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"The Cheikh Anta Diop University of Dakar does not intend to give any approval or disapproval to the opinions expressed in this thesis. These opinions are the author's own."

DEDICATION

To my family

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LIST OF ACRONYMS:

ACLED:	African Conflict Location and Events Data
CCKP:	World Bank Climate Change Knowledge portal
CPR:	Common Pool Resource
DRA:	Regional Direction of Agriculture
ECOWAS:	Economic Community of West African States
EMOP :	Enquête Modulaire Permanent au Près des Ménages
ENCOP:	Environment and Conflicts Project
GDP:	Gross Domestic Product
GECHS:	Global Environmental Change and Human Security project
INSTAT :	Institut National de la Statistique (Mali)
IPCC:	Intergovernmental Panel on Climate Change
ND-GAIN:	Notre Dame Global Adaptation Initiative
NSSA:	Non- Sub-Sahara Africa
PITF:	The Political Instability Task Force
PRIO:	Peace Research Institute of Oslo
RGPH :	Recensement Général de la Population et de l'Habitat (Mali)
SCAD:	The Social Conflict Analysis Database
SSA:	Sub-Saharan Africa
TC:	Tragedy of the Commons
UCDP:	Uppsala Conflict Data Program
USAID:	United States Agency for International Development
USHMM:	United States Holocaust Memorial Museum

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ABSTRACT:

The potential effect of climate change on violent conflict has remained one of the livelier debates across the world for several decades. Surprisingly, despite the large number of studies devoted to that, results remain so far inconclusive and even contradictory sometimes. Although there is no consensus yet, this may not be sufficient to conclude the absence of relationships. Instead, in this dissertation we suggest that the impacts of climate change on violent conflict are conditional on the sensitivity of livelihoods to climate change and the resulting conflict-sensitive coping practices developed at the individual level. Hence, our main objective is to explores how do climate change-induced deterioration of livelihoods and the resulting adaptation practices affect the likelihood of conflict in Central Mali. This is a region highly susceptible to climatic extreme shocks and mired in armed conflict for so long time. Specifically, we aim to: (i) evaluate the perceptions of local communities on climate change and its economic impacts on livelihoods in Central Mali; (ii) estimate the influence of livelihoods as affected by climate change on people's support for violence; (iii) assess the effect of increase in farm size as exacerbated by climate change and related livelihoods loss on people intergroup relations. Primary data was collected on households for tackling these objectives. The data have been analyzed using different econometrical approaches. Hence, a Multinomial Probit and binary logit models were employed for the specific objective one. The second and third objectives were addressed using the Recursive Bivariate regression model. In summary, the results show that local communities in Central Mali do perceive the changes occurring in weather and their negative effects on livelihoods. As a consequence, people develop coping practices (which are very often conflict-sensitive) likely to disrupt their intergroup relations and further increasing the willingness of supporting the use of violence in times of crises. In line with these results, we believe that policies providing local communities affected by climate change with alternative livelihoods strategies would improve their resilience capacity. Moreover, engaging local communities in collectively-designed adaptation strategies could help to better manage the societal implications of environmental change on conflict. In addition, it is also essential to clearly define land ownership rights, as well as the boundaries of cropping and grazing areas and pastoral routes, in order to break the connection between climate change and conflict.

Keywords: Climate Change, Livelihoods, Support for Violence, Recursive Bivariate Regression, Mopti region.

RESUME

Depuis plusieurs décennies, l'effet potentiel du changement climatique sur les conflits et violences communautaires est resté l'un des débats les plus animés à travers le monde. Cependant, malgré le grand nombre d'études consacrées à cela, les résultats restent jusqu'à présent peu concluants et même parfois contradictoires. Bien qu'il n'y ait toujours pas de consensus, cela n'est pas suffisant pour exclure l'existence de relations. En effet, dans cette thèse, nous suggérons que les effets du changement climatique sur les conflits dépendent d'une part de la sensibilité des moyens de subsistance au changement climatique et d'autre part des pratiques d'adaptation (moins coopératives et sensibles aux conflits) développées au l'échelle individuel. Par conséquent, notre objectif principal est d'explorer l'effet de la détérioration des moyens de subsistance induite par le changement climatique et des pratiques d'adaptation qui en résultent sur la propension des individus à soutenir le recours à la violence dans le Centre du Mali. Plus spécifiquement, il s'agira de : (i) évaluer les perceptions des communautés locales sur le changement climatique et ses effets sur les moyens de subsistance dans le Centre du Mali ; (ii) estimer l'influence des moyens de subsistance tels qu'affectés par le changement climatique sur la susceptibilité des individus à soutenir le recours à la violence ; (iii) évaluer l'effet de l'accroissement des terres cultivées exacerbée par le changement climatique et la perte de moyens de subsistance qui en découle, sur les relations intergroupes. Des données primaires ont été collectées sur les ménages pour tester les hypothèses. Ces données ont été analysées selon différentes approches économétriques (notamment le Probit multinomial, le Probit binaire et le Probit bivarié récursive). En résumé, les résultats montrent que le changement climatique affecte négativement les moyens de subsistance et les conditions de vie. En conséquence, les individus affectés développent des pratiques d'adaptation moins coopératives (et plus sensibles aux conflits) qui détériorent les relations intergroupes et augmentent la propension à soutenir le recours à la violence en temps de crise. Conformément à ces résultats, nous pensons que des politiques fournissant aux communautés locales affectées (par le changement climatique) des stratégies de subsistance alternatives et des stratégies d'adaptation développées collectivement pourraient aider à mieux gérer les implications sociétales du changement environnemental sur les conflits.

