to be driven by more than just religious and ethnic factors, for instance, also by environmental or economic ones. Thus, this master thesis is going to elaborate on the profound causes of this conflict. The main focus will thereby be on climate change as a central driver of conflict. For instance, research by Okpara et al. suggests that the unprecedented hydrological changes in the Lake Chad region due to the shrinkage of the lake between 1960 and 2000 have led to large social disruptions and regional insecurity (Okpara et al., 2015).

Nigeria being a bordering state to the former lake boundaries and considering the fact that Nigeria's dry season usually runs from November to March – the period with the most incidents in the conflict between herdsmen and farmers – environmental and climate change seem to be plausible reasons for conflict within the country. In order to analyze the contributing extent of climate change to the herdsmen-farmers conflict, geographic information systems (GIS) will be applied as the central set of tools. This has the advantage that a range of different contributing and inherently geographic factors of the conflict can be represented as spatial layers and further analyzed using GIS.

The use of GIS as a method will be further discussed later in this thesis. Therefore, the only information given at this point is that there will be two different parts of analysis. At first, a spatio-temporal analytical framework will be applied to compare multiple indicators of climate change in Nigeria and Ghana. For instance, land cover change serves as a criterion for climate change. This allows to analyze, whether Nigeria has been more influenced by land cover change than other comparable countries, which, contrary to Nigeria, have not experienced this amount of violence during the recent years.

As a second step, a variety of other factors of conflict will be elaborated on and applied to the case of Nigeria. Such a multicriteria approach allows for a differentiated analysis of the underlying causes of the conflict in Nigeria, therefore facilitating a more convincing argumentation on the influence of climate change on this conflict. As a result, this approach can be further used in other conflict studies.

This thesis will thereby follow the subsequent structure: After this introduction, a deeper insight into the conflict between herdsmen and farmers in Nigeria will be given. This is necessary to comprehend the underlying methodological considerations, especially since the conflict is only hardly observed in foreign media. Building on this understanding of the conflict, the research aim, design, and methods can be worked out in more detail.

Connecting to this chapter, the basic theoretical concepts and theories will be discussed. As already outlined, the topic will be investigated in the context of climate change and based on previous scientific research on armed conflict and peace, while GIS serves as the main geographic tool and method. Therefore, the scientific concepts of "climate change" and "armed conflict" have to be elaborated on.

After having discussed the relevant theoretical background to this thesis, the actual connection between climate change and violent conflict in the particular example of Nigeria will be worked out by first comparing environmental change in Ghana and Nigeria and afterwards considering the other factors of conflict that can matter in Nigeria in a regression analysis in GIS. This analysis also requires a geographic discussion of the research area, thereby focusing also on the climatic and historic circumstances of Nigeria, but also of Ghana as the country Nigeria is compared with.

Subsequently, a further discussion will be done which brings together the results from the two analytical parts of the thesis. Conclusive, a final summary on the suitability and transferability of the methodological approach of the discussed example for other studies of conflict is made.

1.1 The Background: Current Conflict in Nigeria

Since the independence of most African countries in the 1960s, the continent has undergone an increasing number of conflicts, as will be further discussed in Chapter 2.2. The common feature of these conflicts is however not an interstate, but an intrastate dispute about overlapping and interconnected motives such as ideologies, ethnicities, religions and political power, but also access to resources and their use and management, mostly linked to land, which serves as a central source of livelihoods for large parts of the population (Ejigu, 2009, p. 885).

In this regard, it is not surprising that even the Rwandan genocide of the Hutu ethnic group against the Tutsi, which is usually considered an ethnic conflict, has a certain connection to land use disputes. In fact, the word Tutsi rather refers to “people who own cattle” than to a specific ethnic group, just as Hutu means “people who farm”. Therefore, Ejigu argues that a general reduction of average farm size from 2 to 0.7 hectares per family has centrally contributed to the armed conflict in Rwanda, making the conflict also a conflict about natural resources and their use (Ejigu, 2009, pp. 886–891).

Similar observations can be made in other African countries. In several West African countries, it is often the ethnic group of the Fulani, who are involved in conflict. Also being named among others as Fulbe, Fula, and Peul, this ethnic group being native to most of the Sahel countries stretching from Senegal to Ethiopia mainly consists of nomadic herders, making them one of the main actors in disputes over the use of natural resources such as clean water and grazing land. Over the centuries, the Fulani have developed a mainly pastoralist livelihood strategy by practicing nomadic or semi-nomadic cattle husbandry in order to deal with the arid and semi-arid climate predominant in the region. Consequently, the herdsmen drive their cattle north during the rainy season, while they move southwards during the dry season, when water becomes scarce in the northern Sahelian zone. This type of seasonal wandering, also called transhumance, has experienced various difficulties during the last decades despite its cost-efficient and environmentally adapted character (Cabot, 2017, 13–14).

Most of the challenges are arising from climate change. Due to an increasing intensity of droughts, land degradation, and desertification, the Fulani herdsmen often react by moving their pastoralist activities along fixed routes south in order to find suitable pastures for their cattle. Another coping strategy is the adoption of a non-nomadic lifestyle by settling in areas, which are suitable for all-year pastoralism. However, these adaptations to climate change create an increasing pressure on natural resources such as land due to the proximity of new cattle farms to local agricultural farms (Cabot, 2017, pp. 14–15).

These environmental issues are further aggravated by an intensification of agricultural activities. Initially, farmers used so-called *fadama* land, referring to floodplains, only for rainy season crop production, while livestock could use the areas for dry season grazing. Since farmers nowadays often apply irrigation farming, they can use their land all-year, forcing the cattle herds off the original grazing lands (Dimelu et al., 2016, pp. 147–148).

Nevertheless, climate change and following environmental challenges are not the only reasons which are said to contribute to the conflicts between Fulani herdsmen and farmers. The majority of the Fulani are Muslims, while the local farmers are usually Christians. Therefore, it is not only a conflict between "indigenes" and new "settlers", as Majekodunmi et al. describe it, but also one between Christians and Muslims (Majekodunmi et al., 2014, p. 3). Additionally, while the herdsmen belong to the Fulani ethnicity, the farmers are mostly part of other ethnicities, making the herdsmen-farmers conflicts in West Africa not only an environmental, but also societal conflict (Cabot, 2017, pp. 35–36).

Official numbers provided by the Nigerian authorities regarding the extent of the conflict in terms of incidents or fatalities do not exist. Therefore, data and estimates by NGOs and research institutes need to be considered to estimate the dimensions of the conflict. For instance, the CFR publishes a weekly security update for Nigeria, which includes most of the reported violent incidents in Nigeria since 2011 (Campbell, 2020). This dataset divides the incidents by actors, including sectarian actors. The label "sectarian actors" includes and mainly consists of the incidents in the herdsmen-farmers conflict. Even though the attribution "sectarian" does not cover the above-outlined complexity of the conflict, the collected data allow for a thorough quantitative evaluation of the conflict.

Between May 2011 and January 2021, the CFR has gathered a total of 1,366 violent incidents in the sectarian sector. Further filtering the spreadsheet to the terms "Fulani" and "herd" to detect all the entries including "herdsman/herdsmen" and "herder", the dataset still contains a total of 568 incidents with 4,735 people being killed. Including all the different actors, 604 incidents in relation to Fulani and herdsmen can be identified (Campbell, 2021). However, this number should be considered a minimum number, since incidents also tend to be perceived as committed by other actors, such as bandits.

This becomes also evident when comparing the numbers by CFR to those of NGOs such as Amnesty International or the International Committee on Nigeria (ICON). Especially the latter appears to overestimate the extent of the conflict number-wise, showing also a clear bias towards labelling the herdsmen-farmers conflict as attacks by Fulani Muslim militants and extremists, pursuing a religiously motivated genocide against Christian communities (ICON & PSJ, 2020, 15–17). The data provided by ICON in cooperation with the International Organisation on Peace-building & Social Justice (PSJ) suggests a total of 18,834 deaths caused by "Fulani Militants", as they are called in their publication, in 1,961 incidents between January 2000 and January 2020 (ICON & PSJ, 2020, p. 122-129).

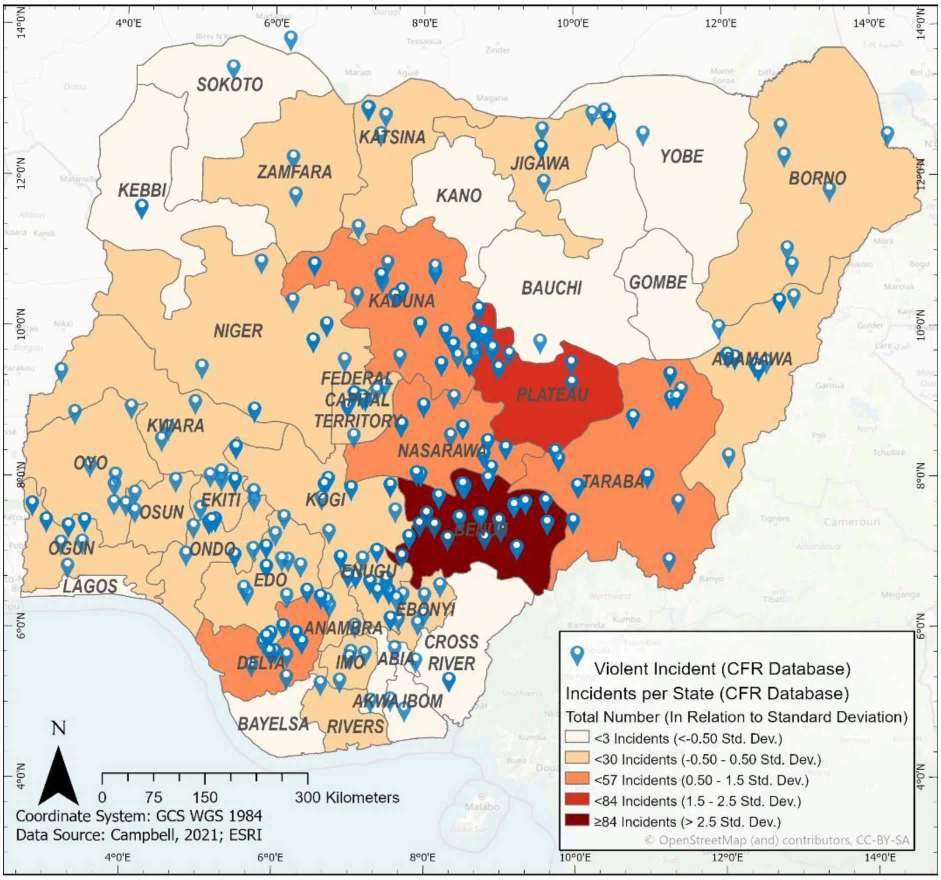


Figure 1: Incidents in the herdsmen-farmers conflict in Nigeria between May 2011 and January 2021 based on the Nigeria Security Tracker by CFR (with the use of: Esri, 2013; 2020).

In their report, which tries to portray the conflict both from the herdsmen's and farmers' view, Amnesty International estimates the death toll in the conflict between herdsmen and farmers with at least 3,641 between January 2016 and October 2018, whereof 57% died only in 2018. Most of the incidents thereby occurred in the states Benue, Kaduna, Nasarawa, Plateau, and Taraba (see Figure 1), which belong to the Middle Belt, a central Nigerian, ethnically and religiously heterogeneous transition zone between the ethnically and religiously homogeneous North and South (Amnesty International, 2018, pp. 5–6).

Besides the Nigeria Security Tracker by CFR, the Uppsala Conflict Data Program (UCDP) provides a database on armed conflict, which contains a large number of incidents in the herdsmen-farmers conflict in Nigeria. Just as with the data provided by CFR, the actors have to be filtered to the terms "Fulani" and "herd" in order to reduce the data to incidents related to Fulani or herding activities. When further excluding incidents, in which one of the actors is either Boko Haram or the Islamic State, a total of 689 incidents with 6,991 fatalities remains. As a result, the incidents are concentrated in the Middle Belt states in most cases (see Figure 2).

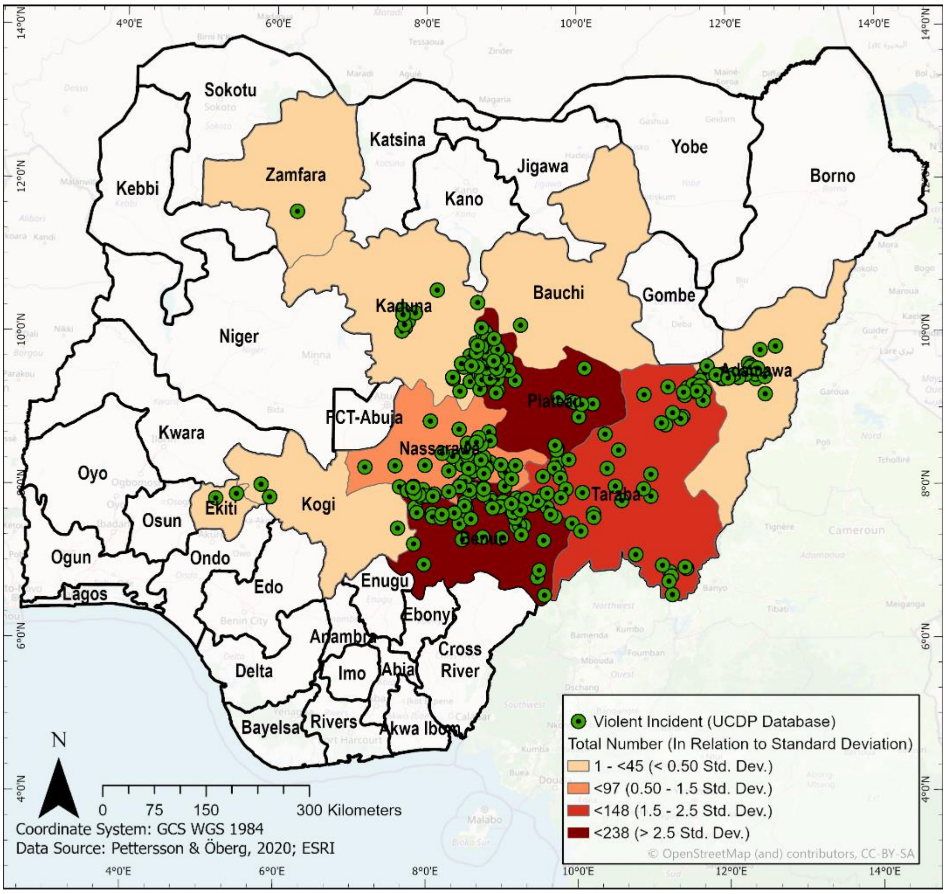


Figure 2: Incidents in the herdsmen-farmers conflict in Nigeria between 1996 and 2019 based on UCDP (with the use of: Esri, 2013; 2020).

Assuming the correctness of the ICG numbers, estimating 1,300 deaths in the first half of 2018 (ICG, 2018, p. 1), these numbers suggest that almost 75% of the deaths in 2018 occurred during the first six months of the year, partly coinciding with the dry season in Nigeria. Hence, a connection between dry season and increased violence is at least possible.

This is also in accordance with the numbers provided by CFR (see Figure 3). According to their dataset, the total number of incidents are increasing in December and usually reach higher levels between January and June before the incidents get less, having least cases in November (Campbell, 2020).

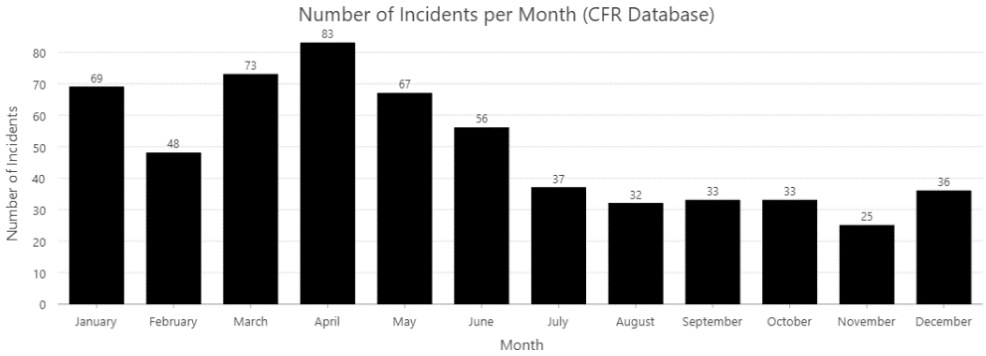


Figure 3: Bar chart of the total number of incidents in the herdsmen-farmers conflict per month between 2012 and 2020 based on the Nigeria Security Tracker by CFR.

A similar trend is visible from the UCDP dataset (see Figure 4). In all the incidents that were recorded from 1996 to 2019, most violent incidents occurred between January and June. However, February has a lower number of incidents than both January and the four succeeding months, while January and April are the months with the most incidents.

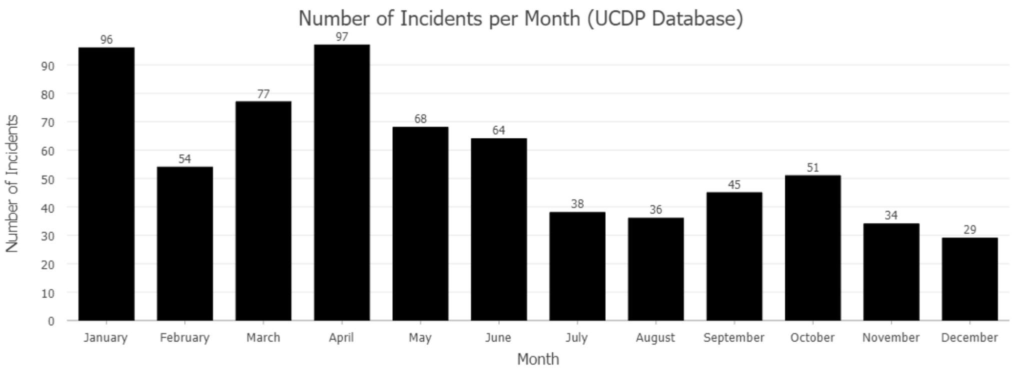


Figure 4: Bar chart of the total number of incidents in the herdsmen-farmers conflict per month between 1996 and 2019 based on UCDP.

Furthermore, the numbers suggest an annual increase in incidents during the last years, according to the database by CFR. An exception to this trend is the year 2018, which appears to have been an extraordinary violent year measured in the number of incidents (see Figure 5).

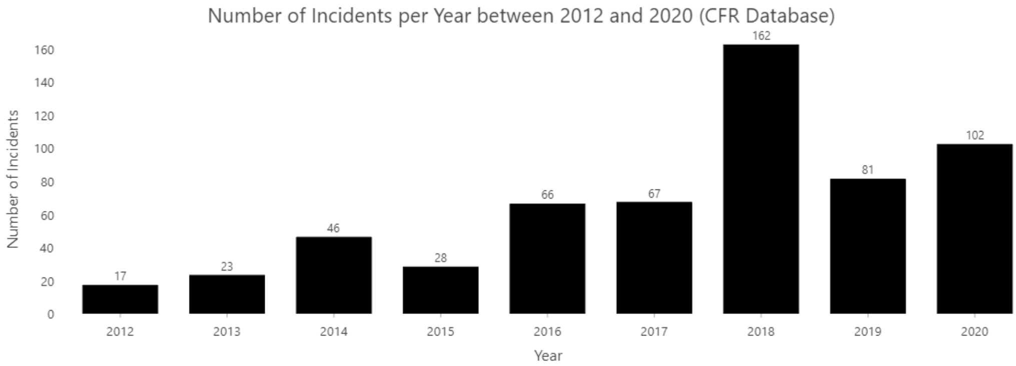


Figure 5: Bar chart of the total number of incidents in the herdsmen-farmers conflict between 2012 and 2020 based on the Nigeria Security Tracker by CFR.

Just as with the monthly distribution of incidents, the UCDP database shows a rather similar trend in the yearly distribution as the dataset by CFR. This time, data between 1996 and 2019 are visualized (see Figure 6). While the years until 2009 remained rather nonviolent with single-digit numbers of cases, 2010 saw an increase in incidents until 2014 before a decline in incidents occurred in 2015, approximately halving the numbers. In contrast to the numbers provided by CFR, the numbers by UCDP remain at lower levels for the years 2016, 2017 and 2019 than they did in the three years prior to 2015. Nevertheless, 2018 clearly distinguishes itself from the other years in the UCDP database as well.

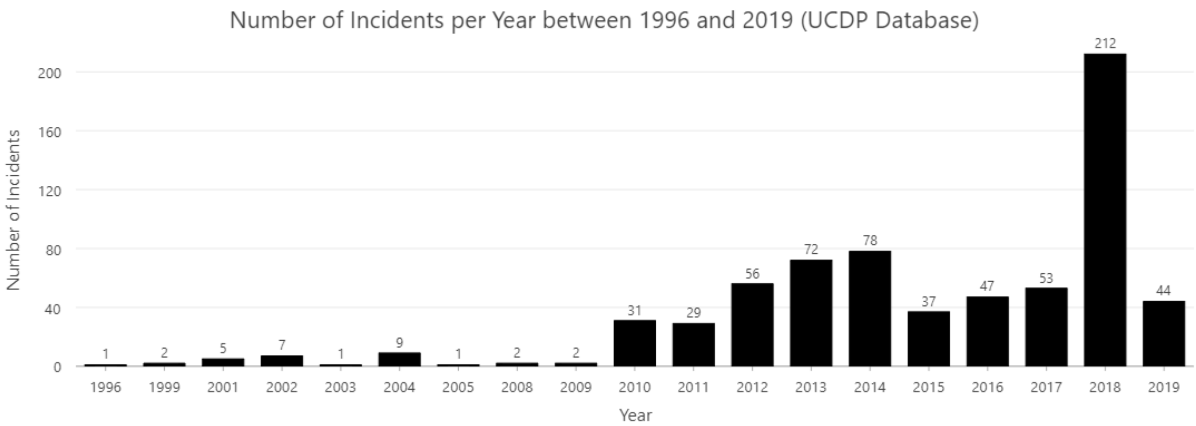


Figure 6: Bar chart of the total number of incidents in the herdsmen-farmers conflict between 1996 and 2019 based on UCDP.

It is not only the wide range in statistics that make prove of the ambiguity and complexity of the herdsmen-farmers conflict in Nigeria, but also in the ways, the above-mentioned reports label the violent incidents in the country, ranging from conflicts about farmland to genocide. For instance, after having done research in Nigeria, Amnesty International draws the conclusion that most of the incidents are caused by questions of land ownership, which snowballed into more violence due to retaliatory actions and the ethnic background of the involved communities (Amnesty International, 2018, p. 7). In contrast, ICON interprets the conflict as a "targeted religious genocide [...] conducted against Christians" (ICON & PSJ, 2020, pp. 16–17).

1.2 Research Questions and Research Design

Conflicts about land use as described in the previous subchapter, particularly between farmers and herdsmen, are rather common in large parts of sub-Saharan Africa. These conflicts, however, seem to be rather difficult to identify due to the complexity of underlying causes of conflict. In addition, even though the causes might be similar, the various conflicts in Africa have overly different outcomes. For instance, why is the conflict between herdsmen and farmers in Nigeria influenced by this degree of violence, while the same actors manage to solve the issues less violent in countries such as Mali, Burkina Faso, or Ghana? Due to the emphasis on climate change as a fundamental factor for the conflict in research and the public discourse, a central question therefore has to be, whether Nigeria is more severely negatively impacted by climate change than comparable countries with no or less violence? This leads to the question of whether there are other hidden factors that contribute to the violence in Nigeria as opposed to the other countries? In return, it has to be asked which other factors can or actually do contribute to the conflict? In order to find answers to these questions, it has to be discussed, what constitutes a conflict and how can climate change be identified and measured?

Consequently, the research design has to be aligned along these questions. First, the rather abstract term "climate change" has to be operationalized in a way, which allows to derive concrete criteria for an analysis of how climate change influences conflict in Nigeria. This also requires distinguishing natural climate variability as a reason for nomadism from the contemporary man-made climate change (see Chapter 2.1).

Second, a profound analysis of conflict has to be made. This includes the discussion of the terms “conflict” and “peace”, as well as a consideration of the connection between climate change and conflict. In this regard, Chapter 2.2 will also elaborate on resources and its role for conflict in a changing environment due to climate change. Consequently, several factors of conflict will be worked out that can be used for the actual analysis as a third step.

Third, these findings will have to be brought together in a comparative analysis. For this, GIS will be applied as the main method to provide an improved basic understanding of the conflict by linking the different research foci and explanations on the conflict. Chapter 3 will therefore discuss, how climate change and conflict can be analyzed using GIS as well as which data are required for such an analysis. These insights will then be used for a spatio-temporal comparison of the influence of climate change on Nigeria and Ghana, as well as for a subsequent regression analysis, which focuses on the connection between climate change and conflict in the present conflict between herdsmen and farmers (see Chapter 4). Consequently, other factors of conflict are considered for Nigeria to allow for conclusions on the contribution of climate change to the conflict.

2 Underlying Theory and Relevant Concepts

This thesis covers two central fields of research: climate change and violent conflict. Before these topics can be operationalized for the purpose of this thesis, these research areas have to be discussed and brought into connection. Therefore, the purpose of this chapter is to first outline climate change and its effects on Nigeria as well as to highlight its difference to a certain natural climate variability. Second, conflict and peace will be considered as two interconnected concepts to work out factors that contribute to violent conflict. In this context, recent research on the connection between climate change and violent conflict will be discussed.

2.1 Natural Climate Variability and Man-made Climate Change

Climate change is probably one of the most – and also most ambiguously – discussed contemporary topics. Therefore, a full overview over research on climate change cannot be given. Nevertheless, some important aspects for this research have to be outlined. First, the term "climate" requires a definition. Thereby, it has to be highlighted that climate per se is prone to a certain natural variability. This allows for a differentiation of climate change from natural changes and consequently for the identification of manifesting effects of climate change. In return, these factors can be used for the analysis later in this thesis.

2.1.1 Natural Climate Variability

In their latest assessment report, the Intergovernmental Panel on Climate Change (IPCC) defines climate *"as the average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time [...]. The classical period for averaging these variables is 30 years, as defined by the World Meteorological*

Organization. The relevant quantities are most often surface variables such as temperature, precipitation and wind" (IPCC, 2014, p. 1450).

Consequently, climate refers to the average long-term weather observations for a specific place or region. This already implies that climate is not a constant value but composed of various averaged factors. Hence, the *"variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all spatial and temporal scales beyond that of individual weather events [...] due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability)"* (IPCC, 2014, p. 1451) are referred to as climate variability, according to the IPCC.

As a result, the climate system naturally underlies certain dynamics, which transform the system in addition to the anthropogenic forcings (IPCC, 2014, p. 1451). Therefore, when arguing on climate change, it is necessary to differentiate between a certain natural variability, both internal and external, and the manmade contribution to external variability (see Chapter 2.1.2).

For instance, as stated by the Milankovitch theory, the earth's climate is underlying the influence of four interconnected extraterrestrial factors caused by the planetary motion of the Earth around the Sun and the rotation of the Earth itself: the eccentricity, the obliquity, the precession and terrestrial insolation, which have cyclicities ranging from 21,000 years to 92,000 years (Berger, 2012, pp. 118–119). Besides these orbital influences, also changes in radiation on the earth account for a certain climate variability due to external factors, for instance, caused by alterations in aerosol or greenhouse gas concentrations in the atmosphere, known as radiative forcing (IPCC, 2014, p. 1460). As a result, paleoclimatologists have identified a climate cyclicity of 100,000 years during Pleistocene. Each new cycle is thereby initiated by a rather abrupt change in climate, known as Dansgaard-Oeschger events (Ganopolski & Calov, 2012, pp. 50–54).

Nevertheless, even without external factors, climate will show both periodic and chaotic variations on different spatial and temporal scales (IPCC, 2014, p. 121). For instance, the El Niño Southern Oscillation (ENSO) is a cyclical ocean-climate phenomenon usually reoccurring at an interannual scale over the tropical Pacific (IPCC, 2014, 1240). In short, ENSO influences the water currents in the Pacific ocean, impacting on the trade winds, sea surface temperatures, and precipitation patterns mainly in the tropical Pacific, but also in other parts of the world

(IPCC, 2014, p. 1453). For example, Western Africa experiences slightly colder temperatures than usual in a reversed ENSO mode, called La Niña (Sarachik & Cane, 2010, 2–8).

Similar modes of climate variability exist for the Atlantic. For the North Atlantic, the Atlantic Multidecadal Oscillation (AMO) shows a 70 years cyclicity. In the tropical Atlantic, the Atlantic Meridional Mode is the dominant type of interannual variability, but rather influences the hurricane activity in the Caribbean. Furthermore, there exists the Atlantic Niño, which resembles the Pacific ENSO (IPCC, 2014, pp. 801–803). Generally, both AMO and Atlantic Niño impact on air temperatures and rainfall patterns in the Atlantic region. Concerning the influence on climate and weather in Africa, both AMO and Atlantic Niño influence the West African monsoons and rainfall in the Sahelian zone (IPCC, 2014, p. 1224).

The fact that natural climate variability has an impact on mankind has already been proven in several research projects. For instance, Ray et al. argue that interannual climate variability impacts on the crop yield for the researched plants maize, rice, wheat, and soybeans. In general, between 32 and 39% of yield variability can be explained by climate variability. Nevertheless, large regional variations and variations between the types of plants exist. Still, yield variability has an influence on especially rural communities in the Global South due to their continued reliance on subsistence production (Ray et al., 2015, pp. 2–5).

In her research on the Talgar region in Kazakhstan, Chang, for example, outlines that nomadic pastoralism only emerged because of a climatic shift from a colder and wetter climate between 1000 and 500 BC to a warmer and drier climate between 500 BC and 100 AD. This form of husbandry thereby served as a means for minimizing risks due to the climatic and environmental conditions, especially since drought had impacts on the crop harvests. By exercising nomadism, herds could consist of larger numbers of animals than it would have been possible with settled husbandry. Furthermore, herding took place in different locations and at different times of the year than farming (Chang, 2017, 176–178).

Especially this latter point resembles the traditional agricultural patterns in Nigeria presented in chapter 1.1. Therefore, this form of segregated agriculture seems to already be a form of coping strategy to natural climate variabilities, which has worked for many generations. Hence, both the nomadic pastoralists in the Talgar region and in Nigeria appear to have adaptation strategies for the regular climate variabilities.

This raises the question, whether climatic conditions have changed in a way during the last decades that goes beyond the ordinary variabilities, for instance due to anthropogenic climate change, so that the common strategies do no longer suffice, which results in a conflict about resources.

Buhaug however argues that climate variability is an insufficient factor for explaining violent conflict. In his analysis, no significant effect of precipitation and temperature anomalies on the risk for civil war in Sub-Saharan Africa could be identified. In contrast, he considers ethnic, political, and economic reasons behind conflict. Still, Buhaug acknowledges that an increasing global warming during the first decade of the 21st century, especially when reaching certain tipping points (see Chapter 2.1.3), can change these findings (Buhaug, 2010). Nevertheless, this also raises the question, whether climate change only serves as an explanation for conflict, while other hidden factors are more relevant (see Chapter 2.2.2).

2.1.2 Anthropogenic Climate Change as Opposed to Natural Climate Variability

Before focusing on the effects of climate change especially in the Sahel, it is however necessary to define anthropogenic climate change in distinction to natural climate variability. The IPCC generally defines climate change as *"a change in the state of the climate that can be identified [...] by changes in the mean and/or the variability of its properties, and that persists for an extended period [...]. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use"* (IPCC, 2014, p. 1450). Therefore, the IPCC also includes natural climate variability in their definition as a cause for climate change.

In contrast, the United Nations Framework Convention on Climate Change (UNFCCC) relates climate change solely to an anthropogenic cause by defining climate change as *"a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods"* (United Nations, 1992, p. 7). This definition therefore recognizes natural climate variability as a factor for alterations in climate but attributes the current climate change to human activities.

As described in chapter 2.1.1, natural climate variability can cause abrupt changes in climate, while also evolving on large time scales. However, the current climate change distinguishes itself from earlier changes due to its causes and qualities of change, which will be briefly outlined in the following. Therefore, when referring to climate change in this thesis, it is understood in the sense of the UNFCCC definition as a consequence of human activity.

This understanding is also insofar adequate, as the IPCC states that it is very likely, referring to 90 to 100%, that the observed rise in global mean surface temperatures is caused by the anthropogenically caused increase of greenhouse gas concentrations in the atmosphere. Thereby, greenhouse gas forcings have already, with a likeliness of 66 to 100%, contributed to a warming of between 0.5°C and 1.3°C between 1951 and 2010, whereas contributions from other anthropogenic forcings only account for 0.1°C. Moreover, natural forcings and internal climate variability also caused a warming of 0.1°C at a maximum during the same time period (IPCC, 2014, 869).

This reasoning is substantiated by the observed changes in atmospheric greenhouse gas concentrations over time. Ice core measurements prove that concentration changes of greenhouse gases such as CO_2, CH_4, and N_2O have always occurred during the last 11,000 years, often in association with the Dansgaard-Oeschger events (see chapter 2.1.1). However, in terms of CO_2, these changes only varied between 260 and 280 ppm, while the concentration has rapidly increased to more than 400 ppm as of February 2021 (see Figure 7). Simultaneously, the atmospheric concentrations for CH_4 and N_2O have also increased to levels over the ordinary fluctuations during the last 11,000 years (IPCC, 2014, pp. 483–485).

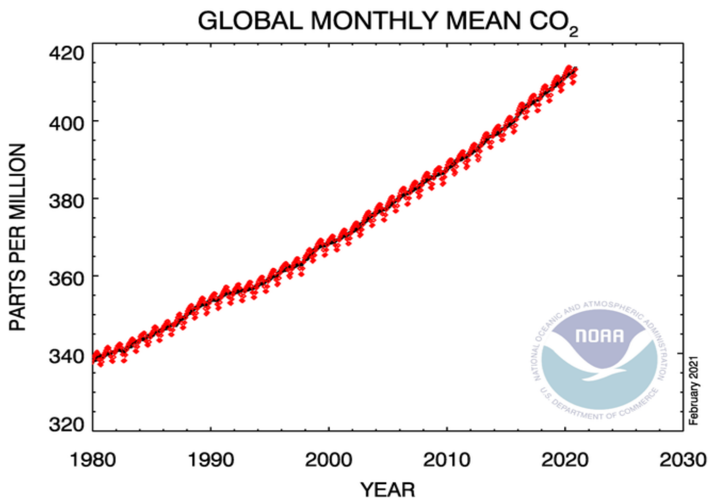


Figure 7: Global monthly atmospheric mean CO_2 concentrations in parts per million between 1980 and February 2021 (National Oceanic and Atmospheric Administration, 2021).

2.1.3 Tipping Points – Irreversible Transformations of the Sahelian zone

These strong interventions in the natural climate system do not remain without effects on climate and earth. As the IPCC constates, the *"continued emissions of greenhouse gases will cause further warming and changes in all components of the climate system"* (IPCC, 2014, p. 19). Dependent on the future emissions of greenhouse gases, aerosol particles and other climate forcing factors, various different pathways of future climate change have been worked out in Representative Concentration Pathways (RCPs) by the IPCC in order to allow for the creation of climate models (IPCC, 2014, 79).

These new scenarios from the fifth assessment report differ in their values on radiative forcing, ranging from a reduction of radiative forcing (RCP 2.6) to four times the radiative forcing (RCP 8.5) compared to the current levels (IPCC, 2014, pp. 147–150). On the basis of these scenarios, various varied assumptions on the future influence of climate change concerning temperature change, changes in the atmospheric circulation, in the water cycle, in the cryosphere and in the ocean were made (IPCC, 2014, pp. 1031–1033).

While a discussion of the detailed implications of the various scenarios would go far beyond the scope of this thesis and will therefore remain undiscussed, it is in this regard necessary to discuss the topic of irreversibility and tipping points. The concept of irreversibility refers to a perturbed state of a dynamical system in which *"the recovery timescale from this state due to natural processes is significantly longer than the time it takes for the system to reach this perturbed state"* (IPCC, 2014, p. 1456).

This is often the case when global or regional climate changes from one stable state to another stable state occur. Thereby, a critical threshold is crossed, which is referred to as a "tipping point". Accordingly, it might be impossible for climate to return to the former stable state, making the crossing of tipping points often irreversible (IPCC, 2014, p. 1463). Some of these tipping points can already be exceeded in case of a warming of 1°C or 2°C, while current trajectories of greenhouse gas emissions tend to cause a warming of 3°C (Lenton et al., 2019).

While most of the major tipping points are located in polar regions, for instance a possible melting of the Greenland and West Antarctic ice sheets, irreversible transformations in the Atlantic meridional overturning circulation, the Amazon rainforest, and the ENSO can result in disproportionate climate system responses as well (Kriegler et al., 2009, p. 5041). This does not seem to affect Northern and Central Nigeria at first sight. However, certain interactions between tipping points seem at least likely, impacting on both socioeconomic and ecological systems in Sub-Saharan Africa (Kriegler et al., 2009, pp. 5044–5045).

In terms of the African Sahelian zone, research has not yet come to a common prediction of crucial tipping points and their outcomes. For instance, Lenton et al. predict a greening of the Sahara and Sahelian zone due to its connection to the West African Monsoon, which itself is linked to the sea surface temperatures. If global warming reaches approximately 3°C, sea surface temperatures will rise enough to cause a wetting effect on the Sahelian zone. In contrast, other climate projections predict an increase in drought years or a general drying of the Sahel due to a complete collapse of the West African Monsoon (Lenton et al., 2008, p. 1790).

Furthermore, a special report on global warming by the IPCC constates a low confidence in terms of a possible greening of the Sahara when reaching the tipping point of a global warming of 3°C and highlights that, despite a possible greening, the negative effects of strong regional warming and its impacts on agriculture and human health would outweigh the greening effect (Masson-Delmotte et al., 2018, pp. 262–263).

Desertification, referring to *"land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities"* (United Nations, 1994, p. 4), and counteractions in order to prevent desertification therefore play a central role, especially since the Sahel region (see Figure 8) appears to be one of the regions with the highest risk of desertification (Ikazaki, 2015, p. 372). Land degradation in this regard means a *"reduction or loss [...] of the biological or economic productivity and complexity of rainfed cropland, irrigated cropland, or range, pasture, forest and woodlands resulting from land uses or from a process or combination of processes [...] such as soil erosion caused by wind and/or water; deterioration of the physical, chemical and biological or economic properties of soil; and long-term loss of natural vegetation"* (United Nations, 1994, pp. 4–5). In the Sahel region, it is mainly wind erosion that is causing land degradation and desertification by removing the topsoil of a field in the event of strong winds, thereby also contributing to a reduction of soil nutrients and soil productivity (Ikazaki, 2015, p. 375).

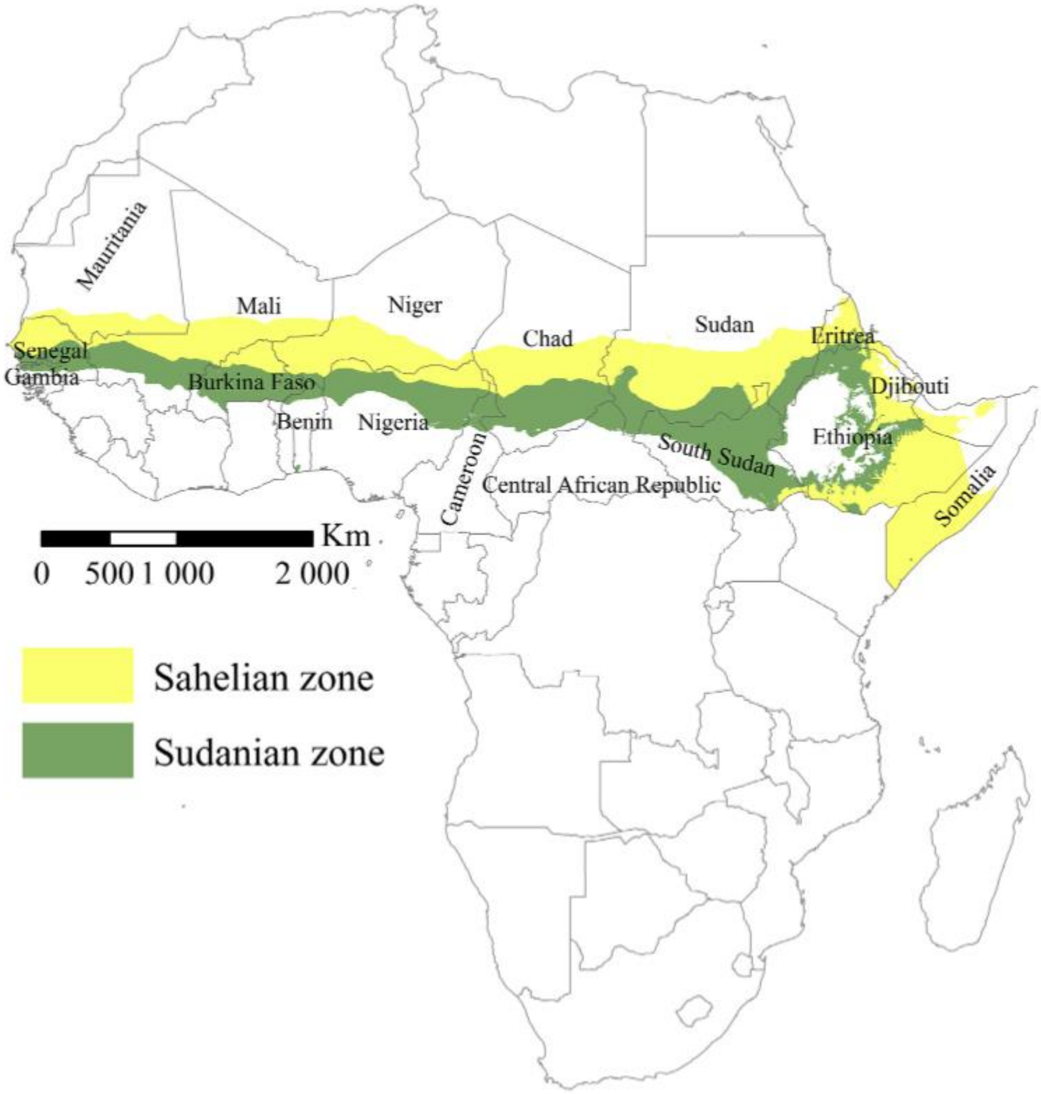


Figure 8: The Sahelian and the related Sudanian zone based on precipitation levels of 200 - 1.000 mm/y (Karlson & Ostwald, 2016, based on (Hijmans et al., 2005).

An example from this region, which shows that large changes of the environment and land degradation can heavily impact on both the ecosystem and the socioeconomic system, is the shrinkage of Lake Chad, as mentioned in the introduction.

The shrinkage of Lake Chad can however not only be explained by climate change. It is rather due to population growth and an intensification of agriculture causing higher water withdrawals for irrigation, which led to an overconsumption of available water resources. Nevertheless, once spanning over an area of 25,000 km² in the 1960s, the lake nowadays only consists of two small and separated water bodies, while other former lake areas turned into barren and arid landscape (Okpara et al., 2016, pp. 782–783). Still, climate variability and climate change contribute to the developments by altering the river flows, which feed the lake, by changing the evaporation and by impacting on the water quality through the precipitation of chemical elements (Okpara et al., 2015, p. 317).

As a result, arable land has become more infertile during the last decades, which requires higher investments for the farmers in the form of fertilizers, pesticides, and motorized gasoline. Nonetheless, the versatility of the ecosystem decreased, resulting in a reduction of productivity both in fishery, agriculture, and pastoralism. Simultaneously, population pressure caused the emergence of new villages, which, in return, also intensified the competition over the limited resources (Okpara et al., 2016, 786–788).

Consequently, the shrinkage of Lake Chad has led to a deterioration of people's livelihoods by affecting the central pillars of life, including fishing, farming, hunting, and herding. As Owonikoko and Momodu outline, this has caused social disruptions and general instability in the region since the beginning of the lake's shrinkage, thereby contributing to crime, banditry and conflicts, also essentially to farmer-pastoralist conflicts (Owonikoko & Momodu, 2020, pp. 1314–1315).

These findings already imply a connection between both environmental and climate change and the conflicts in Nigeria. Before discussing the topic of conflicts and its connection to climate change more in detail, it is still necessary to outline central factors of climate change that will be relevant for analyzing climate change with GIS.

2.1.4 Effects of Climate Change on West Africa

As described in the previous subchapters, climate change affects many different parts of the natural environment and social life, whereof not all are directly measurable, for instance in a GIS. In order to keep this subchapter in an appropriate length, the identified factors of climate change are selected based on their applicability in GIS as the main method for this thesis and their relevance for Western Africa. Hence, this chapter does not provide a comprehensive list of all effects of climate change, but rather focuses on the physical impacts of climate change on the environment, which could contribute to the herdsmen-farmers conflict in Nigeria.

Besides those effects to be expected, when exceeding certain tipping points (see Chapter 2.1.3), there are various other factors of climate change that research expects to manifest with climate change in Western Africa.

Especially affected by climate change are certainly the savannah and rainforest ecosystems. This is particularly true for the rainforests, which fall victim to deforestation at a rate closely linked to global warming. Natural climate variability might contribute as well due to higher rainfall or drought. An expected increase in the fire frequency can additionally accelerate deforestation. Consequently, large parts of rainforest possibly get replaced by savannah and grassland (Hoegh-Guldberg et al., 2018, p. 263).

In their research, Hirota et al. identify a close relation of tree cover and rainfall as well. Despite a certain resilience of stable ecozones, rainforest can transform into savannah, just as savannah can transform into treeless dryland if the ecozones’ responses to perturbations such as drought or logging are no longer sufficient. Accordingly, wetter years, for instance as a response to ENSO events, increase the probability of a restoration to a former state (Hirota et al., 2011).

In relation to deforestation, agricultural production reduces in accordance with global warming. This is especially the case for the Sahelian zone, where the yield of maize or beans might decrease by more than 50% in case of a global warming exceeding 4°C. Furthermore, increased temperatures can cause fungal growth, which further decreases yields. Similarly, livestock production, which is an important source for a range of products in the Sahel, is highly dependent on natural resources, such as fodder and water, and therefore vulnerable to climate change, particularly drought and land degradation (Serdeczny et al., 2017, pp. 1591–1592).

Consequently, it is not only the natural vegetation that is highly dependent on rainfall and temperatures, but also agriculture and livestock production. Therefore, changes in these two factors have to be considered as well when analyzing climate change. In terms of rainfall, projections concerning the future trajectories are not clear yet due to the chaotic nature of rainfall and therefore vary in their results (Zinyengere & Crespo, 2017, pp. 22–23).

In addition, Wang et al. see a correlation between the Saharan Heat Low, which is a June-to-August phenomenon in the western Sahara and which changes in temperatures and thickness on an interannual time scale, and both emitted dust in the Sahara and rainfall in the Sahelian zone, thereby also influencing the West African monsoon (Wang et al., 2015). These interconnections of natural climate phenomena therefore further complicate analyses and projections of rainfall changes due to climate change.

More certainty about the impact of climate change on rainfall in Western Africa exists in terms of extreme weather events. Very wet days are likely to increase by 30 to 70% for Western tropical Africa, just as very dry days seem to increase at similar rates as well, depending on the projected emission scenario (Serdeczny et al., 2017, pp. 1587–1589).

In terms of temperature changes, projections show a more unified result. For example, projections for the Southern African countries indicate an increase between 1.5°C and 7°C dependent on the projection and emission scenario (Zinyengere & Crespo, 2017, pp. 19–22).

For low-emission scenarios, the projected warming tends to be slightly lower for Africa than for the global world. However, the high-emission scenario connected to a global warming of 4°C predicts a warming of 5°C for Sub-Saharan Africa until 2100 compared to the temperature levels between 1951 and 1980. This would cause a rather unusual warming compared to past fluctuations. Furthermore, heat extremes are projected to increase in all emission scenarios, which is similarly unusually high compared to global projections (Serdeczny et al., 2017, pp. 1586–1587). In addition, the total number of particularly hot nights will increase just as the length of these unusual heatwaves, both at a percentage varying in dependence on the emission scenario (Hoegh-Guldberg et al., 2018, p. 261).

In summary, Western Africa and the Sahel zone tend to be especially impacted by climate change, according to the projections of future trajectories. While changes in the rainfall pattern continue to be uncertain, an increase in average temperatures and heat extremes can be expected. Accordingly, also the ecosystem will be particularly affected, presumably causing degradation of the land cover, as well as a reduction of both agricultural potentials and livestock production. Since climate change is already a factor in the global climate, these projections might already be partly at work in the affected regions of the herdsmen-farmers conflict in Nigeria.

2.2 Conflict and Peace Studies

Before analyzing the impact of climate change on this conflict, it is relevant to elaborate on the concepts conflict and peace. This necessitates a definition of conflict, as well as of peace as a connected term. Based on this, relevant research on conflict will be discussed. This allows for outlining various factors of violent conflict, which can later be analyzed in the context of climate change. Therefore, this chapter also includes a discussion of research, which links violent conflict and climate change.

2.2.1 Defining Conflict and Peace

The definition of conflict depends on the field and perspective it is researched from, which makes "conflict" a term that can be defined in a variety of ways. From a social scientific perspective, the term describes *"a contest between two or more actors (individuals, societal groups, states, or groups of states) over scarce and sought-after material and immaterial goods, where the parties pursue contradictory aims or means"* (Brauch & Scheffran, 2012, p. 3).

Conflict can further be differentiated dependent on the respective object or reason, such as political, economic, environmental, societal, or social, just as it can be distinguished by their values, contesting ideologies, or social systems, as well as in consideration of the peaceful, violent, or devastating nature of the conflict and the used means (Brauch & Scheffran, 2012, p. 3).

Due to this range of perspectives on conflict, further concrete definitions have been established. For instance, the UCDP has included data on armed conflict in their database, while defining armed conflict as *"a contested incompatibility that concerns government or territory or both where the use of armed force between two parties results in at least 25 battle-related deaths. Of these two parties, at least one is the government of a state"* (Gleditsch et al., 2016, pp. 618–619). Even though the conflicting parties in the discussed herdsmen-farmers conflict in Nigeria are using armament, this definition does not apply due to the lack of involvement of both federal and state governments, which hesitated to address the conflict at all at first and then opted to try solving the conflict by passing resolutions and bills in order to clarify the land use rights (Ezemenaka & Ekumaoko, 2018, pp. 40–41).

For the purpose of this thesis, the understanding of conflict will therefore remain broad in the sense of defining it merely as violent contest between herdsmen and farmers over scarce, but sought-after resources such as access to fertile land and water, which is fought over by the use of arms.

When conceptualizing peace, one could possibly invert the definition of conflict and describe peace as the absence of a contest over scarce and sought-after resources. Without the intention of discussing the different theories on peace, this understanding would not get close enough to the core of peace. For instance, peace is also about mutual and sufficient security of the involved parties in a conflict. This means that all the involved parties have to agree that peace would be the better solution than violence by realizing that this can only be achieved by cooperation

(Galtung et al., 2000, p. 4). In case of other conflicts, it might be self-determination in terms of the own territory and its resources (Galtung et al., 2000, pp. 10–11).

Since the reasons for and causes of violent conflict are manifold, the underlying factors of peace are manifold as well. Therefore, Galtung et al. refrain from establishing a definition of ‘peace’, since this would imply a common, final solution to all violent conflicts and the shape of peace. Rather, it is important to understand the various causes of violence and the problems in order to establish outcome alternatives and future prevention of violence (Galtung et al., 2000, pp. 14–15).

This argumentation accordingly suggests that peace is seen as the non-violent state or phase after a conflict. Therefore, peace can be considered as the consequence of solving a conflict. This also means that peace and conflict do not exist simultaneously. Once a conflict arises, non-violent phases should rather be understood as a lingering conflict that might erupt again.

On this reading, the conflict in Nigeria between herdsmen and farmers can only be solved in cooperation of the two involved groups. Accordingly, this requires a comprehensive understanding of the causes for the conflict.

2.2.2 Research on Violent Conflicts and Its Relation to Climate Change

In terms of the quantification of conflicts, the UCDP provides a comprehensive database for armed conflicts worldwide. According to their data, the last years have seen a strong growth in armed conflicts since 2012, reaching the highest number of armed, state-based conflicts since World War II along with the year 1991 (see Figure 9).

Among these recent conflicts since 2013, the highest increase is visible in Africa. However, it is not only the state-based conflicts, which refer to the involvement of a government, but also non-state conflicts, which as well increased mainly in Africa since 2010 (see Figure 10). Even though Africa has always been the region with most conflicts of these types, the total number has even increased to the highest since 1989 with its peak in 2017.

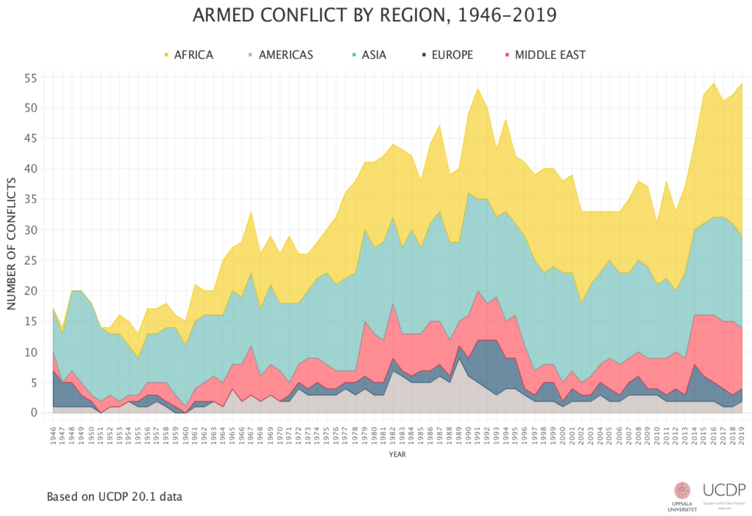


Figure 9: State-based Armed Conflicts by Region between 1946 and 2019 based on UCDP (Pettersson & Öberg, 2020, p. 599).