Mots clés : changement climatique, moyens de subsistance, soutien à la violence, régression bivariée récursive, région de Mopti.

1 INTRODUCTION:

1.1 Background:

Climate change is one of the most prominent challenges facing the entire humanity. Particularly the Sahelian countries such as Mali were since the early 1970s, temperature has risen by up to 1.3 degree Celsius compared to 1 degree Celsius for the rest of the planet. Meanwhile, the average rainfall in Mali decreases by 20–30% (Nyong, 2006; Rose, 2015; Sanogo et al., 2020). The consequences on people and livelihoods are disastrous as increased temperature and severe shortages of rainfall (drought) generally lead to failing harvest, famine, massif animal death as well as mass displacement. These have placed huge strains on rural communities and are heavily undermining their ability to provide basic livelihoods (International Crisis Group, 2020). More interestingly, the livelihood activities such as agriculture, livestock breeding as well as fishing which were known as source of cohesion, cooperation and complementarity, are no more than source of vicious competitions and tensions under climate change negative chocks. As a result, the cooperation and the cohabitation as well as the complementarity which existed in the rural area for centuries is disrupting, further giving way to more and frequent violent conflict. By violent conflict, we mean, a phenomenon at a communal scale (inter and intra communal) that must involve at least one person or group (organization) with a contested claim against another person or group, where at least one of these person/groups is using violent force.

Yet, at the core of the environmental and security debate is the claim that climate change, along with its adverse effects could trigger off violent conflict according to various policymakers and political leaders (See for instance, Ide et al., 2020; Raleigh & Kniveton, 2012; Theisen, 2012). However, the relationship between climate change and violent conflict is not straightforward as being portrayed by policymakers (and political leaders) and academic scholars has so far provided ambiguous, inconsistent and limited empirical evidence in support of the above contentions (Koubi, 2019; Mbaye, 2020; Theisen et al., 2013; Von Uexkull, 2014).

Understanding and investigating the societal implications of climate change is ongoing since 1960 (see Busby, 2016). From a theoretical perspective, it is argued that the different manifestations of climate change (such as droughts, floods, storms and so) might lead to an alteration in the availability of key natural resources such as fresh water, arable land and fodder which will in turn lead to an increase in the competition between these resources' users (the neo-Malthusian theory).

This competition may therefore result in conflict, since more powerful groups may strive to shift the resource distribution in their own favor (T. F. Homer-Dixon, 1999). Another potential pathway proposed, is the climate-induced migration mechanism. For instance, Reuveny (2007) argue that, people with less adaptation capacity may have to leave the affected area when facing severe environmental problems thereby causing conflict in the receiving area. the third pathway, suggest that, in an agriculture based economic, the adverse effects of climate change will probably lead to a loss of livelihood, a reduction of income in the agricultural sector as well as to an increase in the unemployment. This situation, might therefore facilitate mobilization for violence since employment opportunities within the regular economic sector are reduced (Hsiang et al., 2013; Miguel et al., 2004).