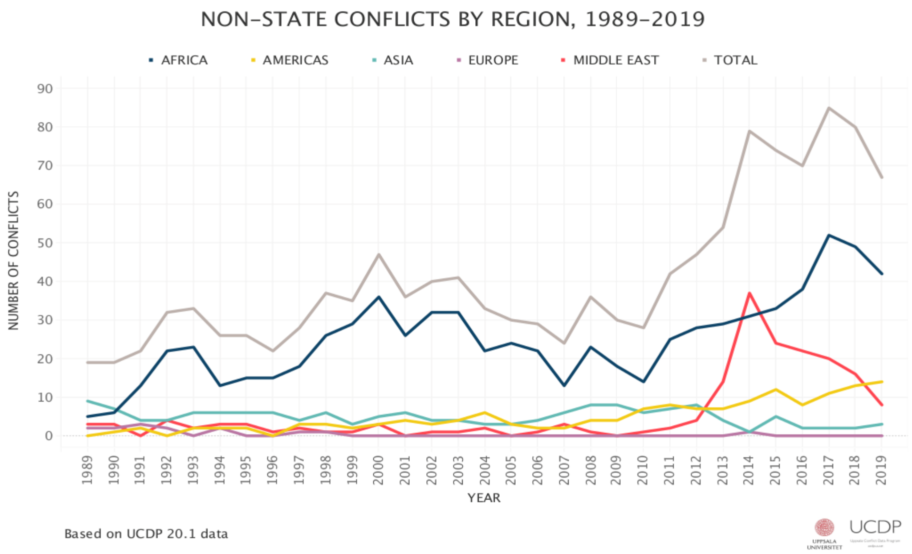


Figure 10: Non-State Conflicts by Region between 1989 and 2019 based on UCDP (Pettersson & Öberg, 2020).

Research has therefore attempted to identify the reasons behind the general increase in worldwide state-based and non-state conflicts as well as the causes for the rising number of conflicts in Africa. The results can consequently be used in the analysis of the herdsmen-farmers conflict in Nigeria. Due to the large extent of research on worldwide conflicts, the following discussion will focus on intrastate conflicts in connection to environmental change and resources in Africa. This is also in line with the definition presented in the previous subchapter, which states that violent conflict is centrally arranged around the access to or the denial of material and immaterial goods and resources (see Chapter 2.2.1). In close connection to resources is land, as this is the location where resources can be found and exploited.

Among the first researching on this topic, Homer-Dixon investigated the linkages between environmental scarcity and conflict, which led to the expectation that violent conflicts will increase in the years to come as a consequence of environmental scarcity, especially in poorer countries due to their lack of economic and political stability and resources. Among the five different types of conflicts stemming from environmental scarcity, Homer-Dixon expected ethnic conflicts resulting from migration and social segregation as well as civil unrest, including banditry, arising from a reduced economic productivity and the states' ability to react as the two most likely types of conflict, both reminding of the situation in Nigeria, as outlined in chapter 1.1 (Homer-Dixon, 1999, pp. 4–5).

Homer-Dixon thereby defines environmental scarcity as the *"scarcity of renewable resources, such as cropland, forests, river water, and fish stocks. This scarcity can arise [...] from depletion or degradation of the resource, from increased demand for it, and from unequal distribution"* (Homer-Dixon, 1999, pp. 8–9). Consequently, environmental scarcity can originate from depletion and degradation of a resource as part of a complex interplay including the physical vulnerability, the resource-consuming population's size and the applied technologies and practices during consumption. Nevertheless, scarcity can also develop due to a rise in demand for a resource, for instance as a consequence of population growth, or a general imbalance in the distribution, which is referred to as structural scarcity. Especially structural scarcity can contribute to conflict, since parts of the population only obtain an insufficient access to the resources (Homer-Dixon, 1999, pp. 14–15).

This highlights that environmental scarcity is not necessarily caused by climate change, but also by an overexploitation of resources, which in return can be interpreted as the result of an overuse of natural resources in the atmosphere and on the land surface (see Chapter 2.1.2). However, it has to be emphasized that environmental scarcity is not the sole reason for migration, poverty or conflicts. There are always economic, political, or social factors involved, for instance resulting from insufficient legislation concerning property rights or political disputes about control over a territory (Homer-Dixon, 1999, pp. 16–17). Chapter 2.2.3 will therefore give a short presentation of these contextual, non-climatic causes of conflict.

Furthermore, societies are not predetermined in their adaptation to environmental scarcity. In this regard, Homer-Dixon introduces the concept of ingenuity referring to the ability to successfully adapt to this scarcity by using the society’s social and technological abilities. However, certain factors can limit the ingenuity in societies, creating an ingenuity gap between societies which create enough ingenuity to adapt to environmental scarcity and societies which do not (Homer-Dixon, 1999, p. 125).

Generally, Homer-Dixon’s research joins the ranks of a debate, which has been going on for centuries and centrally evolves around the relationship between population growth, natural resource scarcity, and prosperity. Homer-Dixon identifies three different main positions in this debate. First, the neo-Malthusians, which build on Thomas Malthus’ ideas, argue that resources strictly limit the growth of human population and consumption. Once these limits are exceeded, poverty and social disruptions arise. Second, and in opposition to the neo-Malthusian arguing, economic optimists state that properly functioning institutions allow for a conservation and substitution of resources, which leads to the assumption that resource scarcity does not exist. Third, distributionists, as Homer-Dixon calls this group, rather state that the issue is not a lack of resources but a maldistribution of resources and wealth (Homer-Dixon, 1999, p. 28).

More recent research continues to pick up on these ideas, especially on Homer-Dixon’s research. For instance, Buhaug, Gleditsch and Theisen identify five social effects of climate change that can contribute to conflict. This entails reduced state income, which impacts on the state’s ability to deliver public goods and politically legitimize their power, an increase in competition about scarce resources in both heterogeneous and subsistence-economy societies, the emergence of social tensions due to efforts to adapt to or mitigate climate change, and a general deterioration of environmental conditions (Buhaug et al., 2010, p. 81).

Consequently, climate change and its effects are rather the original causes than the ultimate reasons for conflict, which further impact on the social, economic, and political factors, which, in return, can contribute to a higher risk of conflict (see Figure 11).

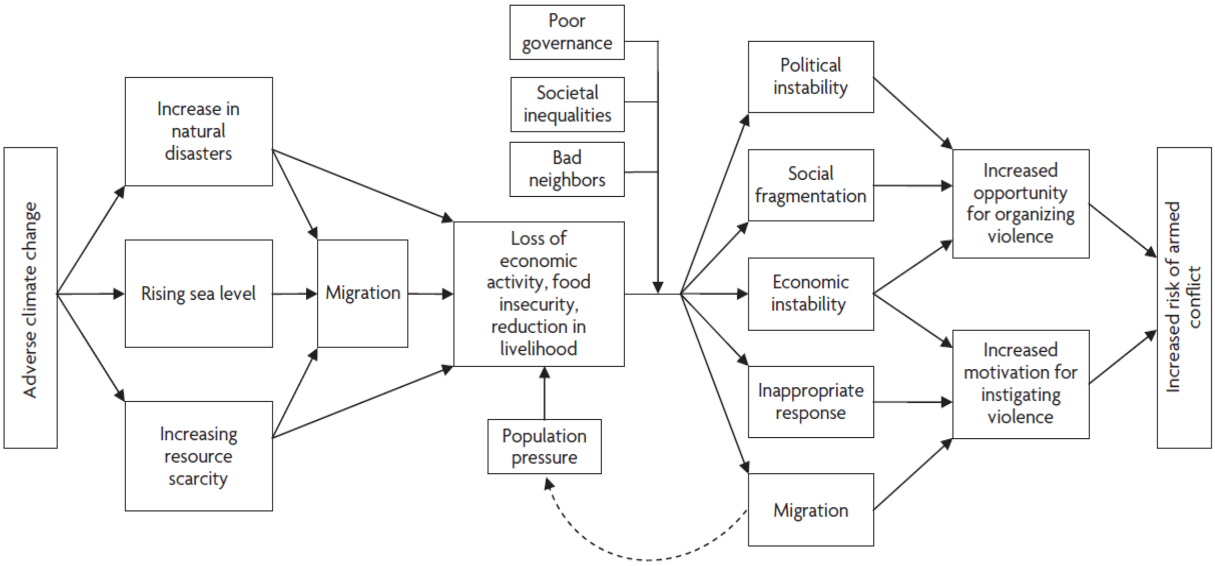


Figure 11: Possible Pathways from Climate Change to Conflict (Buhaug et al., 2010, p. 82).

The risk of conflict is further dependent on the type of climate change effect. Since gradual changes, including desertification and sea-level rise, usually allow for a gradual response, it is mostly sudden change, for instance due to climate variability and natural hazards, which can aggravate the consequences in case a society is unprepared or unable to exercise immediate adoption mechanisms. By stating this, Buhaug et al. refer to the ingenuity gap established by Homer-Dixon as outlined above (Buhaug et al., 2010, pp. 77–78).

Still, Buhaug et al. criticize that the relationship between resource scarcity and conflict has not yet been convincingly highlighted by research, which mainly engaged with case studies instead of statistical evidence, which would allow for a certain generalization. Therefore, this relationship is rather indicative. In fact, in 2010, the developments in conflict even contradicted the trajectory of global warming (Buhaug et al., 2010, p. 93).

In a research on the correlation of climate variability, food production, and violent conflict, Buhaug, Benjaminsen, Sjaastad and Theisen statistically outline a linkage between climate variability and food production for Sub-Saharan Africa. Especially in the Sahelian and East African semi-arid countries, food production and agricultural output in general are responsive to rainfall variabilities, even though this connection is nonlinear. A weaker effect could be identified for yearly mean temperatures on crop yields. However, an empirical connection between agricultural production and conflict remains insignificant and therefore is not assumed by the authors, thereby contradicting the scarcity thesis by Homer-Dixon. Nevertheless, the authors acknowledge that this study cannot capture localized dynamics, which could contribute to violence, even though it still remains more likely that social, political, and economic contexts impact on stability and peace in Africa than climate change (Buhaug et al., 2015).

Another quantitative study on the connection between climate variability and conflict with a focus on Sub-Saharan Africa investigates the role of renewable resource scarcity, especially water, for herder-farmer or herder-herder conflicts in Western and Eastern Africa by conducting a comparative analysis of case studies. As a result, the study suggests a connection between social conflicts and renewable resources. The access to, the use of, and the availability of land and water are a crucial factor when it comes to social stability in the investigated case studies. However, resource scarcity neither seems to be an issue for conflict in half of the 18 cases, nor is it the main driver of conflict. Therefore, increased pressure on resources or resource scarcity does not seem to significantly impact on conflict. It is rather more likely that political inequalities and accordingly unequal control of and access to resources as well as in-migration to an area can contribute to conflict. Consequently, the authors argue that it is more an inter-connectedness of resources and political processes that drive conflict. Thereby, it is necessary to differentiate between physical resource scarcity and distributional issues (Seter et al., 2018).

In contrast, Hsiang, Burke and Miguel argue, based on an analysis of 60 quantitative studies covering different periods of time during the last 12,000 years, that human conflict is indeed connected to climate change. As opposed to Buhaug et al., Hsiang et al. also identify a stronger effect of temperature change on violence than of rainfall change. Basing the research on psychology and economics, the authors argue that aggressive and violent actions tend to be more, the higher the temperatures. Therefore, it is to be expected that personal violence and property crime will increase with rising temperatures and more extreme rainfall events. This is also valid for intergroup violence, and, in case of rather high levels of climatological stress, even a breakdown of political institutions appears possible to Hsiang et al. However, they acknowledge the influence of other factors on the likeliness and severity of conflict, such as income (Hsiang et al., 2013).

Besides these two contradicting views concerning the connection of resource scarcity and violent conflict in times of climate change, research has established a third interpretation on linkages between resource and conflict in what is called the “resource curse” or “paradox of plenty”.

Sachs and Warner thereby state that resource-rich economies from the Global South often perform considerably worse in terms of the development of the Gross Domestic Product (GDP) than national economies with fewer resources. This assumption is based on the initial observation that this pattern is true for a sample of 97 countries from the Global South between the years 1970 to 1989, when associating the growth per capita and the share of natural resource exports in GDP during this period. According to Sachs and Warner, this thesis even remains valid when taking into account other factors of economic growth, such as trade policies, resource dependence, integration of the economy into the global market, the average investment, and the quality of bureaucracy. This is furthermore especially the case for Sub-Saharan Africa (Sachs & Warner, 1995).

In a subsequent research, Sachs and Warner further refine their earlier findings. By adding geographic and climatic variables to the earlier research, such as proximity to the sea, distance to the closest major port, the percentage location of the land area in the geographic tropics, and an index for the occurrence of malaria in the country, the authors try to consider the geographic predeterminations for the economic growth of a country. However, the earlier result indicating that the economies of countries with many natural resources tend to grow at slower rates than resource-poor economies remains valid, according to Sachs and Warner (Sachs & Warner, 2001). This also specifically applies to Nigeria, which has to be considered a resource-abundant country (Sachs & Warner, 2001, p. 828).

While Sachs and Warner remain on the economic dimension of resource abundance, other research tries to connect resource abundance to conflict. For instance, Lujala discusses the question whether the access to abundant natural resources facilitates armed conflict for rebel groups and whether resources prolong the duration of conflicts. Earlier research thereby introduced two main arguments. First, resources itself provide enough motivation for rebel groups to engage in conflict. Second, countries with vast resources tend to experience policy choices and a weak state to the disadvantage of the society. Based on the observation that resource-rich countries tend to be more involved in civil conflicts, Lujala therefore divides his research into direct effects on the rebel movements and indirect political and economic effects which influence conflicts through the state as discussed above. In terms of the direct effects, rebel movements can be described as a type of economic entity, which have to pay the members more than non-conflict incomes would allow in order to maintain incentives for the conflict. Under consideration of natural resources such as hydrocarbons, diamonds and other gemstones, Lujala argues that the risk for conflicts not only increases with the degree of natural resources, but also the average duration of conflicts prolongs, if the resources are to be found within the conflict zone, no matter whether the resources can be exploited during the conflict or not (Lujala, 2010).

Based on Lujala’s research, Obi further discusses the relevance of oil for conflict in oil-rich African countries such as Nigeria. Oil is an especially important resource due to it being a key element in the global economy, involving the African states in a transnational economic network with powerful multinational corporations that dominate the technologies concerning the exploitation of resources. Therefore, Obi states that the societies of the affected countries hardly profit from the resources. Specifically in Nigeria, oil is considered to be a reason for the recent conflicts in the Niger Delta, which have their roots in the civil war, but have experienced a new upsurge in consequence of the oil boom. The Niger Delta is also the state with the most incidents involving Fulani alongside the Middle Belt states according to CFR data (see Figure 1). However, Obi argues that the roots of the conflict do not lie in oil. It is more the unequal power relations and resource distribution around the exploitation of oil that create conflict, resulting in an increasing affluence of the state and transnational elites, while the local communities have to deal with pollution and expropriation. Consequently, oil resources should not be seen as a cause for conflict, but rather the unequal social conditions, which are reinforced by the exploitation of resources (Obi, 2010).

While most research on the connection of resource abundance and conflict evolves around mineral resources, the earlier discussed literature on resource scarcity and conflict rather considers natural resources such as water or land. Nevertheless, both perspectives could not entirely demonstrate the connection between resource abundance or scarcity and conflict so far, just as both could not conclusively clarify the role of climate change for conflict. Therefore, the question remains whether climate change is a driver of conflict.

Something that unites the contrary perspectives on the connections between resources and conflicts is the assumption of indirect effects of climate change on conflicts, as visible in both Buhaug et al. (2010) and Homer-Dixon (1999) just as in Lujala (2012). These indirect connections are mostly outlined as created through economic growth and the effects of climate change on people’s financial livelihoods. However, changes in precipitation and temperatures can impact on the livelihoods in such a negative way that they might directly provide reasons for conflict, especially when these changes occur abnormally or with increased variability (Theisen et al., 2013, p. 621).

2.2.3 Non-Climate-Change Related Factors of Conflict

Based on the observations from the previous subchapter that climate change mainly has an indirect impact on conflict, also other non-climate change-related factors have to be considered when analyzing the causes of the conflict between herdsmen and farmers in Nigeria.

As Buhaug and Lujala state, various certain local geographic circumstances can contribute to conflicts as well, such as terrain, subsoil assets, population distribution, or ethnic diversity. Consequently, they see a higher risk for conflict and civil war in remote, rural areas, which are inhabited by a minority group. Also mountainous or forested terrain can contribute to conflict (Buhaug & Lujala, 2005, p. 400). While research on civil conflicts often focuses on national levels, Buhaug and Lujala argue for the consideration of these local factors, as civil conflicts usually take place on a sub-national level (Buhaug & Lujala, 2005, p. 403). Since the herdsmen-farmers conflict in Nigeria also takes place on a sub-national level (see Chapter 1.1), the consideration of local factors is sensible.

Based on this assumption that other factors than environmental ones are involved when it comes to conflict, Bretthauer has conducted research on the economic, political, and social conditions under which violent conflict can arise from scarce land and water resources (Bretthauer, 2017).

Among the 22 interconnected conditions, which are analyzed in the research, are for instance agricultural dependence, poverty, or economic diversification in terms of economic factors, corruption, quality of political institutions, rule of law, or political stability as political conditions, and economic, political and gender inequalities, or access to education as components of social causes (Bretthauer, 2017, 26).

In terms of economic factors, high levels of agriculture mainly contribute to a higher risk of conflict, resulting in agricultural societies being more likely involved in conflict. In countries with low resources in regards of arable land and freshwater, which Bretthauer's research focuses on, agricultural intensity naturally creates more competition about these scarce resources. As a consequence of climate change, this contest might be further aggravated. Simultaneously, a deeper integration into the world market, accompanied by more trade, signifies a lower risk for conflict under the condition that the country is not dependent on a single primary commodity, as also indicated by the discussion on resource abundance (Bretthauer, 2017, pp. 77–79).

When it comes to the political conditions, countries with a rather high level of authoritarianism and especially neopatrimonialism, as it is the case for various mainly African countries, have an increased likeliness for violence. This is further amplified by a low level of rule of law. However, particularly hard authoritarianism can even counteract the potential for conflict to a certain degree, just as effective and non-corrupt bureaucracy does (Bretthauer, 2017, pp. 102–106).

Moreover, violent conflict is more likely to emerge under certain social conditions. Especially when the economic development shows high levels of inequality, certain groups of the society are left vulnerable, which consequently increases the risk of conflict. Thereby, it is mainly economic inequality across groups, which matters, rather than political and gender inequalities or inequalities across individuals due to the potential for the creation of a polarization of the different groups. Furthermore, tertiary education can support the individual's adaptive capacities by allowing the understanding of certain risks, access to and the provision of information, and a generally higher acceptance of societal institutions (Bretthauer, 2017, pp. 132–134).

According to Wallensteen, research on conflict has identified a shift in the debate on causes for conflict since the end of the Cold War. This is also due to the change in conflict patterns. While inter-state conflicts were more common during the Cold War, the last years have seen an emergence of intra-state civil wars. Consequently, new explanations for new conflicts had to be found, thereby challenging the former understanding of a certain comparability of different conflicts. As explanations for this serve aspects such as national governance, including state legitimacy and corruption, international relations, and economic integration, as well as gender inequality or the willingness to solve a conflict. However, it has to be emphasized that regional variations create different outcomes in terms of severity or duration of conflicts (Wallensteen, 2017, 266–270).

Therefore, it is necessary to elaborate on, whether the aforementioned non-climate change-related explanations for conflict are also specifically concerning the herdsmen-farmers conflict in Nigeria. As already outlined in chapter 1, religious and ethnic reasons are often brought forward as reasons for the pastoralist conflict in Nigeria besides climate change and the land use disputes. The latter ones are thereby often caused by a general reduction in farm sizes due to population pressure, itself resulting in land pressure (Ejigu, 2009, pp. 888–890).

Nevertheless, Ejigu also identifies other contributing factors to the herdsmen-farmers conflicts. This includes a weak governance and the lack of viable institutions, which could solve disputes around land use and resources on a juridical level. In consequence, this provides the possibility for disadvantaged groups of the society to organize political and violent groupings in order to counter the perceived inequality. This is especially the case for societies, in which traditional institutions and systems, which used to manage and even solve conflict, are challenged by state power. Furthermore, societal heterogeneity can be considered as contributing to conflict, especially in connection to migration. Resulting from migration, the in-migration to a foreign area is often accompanied by hostile sentiments among the local host community. This aversion can further be reinforced, when the arriving groups have enough power to cause a shifting resource distribution, thereby aggravating resource scarcity among the native groups (Ejigu, 2009, 891–892).

In a qualitative research containing interviews with affected herdsmen and farmers, causes for the pastoralist conflict, which were among others mentioned by the informants, are animal rustling, blocking of water points and of cattle routes through farming activity and commercialization of crop residues from the perspective of the herdsmen. Crop farmers rather perceived crop damage, destruction of farm land, uncontrolled grazing, or pollution of community water sources as a reason for violent incidents (Dimelu et al., 2016, 150).

Similar observations were made by Ndubuisi in his qualitative study on the herdsmen-farmers conflict in Nigeria. According to him, damaged crops due to illegal entering of farmlands and straying cattle have caused violent disputes, as well as ambiguous land property rights. These issues are consequently snowballing to a more and more violent conflict due to the lack of political will to prosecute and arrest perpetrators of violent incidents (Ndubuisi, 2018, pp. 3–4).

As discussed in this chapter, conflict can emerge from a range of different, often interconnected causes. Climate change as a cause for conflict has received much attention in research. However, climate change is seldom perceived as the direct cause for conflict. It is rather considered an indirect cause, further impacting on non-climatic factors. One major topic in this regard is the question of resource scarcity or abundance as a contributing reason for conflict. Thereby, resource scarcity tends to contribute to violence in countries that are highly dependent on agriculture. Resource abundance is observed to be a factor for conflict, when the resource is a mainly mineral resource and the country, the resource is to be found in, is highly dependent on this sole resource. Nevertheless, it usually requires other factors for a conflict to emerge. Both in general research on conflict and in specific studies on herdsmen-farmers conflicts are among others mentioned weak governance, integration in the world market, societal heterogeneity in economic, ethnic, and religious terms, as well as migration as possible contributing causes to conflict. To which extent these factors contribute to the herdsmen-farmers conflict in Nigeria will be elaborated on in the following by the use of GIS as the main method.

3 Methodological Approach and GIS

GIS has evolved as a central tool in research concerning spatial questions. Thereby, GIS is valuable, when it comes to research on locations, patterns, trends and changes, conditions or implications in a certain research area (Heywood et al., 2011, p. 3).

Even though there exists a range of different definitions on GIS, Heywood et al. highlight that these definitions usually entail three central aspects. First, GIS is a computer system, including both hardware and software as well as their utilization in the form of procedures. Second, GIS is processing spatially referenced or geographical data, thereby providing the tools for managing and analyzing the data as the third factor of GIS. Consequently, GIS allows for an inclusion of various distinct databases in order to create new data (Heywood et al., 2011, p. 18).

This makes GIS especially useful for the aim of this research, since various geographic variables can be generated based on the discussed research on climate change and conflict, which are then applied in a regression analysis. The purpose of this chapter is therefore to outline how this analysis is carried out. First, it is relevant to identify suitable factors for the analysis based on the discussions made in chapter 2. The evaluation of the suitability of each factor is thereby based on the considerations made in Chapter 2.2. Second, these factors are operationalized as variables for a further GIS-based analysis. In terms of software, ArcGIS Pro Version 2.7.2 is used.

3.1 General Underlying Considerations

As outlined in chapter 1.2, the research in this master thesis consists of a two-part analysis of the factors of the conflict between herdsmen and farmers in Nigeria. First, climate change as a possible factor of conflict is further investigated. Based on the hypothesis that climate change has had more effects on Nigeria than on other West African countries and therefore can be considered a factor for the conflict, a comparable change detection analysis for Nigeria and

Ghana will be applied. Ghana thereby serves as the country of comparison due to a rather similar geography as Nigeria (see Chapter 4.1).

The second step analyzes whether the impact of climate change has been a statistically significant factor for the conflict by using a regression model. Therefore, besides the factors of climate change, the contribution of other non-climatic factors to the conflict will be investigated.

The main advantage of this approach is that many factors can be analyzed, and a large amount of data can be processed remotely using a GIS software. As a result, a range of conclusions can be drawn based on their statistical likeliness. Consequently, this method allows for an approach to the topic, which tries to consider the different perspectives taken in the conflict, which partly have made prove of a strong tendency to argue in favor of an involved party or in favor of certain arguments.

On the opposite, this method also has several disadvantages. For instance, statistical conclusions only remain predictions based on statistical likeliness. Therefore, important factors which cannot be statistically captured remain hidden. Since factors have to be identified in advance of the analysis, there is a risk that several factors are not considered and therefore left out. Furthermore, factors contributing to the conflict must be operationalized. This contains the risk that these factors are generalized in a way that might not grasp the core of the factor and thereby falsify the analysis. However, there exist tools in GIS that support the process of establishing a trustworthy and reliable regression analysis. As a result, it is important to take various considerations into account when outlining the methodological approach to analyze the causes of conflict and to generate satisfying and valuable results.

First, how or in which way is the analysis done? Second, which spatial divisions are made for the analysis, for instance whether a disaggregated or a regional approach is chosen? Third, which factors are required to analyze the central research questions? Finally, which datasets can provide the required data?

Concerning the first fundamental question including a detailed description of the analysis, the chapters 3.2 and 3.3 will provide further details on how the two-step analysis will be conducted. This includes considerations regarding questions such as, which factors are compared in which way as well as which datasets are used in order to undertake the analysis.

The second decision must be made in terms of the research area. When conducting a comparative GIS analysis, reference areas have to be established in order to compare changes over time and space between these areas. As Buhaug and Rød outline, this is necessary, because there need to be geographic units without violent conflict in order to draw conclusions whether an area is exposed to higher risk of conflict. Consequently, there are three possible approaches to dealing with this issue: a state-based approach where entire countries are compared with each other, a selection of first-order administrative regions or even lower, or the creation of artificial geometric units, such as grid cells. A comparison of entire countries would however assume that countries were homogeneous entities (Buhaug & Rød, 2006, p. 318).

Since the herdsmen-farmers conflict in Nigeria is also considered an intra-state conflict, the analysis must be conducted with the use of sub-national units. As outlined in chapter 1.1, the conflict in Nigeria is regionally concentrated in a few states, allowing for large areas without incidents. Therefore, units on the first-order administrative level might provide decent results. To further refine the results, units consisting of second-level administrative divisions are chosen for both countries. In terms of Nigeria, this are the 774 Local Government Areas (LGAs), whereas Ghana is subdivided into 260 districts. The use of administrative regions instead of a grid is insofar sensible, since most census data, such as income levels or demographic numbers, are provided on regional administrative division levels, which would need to be calculated for a grid. Shapefiles for the LGAs and districts are downloaded from the United Nations Office for the Coordination of Humanitarian Affairs (OCHA) Nigeria for Nigeria (OCHA Nigeria, 2017) and OCHA Regional Office West and Central Africa (ROWCA) for Ghana (OCHA ROWCA, 2021).

This is also relevant for the third fundamental question regarding which factors to include in the analysis. For the first part of the research concerning climate change in Nigeria and Ghana, four criteria will be further investigated: land cover change, average temperatures, precipitation, and wet days. These factors will be further discussed in Chapter 3.2. Regarding the non-climate change-related factors for the second part of the analysis, the considered variables will be ethnic heterogeneity, the relative urbanization rate of the LGAs, the population pressure, the local road density, the petroleum and diamond resource accessibility, the proximity to water resources, and both literacy and poverty rates (see Chapter 3.3).

The next two subchapters will discuss the different factors used in the analysis. Each of the chapters will outline, why the factors are used, how they are used and how they contribute to the results. This also requires an overview of the used datasets.

3.2 Analysis of Climate Change based on Land Cover, Rainfall and Temperature

The analysis of land cover change is based on the land cover datasets provided by the European Space Agency (ESA) Climate Change Initiative (CCI), which contains the global land cover on a spatial resolution of 300m and a temporal resolution from 1992 to 2019, whereof a yearly land cover map is available since 2016. The dataset consists of 37 global land cover types until 2015, 22 different land cover types since 2016 (ESA, 2017; ESA, 2020). Although this dataset has a lower resolution than comparable ones, such as the Globeland30 with its resolution of 30m for ten land cover types in ten-year intervals from 2000 to 2020 (Chen et al., 2015), the ESA CCI land cover dataset has the advantages of a higher temporal resolution, covering a longer period, as well as a more diverse land cover classification, which allows for a finer differentiation when it comes to reclassifying the land cover classes. For instance, agricultural areas can be split into irrigated all-year farming and rainfed farming (see Table 1).

Due to these characteristics, the ESA CCI datasets are highly suitable for a spatio-temporal analysis of land cover change. Thereby, it is not necessary to analyze the changes from one year to the next since land cover change gradually evolves over a longer period. Accordingly, five years have been selected for the land cover change comparison. As the CCI datasets cover the years 1992 to 2019, these two years set the first and last year of comparison for the analysis as well. Therefore, changes can be analyzed over the time span of 28 years, which is close to the 30 years commonly used as reference period to which climate parameters are assessed towards (see Chapter 2.1). To allow for an analysis of the average change rate over time, the years 2000 and 2010 have been selected as two other years of comparison, since these years are approximately the two midpoints in the dataset period. The fifth year of comparison is 2015, since this year sets the midpoint for the most conflict-intense years in Nigeria and is still some years ahead of the most violent year of 2018, thereby allowing for a conclusion on a faster evolving land cover change after 2015 than before.

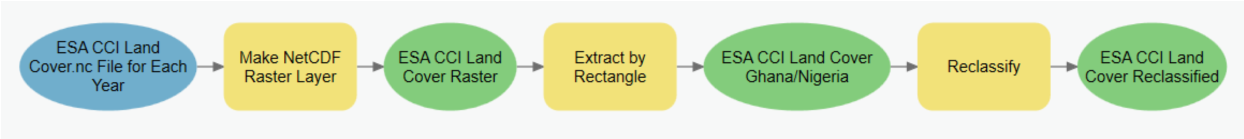


Figure 12: Simplified Workflow from Import to Reclassification for a Single Year of Comparison from the ESA CCI Land Cover Datasets with Blue Input Layers, Green Output Layers and Yellow Worksteps.

Since the datasets are multidimensional raster NetCDF files, they have to first be imported to ArcGIS Pro (see Figure 12). Thereafter, the resulting global layer needs to be further clipped to the extent of Ghana and Nigeria. This results in separate layers of the research area for each year of investigation. In order to make the land cover change between the different years with a varying number of land cover types comparable, the datasets have to be reclassified based on the land cover types of ESA CCI (ESA, 2017, pp. 26–30).

Table 1: Reclassified, Original, and Updated Land cover Classes.

New Land Cover Classes	Original Class Values	Original 37 Land Cover Classes (until 2015)	Updated 22 Land Cover Classes (since 2016)
No Data (0)	0	No Data	No Data
	220	Permanent snow and ice	Permanent snow and ice
All-year Agriculture (1)	20	Cropland, irrigated/post-flooding	Cropland, irrigated or post-flooding
Forest (2)	50	Tree cover, broadleaved, evergreen, closed to open (>15%)	Tree cover, broadleaved, evergreen, closed to open (>15%)
	60	Tree cover, broadleaved, deciduous, closed to open (>15%)	Tree cover, broadleaved, deciduous, closed to open (>15%)
	61	Tree cover, broadleaved, deciduous, closed (>40%)	
	62	Tree cover, broadleaved, deciduous, open (15-40%)	
	70	Tree cover, needleleaved, evergreen, closed to open (>15%)	Tree cover, needleleaved, evergreen, closed to open (>15%)
	71	Tree cover, needleleaved, evergreen, closed (>40%)	
	72	Tree cover, needleleaved, evergreen, open (15-40%)	
	80	Tree cover, needleleaved, deciduous, closed to open (>15%)	Tree cover, needleleaved, deciduous, closed to open (>15%)
	81	Tree cover, needleleaved, deciduous, closed (>40%)	
	82	Tree cover, needleleaved, deciduous, open (15-40%)	
	90	Tree cover, mixed leaf type	Tree cover, mixed leaf type (broadleaved and needleleaved)
	100	Mosaic tree/shrub (>50%)/herbaceous cover (<50%)	Mosaic tree and shrub (>50%) / herbaceous cover (<50%)
	160	Tree cover, flooded, fresh or brackish water	Tree cover, flooded, fresh or brackish water
	170	tree cover, flooded, saline water	Tree cover, flooded, saline water
Grass-/Shrubland (3)	110	Mosaic herbaceous cover (>50%)/tree/shrub (<50%)	Mosaic herbaceous cover (>50%) / tree and shrub (<50%)
	120	Shrubland	Shrubland
	121	Evergreen shrubland	
	122	Deciduous Shrubland	
	130	Grassland	Grassland
Rainfed Agriculture (4)	10	Cropland (rainfed)	Cropland, rainfed
	11	Cropland, rainfed, herbaceous cover	
	12	Cropland, rainfed, tree/shrub cover	
	30	Mosaic cropland (>50%)/natural vegetation (<50%)	Mosaic cropland (>50%)/natural vegetation (<50%)
	40	Mosaic natural vegetation (>50%)/cropland (<50%)	Mosaic natural vegetation (>50%)/cropland (<50%)
Bare Land (5)	140	Lichens and mosses	Lichens and mosses
	150	Sparse vegetation (<15%)	Sparse vegetation (<15%)
	151	Sparse tree (<15%)	
	152	Sparse shrub (<15%)	
	153	Sparce herbaceous cover (<15%)	
	200	Bare areas	Bare areas
	201	consolidated bare areas	
	202	unconsolidated bare areas	
Wetlands (6)	180	shrub or herbaceous cover, flooded, fresh/saline/brackish water	Shrub or herbaceous cover, flooded, fresh/saline/brackish water
Urban areas (7)	190	Urban areas	Urban areas
Water bodies (8)	210	Water bodies	Water bodies

The original 37 respective 22 land cover types are reduced to a total number of eight land cover classes plus a no-data class, divided into the relevant land cover groups for the analysis (see Table 1). Thereby, it is assumed that irrigated land is used for all-year agriculture, and grassand shrubland is usable for pastoralism, whereas rainfed agricultural areas may be used for herding in the dry season.

Under the assumption that dry and bare lands expand due to the expected drying and desertification of the Sahelian zone, this trend could become visible in an increasing land cover for bare land. Simultaneously, an increasing area of agricultural and urban areas with a concurrent reduction in natural land areas such as forests and grasslands could be indicators for an increasing land pressure due to, for instance, the population growth in Nigeria, which would signify that human activities contribute more to land changes than climate change.

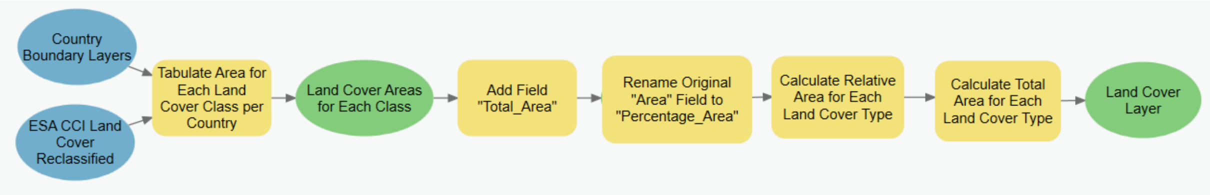


Figure 13: Simplified Workflow for the Calculation of the Total and Relative Areas for Each Reclassified Land Cover Type.

To obtain a general overview of land cover changes on a country level, the absolute and relative land type areas for the reclassified land types are subsequently calculated (see Figure 13). This allows for a first estimation of which periods caused most change regarding the land cover. Thus, certain reference years can be discarded for the following in-depth analysis of land cover change based on the second-order administrative regions.

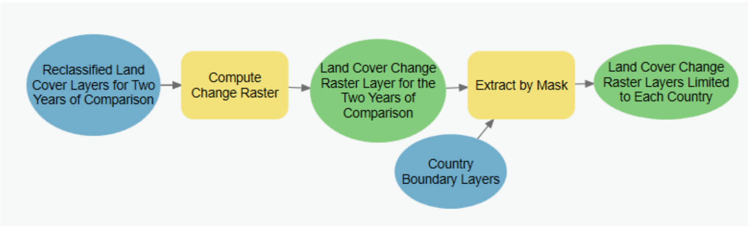


Figure 14: Simplified Workflow for the Creation of Land Cover Change Rasters for Each Country and Period of Comparison.

Therefore, the reclassified land cover layers are used for a change analysis. By computing change rasters (see Figure 14), quantitative conclusions regarding the changes across land cover groups between the different years can be made. Consequently, the direction of the changes becomes evident, thereby allowing for an overview of the causes for the changes. If land cover mostly changes to urban areas, urban and population growth can be considered the main factors for the change. If changes occur in the direction of bare land, soil depletion, soil degradation and desertification are among the likely factors. If grassland transforms into agricultural areas, an intensification and expansion of agricultural activities might be a reason for the land change.

Since the focus of the research is whether land change has an impact on the conflict between herdsmen and farmers, and based on the assumption that a reduction in arable and grazing areas contributes to the conflict, the land change analysis only focuses on transitions from grass- and shrublands, which are considered suitable herding areas, all-year agricultural areas, and rainfed agricultural areas as shared land between farmers and herders to another land cover type when computing the change rasters. This allows for quantitative and qualitative conclusions regarding land changes of these three land cover types by comparing Nigeria to Ghana. Consequently, questions, such as whether change from the three relevant land cover types to other types occur at higher percentages in Nigeria or in Ghana, can be answered.

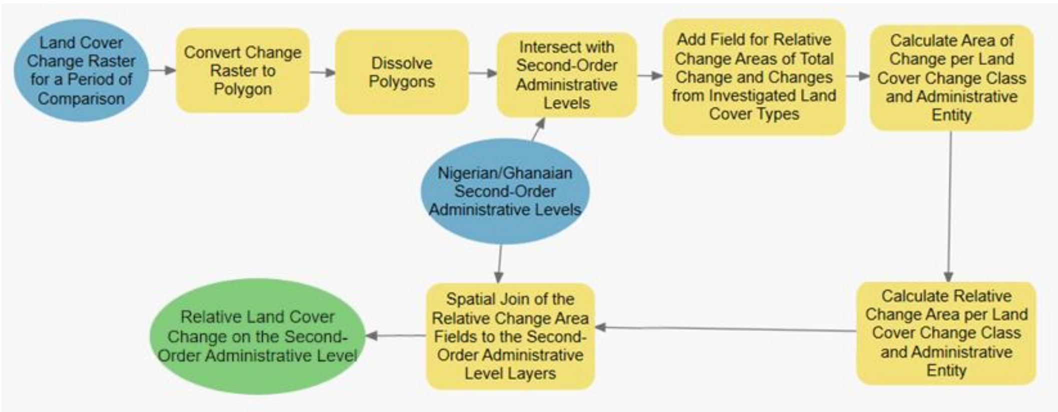


Figure 15: Simplified Workflow for the Calculation of Relative Land Cover Change Areas from the Investigated Land Cover Classes to Another Land Cover Class for one Period of Comparison.

In the last step of the land cover analysis, the land cover changes are quantified on a second-order administrative level (see Figure 15). Therefore, the raster layers are first converted to polygon layers based on the original land cover class. Then, the different polygons for each type are dissolved to the land cover change classes, so that a total of five polygons remains regarding changes from grass- and shrubland, from all-year agricultural areas, and from rainfed agricultural areas, as well as unchanged areas and the other unanalyzed land cover types. These polygons are then intersected with the second-level administrative areas, which creates a polygon layer that contains data on land change for each LGA or district. Based on these data, the absolute and relative land change area for each of the land cover type changes can be calculated. After spatially joining the layer containing the LGAs or districts with the relative land cover change data, a visualization of the LGAs or districts most affected by land cover change from one of the three relevant land cover types can be made. Additionally, the highest affected LGAs of the conflict can be compared to the average values of land change. This data can later also be used for the regression analysis.

As mentioned above, the visualized changes can also be caused by human activities such as urban growth and artificial conversion of natural land to agricultural land. Therefore, precipitation and temperature are two other factors of climate change that must be considered when analyzing climate change as a factor for the conflict between herdsmen and farmers in Nigeria.

The necessary data for these two factors are derived from datasets by the ESA Copernicus Climate Change Service (C3S) Climate Data Store (CDS) (Hersbach et al., 2019) and the Climatic Research Unit gridded Time Series (CRU TS) by the Climatic Research Unit of the University of East Anglia in Norwich (Harris et al., 2020). The C3S CDS dataset provides data on temperatures measured at 2m above the ground and the precipitation at a resolution of a 0.25° grid for the time period of 1979 to 2020 (Hersbach et al., 2019), while the CRU TS dataset also provides among others data on the number of wet days at a resolution of a 0.5° grid for the time period of 1901 to 2020 (Harris et al., 2020, pp. 1–3). Due to the temporal scale of the C3S CDS data of 41 years, CRU TS data on wet days will only be used for the period between 1971 and 2020, equaling to 50 years.

Even though the resolution of these two datasets is smaller than of the land cover datasets, the quality of the results should not be negatively impacted. As outlined in chapter 2.1, climate evolves on large spatial and temporal scales. Therefore, this higher resolution compared to the land cover data rather ignores very local rainfall events and temperature phenomena and considers the general trends on a scale approximately the size of individual LGAs and districts. Consequently, an analysis on changes in temperature and rainfall patterns outlines the general trends in the changes.

To visualize these changes in climatic factors, five steps are necessary (see Figure 16). After importing the multidimensional NetCDF raster layers, a trend raster can be generated by using a harmonic trend type. The Harmonic trend type is required since Nigeria experiences a yearly cyclical weather pattern of rainy and dry season. Therefore, a linear trend would unnecessarily generalize the occurring weather and climate conditions in Nigeria.

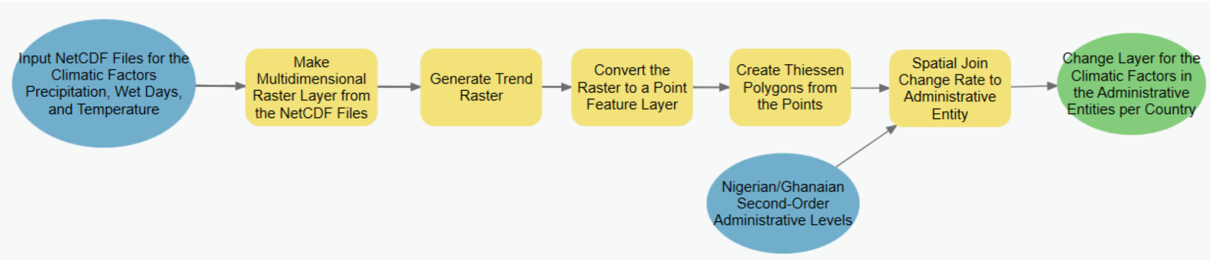


Figure 16: Simplified Workflow for the Calculation of Change Rates of Climate Factors.

The resulting trend raster layer must be further processed to allow for a spatial join with the polygon layer including the LGAs and districts. Therefore, the trend raster is transformed into a point layer. Since several smaller administrative areas might however not intersect with a point, the point layer is transformed into a Thiessen polygon layer. This allows for a spatial join of the administrative areas layers and the trend polygon layer. The result are layers containing the average change data for the investigated climate factors for each LGA or district. Consequently, the second-level administrative areas can be visualized in accordance with the change, which allows for the identification of the LGAs and districts that experienced the most change during the period after 1979. In case of a decrease in precipitation and an increase in average temperatures, it can be assumed that land cover changes can be influenced by climate change. A change in wet days can mean that precipitation occurs in less rainfall events with higher precipitation rates, thereby increasing the likeliness of extreme weather events.

To verify the influence of climate parameters on the conflict between herdsmen and farmers, a generalized linear regression (GLR) analysis is made as the last step of the analysis of climate factors for Nigeria. This allows for a statistical evaluation of the relevance of the climatic factors for the conflict. Therefore, the number of incidents in the conflict in the second-level administrative areas based on both the UCDP and CFR dataset are used for a hot spot-analysis using the Getis-Ord Gi* statistic (see Figure 17a and 17b). This allows for an evaluation of the statistically significant conflict areas for each conflict dataset. Consequently, the hot spot areas with a confidence level of at least 90% are classified as conflict areas, while all the remaining LGAs are non-conflict areas. Finally, this binary variable with the values “0” and “1” serves as the dependent variable. Accordingly, land cover change, precipitation change, temperature change, and the change in wet days are considered the independent variables.

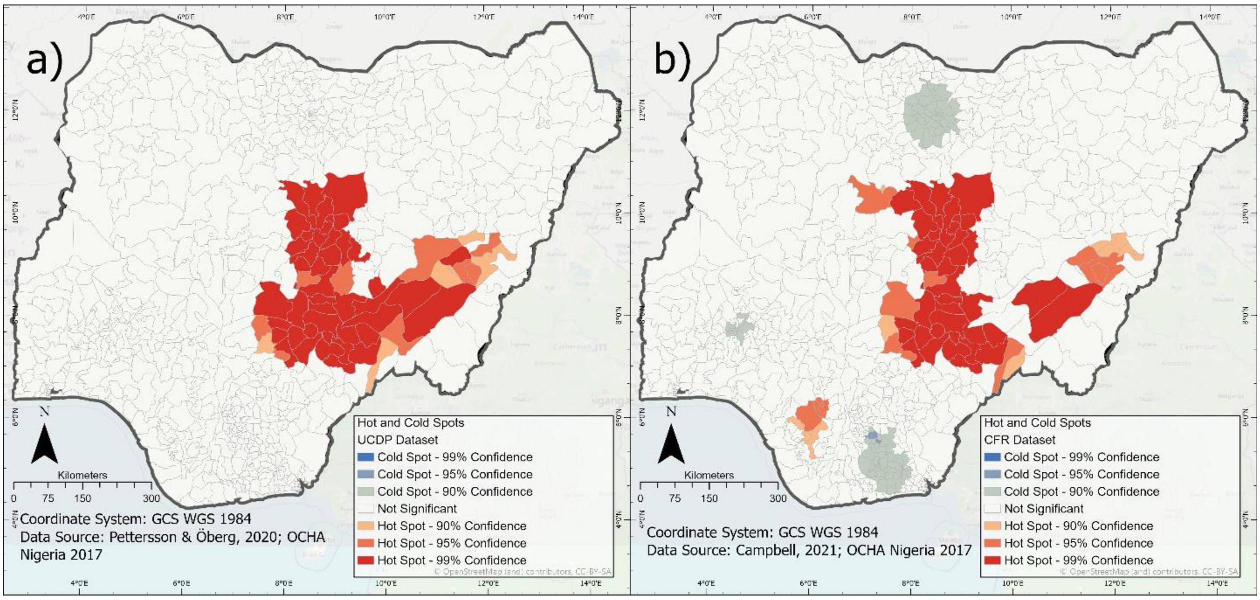


Figure 17: Hot and Cold Spots with Varying Confidence Levels of the Filtered a) UCDP Dataset and b) CFR Dataset.

In case of the precipitation, temperature and wet days, the layers comprising the average changes in each second-level administrative area can be reused. When it comes to the land cover change, a longer period of comparison than the five or ten years as done in the previous parts of the analysis is appropriate in order to consider the gradual character of land cover changes and its impacts on the affected communities. Since the conflict has increased in intensity since 2010, a comparison of land cover between a year before 2010 and the last available data from 2019 are preferred. In order to reuse already processed data, the next earlier comparison year 2000 will serve as the initial point of land cover change for the regression analysis. Thereby, land cover change is represented by the three explanatory variables of land change from all-year agricultural areas, grasslands, and rainfed agricultural areas.

3.3 Analyzing the Non-Climatic Factors of the Herdsmen-Farmers Conflict

In the second part of the analysis, the non-climate related factors are added to the GLR model. Thereby, the model is tested with a range of different combinations of variables. The aim thereby is to remove those variables from the model that do not add additional explanatory potential to the conflict and consequently to find a combination of statistically significant variables, which has the best explanatory potential for the conflict, just like an exploratory regression would automatically do for a continuous dependent variable (Braun & Oswald, 2011, pp. 331–332). Since the dependent variable will be the binary variable indicating conflict and non-conflict areas, an exploratory regression analysis is not possible.

Accordingly, several different factors are included in this part of the analysis. Dependent on the results of the regression analysis for the climatic factors, these factors will be included in this part of the analysis as well.

Among the other explanatory variables, population density and growth can be considered an important aspect contributing to conflict. As discussed in Chapter 1.2, the conflict between herdsmen and farmers in Nigeria is presumably caused by a changing environment disrupting the established agricultural system. In case of the population growth of Nigeria, it can be assumed that a growing population density exerts more stress on land, causing a higher risk for conflict about land use. Therefore, population growth per LGA is used as one variable for the regression model.

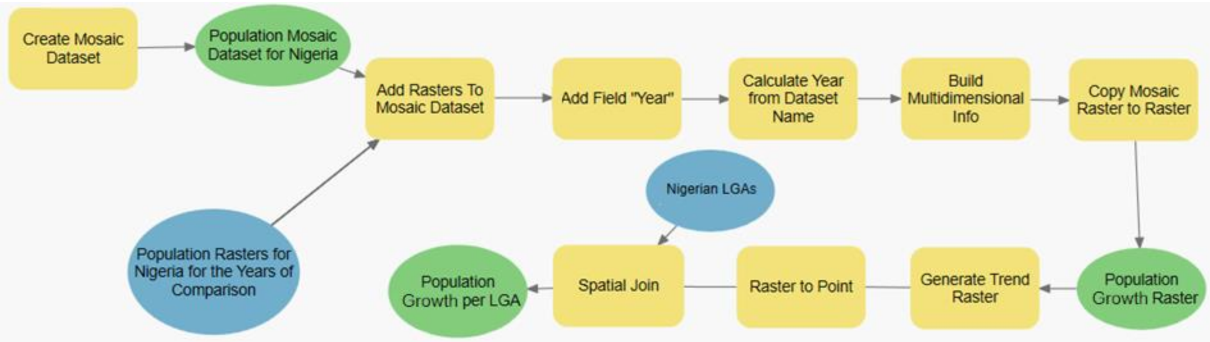


Figure 18: Simplified Workflow for the Calculation of the Population Growth per LGA.

Data are thereby derived from WorldPop (Bondarenko et al., 2020), including population count raster files at a resolution of 100m of Nigeria for the period between 2000 and 2020. Thereby, a multidimensional mosaic dataset consisting of the years 2000, 2005, 2010, 2015, and 2020 is created. Consequently, a trend analysis can be made (see Figure 18) similar to the ones performed for the temperature and rainfall variables in the previous subchapter. Therefore, a linear trend type is used, resulting in a raster layer on the changes in population count per pixel. Next, the raster is transformed into a point layer. This point layer can then be spatially joined with the LGA layer, resulting in the average annual population growth numbers for each LGA during the last 20 years.

Another variable linking to population is the relative urbanization rate of LGAs. It is assumed that people living in urban areas tend to be less dependent on agricultural production in order to generate sufficient income. Therefore, rather urban LGAs are expected to be negatively connected to the risk for conflict. The required data is provided by the ESA CCI Land Cover dataset (ESA, 2017; ESA, 2020), which is also used for the land cover change analysis. For this part of the analysis, the year 2015 as the most violent year in the conflict is used. Based on this, the urban areas are extracted from the land cover layer for 2015 and then transformed to polygons. After dissolving the polygons, the layer is intersected with the LGA layer, creating one polygon of the urban areas for each LGA. This allows for a calculation of the absolute and relative size of urban areas in the LGAs (see Figure 19).

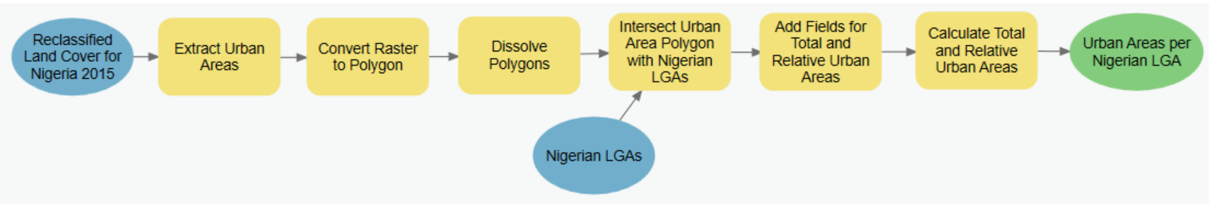


Figure 19: Simplified Workflow for the Calculation of the Relative Urban Areas per LGA.

A similar approach is chosen for the variable regarding the access to all-year water resources (see Figure 20). Based on the ESA CCI Land Cover dataset (ESA, 2017; ESA, 2020), the water bodies of 2015 are extracted from the land cover layer, before the area of the Atlantic Ocean is removed by extracting the inland water bodies. The resulting raster containing the assumed potable water areas are then transformed to a point feature before the distance from each LGA's boundary to the next water body can be calculated. By including the water resource variable, it is assumed that longer distances to water increase the risk of conflict. However, based on the resource abundance discussion in Chapter 2.2.2, the proximity to water areas can as well increase the competition about the right of use, thereby also increasing the risk for conflict.

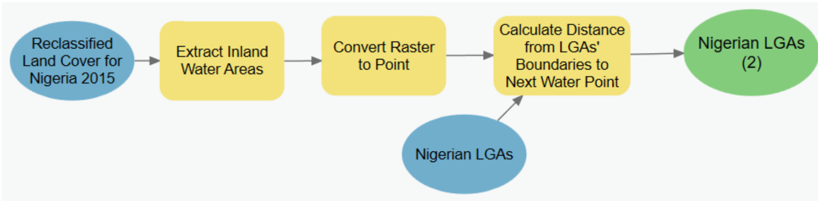


Figure 20: Simplified Workflow for the Calculation of the Distance to the Next Water Resource.

In this regard, the proximity and access to valuable natural resources such as oil and diamonds have to be considered as variables as well. With the use of the global petroleum (Lujala et al., 2007) and the diamond resource (Gilmore et al., 2005) datasets published by the Peace Research Institute Oslo, an analysis of the distance to these resources for each LGA is possible. Therefore, the polygon feature dataset comprising the onshore petroleum and the point feature dataset of the lootable diamond resources are used to calculate the average distance from each LGA to the next resource (see Figure 21). As it was discussed in Chapter 2.2.2, the proximity and access to valuable resources can possibly increase the risk for conflict, even though mineral resources are usually not considered a reason for the conflict between herdsmen and farmers in Nigeria.

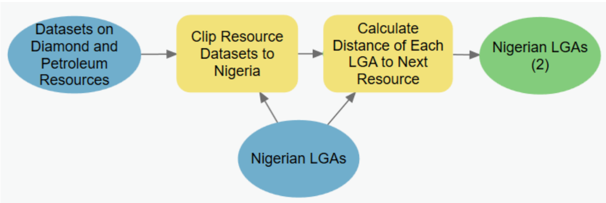


Figure 21: Simplified Workflow for the Calculation of the Distance from Each LGA to the Next Valuable Resource.

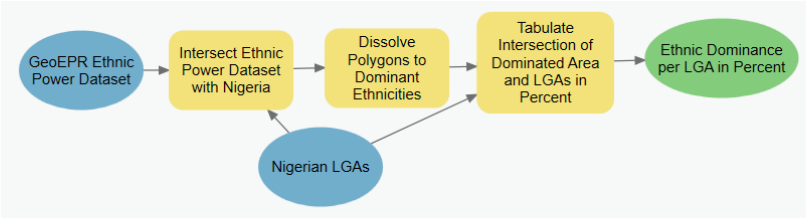


Figure 22: Simplified Workflow for the Calculation of the Ethnic Dominance per LGA in Percent.

Another important variable can be the ethnic dominance in an area. Based on the geo-referencing Ethnic Power Relations dataset (Vogt et al., 2015) and under the assumption that conflict is more likely in areas without a dominant ethnic group, the relative dominance per LGA is used as a variable for the regression analysis. The ethnic group polygon layer from the dataset is intersected with the LGA layer. This allows for the calculation of the total and relative areas of ethnic dominance within each LGA (see Figure 22). The relative values will then be used for the regression analysis.

The next variable is derived from a road network dataset of Nigeria's primary and secondary roads (OCHA Nigeria, 2018). As Buhaug and Rød state, road networks serve as the indicator of a variety of other factors contributing to conflict. For instance, the infrastructure tends to be less developed in areas, where also health conditions or employment rates are worse than in areas with a better developed infrastructure. Simultaneously, road networks are important for exercising state authority as well as trade, since they provide access to the rural areas, which would be harder to reach in case of few or only bad road connections (Buhaug & Rød, 2006, p. 319). Hence, roads serve as an indicator for their integration into the national, or even global economy as well as for the connection to state authorities.

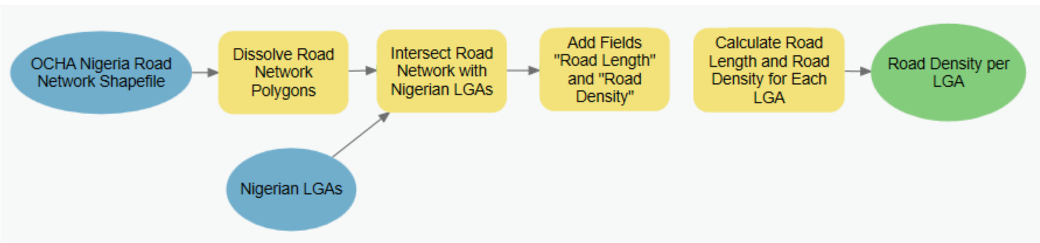


Figure 23: Simplified Workflow for the Calculation of the Road Density per LGA.

This variable is operationalized in road kilometers per square kilometer of the LGA area in order to consider the different sizes of the LGAs. Therefore, the road polyline feature is first dissolved to one polygon comprising the different road types of federal, regional primary, and regional secondary roads and then intersected with the LGA layer. This allows for a calculation of the total road length per LGA and consequently of the road density in road kilometers per square kilometer (see Figure 23).

In addition, the variables literacy rate and poverty rate, referring to incomes of less than $1.25 a day, are included. In terms of the literacy map (Bosco et al., 2017) and the poverty map (Tatem et al., 2013), datasets from the WorldPop database with a spatial resolution of approximately 1km are used. The literacy rate is based on data from 2013, while the poverty data is already from 2010. Since the year 2015 has been used for other variables, these two datasets should as well be suitable to analyze the causes for the conflict and especially for the increase in violence in 2015. Furthermore, it is rather unlikely that the data have significantly changed in a relative understanding since the creation of these datasets. Literacy rates serve as an indicator for the education levels, while poverty rates allow for conclusions regarding the income levels of the population. Thereby, it is assumed that higher rates of literacy are negatively connected to the conflict, whereas higher rates of poverty are expected to be positively connected to the conflict, because low education and income levels cause people to have low livelihood standards, for instance precarious, temporary working conditions, thereby making people dependent on direct access to food and water.

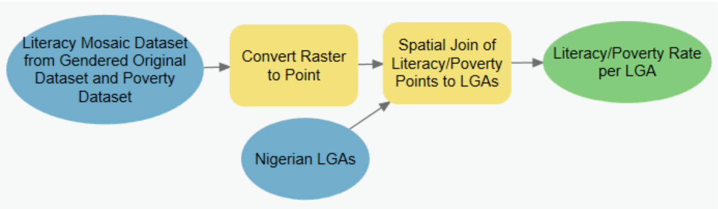


Figure 24: Simplified Workflow for the Calculation of Literacy and Poverty Rates per LGA.

In order to operationalize the data on literacy and poverty (see Figure 24), the raster layers are converted to point layers and then spatially joined to the LGA layers, while the mean value from the joined points is calculated. This results in layers containing the literacy and poverty rates for each LGA. For the operationalization of the literacy data, the literacy values for men and women must be combined by calculating the mean value, resulting in a cross-gender literacy rate layer.

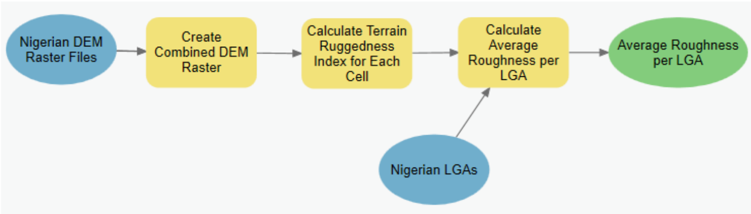


Figure 25: Simplified Workflow for the Calculation of the Average Terrain Roughness per LGA.

As outlined in Chapter 2.2.3, remote areas in mountainous and hard-to-reach areas can increase the risk for conflict. Therefore, a digital elevation model of Nigeria will be used to analyze the influence of mountainous terrain for the herdsmen-farmers conflict (see Figure 25). The underlying digital elevation model is derived from the ALOS World 3D - 30m dataset (Tadono et al., 2014) with its spatial resolution of 30m. Even though this is a digital surface model, including also objects on the ground, its resolution allows for a detailed analysis of the terrain roughness. The roughness of terrain can thereby be expressed by the Terrain Ruggedness Index, which results from the elevation change between one grid cell in a raster to its eight neighbor grid cells, calculated by the square root of the squared elevation differences to each neighboring grid cell (Riley et al., 1999).

The consequent ruggedness raster layer can then be used for the calculation of the average terrain ruggedness of each LGA (see Figure 25). Thereby, it is assumed that a rougher terrain is harder to reach and to control, which makes these areas less likely for governmental intervention, and which might provide incentives to solve controversies between herdsmen and farmers violently without mediation from governmental authorities. Simultaneously, too rough terrain is not suitable for intensive agriculture and herding, which might reduce the risk for conflict between herdsmen and farmers.

All these variables (see Table 2) will then be joined to the conflict layer. The resulting layer can then be used for the regression analysis, which is, as mentioned above, made for the data from the UCDP dataset and for the data from the CFR dataset with the incident values as the response variable. The spatial resolution thereby are the second-level administrative regions.

Table 2: Overview over the Dependent and Independent Variables in the Generalized Linear Regression Analysis.

Variable Type	Variable Name	Description	Unit	Value Range
Dependent Variable	ConflArea_CFR	Conflict Hotspots based on the CFR Dataset	dimensionless	0 (no conflict); 1 (conflict)
	ConflArea_UCDP	Conflict Hotspots based on the UCDP Dataset	dimensionless	0 (no conflict); 1 (conflict)
Exploratory Variable	Rel_Change_1	Relative Change Area from All-Year Agricultural Land between 2000 and 2019	% of the LGA's area	0.00% – 0.20%
	Rel_Change_3	Relative Change Area from Grass-/Shrubland between 2000 and 2019	% of the LGA's area	0.00% – 47.47%
	Rel_Change_4	Relative Change Area from Rainfed Agricultural Land between 2000 and 2019	% of the LGA's area	0.00% – 19.75%
	Temp_Change	Yearly Average Temperature Change between 1979 to 2020	K	0.000006 – 0.000081
	Precip_Change	Yearly Average Precipitation Change between 1979 to 2020	mm	-0.00000011 – 0.00000014
	WetDay_Change	Wet Days Change between 1971 to 2020	days per month	-0.00060 – -0.00011
	PopGrowth	Population Growth between 2000 and 2020	people per km^2	0.0024 – 7.5676
	Rel_UrbanArea	Relative Urban Area of the LGA in 2015	km/km^2	0% – 100%
	Water_Distance	Distance to the Closest Water Body (River, Lake)	km	0.000 – 85.852
	Resource_Dist	Distance to Valuable Resources (Diamonds, Oil)	km	0.000 – 805.677
	Dominance_Per	Relative Ethnic Dominance	% of the LGA's area	0% – 100%
	Road_Den	Road Density	km/km^2	0.00 – 0.81
	Poverty_Perc	Percentage of the Population Living in Poverty ($ 1.25)	% of the LGA's population	2.76% – 91.99%
	Literacy_Perc	Percentage of the Population Being Literate	% of the LGA's population	6.24% – 98.16%
	Roughness	Terrain Ruggedness Index Measuring Average Elevation Difference between LGA's Grid Cells	m	1.61 – 25.56

4 Connecting Climate Change and Conflict in GIS

Based on the theoretical background outlined in chapter 2 and the methodological approach described in chapter 3, the conflict between herdsmen and farmers in Nigeria can be further investigated regarding its causes. Before this is done, the geographic background of the research has to be given. Therefore, the next subchapter will further describe the research area of Nigeria and Ghana. After that, the influence of climate change on the conflict in Nigeria will be worked out in comparison to Ghana. Subsequently, the other factors of conflict (Chapter 3) will be included in the analysis. The chapter then concludes with a discussion of the results of the analysis.

4.1 The Research Area

Both Ghana and Nigeria belong geographically to Western Africa. According to the United Nations data service, Nigeria has a surface area of 923,768 km^2 and a population of 206 million people in 2020, which equals to a population density of 226.3 inhabitants per km^2. The capital is Abuja (UNdata, 2020b). Bordering countries are Benin, Niger, Chad, and Cameroon.

Ghana, which borders to the Ivory Coast, Burkina Faso, and Togo, has a surface area of 238,537 km^2 and a population of 31 million people in 2020. Therefore, the population density is 136.6 inhabitants per km^2. The capital and largest city is Accra (UNdata, 2020a).

Climate-wise, the two countries show certain similarities according to the latest Köppen-Geiger climate classification maps. Both bordering to the Atlantic Ocean in the South, the southern areas of the countries show predominantly tropical monsoon climate, which changes to tropical savannah climate further north. Due to Nigeria stretching slightly further south than Ghana, the southernmost part of Nigeria has a tropical rainforest climate. Since Nigeria also stretches further north than Ghana, the northern areas of Nigeria have an arid, hot steppe climate or, in the case of the Northeast, an arid, hot desert climate. The Middle-Belt, however, is located in the tropical savannah climate zone (Beck et al., 2018).

Temperatures in Ghana are generally relatively high with about 26 to 32 degrees Celsius in the southern rainforest region and up to 43 degrees Celsius in the North of the country, especially during the dry season between November and April, when dry trade winds, known as the Harmattan, reach the country. During the rainy season, which lasts with geographic variations from May to September, rainfalls range from 762 millimeters in the North to 2032 millimeters in the Southwest (Gocking, 2005, p. 2). The temperatures and rainfall in Nigeria are comparable to those in Ghana. Rainfalls also increase from north to south with a rainy season lasting from May to October and the influence of Harmattan in the dry season during the other half of the year (Falola & Heaton, 2009, p. 2).

In terms of history, Ghana and Nigeria share certain common features. Starting from the late nineteenth century, the British colonialized the area that should become Nigeria at independence in 1960. In 1914, the current borders where set, when the British rulers merged the colonial protectorates to a unified colonial territory. In this colonization process, the former independent states and independent local communities, which have existed in the region for many centuries, were brought under control under a British system of governing through the already established indigenous institutions. After independence as a federal republic in 1960, the country experienced several violent conflicts over power, domination, secession, and resources. This political instability is created by a politicization of the regional, ethnic, and religious identities, escalating into a civil war between 1967 and 1970. During several periods since independence, the country was under military rule, making military coups a regular phenomenon in Nigeria’s recent history (Falola & Heaton, 2009, 6–9). In 1999, the current Fourth Republic was established, which signified a contemporary end to the regular military coups d’état (Falola & Heaton, 2009, p. 235).

In Ghana, regional independent states began to emerge from the tenth century onwards. By the 18th century, most of the northern parts of the areas belonging to the contemporary Ghanaian state were dominated by the Asante Confederacy. The south was soon colonized by Europeans. Beginning with the Portuguese, who built first trading posts as early as at the end of the 15th century, other European nations, such as the British, followed. In 1902, the British established a united colonial protectorate comprising the areas west of the Volta. After independence in 1957 and the establishment of Ghana as a republic in 1960, the country also experienced several military coups. After the elections in 1992, the Fourth Republic of Ghana has been proclaimed, initiating a democratic period lasting until current times (Gocking, 2005, 11–14).

The Nigerian economy became highly dependent on the oil revenues since independence. Oil production initially began in the late 1950s and rapidly rose during the 1970s' "oil boom", making Nigeria the leading oil exporter in Africa. Nevertheless, the revenues never benefitted the whole country, but only the elites due to a considerable mismanagement of public funds, according to Falola and Heaton. A smaller relevance has the export of agricultural products such as palm oil, cocoa, groundnut, and cotton. The extraction and export of minerals such as tin and coal also have certain relevance for the Nigerian economy (Falola & Heaton, 2009, pp. 10–12).

In contrast to Nigeria, Ghana is less dependent on one single export resource. Until the 2000s, the most important export products were gold, cocoa, and palm oil, and, to lesser extent, diamonds (Gocking, 2005, 3–8). In 2007, the Jubilee oil field off the Ghanaian coast was discovered. Since then, other considerable oil fields have been found, making oil an emerging significant resource for the Ghanaian economy (Obeng-Odoom, 2013, pp. 658–659). With the beginning of the oil production in 2011, the Ghanaian Government also passed the Petroleum Revenue Management Act, which, unlike in Nigeria, aims at financing development projects from the oil revenues all over the country (Ogbe & Lujala, 2021).

The Nigerian population is very diverse. More than 200 different ethno-linguistic groups exist in the country. However, the three groups of the Hausa, Yoruba, and Igbo dominate the country, each comprising approximately 20% of the population. Resulting from this ethnic diversity, also over 250 different languages exist in the country. In terms of religion, Sunni Islam and Christianity are with 50% respectively 40% the two dominant religions in the country. As outlined in Chapter 1.1, the North is thereby dominated by Muslims, while the population in the South is mostly Christian (Falola & Heaton, 2009, pp. 4–5).

Ghana is less diverse in ethnic and religious groups. With almost half of the population being of Akan descent, the Akan languages also constitute the most important languages. Other larger groups are the Mole-Dagbani with 16% of the population and the Ewe with 13%. In terms of religion, the different forms of Christianity make up about two thirds of the population. The Islam plays a central role in the North of the country, making it the second-most important religion with about 16% of the countrywide population (Gocking, 2005, pp. 8–11).

4.2 Influence of Climate Change on Conflict in Nigeria

In accordance with the climatic zones, the geographical characteristics of Nigeria can be described as trichotomous. The North is characterized by the savannah plains and semi-desert Sahel areas in the extreme North, while the southern areas consist of vast forests. In between these two zones, the middle belt forms a hilly transition zone between the North and South (Falola & Heaton, 2009, p. 2). Ghana has a similar geographic characteristic. Different types of rain forests are the dominant land cover in the southern parts, while the North primarily consists of savannah woodlands (Gocking, 2005, p. 2). A distinct semi-desert zone does not exist in Ghana due to the lesser land expansion to the north compared to Nigeria. The following subchapter will analyze how these characteristics changed during the last decades to analyze whether climate change contributes to the herdsmen-farmers conflict.

4.2.1 Comparing Land Cover Change in Nigeria and Ghana between 1992 and 2019

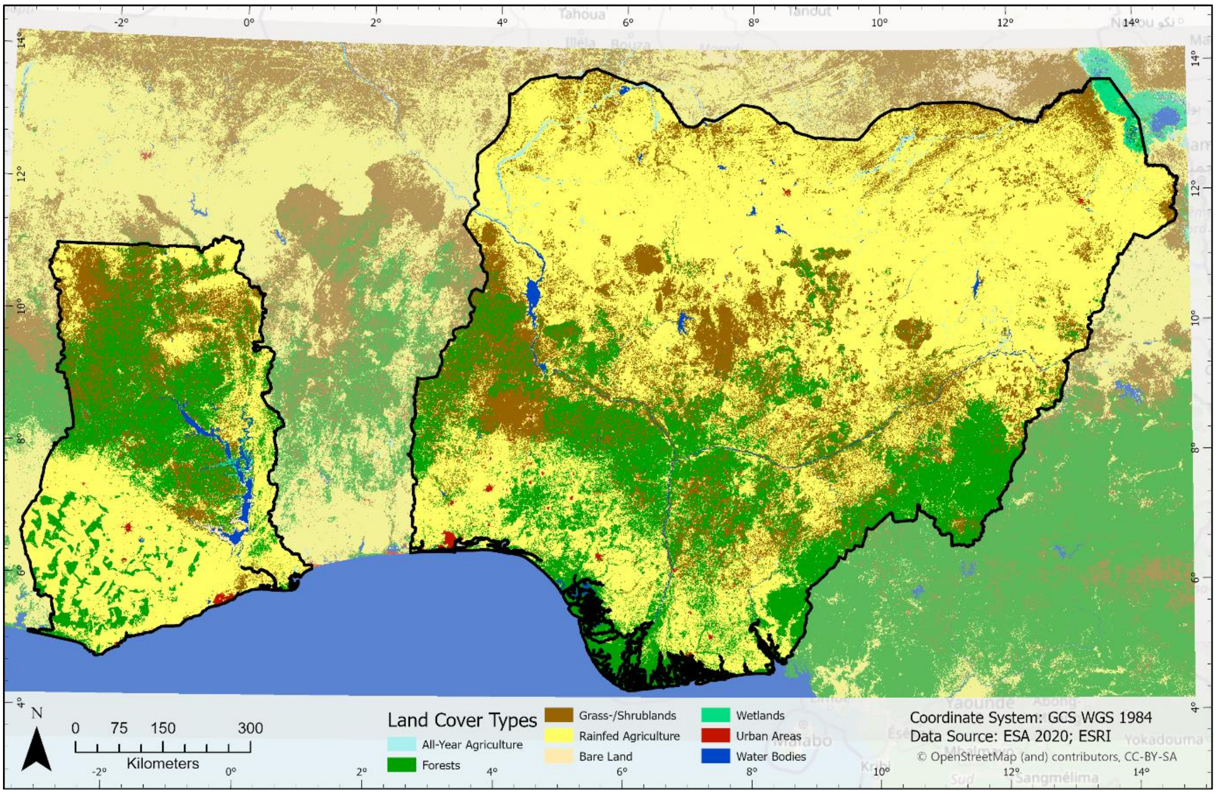


Figure 26: Land Cover of Nigeria and Ghana in 1992.

As becomes evident from the land cover maps of 1992 (see Figure 26), large areas of Ghana's South and Nigeria's North are used for rainfed agriculture. All-year agricultural farming is mostly exercised along the rivers in Northern Nigeria, whereas in Ghana, this type of agriculture is limited to a few areas near Lake Volta. Especially the North of Ghana and the Middle Belt region in Nigeria consist of forests and grass- and shrublands. In relative numbers, Nigeria's land cover consisted to almost 60% of rainfed agricultural areas and to almost 20% of both forests and grasslands including shrublands in 1992 (see Table 3). Ghana had a slightly lower share in rainfed agricultural areas, but a higher percentage in forest areas (see Table 4).

Table 3: Relative and Total Land Cover Type Areas in Nigeria.

Land Cover	*1992*		*2000*		*2010*		*2015*		*2019*	
	Area (%)	*Area (km²)*	*Area (%)*	*Area (km²)*	*Area (%)*	*Area (km²)*	*Area (%)*	*Area (km²)*	*Area (%)*	*Area (km²)*
All-year Agriculture	0.71 %	6,556.75	0.75 %	6,978.47	0.77 %	7,087.61	0.77 %	7,085.71	0.76 %	7,056.57
Forests	19.18 %	177,192.59	20.18 %	186,429.83	20.96 %	193,590.02	21.00 %	194,067.54	22.23 %	205,388.01
Grass-/Shrublands	19.39 %	179,115.07	16.47 %	152,150.13	13.27 %	122,556.90	12.78 %	118,053.19	12.01 %	110,918.05
Rainfed Agriculture	59.10 %	545,921.68	60.94 %	562,965.86	63.08 %	582,729.19	63.36 %	585,321.47	62.74 %	579,618.05
Bare Lands	0.08 %	694.00	0.07 %	630.57	0.09 %	797.81	0.09 %	796.67	0.11 %	1,021.81
Wetlands	0.43 %	3,949.81	0.42 %	3,896.95	0.44 %	4,020.47	0.44 %	4,035.52	0.43 %	3,991.33
Urban Areas	0.27 %	2,461.05	0.31 %	2,861.14	0.56 %	5,212.00	0.71 %	6,530.09	0.83 %	7,702.57
Water Bodies	0.85 %	7,877.04	0.85 %	7,855.04	0.84 %	7,774.00	0.85 %	7,877.81	0.87 %	8,071.62

Table 4: Relative and Total Land Cover Type Areas in Ghana.

Land Cover	*1992*		*2000*		*2010*		*2015*		*2019*	
	Area (%)	*Area (km²)*	*Area (%)*	*Area (km²)*	*Area (%)*	*Area (km²)*	*Area (%)*	*Area (km²)*	*Area (%)*	*Area (km²)*
All-year Agriculture	0.07 %	162.17	0.07 %	163.30	0.07 %	175.71	0.07 %	176.65	0.07 %	173.83
Forests	30.27 %	72,212.03	32.66 %	77,901.90	35.27 %	84,120.80	35.33 %	84,276.58	37.11 %	88,512.79
Grass-/Shrublands	20.37 %	48,594.29	17.16 %	40,922.96	13.91 %	33,169.84	13.35 %	31,840.47	12.17 %	29,030.84
Rainfed Agriculture	46.21 %	110,228.71	46.79 %	111,615.15	47.16 %	112,492.97	47.42 %	113,107.82	46.68 %	111,358.49
Bare Lands	0.47 %	1,111.63	0.02 %	47.57	0.02 %	38.92	0.02 %	46.35	0.02 %	58.76
Wetlands	0.31 %	732.65	0.05 %	127.67	0.04 %	103.98	0.02 %	44.09	0.02 %	43.90
Urban Areas	0.43 %	1,032.38	0.54 %	1,284.15	0.81 %	1,928.90	0.96 %	2,279.86	1.09 %	2,611.73
Water Bodies	1.87 %	4,459.12	2.71 %	6,470.29	2.73 %	6,501.88	2.83 %	6,761.17	2.83 %	6,742.65

It is certainly the areas dominated by rainfed agriculture that experience the most transformations already until 2000 (see Figure 27). Former grass- and shrublands, which could serve as natural pastures for the cattle, are transformed into rainfed agricultural areas in Nigeria. This is mostly in areas already dominated by rainfed agriculture. In the forest areas of Northern Ghana and the Nigerian Middle Belt, grass- and shrublands are rather transforming into forest as well. Larger areas, which consist of coherent grass- and shrublands, remain however unchanged both in Ghana and Nigeria. Consequently, grass- and shrublands reduce the most in both Ghana (see Table 4) and Nigeria (see Table 3), while mainly rainfed agricultural areas as well as forests expand.

The considerable increase in water areas in Ghana between 1992 and 2000 is caused by changes in the land cover type of areas, which are part of the Lake Volta basin. This man-made lake contributes a major part of the water areas in Ghana. While certain areas are described as bare lands and wetlands in the CCI land cover for 1992 (see Figure 11), these areas are attributed to the water areas for the land cover in 2000 (see Figure 12). The cause for this change might be in low water levels of the lake in 1992 or an erroneous land cover classification in this part. Consequently, the reduction in bare lands and wetlands between 1992 and 2000 in the land cover maps for Ghana is also caused by this issue.

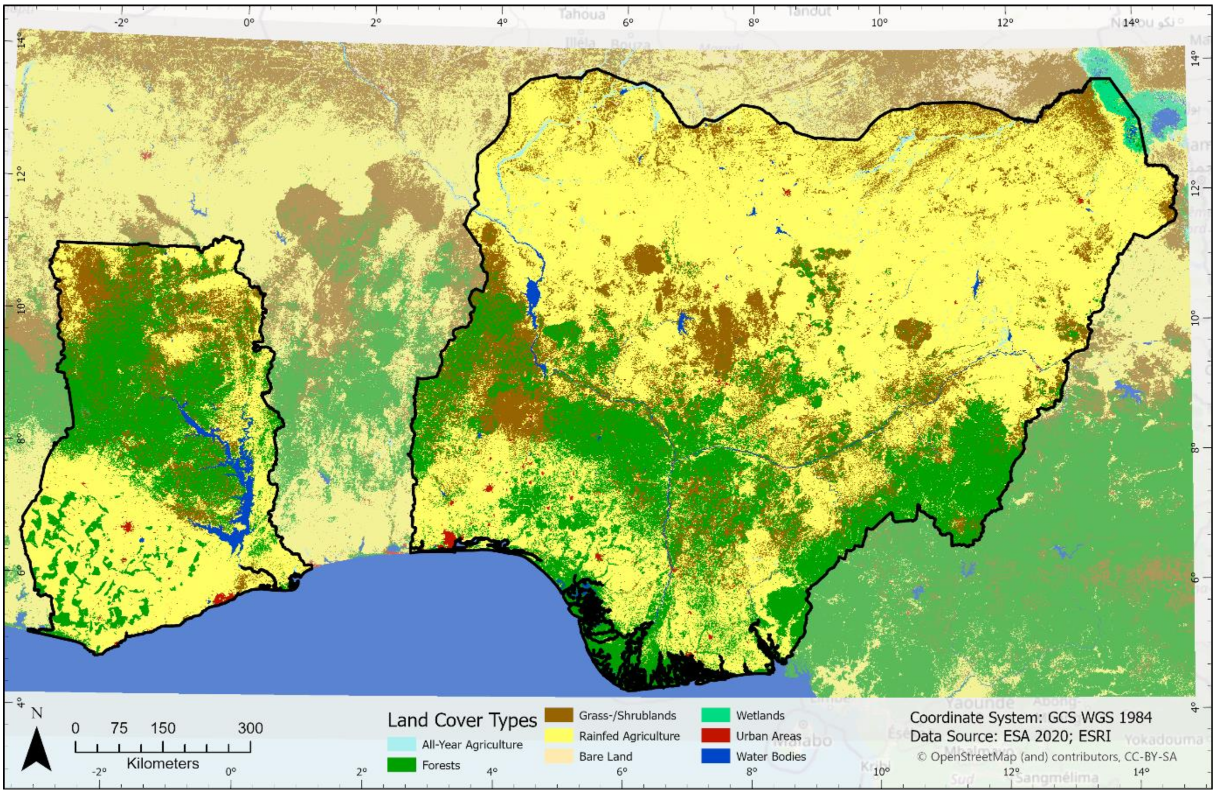


Figure 27: Land Cover of Nigeria and Ghana in 2000.

Between the years 2000 and 2010, the earlier trends seem to continue for the most part (see Figure 28, Tables 3 and 4). Nevertheless, larger grass- and shrubland areas are challenged by a further expansion of rainfed agricultural areas, resulting in a loss of grass- and shrubland along the outer edges. In addition, the expansion of urban areas at the cost of mostly rainfed agricultural areas becomes evident during this period. Especially in Nigeria's Southwest, several urban areas grow rapidly.

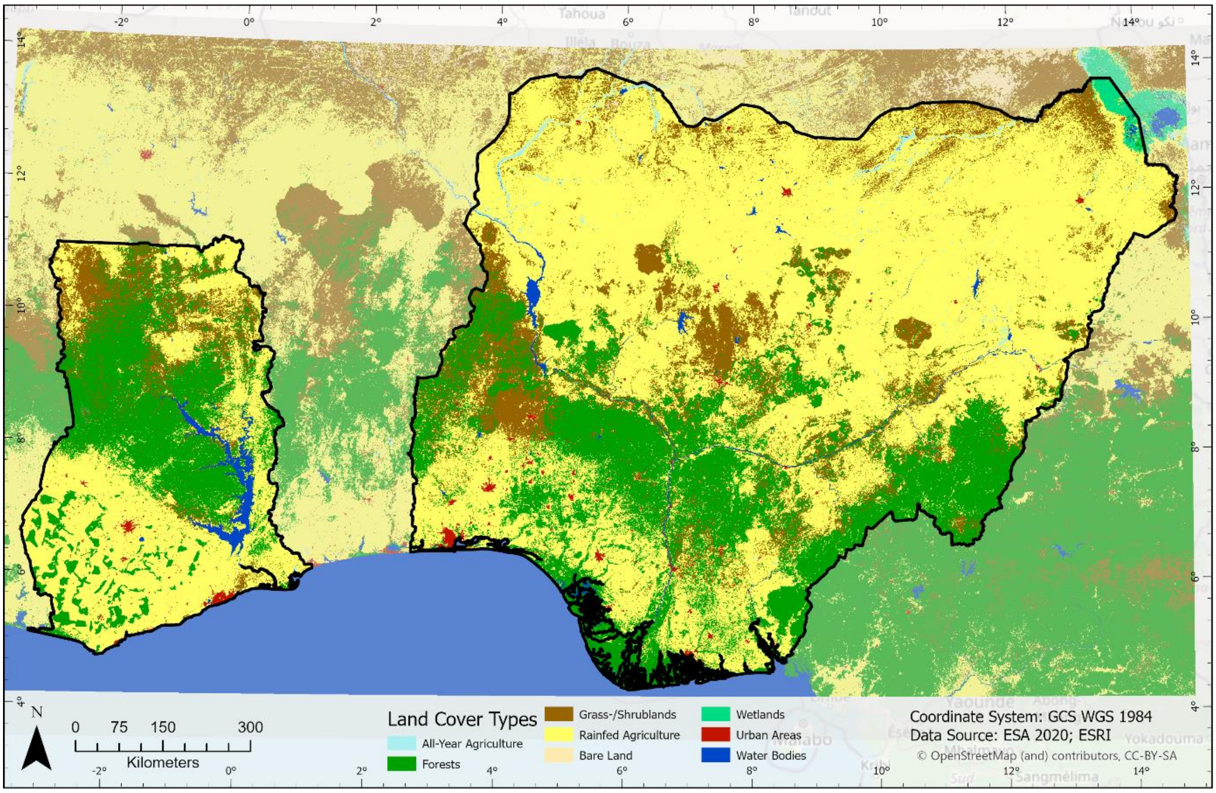


Figure 28: Land Cover of Nigeria and Ghana in 2010.

Also during the next five years until 2015, all these trends continue (see Tables 3 and 4), even though at smaller rates at first sight as a consequence of the shorter timeframe. Small areas of grass- and shrublands are transforming into the locally more dominant land cover types of either rainfed agricultural areas or forests, while large areas of grass- and shrublands remain mostly unchanged (see Figure 29). Moreover, urban areas continue to expand in both countries. Most apparent is certainly the creation of a new lake in central Ghana close to the border to the Ivory Coast. This is caused by the construction of Bui Dam, which was commissioned in 2013 and caused the creation of an artificial water reservoir (Owusu et al., 2019, pp. 490–491).

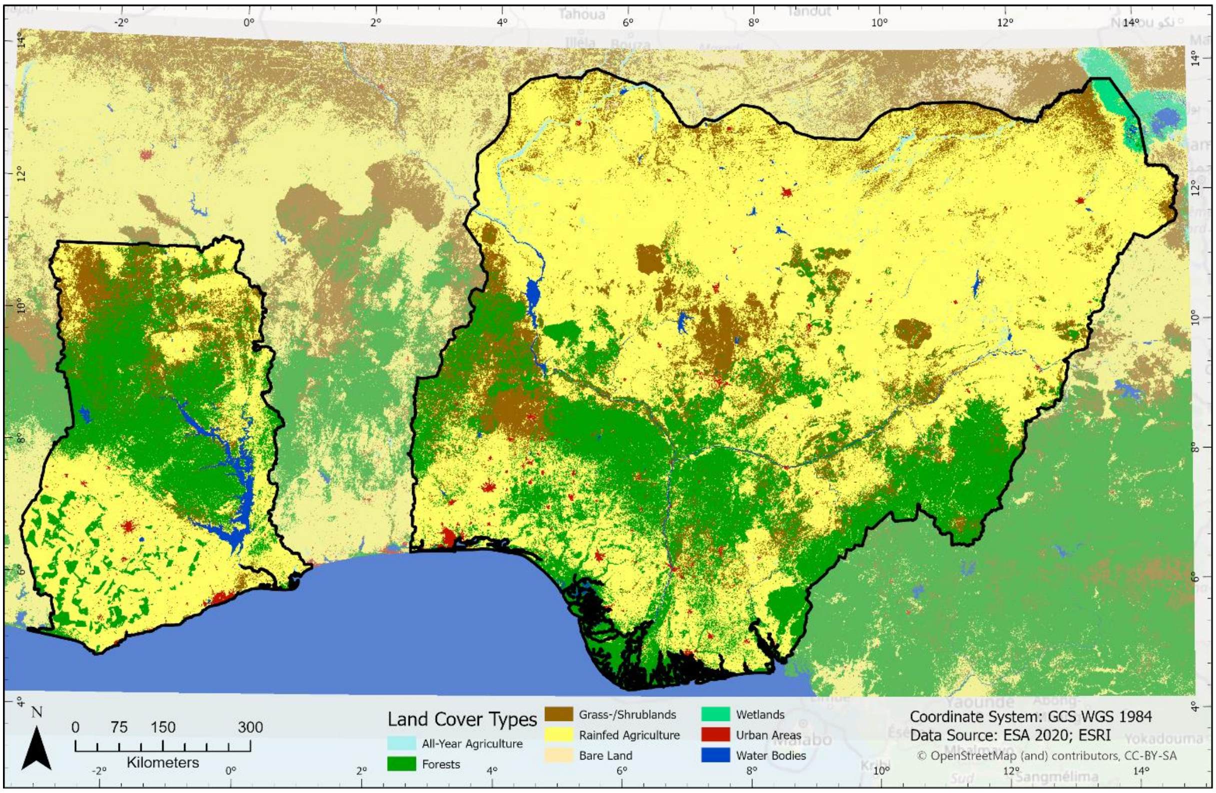


Figure 29: Land Cover of Nigeria and Ghana in 2015.

The transformations until 2019 show a slightly different pattern than the years before in Nigeria, while the most trends remain in Ghana (see Figure 30). In both countries, forests and urban areas continue to expand, whereas grass- and shrublands reduce. In addition, rainfed agricultural areas also experience a decline in their relative areas (see Tables 3 and 4). All-year agricultural areas remain at relatively constant levels throughout the entire period. In Nigeria, new forest areas mainly surface in the North of the country, while grass- and shrublands predominantly get replaced by forests and rainfed agricultural areas in Central Nigeria. In addition, a bare, desert-like area gets visible in the far Northwest of the country. This might be an indicator for a progressing desertification in the northern parts of Nigeria. Since the land cover maps for 2019 are not part of the original land cover maps covering 1992 to 2015, these changes might also be due to a slightly different classification in the 2019 land cover data.

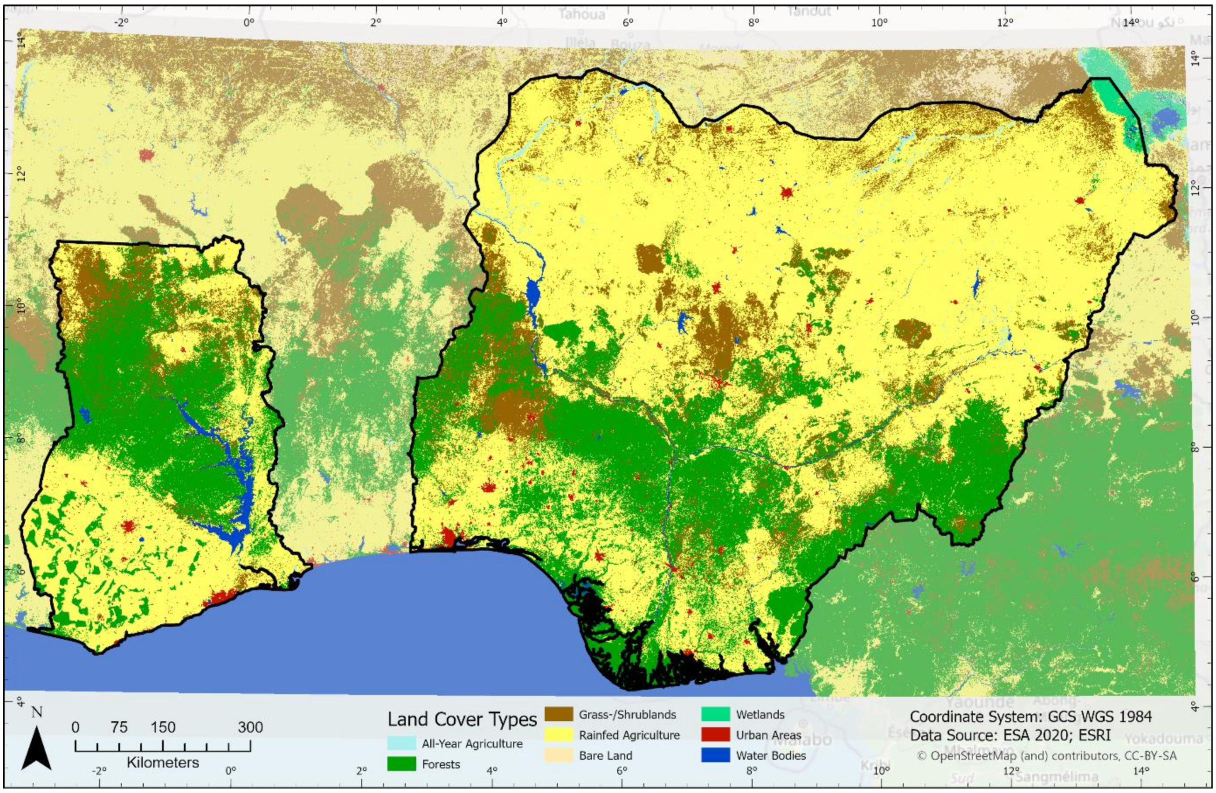


Figure 30: Land Cover of Nigeria and Ghana in 2019.

The tables 5 and 6 visualize the quantitative directions of the land cover changes from the three relevant land cover types of all-year agriculture, grass-/shrublands and rainfed agriculture.

In both Nigeria and Ghana, land changes from the three investigated original land cover types usually occur from grass- and shrublands to other land cover types with values of 70 to 90% of the investigated land cover changes for all the periods except for 2015 to 2019, when the numbers decline to 47% in Nigeria and 51% in Ghana. Change usually occurs to rainfed agriculture in Nigeria, but with declining numbers. In Ghana, grass- and shrublands rather change to forests, while changes to rainfed agriculture only make up 13% to 23% except for the period between 2010 and 2015, when the relative change increases to almost 58%. However, some of the change to forests is explained by the reclassification of the original land cover classes. Since grass- and shrublands include less dense forest areas, these areas can become part of the forest classification, when the threshold for the density is surpassed due to a more heavily vegetated forest.

Table 5: Relative Comparison of Land Cover Change Directions in Nigeria from the Land Cover Types All-Year Agriculture, Grass-/Shrublands, and Rainfed Agriculture

Relative Land Cover Change	*1992-2000*	*2000-2010*	*2010-2015*	*2015-2019*
From all-year agriculture (1) …	**0.007 %**	**0.055 %**	**0.269 %**	**0.319 %**
... to forests (2)	< 0.001 %	0.001 %	0.025 %	0.178 %
... to grass-/shrublands (3)	0.003 %	0.021 %	0.084 %	0.064 %
... to rainfed agriculture (4)	-	-	-	-
... to bare lands (5)	-	-	-	-
... to wetlands (6)	-	-	-	-
... to urban areas (7)	0.004 %	0.033 %	0.091 %	0.039 %
... to water bodies (8)	-	-	0.069 %	0.038 %
From grass-/shrublands (3) …	**89.390 %**	**85.168 %**	**71.803 %**	**47.361 %**
... to all-year agriculture (1)	1.221 %	0.304 %	0.231 %	0.160 %
... to forests (2)	26.060 %	22.842 %	11.753 %	28.757 %
... to rainfed agriculture (4)	61.703 %	60.469 %	57.558 %	16.629 %
... to bare lands (5)	0.066 %	0.461 %	0.139 %	1.234 %
... to wetlands (6)	-	-	-	-
... to urban areas (7)	0.237 %	0.970 %	2.040 %	0.419 %
... to water bodies (8)	0.103 %	0.122 %	0.082 %	0.162 %
From rainfed agriculture (4) …	**10.603 %**	**14.776 %**	**27.930 %**	**52.469 %**
... to all-year agriculture (1)	-	< 0.001 %	-	-
... to forests (2)	5.929 %	7.094 %	6.495 %	38.330 %
... to grass-/shrublands (3)	3.916 %	3.219 %	7.533 %	8.286 %
... to bare lands (5)	-	< 0.001 %	-	0.002 %
... to wetlands (6)	-	-	-	0.002 %
... to urban areas (7)	0.689 %	4.457 %	13.406 %	5.553 %
... to water bodies (8)	0.069 %	0.006 %	0.496 %	0.148 %

Table 6: Relative Comparison of Land Cover Change Directions in Ghana from the Land Cover Types All-Year Agriculture, Grass-/Shrublands, and Rainfed Agriculture

Relative Land Cover Change	*1992-2000*	*2000-2010*	*2010-2015*	*2015-2019*
From all-year agriculture (1) …	**0.027 %**	**0.034 %**	**0.146 %**	**0.090 %**
... to forests (2)	0.020 %	0.022 %	0.128 %	0.079 %
... to grass-/shrublands (3)	-	0.003 %	-	0.002 %
... to rainfed agriculture (4)	-	-	-	-
... to bare lands (5)	-	-	-	-
... to wetlands (6)	-	-	-	-
... to urban areas (7)	0.007 %	0.009 %	0.018 %	0.009 %
... to water bodies (8)	-	-	-	-
From grass-/shrublands (3) …	**88.601 %**	**79.097 %**	**73.858 %**	**51.235 %**
... to all-year agriculture (1)	0.039 %	0.149 %	0.183 %	0.045 %
... to forests (2)	73.385 %	56.030 %	9.387 %	35.431 %
... to rainfed agriculture (4)	13.382 %	22.512 %	57.950 %	15.400 %
... to bare lands (5)	0.002 %	0.005 %	0.035 %	-
... to wetlands (6)	-	0.001 %	-	-
... to urban areas (7)	0.163 %	0.272 %	0.418 %	0.329 %
... to water bodies (8)	1.630 %	0.128 %	5.885 %	0.030 %
From rainfed agriculture (4) …	**11.372 %**	**20.869 %**	**25.995 %**	**48.675 %**
... to all-year agriculture (1)	-	-	-	-
... to forests (2)	6.129 %	14.521 %	7.864 %	41.011 %
... to grass-/shrublands (3)	0.228 %	0.767 %	3.350 %	2.160 %
... to bare lands (5)	-	0.006 %	-	0.002 %
... to wetlands (6)	-	-	-	-
... to urban areas (7)	2.258 %	5.445 %	14.696 %	5.476 %
... to water bodies (8)	2.757 %	0.130 %	0.085 %	0.026 %

Changes from grass- and shrubland to urban areas are of less importance. While peaking at 2% in Nigeria during the period between 2010 and 2015, the numbers usually range below 1%. In Ghana, the numbers are generally even below 0.5%. In contrast, changes from rainfed agricultural areas to urban areas make up a larger part of the total land cover changes with up to almost 15 percent in Ghana between 2010 and 2015.

Just as with the transformations from grass- and shrublands, larger changes to forests also occur from rainfed agriculture. Ranging from 6% to 7% during the first periods of comparison, the changes reach more than 38% between 2015 and 2019 in Nigeria. Similarly, Ghana experiences 41% change to forests between the same period, whereas the numbers remained at six to 14.5% during the earlier periods of comparison.

In general, land cover changes from rainfed agriculture show an inverted trend compared to changes from grass- and shrubland. While the numbers are relatively low in the first period of comparison with 10.6% in Nigeria and 11.4% in Ghana, the numbers increase to 52.5% in Nigeria and 48.7% in Ghana for the last period, which is mainly due to the above-mentioned changes to forest areas. An increasing trend is thereby also visible in changes from rainfed agricultural areas to grass- and shrublands.

Both changes to bare land and from all-year agricultural areas only matter to a little extent in both countries during the periods of comparison with numbers of less than 1% of the investigated land cover changes for each period. The little changes from all-year agricultural areas are also explained by the low extent of all-year irrigation farming areas, as outlined earlier in this chapter.

The next part of the analysis refers to the spatial distribution of these changes during the different periods of comparison. Therefore, the relative percentage of land cover change within the different second-order administrative divisions for the two original land cover types rainfed-agricultural areas and grass- and shrublands are investigated. Due to the low extent of all-year irrigation farming, this land cover change is of less relevance and will therefore not be considered.

As discussed above, changes in grass- and shrubland are the most common land changes among the investigated original land cover types. Simultaneously, these areas are the most important grazing areas for the cattle herds. If these land changes from grass- and shrubland to the other land types mainly occur in the affected regions of the Middle Belt, a connection to the conflict has to be considered. This will later be investigated in the OLS regression analysis.

Figure 31 shows the relative land change of former grass- and shrublands in percent on the basis of the Nigerian LGAs and the Ghanaian districts for the four periods of comparison. Due to the shorter periods of time between 2010 and 2015 as well as between 2015 and 2019, the value classes were halved in order to consider the differences in the time periods. Because of the different sizes in the areas of the second-order administrative divisions, relative values are given, which allows for a better comparison of the different areas.

During the first two periods (see Figures 31a and 31b), changes in grass- and shrublands mostly occur in LGAs of central Nigeria at change rates of up to 28.7 % of the LGA’s total area. Especially in the period from 2000 to 2010, the focus of change in Nigeria is in the states of Kogi, Enugu, and Benue, with the latter one being the most affected state in the herdsmen-farmers conflict, according to both the CFR and UCDP datasets. During the same periods in Ghana, grass- and shrubland transformations are spatially concentrated to Western and Central Ghana with change rates partly reaching more than 20%.

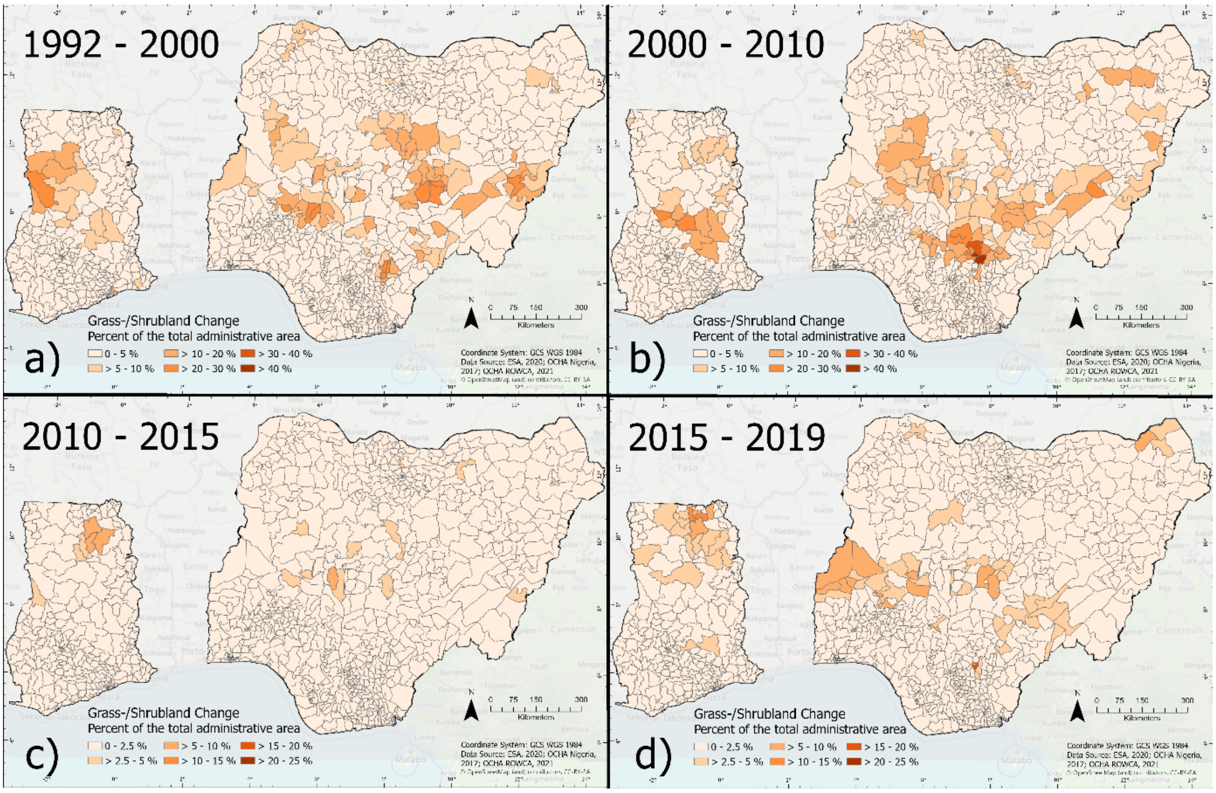


Figure 31: Relative Grass- and Shrubland Change per LGA and District during the Periods a) 1992 to 2000, b) 2000 to 2010, c) 2010 to 2015, and d) 2015 to 2019.

During the next five years (see Figure 31c), transformations of grass- and shrublands are occurring less frequently. Only a few LGAs, which are again mostly located in central Nigeria, experience a change rate of between 2.5% and 10% of their total area. In Ghana, a similar trend is visible. Only six of the 260 districts have change rates of more than 2.5%. Five of them are thereby concentrated in the northeastern part of the country.

During the period between 2015 and 2019 (see Figure 31d), more LGAs and districts experience higher rates of changes in their grass- and shrublands, while the most of these LGAs are in the West close to the border to Benin. Only one LGA reaches thereby change rates of more than 15%. In Ghana, it is mostly the northern parts that experience the highest change, whereof two districts reach values of slightly more than 10%.

Consequently, it can be stated that the land cover change of grass- and shrubland to other types in Nigeria is spatially mostly concentrated in the central parts of the country, closely linked to the Middle Belt. In Ghana, it is mostly the northern areas, which have the highest change rates. However, the most affected second-level administrative divisions are usually varying between the different periods of observation. Furthermore, the relative change rates of Nigeria and of Ghana are usually relatively even, with Nigeria having slightly higher values.

The spatial distribution of land cover change from rainfed agricultural areas to other land cover types is contrastingly rather different to the one from grass- and shrublands in both countries, as Figure 32 makes prove of.

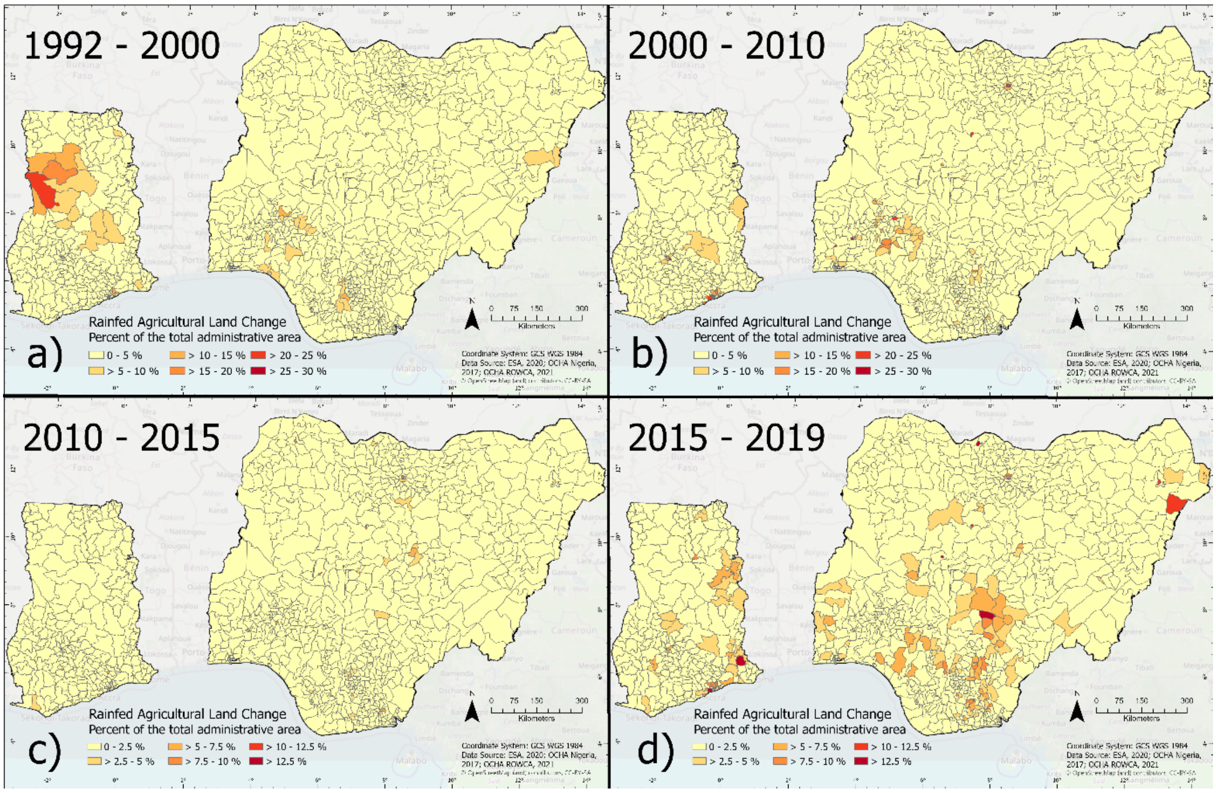


Figure 32: Relative Rainfed Agricultural Land Change per LGA and District during the Periods a) 1992 to 2000, b) 2000 to 2010, c) 2010 to 2015, and d) 2015 to 2019.

Only 20 of the 774 Nigerian LGAs have change rates of more than 5% during the period between 1992 and 2000 (see Figure 32a) with the highest value being 11.8% in the southeastern part of the country. Generally, the affected LGAs are mostly located in the South of Nigeria in the outskirts of cities. Similarly, the most affected districts in Ghana are circularly located around the city of Kumasi. Apart from these districts, there are only five other districts in Ghana, which have change rates of more than 5% during this period.

This trend continues during the period between 2000 and 2010 (see Figure 32b). In Ghana, three clusters of districts with change rates of more than 5% are visible around the cities of Kumasi, Accra, and Sekondi-Takoradi. In Nigeria, the most affected LGAs are also part of the country's urban areas, for instance close to the cities Kano, Kaduna, Ondo, and Ibadan. The maximum values in both countries are reaching almost 30%.

These observations do not change much during the period between 2010 and 2015 (see Figure 32c), even though at lower change rates with not more than 6.4% in Ghana's districts and not more than 20% in Nigeria's LGAs, which all are close to cities.

During the period between 2015 and 2019 (see Figure 32d), the spatial distribution of the previous periods slightly changes. Even though urban and peri-urban LGAs and districts still dominate the highest change rates, various rather rural LGAs and districts experience higher change rates in their changes from rainfed agriculture to other land cover types than they did in the periods before. In Nigeria, this mainly affects LGAs in the states of Benue and Nasarawa, two of the most affected states in the herdsmen-farmers conflict, as well as numerous LGAs further south. In Ghana, the most affected districts besides those in the vicinity of Accra are all located in the eastern parts of the country. Here, the relative land change values also reach numbers of up to 21%, just as it is the case in Nigeria during this period.

When it comes to land cover change from rainfed agricultural areas to other land cover types, both countries accordingly show a similar pattern during the whole period. The most affected areas are usually peri-urban and urban areas. Due to the large population growth in the two countries and the fact that a considerable amount of the changes occurs in the direction of urban areas, pressure on land is likely to cause these changes in the urban areas.

4.2.2 Comparing Changes in Climate Factors in Nigeria and Ghana since the 1970s

Since land cover change is not the only factor of climate change, the three other climate factors of temperature change, precipitation change, and change in wet days are as well investigated and later added to the model for the regression analysis to explain the conflict.

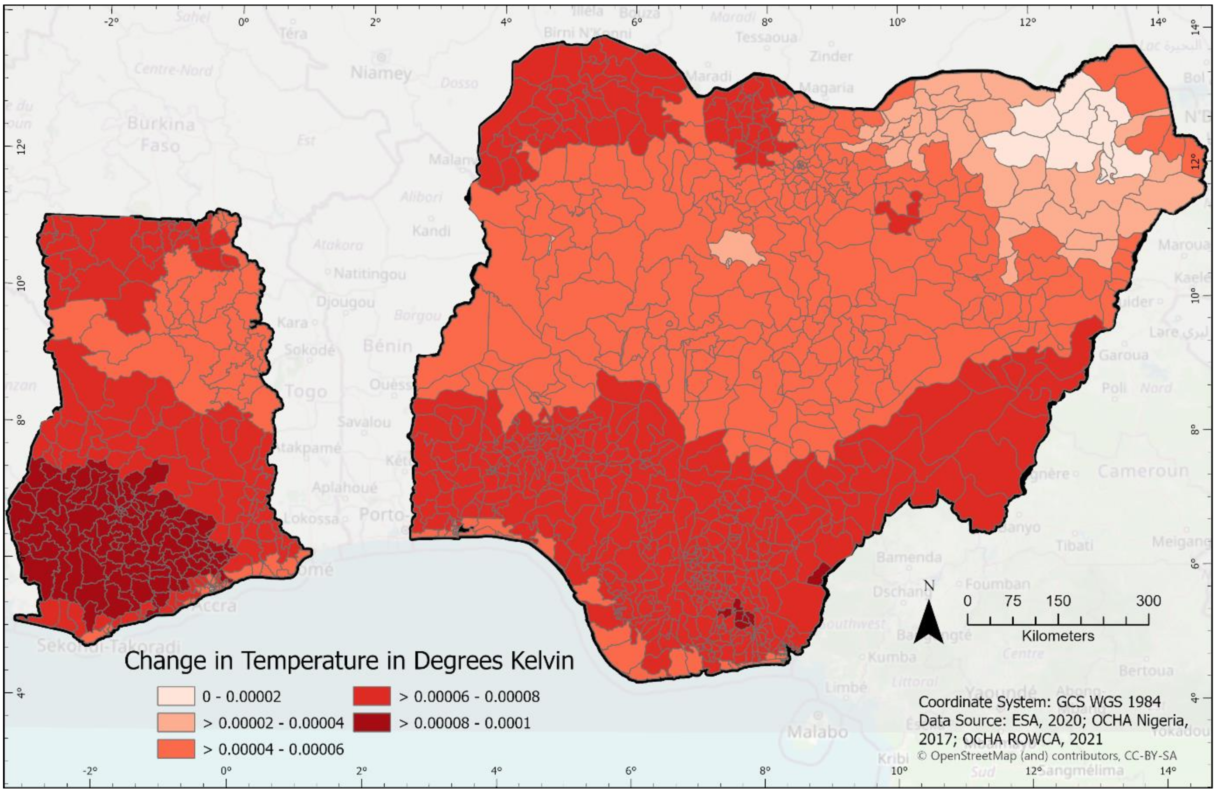


Figure 33: Change in Monthly Mean Temperatures per LGA and District between 1971 and 2020.

In terms of temperature change, all districts and LGAs experience at least some, but very little increase in average temperatures over the analyzed period from 1979 to 2020 (see Figure 33). While the temperature increase in the Northeast of Nigeria is hardly observable at rates of less than 2×10^{-5} K, the numbers are slightly increasing in southward and westward direction. The areas with the highest increase of approximately 8×10^{-5} K are located in the Southeast of the country. The northwestern part also has comparably higher values of 7×10^{-5} to 8×10^{-5} K.

Even higher increase rates than in Nigeria are observable in Ghana’s southwestern rainforest areas. The values here are getting close to 1×10^{-4} K during the period of 41 years. Just as in Nigeria, the values are decreasing in a northeastern direction, while the far Northwest experiences a slightly higher increase in temperatures of about 6 x 10^{-5} K. The generally lowest values are found in the Southeast of Ghana with values of 3.5 x 10^{-5} K in the areas around Accra. Consequently, Ghana experiences a slightly higher temperature rise of 7.3 x 10^{-5} K compared to Nigeria with an average of 6.1 x 10^{-5} Kelvin.

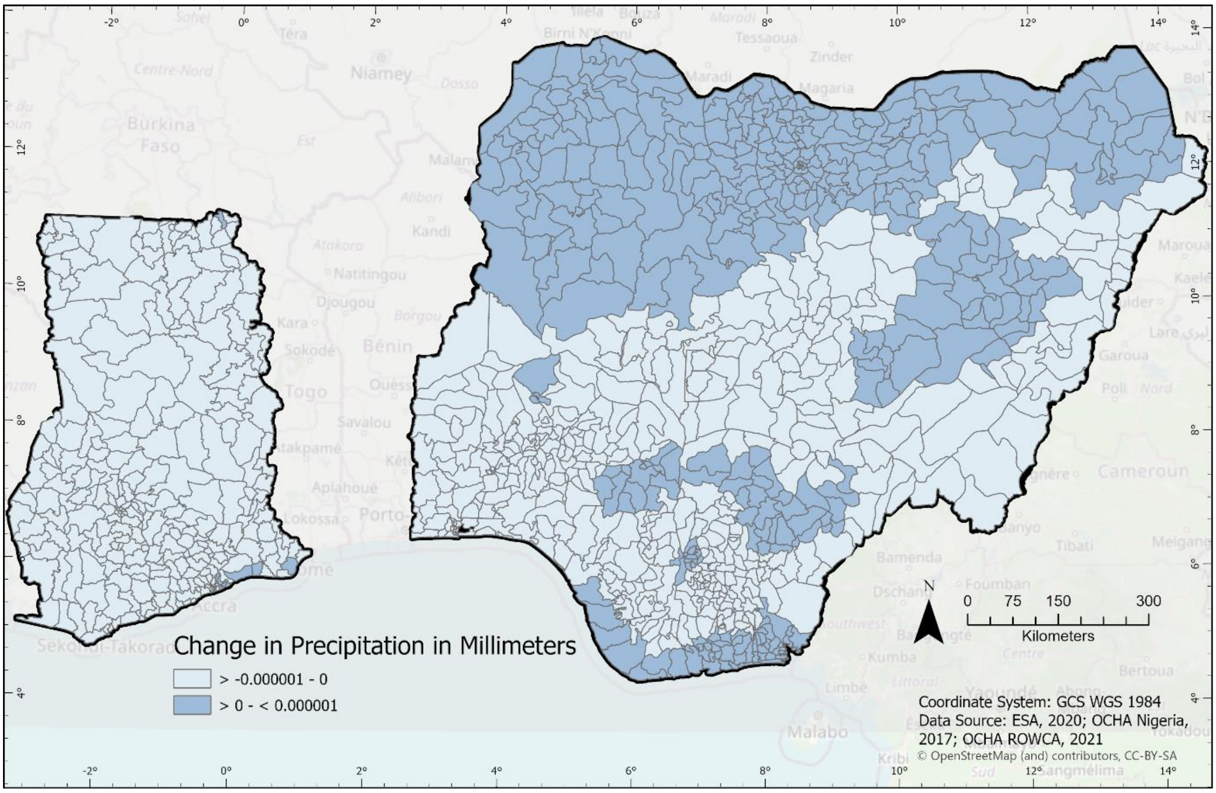


Figure 34: Change in Monthly Average Precipitation per LGA and District between 1971 and 2020.

In terms of changes in precipitation over the same period from 1979 to 2020 (see Figure 34), a considerable increase or decrease in rainfall amounts is neither observable for Ghana nor for Nigeria. The values thereby only reach mean change rates in the hundred millionth millimeters and minimum as well as maximum values in the ten millionth millimeters. In case of eleven of the 260 districts in Ghana, the values are slightly positive. In Nigeria, mainly all the LGAs of the northern part of the country have positive values, just as some LGAs in the far South and the Middle Belt. Due to these insignificant change rates, precipitation can already be considered a factor that is not contributing to the herdsmen-farmers conflict, which will have to be confirmed in the regression analysis.

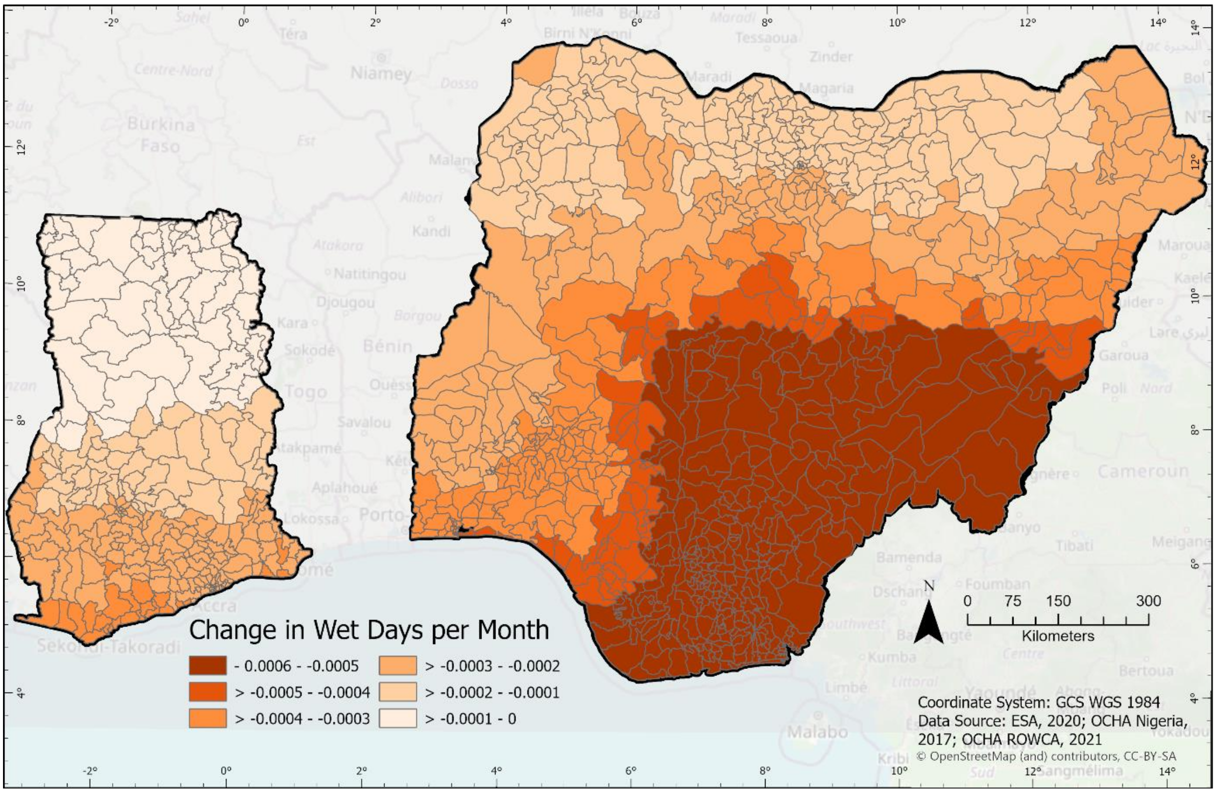


Figure 35: Change in Wet Days per LGA and district between 1979 and 2020.

A decrease in wet days per month can be identified all over Nigeria and Ghana (see Figure 35). While the northern half of Ghana does not experience a decline of more than 1 x 10^{-4} days per month, the values are slightly increasing in a southward direction. Consequently, a decrease in wet days of 3.5 x 10^{-4} days per month can be identified for the southwestern parts of Ghana. Even though Nigeria experiences a similar pattern of increasing change rates from north to south, the values are generally higher than in Ghana with a mean value of -3.9 x 10^{-4} days per month compared to -1.9 x 10^{-4} days per month. Therefore, the North of Nigeria experiences only a change of -1.1 x 10^{-4} days per month, while the southeastern parts of Nigeria, including the Middle Belt regions, that are affected by the herdsmen-farmers conflict, have a decrease of 6 x 10^{-4} days per month.

Therefore, it is not only land cover change (see Chapter 4.2.1), but also the climatic factors of precipitation, wet days, and temperature, which show no considerable differences in changes during the investigated period for Ghana and Nigeria. Therefore, a regression analysis is employed as the next step of the analysis to draw conclusions on the actual relevance of climate change for the herdsmen-farmers conflict.

4.2.3 Analyzing the Relevance of Climate Factors for the Herdsmen-Farmers Conflict by the Use of a Generalized Linear Regression Model

The relevance of all these factors for the herdsmen-farmers conflict has now to be further investigated. For this, the GLR analysis is used with the binary classified conflict areas as the response variable and the other variables as the explanatory variables. Due to the differences in the conflict datasets provided by CFR and UCDP, a GLR analysis is made for each of the datasets as the dependent variable.

Table 7: Results of the GLR Analysis of the Climatic Factors for the CFR Dataset

INDEPENDENT VARIABLES	COEFFICIENT	STD.ERROR	Z-STATISTIC	PROBABILITY
INTERCEPT	-2.904829	0.719034	-4.039906	0.000053*
REL_CHANGE_1	86.032840	155.8867	0.551893	0.581021
REL_CHANGE_3	-3.111933	2.607149	-1.193616	0.232628
REL_CHANGE_4	-518330.25	25886416.24	-0.020023	0.984025
TEMP_CHANGE	-89818.04	13558.43	-6.624515	0.000000*
PRECIP_CHANGE	-22344017.61	7421429.38	-3.010743	0.002606*
WETDAY_CHANGE	-12480.34	1755.518	-7.109207	0.000000*

GLR Diagnostics:

Input Features:	Nigeria LGA's	Dependent Variable:	Conflict Areas (CFR)
Number of Observations:	774	Akaike's Information Criterion (AICc):	334.753439
# of observations equal to 1:	65	% Deviance Explained:	0.281819
Joint Wald Statistics:	125.808363	Prob(>chi-squared), degrees of freedom:	0.000000*

Confusion Matrix:

		Predicted	
		0	**1**
Actual	**0**	**695**	**14**
	1	**57**	**8**

Notes on Interpretation
* An asterisk next to a number indicates a statistically significant p-value ($p < 0,01$).
Coefficient: Represents the strength and type of relationship between each explanatory variable and the dependent variable.
Probability: Asterisk (*) indicates a coefficient is statistically significant ($p < 0,01$)
Akaike's Information Criterion (AICc): Measures of model fit/performance.
% Deviance Explained: The proportion of dependent variable variance accounted for by the explanatory variable.

When running the GLR analysis for the CFR dataset (see Table 7) with all the six climate factors, the model explains 28.2% of the dependent variable, as is given by the value for the explained deviance. This means that all the climate factors would explain 28.2% of the incidents in the herdsmen-farmers conflict. Due to the significant Joint Wald Statistics, it can be assumed that the model is effectively explaining this percentage of the conflict. The accuracy of the total classification as visible from the confusion matrix is rather high with a correct prediction of

703 of the 774 LGAs belong to either conflict or non-conflict areas, equaling to a 90.83% prediction accuracy.

In terms of the individual explanatory variables, all the three land cover change variables have insignificant probability values. The other climatic variables of temperature, precipitation and wet days change are statistically significant for the explanation of the response variable, assuming a significance level of 0.01. The coefficients of these explanatory variables are rather low negative values, indicating a strong negative relation between conflict areas and changes in the climatic parameters. However, the standard error values are also rather high, referring to a low precision of the estimated values, as a consequence of the low change rates outlined above.

Table 8: Results of the GLR Analysis of the Climatic Factors for the UCDP Dataset

INDEPENDENT VARIABLES	COEFFICIENT	STD.ERROR	Z-STATISTIC	PROBABILITY
INTERCEPT	-3.638490	0.843482	-4.313653	0.000016*
REL_CHANGE_1	101.008813	163.276780	0.618636	0.536157
REL_CHANGE_3	-1.391524	2.510587	-0.554262	0.579399
REL_CHANGE_4	-497828.83	25695583.62	-0.019374	0.984543
TEMP_CHANGE	-116111.98	15639.08	-7.424476	0.000000*
PRECIP_CHANGE	-21421032.52	7640282.35	-2.803696	0.005052*
WETDAY_CHANGE	-16618.46	2197.806	-7.561392	0.000000*

GLR Diagnostics:

Input Features:	Nigeria LGA's	Dependent Variable:	Conflict Areas (UCDP)
Number of Observations:	774	Akaike's Information Criterion (AICc):	286.619449
# of observations equal to 1:	61	% Deviance Explained:	0.361928
Joint Wald Statistics:	154.552718	Prob(>chi-squared), degrees of freedom:	0.000000*

Confusion Matrix:

		Predicted	
		0	**1**
Actual	**0**	**694**	**19**
	1	**49**	**12**

Notes on Interpretation
* An asterisk next to a number indicates a statistically significant p-value (p < 0,01).
Coefficient: Represents the strength and type of relationship between each explanatory variable and the dependent variable.
Probability: Asterisk (*) indicates a coefficient is statistically significant (p < 0,01)
Akaike's Information Criterion (AICc): Measures of model fit/performance.
% Deviance Explained: The proportion of dependent variable variance accounted for by the explanatory variable.

The GLR analysis of the climatic factors with the UCDP dataset used for the response variable (see Table 8) generates similar results as when using the CFR dataset. This time, the model explains 36.2% of the dependent variable, while the Joint Wald Statistics is again statistically significant. The prediction accuracy is also slightly higher with a percentage of 91.21%, just as the Akaike's Information Criterion (AICc). Consequently, using the UCDP dataset provides a better model than the CFR dataset.

Similarities between the two models also exist regarding the individual independent variables. Again, the three land cover change variables are not statistically significant for explaining the variations in the dependent variable, whereas the other three climate variables are statistically significant, again with low negative values and high standard errors.

Table 9: Results of the GLR Analysis of the Statistically Significant Climatic Factors for the UCDP Dataset, and for the CFR Dataset

INDEPENDENT VARIABLES	COEFFICIENT	STD.ERROR	PROBABILITY
INTERCEPT	-3.485896	0.829897	0.000027*
TEMP_CHANGE	-120016.08	15160.90	0.000000*
PRECIP_CHANGE	-26937948.15	7169430.96	0.000172*
WETDAY_CHANGE	-16244.39	2101.433	0.000000*

GLR Diagnostics:

Input Features:	Nigeria LGA's	Dependent Variable:	Conflict Areas (UCDP)
Number of Observations:	774	Akaike's Information Criterion (AICc):	291.408145
# of observations equal to 1:	61	% Deviance Explained:	0.336443
Joint Wald Statistics:	143.669946	Prob(>chi-squared), degrees of freedom:	0.000000*

Confusion Matrix:

		Predicted 0	Predicted 1
Actual	0	696	17
	1	50	11

INDEPENDENT VARIABLES	COEFFICIENT	STD.ERROR	PROBABILITY
INTERCEPT	-2.787874	0.708044	0.000082*
TEMP_CHANGE	-92774.93	13025.84	0.000000*
PRECIP_CHANGE	-26501175.03	7043676.55	0.000168*
WETDAY_CHANGE	-11960.16	1664.429	0.000000*

GLR Diagnostics:

Input Features:	Nigeria LGA's	Dependent Variable:	Conflict Areas (CFR)
Number of Observations:	774	Akaike's Information Criterion (AICc):	342.183079
# of observations equal to 1:	65	% Deviance Explained:	0.251525
Joint Wald Statistics:	112.284647	Prob(>chi-squared), degrees of freedom:	0.000000*

Confusion Matrix:

		Predicted 0	Predicted 1
Actual	0	696	13
	1	58	7

Notes on Interpretation
* An asterisk next to a number indicates a statistically significant p-value (p < 0,01).
Coefficient: Represents the strength and type of relationship between each explanatory variable and the dependent variable.
Probability: Asterisk (*) indicates a coefficient is statistically significant (p < 0,01)
Akaike's Information Criterion (AICc): Measures of model fit/performance.
% Deviance Explained: The proportion of dependent variable variance accounted for by the explanatory variable.

Due to the statistical insignificance of the land cover change variables, the models are rerun with only the other climate variables as explanatory variables (see Table 9). For both datasets, the model performances only slightly decrease, when considering the AICc values and the explained deviance, while the overall prediction accuracy remains on similar levels.

To analyze the random distribution of the residuals of the GLR's models, a spatial autocorrelation test with the Global Moran's I statistic is made. For both the UCDP (see Figure 36a) and the CFR dataset (see Figure 36b), the residuals of the model are statistically significantly clustered with z-scores of 41.96 when using the UCDP dataset and 37.54 with the CFR dataset. This means that the regression models do not sufficiently explain the variance in the dependent variables. Accordingly, only the climate factors can not solely explain the herdsmen-farmers conflict. As already assumed, other factors without a relation to climate change have to be included as explanatory variables in order to allow for a thorough conclusion on the factors contributing to the herdsmen-farmers conflict.

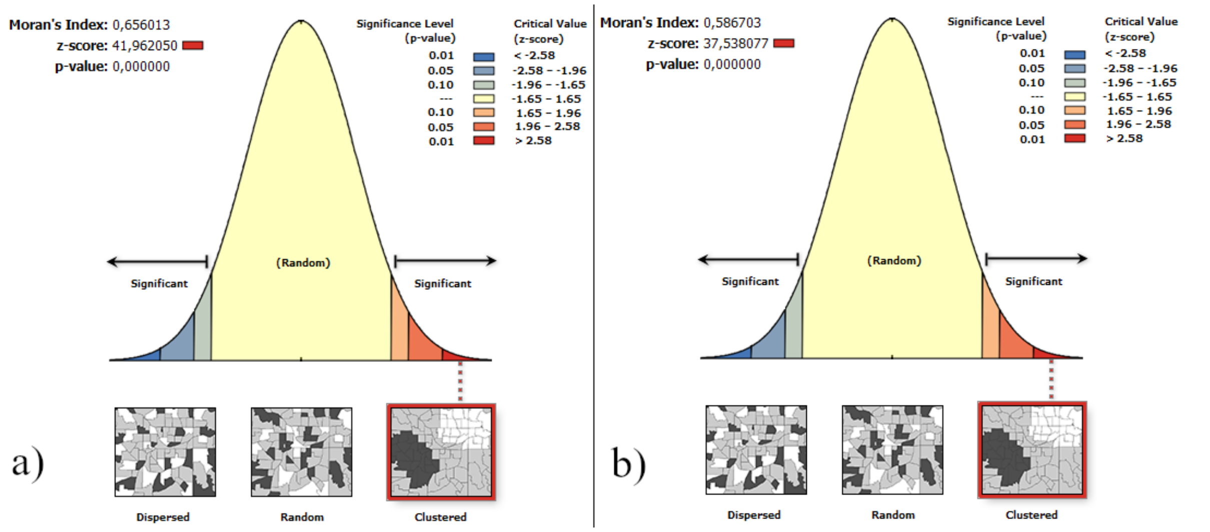


Figure 36: Spatial Autocorrelation (Global Moran's I) for a) the UCDP dataset model and b) the CFR dataset model.

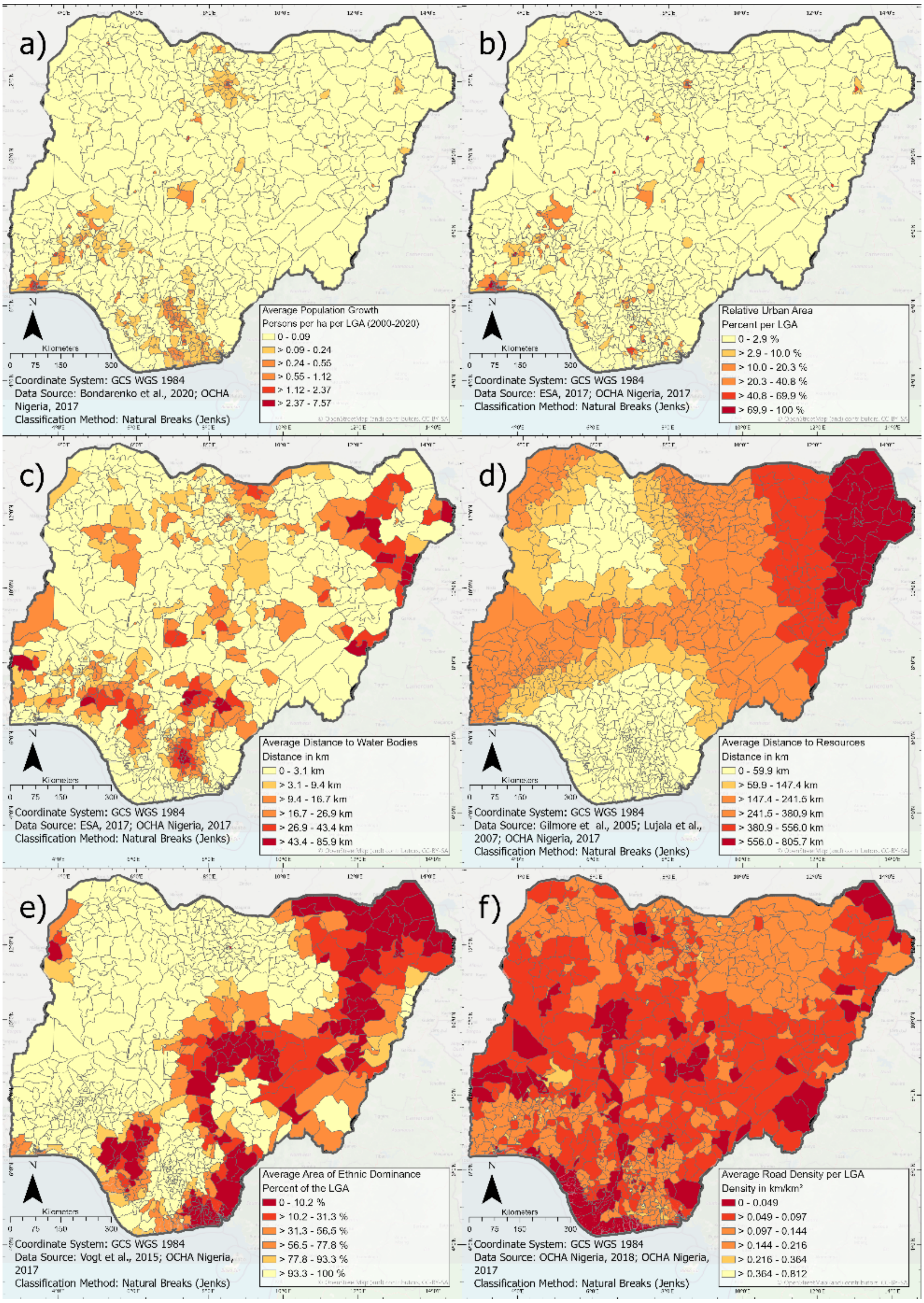
4.3 Considering Other Reasons of Conflict

For the last part of the analysis, non-climatic factors are included, which are then used for another regression analysis that aims at finding a better model for explaining the herdsmen-farmers conflict in Nigeria than the models only including climatic factors could. Therefore, the nine additional non-climate change-related variables presented in Chapter 3.3 are added to the model.

In terms of the factor of population growth, it has been assumed that a higher growth rate will increase the risk for conflict due to exerting more stress on land. The highest population growth rates are found in the urban areas, mainly in Southwestern Nigeria in the vicinity of Lagos (see Figure 37a). Other areas of large population growth are in Southeastern Nigeria and the cities Kano, Abuja, Ibadan, and Ilorin.

The LGAs with the highest urban rates (see Figure 37b) are consequently also to be found in proximity to the largest cities. According to the initial hypothesis, these highly urban areas are less likely to experience conflict. Just as with population growth, the Middle Belt areas, which are most affected by the herdsmen-farmers conflict, mainly belong to the class with the lowest values.

The average distance to water in rivers and lakes (see Figure 37c) varies considerably over Nigeria. Dependent on the perspective in the discussion about resource scarcity and abundance, the areas with a higher distance, which are rather located in the Northeast and South of the country, might have a higher or lower risk for conflict.



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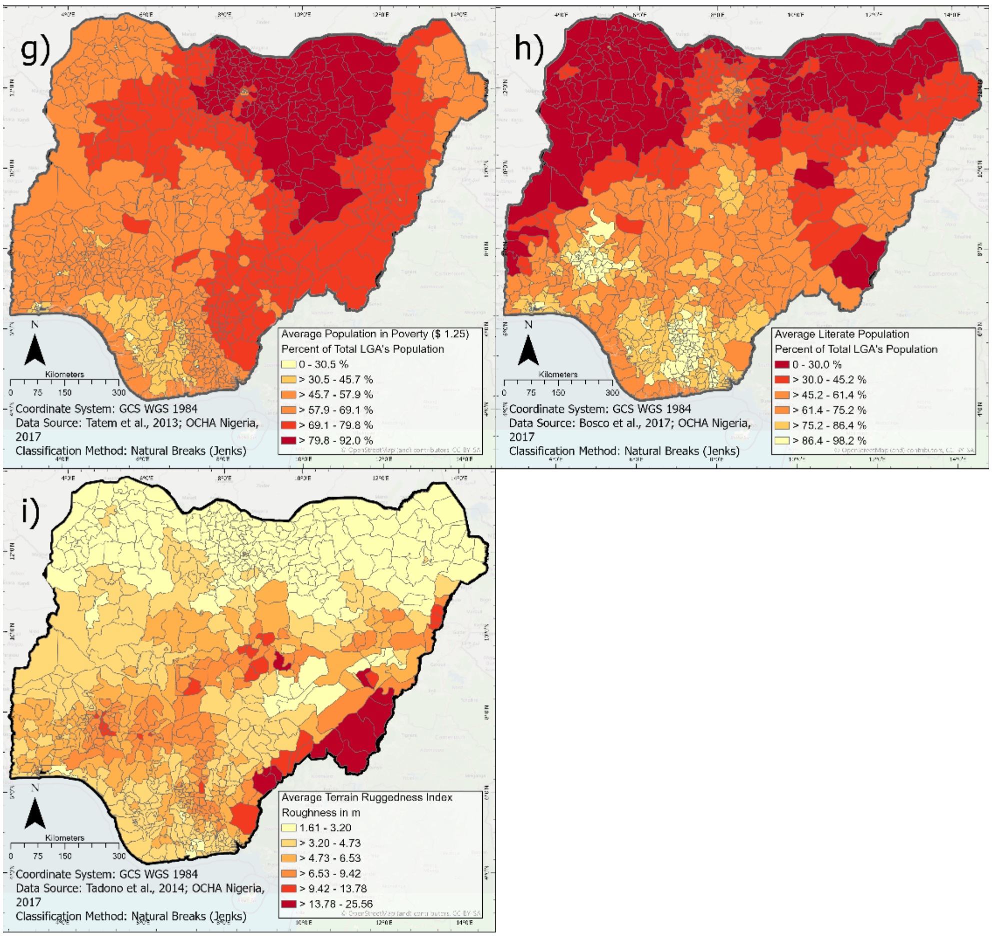

Figure 37: Non-climatic Factors Concerning a) Population Growth, b) Relative Urban Areas, c) Distance to Water Bodies, d) Distance to the Resources Diamonds and Petroleum, e) Ethnic Dominance, f) Road Density, g) Poverty, h) Literacy, and i) Terrain Roughness per LGA.

The resources of diamonds and petroleum are to be found in the Northwest and South of Nigeria. Therefore, the distances of the LGAs to these resources increase in the Middle Belt and especially the Northeast of the country (see Figure 37d). In this regard, literature has as well not agreed on whether the potential for conflict increases with or without the access to resources (see Chapter 2.2.3).

The ethnically most heterogeneous LGAs are generally located in the East of Nigeria (see Figure 37e). According to the established hypothesis, the regression analysis should find that these regions have an increased risk of conflict. Therefore, the conflict areas in the herdsmen-farmers conflict with their ethnic heterogeneity should also have a higher likeliness for conflict.

In terms of primary and secondary road density per LGA, the spatial distribution throughout Nigeria is rather irregular (see Figure 37f). The LGAs with the lowest road density are found in the parts of the Niger Delta close to the sea as well as along a north-south axis through the

Center of Nigeria. The highest values are in urban LGAs, followed by a rather dense road network in the northern parts of the country. The Middle Belt region LGAs have a varying road density of low to medium values. Therefore, the access to these areas is more difficult than elsewhere, which might increase the risk for conflict, according to the original hypothesis.

The percentage of people living in poverty of less than $ 1.25 per day increases in Nigeria from south to north (see Figure 37g). Thereby, the oil-rich urban areas of Southern Nigeria have the lowest rate of poverty, while the rural Central North of the country has the highest values. The Middle Belt ranks in the medium values, which contradicts the hypothesis that the herdsmen-farmers conflict might be driven by high poverty levels.

Also, in terms of literacy rates, the Middle Belt region ranks in the medium to upper values (see Figure 37h). Throughout Nigeria, the literacy rate decreases from south to north. Along with the vicinities of the city of Ilorin, the highest literacy rates are found in the Southeast of Nigeria, while the North and Northwest have the lowest rates. Therefore, a contradiction to the initial hypothesis that low literacy rates can contribute to the herdsmen-farmers conflict is likely prior to the regression analysis.

Furthermore, the values for the average terrain roughness are also only in the medium values for the Middle Belt region (see Figure 37i). The LGAs with the highest roughness values are in the East of the country. Higher terrain ruggedness index values also occur in Central Nigeria. The areas with the least terrain roughness are to be found in Northern Nigeria. With reference to the hypothesis that a rougher terrain increases the risk for conflict, the observation in the regression analysis should be that the Middle Belt does not have a higher risk for conflict due to the moderate hilliness of the terrain.

Consequently, most of the hypotheses concerning the non-climatic factors that were considered relevant for the herdsmen-farmers conflict do not seem to apply for the Middle Belt region based on the spatial distribution of these factors in the country. The statistical proof is made using the GLR analysis.

For each of the dependent variable datasets, six models with varying compositions of independent variables have been run. The first model consisted of all the 15 variables. With the CFR dataset as the basis for the response variable, the four variables temperature change (see Table 10), precipitation change, wet day change, and the percentage of urban areas per LGA show statistically significant p-values of below 0.01, while the whole model explains a total of 33.3 % of the variance in the response variable.

Table 10: GLR Analysis for all Independent Variables with the CFR Dataset as the Dependent Variable

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Intercept	-5.312 (0.005**)	-2.689 (0.000**)	-6.809 (0.000**)	-6.210 (0.000**)	-6.270 (0.000**)	-5.913 (0.000**)
All-year Agriculture Change	60.903 (0.717)			20.121 (0.905)		
Grassland Change	-3.434 (0.234)			-4.086 (0.135)		
Rainfed Agriculture Change	-479325.177 (0.986)			-488569.264 (0.985)		
Temperature Change	-90510.302 (0.000**)	-91963.269 (0.000**)	-94782.204 (0.000**)	-90032.507 (0.000**)		
Precipitation Change	-33174187.532 (0.000**)	-27518933.770 (0.000**)	-31765837.131 (0.000**)	-28814028.745 (0.001**)		
Wet Day Change	-9688.342 (0.000**)	-11707.479 (0.000**)	-10436.935 (0.000**)	-10765.744 (0.000**)		
Population Growth	-4.851 (0.019*)		-5.089 (0.019*)	-4.526 (0.033*)	-6.607 (0.003**)	-7.166 (0.002**)
Urban Areas	8.869 (0.006**)	-0.775 (0.461)	7.410 (0.005**)	6.717 (0.014*)	11.134 (0.000**)	11.985 (0.000**)
Water Distance	-0.000 (0.626)				-0.000 (0.522)	
Resource Distance	-0.000 (0.345)				0.000 (0.308)	
Dominance Rate	-0.005 (0.264)			-0.002 (0.574)	-0.011 (0.001**)	-0.012 (0.000**)
Road Density	-5.376 (0.112)				-9.469 (0.001**)	-9.705 (0.001**)
Poverty Percentage	4.487 (0.013*)		4.351 (0.012*)	3.696 (0.032*)	4.281 (0.004**)	4.612 (0.001**)
Literacy Percentage	3.362 (0.027*)		3.426 (0.016*)	3.143 (0.030*)	4.377 (0.000**)	4.105 (0.000**)
Terrain Roughness	-0.033 (0.559)				0.031 (0.481)	

GLR Diagnostics:	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Akaike's Information Criterion (AICc)	330.273	353.570	329.540	326.984	393.089	388.810
% Deviance Explained	0.333	0.253	0.298	0.322	0.165	0.161
Joint Wald Statistics	148.860	112.924	133.064	143.842	73.615	71.752
Prob (>chi-squared)	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**

Dependent Variable: Conflict Areas (CFR)
Number of Observations: 774; Number of Observations equal to 1: 61
The values given are the coefficient and its p-value in brackets.
* Statistically significant variable with p-value < 0.1
** Statistically significant variable with p-value < 0.01

The same model with the UCDP dataset used for the response variable (see Table 11) explains 57.8 % of the variance with a lower AICc. Thereby, the variables of the percentages living in poverty and being literate as well as the population growth are statistically significant at p-values of below 0.01 in addition to the other four variables that were already statistically significant in the model using the CFR dataset.

The second model only included the statistically significant variables at p-values of below 0.01 from the first model. While all the used explanatory variables remain significant in the UCDP dataset model, the urban areas variable in the CFR dataset model is no longer statistically significant. In addition, it changes its positive coefficient and thereby influence on the conflict to a negative. Furthermore, the AICc increases in the CFR model, while the explained deviance reduces, which refers to a worse model. The UCDP model even has a lower AICc with a slightly lower explained deviance, signifying an almost similar performance of the two models.

The third model is run with all the statistically significant variables at a p-value below 0.1. This means that the variables poverty, literacy, and population growth are added to the second CFR dataset model, which results in the so-far lowest AICc and a higher explained deviance than in model two. The three added variables remain also significant with a p-value below 0.1, while the other variables remain below 0.01.

In the UCDP dataset model, only the road density variable is added to the variables of model 2. This variable thereby remains at a p-value below 0.1, while all the other values also remain at p-values below 0.01. This model has the lowest AICc of all models and an explained deviance of 56.0%, thereby almost being as high as in the first model.

Since the central arguments in the discussions on the herdsmen-farmers conflict are climate change and social factors, especially ethnicity, Model 4 includes all the factors of climate change and the social factors population growth, percentage of urban areas per LGA, ethnic dominance, poverty rates, and literacy percentage. This results in the model with the lowest AICc among the CFR dataset models with a comparably high explained deviance. Except for the land cover change and ethnic dominance variables, all the other variables have a statistical significance with p-values below 0.1. The same accounts for the UCDP dataset model, which has similar overall values as the first model.

The models 5 and 6 consider only the non-climate change-related factors. While model 5 contains all these variables, only the statistically significant variables with p-values below 0.01 have been used in Model 6. However, these models perform rather poorly compared to the other ones by having the highest AICc values and the lowest explained deviance for both the CFR and the UCDP datasets.

Table 11: GLR Analysis for all Independent Variables with the UCDP Dataset as the Dependent Variable

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Intercept	-20.162 (0.000**)	-20.151 (0.000**)	-19.902 (0.000**)	-20.213 (0.000**)	-14.475 (0.000**)	-16.264 (0.000**)
All-year Agriculture Change	54.711 (0.777)			-20.720 (0.905)		
Grassland Change	0.340 (0.910)			-1.905 (0.491)		
Rainfed Agriculture Change	-372277.983 (0.988)			-356317.142 (0.988)		
Temperature Change	-14022.946 (0.000**)	-149410.567 (0.000**)	-150779.312 (0.000**)	-153431.668 (0.000**)		
Precipitation Change	- 53680448.325 (0.000**)	- 51657432.919 (0.000**)	- 51133743.990 (0.000**)	- 49847217.112 (0.000**)		
Wet Day Change	-16886.234 (0.000**)	-16891.722 (0.000**)	-16440.877 (0.000**)	-17370.394 (0.000**)		
Population Growth	-19.031 (0.008**)	-18.968 (0.003**)	-18.858 (0.004**)	-20.023 (0.003**)	-26.604 (0.000**)	-30.376 (0.000**)
Urban Areas	24.014 (0.001**)	20.529 (0.000**)	24.678 (0.000**)	21.254 (0.000**)	27.802 (0.000**)	31.371 (0.000**)
Water Distance	-0.000 (0.164)				-0.000 (0.324)	
Resource Distance	-0.000 (0.524)				0.000 (0.075*)	
Dominance Rate	-0.000 (0.991)			0.004 (0.519)	-0.009 (0.025*)	
Road Density	-10.264 (0.063*)		-9.174 (0.055*)		-13.489 (0.002**)	-13.621 (0.001**)
Poverty Percentage	18.801 (0.000**)	18.731 (0.000**)	19.291 (0.000**)	18.631 (0.000**)	12.886 (0.000**)	15.199 (0.000**)
Literacy Percentage	9.784 (0.000**)	8.648 (0.000**)	9.293 (0.000**)	8.901 (0.000**)	9.688 (0.000**)	9.717 (0.000**)
Terrain Roughness	-0.077 (0.239)				-0.010 (0.831)	

GLR Diagnostics:	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Akaike's Information Criterion (AICc)	212.857	207.653	206.036	213.124	285.305	289.271
% Deviance Explained	0.578	0.552	0.560	0.558	0.379	0.351
Joint Wald Statistics	246.887	235.561	239.225	238.312	162.009	149.865
Prob (>chi-squared)	0.000**	0.000**	0.000*	0.000**	0.000**	0.000**

Dependent Variable: Conflict Areas (UCDP)
Number of Observations: 774; Number of Observations equal to 1: 65
The values given are the coefficient and its p-value in brackets.
* Statistically significant variable with p-value < 0.1
** Statistically significant variable with p-value < 0.01

Consequently, the climate change variables of temperature, precipitation, and wet days change matter in the models with the highest explanatory potential, whereas land cover change is of less relevance. Apart from these variables, poverty rates, literacy rates, urban areas, and population growth are relevant for most of the models. While the last one has a negative connection to conflict, the other three are positively linked to the herdsmen-farmers conflict. This means that a higher population growth seems to reduce the likeliness of conflict, while large urban areas, a high poverty percentage, and a high literacy percentage rather contribute to the conflict. Simultaneously, ethnic heterogeneity, which is often used as an explanation for the herdsmen-farmers conflict, does not matter for the conflict, having coefficient values approximating zero in all the models, thereby signifying no influence on the conflict.

4.4 Discussion of the Results

These findings are accordingly partly challenging the focus of the discussion in research on the two topics of climate change and ethnicity as the main factors for the herdsmen-farmers conflict. Especially the first part of the analysis tried to investigate the relevance of climate change for the violent conflict more profoundly by investigating whether climate change is more prevalent in Nigeria than in Ghana, where disputes between herdsmen and farmers can be predominantly solved non-violently.

According to the results of the land cover change analysis as one of the factors contributing to climate change, both Ghana and Nigeria equally experience considerable changes in land cover. In Nigeria, the changes consequently also occur in the affected regions of the herdsmen-farmers conflict. During the period between 1992 and 2015, most of the land change was from grass- and shrublands to other land cover types, most often to rainfed agriculture, but also to forests. After 2015 and hence after the increase in violent incidents since 2010, the change pattern inverted to an increased conversion of rainfed agricultural areas into the more natural land covers of grass- and shrublands as well as forests in the exact same area.

This phenomenon might be explainable by findings of Soomiyol and Fadairo, who concluded in their research on the effects of the conflict on the household level that about three quarters of the interviewed farmers changed their farming habits from cultivating large areas further away from their own houses to smaller fields close to their place of living, which also reduced agricultural production (Soomiyol & Fadairo, 2020, p. 100). While farmers previously tended to expand their areas of agricultural production, they are now rather reducing the size of their fields, giving thereby up formerly cultivated areas, which can now revert to grass- and shrublands or even forests.

Consequently, the question concerning the impact of climate change remains. Since most land cover changes in Nigeria occur in the direction of artificial land covers such as agricultural and urban areas, it can be assumed that most of the land cover change is human-induced.

This is especially a consequence of the population growth, which occurs in many African countries and which increases the pressure on land areas and resources and thereby also the competition about these resources. Nevertheless, Soomiyol and Fadairo highlight that desertification as a cause of climate change also occurs in the far-north of Nigeria, as also seen in the expansion of bare land in the land cover analysis. Even though the conflict areas are therefore not directly affected by desertification, the herdsmen are forced to migrate southward into these conflict areas, resulting in an increased competition about land resources (Soomiyol & Fadairo, 2020, pp. 93–94).

In contrast, Benjaminsen et al. have rather identified that climate change and climate variability are not to blame for conflicts in the Sahel zone. Based on research along the Niger River in the Mopti region in Mali, they state that it is rather political and economic factors, such as political instability or judicial insecurity, than climate change that contribute to conflict (Benjaminsen et al., 2012).

The findings of this thesis accordingly tend to support the reasoning of Benjaminsen et al. Neither the factors of land cover change nor the other factors concerning climate change showed a considerable difference between Ghana and Nigeria. Even though both countries experience an increase in average temperatures and a decrease in wet days, while precipitation remains almost unchanged, the most affected areas of temperature rise are found in Ghana and not in Nigeria. In contrast, the most change in wet days occurs in Southeastern Nigeria.

Nevertheless, it also still has to be proven that the small changes in these factors have more than just a statistical impact on the conflict. Maximum changes of ten thousandth Kelvin in monthly average temperatures over a period of 40 years are not likely to be recognizable by humans at all, just as changes in wet days of converted less than a minute per month over the same period. The fact that precipitation did not change, while the number of wet days per month reduced, might however indicate a decrease in rainfall events which, in return, have a higher rainfall intensity. Still, this change is very marginal and consequently rather unlikely to influence human behavior, even though the regression analysis indicates a statistical significance for these variables in the herdsmen-farmers conflict. However, the large standard error for these factors (see Tables 8 and 9) also indicates that the results are inconclusive.

Furthermore, parts of the identified change rates can be attributed to natural climate variability. As discussed in Chapter 2.1.1, the different irregular, but cyclical modes of climate variability, such as ENSO and Atlantic Niño, show a cyclicity of several decades. Therefore, the identified analyzed period of 40 to 50 years is still less than the natural cyclicity of some of these phenomena, such as the AMO with its cyclicity of 70 years.

In accordance with the above-mentioned findings by Benjaminsen et al., the literature also ascribes an important relevance to the issue of insecurity in the North of Nigeria, which indirectly influences the Middle Belt. For instance, the activities of Boko Haram in northeastern Nigeria as well as rural banditry and cattle rustling in Northwestern and North-Central Nigeria are further animating herdsmen to migrate south (Soomiyol & Fadairo, 2020, p. 94).

It is not only the threats to security in Northern Nigeria, but also aspects creating insecurity directly in the Middle Belt. As Chukwuma states, the herdsmen-farmers conflict is thereby often explained along the three discourses of securitization, Fulanization, and sedentarization. Securitization thereby addresses the use of firearms in the conflict, which causes argumentations connecting the Fulani herdsmen to terrorism, which needs to be countered by military or vigilante actions. Similarly, the discourse of Fulanization describes the Fulani as religious missionaries, who intend to conquer and dominate the heterogeneous Middle-Belt. Lastly, proponents of the discourse of sedentarization argue that forced sedentariness for the herding groups will reduce the conflict potential stemming from the issues related to nomadism in order to secure the herdsmen’s livelihoods and the food production in Nigeria (Chukwuma, 2020, 64–70).

These observations regarding rather emotional and subjective perspectives on the conflict among the affected people also pose questions to the layout of the analysis. The central question, and issue, hereby is how to operationalize rather abstract factors, such as feelings and emotions, so that they can be used in a regression analysis. This also applies to the outlined history of civil war and coups d’état in Nigeria. These incidents might still influence the people in their behavior in dealing with arising problems and disagreements.

For instance, the already mentioned Nigerian civil war, which took place in the southeastern part of the country, where secessionists proclaimed the independent state of Biafra, is still lingering in the country, especially due to the rapid and, according to Chukwuma, selective labeling of the secessionists as a terrorist group by the government (Chukwuma, 2020, p. 65). Ezemenaka and Ekumaoko even state a resurgence of the Biafra agitations (Ezemenaka & Ekumaoko, 2018, p. 43), just as Chiluwa and Chiluwa do (Chiluwa & Chiluwa, 2020, p. 17).

Besides this question of how to operationalize not directly measurable factors, the layout of the regression analysis in this thesis has to be discussed. The first consideration is thereby addressing the chosen spatial resolution of analysis. By choosing the LGAs and districts as the spatial units, it was assumed that most of the used datasets were already provided on this administrative level. This might be the case for countries with a solid data basis, where every administrative entity keeps reliable statistics. However, most of the used variables in this analysis are based on calculated grid rasters, whose cell values are then averaged to zonal numbers for the LGAs. Therefore, these data already only provide estimates due to the statistical approach. The conversion from the grid raster to the LGA and district levels consequently further distort the values, resulting in inaccurate values and results in the regression analysis. Since the grid rasters have different spatial resolutions, recalculations resulting in slight distortions would nevertheless have been necessary.

Another factor limiting the quality of the regression analysis is the underlying conflict data. The issue thereby is, how to define, which incidents are part of the herdsmen-farmers conflict and which are not. Due to the many different actors and their indistinct motives, both the CFR and UCDP datasets can only be filtered by broad categories (see Chapter 1.1), thereby containing the risk for the inclusion of non-related or the exclusion of relevant incidents. Therefore, the underlying datasets for the dependent variable itself contain certain inaccuracies, which distort the results of the analysis.

Lastly, during this analysis, the violent conflict between herdsmen and farmers has been considered an intrastate conflict without linkages and influences from outside the country. Even though the existing research on the conflict does not indicate a transnational level to the conflict, several facts challenge this perspective. As it is the case for many African ethnicities, also the Fulani are not only limited to Nigeria (see Chapter 1.1). Being spread across the whole Sahel zone, an international dimension is naturally given. Furthermore, the current globalized world sees the emergence of foreign activities also in agriculture, resulting in what is called "land grab" especially in African countries. To which extent this is relevant in Nigeria in addition to the already existing dominance of the oil sector by foreign companies, would need further analysis.

5 Conclusion

The results of this thesis therefore encourage for some more profound and extensive research, which address some of the considerations concerning the improvement of the used data's quality. This includes an approach to operationalize the factors for the regression analysis, which are not directly measurable, or to apply a grid raster analysis instead of using second-order administrative divisions to create a more convincing model for the factors of conflict.

Furthermore, this thesis only analyzes the conflict between herdsmen and farmers in Nigeria's Middle-Belt. Hence, no statements on the generalizability of the approach can be given. Since conflicts between herdsmen and farmers are occurring in various countries, it might be worth analyzing, whether some of the factors used in this thesis also apply elsewhere.

However, this thesis has tried to address the versatile causes of conflict between the Fulani herdsmen and farmers of other ethnicities in Nigeria. Thereby, the focus was on climate change as the most dominant cause of conflict. Nigeria has certainly experienced large conversions in the land cover. However, the little changes in temperatures, wet days, and precipitation accompanied by the generally high population growth in the country make it more likely that these land cover changes are directly linked to urbanization and an intensification of agriculture to meet the needs of the population, rather than being direct consequences of climate change.

Nevertheless, climate change certainly is of relevance for the herdsmen-farmers conflict, even though this is rather indirectly. Northern Nigeria experiences a desertification of formerly arable lands. The resulting migrations to the south are thereby aggravated by an increasing insecurity in the affected regions, which experience activities of the terrorist organization Boko Haram, as well as banditry, criminality, and cattle rustling.

In addition, the statistical analysis has found a relevance of precipitation, temperature, and wet days change in the affected areas of the conflict. The little extent of changes however suggests the necessity of a more in-depth evaluation of this significance, which would have gone beyond the scope of this thesis. Nonetheless, it becomes evident that it is rather a plethora of different issues that contribute to the extent of violence in the conflict than individual causes.

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