Many scholars have attempted to give empirical evidence that climate change affects conflict outcomes. For example, in a study on Sub-Sharan Africa, Hendrix & Salehyan (2012), have examined whether deviations from normal rainfall patterns affect the propensity for individuals and groups to engage in disruptive activities such as demonstrations, riots, strikes, communal conflict, and anti-government violence using a data base of 6000 instances of social conflict over 20 years. Their result confirms the existence of a strong relationship between environmental changes and social conflict. In a similar way, Burke et al. (2009), assessed the potential impact of climate change on armed conflict and found as well a strong linkages between armed conflict and temperature in Africa with one degree centigrade leading to 4.5 percent increase in conflict incidence in the same year and to 0.9 percent increase in the next year. Investigating the linkage between violent conflict in Europe and various reconstructions of temperature and precipitation, Tol & Wagner (2010) come to the conclusion that conflict was more intense during colder period. In a meta-review in which Hsiang et al. (2013) assembled and analyze sixty quantitative papers which pay close attention to the climate-conflict nexus The result suggests a strong causal evidence linking environmental changes to conflict across a range of spatial and temporal scales and across all major regions of the world with each one standard deviation change in climate in terms of warmer temperatures or more extreme rainfall leading to 4% increase in the frequency of interpersonal violence and 14% in the frequency of intergroup conflict. Although, these study constitute an important advance in the search for the link climate change and conflict outbreak, the

results remain heavily contested as the conclusion of a direct association[1] between climate change and conflict differ from those reached by numerous other authors (Buhaug, 2010; Hsiang & Burke, 2014; Klomp & Bulte, 2013).

The potential direct association assessment being inconclusive, the literature has productively turned to studying the indirect pathways and mediating factors between climatic events and armed conflict (J. Busby, 2018). These include mainly: the adverse economic outcomes pathways, the migration pathways and the contextual factors.

The adverse economic conditions pathways suppose that climatic shocks could affect conflict onset by substantially reducing: economic growth, agricultural output, industrial output and political stability (Dell et al., 2012; Koubi, 2017). Several authors have given support for the existence of such a pathway. For instance, in a pioneering work, Miguel et al. (2004), assessed the impact of economic conditions on the likelihood of civil conflict over 41 African countries during 1981-1999. By using rainfall variation as an instrumental variable for economic growth, they found that growth is strongly negatively related to civil conflict in Africa. However, (Ciccone, 2011), come to a different result when re-evaluating the Miguel et al. (2004)'s work with an extension of the study's period. The main difference between both approaches is that Ciccone (2011) focus on the correlation between civil conflict and current as well as lagged rainfall levels when Miguel et al. (2004) focus on rainfall growth. Indeed, he argued that, the use of year-on-year rainfall growth may be misleading since it reflects either a positive as rainfall shock or a reversal to normal conditions. By re-examining economic shocks and civil conflict, Miguel & Satyanath (2011) reply and show that, Miguel et al. (2004) findings hold even using rainfall levels as instrument for economic growth this is explained by the fact Ciccone (2011), rather than using rainfall level as instrument for economic growth, directly focuses on the reduced form results, the regressions of civil conflict on rainfall levels.

In the same logic, Caruso et al. (2016), used an instrumental approach to uncover the effect of variations in minimum temperature on the emergence of actual violence in Indonesia over the period 1993-2003, through the effect on food availability, captured by rice crops per capita. He

[1] **Direct association** here means the regression of conflict variables such as conflict onset or conflict incidence directly on climatic variables such as temperature, precipitation, rainfall level and so on.

found that an increase of the minimum temperature during the month of December which is the core month of the rice growing season in Indonesia, determines an increase in violence driven by the reduction in future rice production per capita. Similarly, Jun (2017), found that, a high temperature during maize growing season reduced the crop's yield, which in turn increased the incidence of civil conflict in Sub-Saharan Africa.

According to Reuveny (2007), climate-induced migration might lead to conflict in the receiving areas through mainly four channels. The first channel suppose that environmental migrants may burden economic and resource bases in their new places, and may lead to competition between them and residents which may furthermore translate into violent conflict. The second channel suppose that conflict might spur conflict between migrants and residents because of their difference in cultures, in ethnic groups or religious affiliation which could entail unstable ethnic balance. The third channel suggest that Environmental migration could generate distrust between the area of the migration's origin and host area. The last channel supposes that the conflict may also follow existing socioeconomic fault lines. Koubi et al. (2018) in their study on five developing countries choose to focus on the factors behind and consequences of migration at the individual level. They conclude by saying that, migrants who are likely to perceive conflict in their new locations are those who experienced gradual, long-term environmental events in their former homes than those who experienced sudden, short-term environmental events. In almost the same logic Ghimire et al. (2015), assessed the effect of displacement induced by floods on conflict using data for 126 countries over the period 1985-2009. They found that, environmental migration instead of provoking new conflict, fueled the existent one.

Recent research also show that the combination and interaction of climate adverse economic conditions with socioeconomic and political factors are critical to influencing conflict (Koubi, 2017). For instance, Koubi et al. (2012), found that non-democratic countries are more likely to experience civil conflict under a deteriorate economic conditions when facing climatic shocks. In a study carried out on land invasion in Brazil, Hidalgo et al. (2010), using adverse economic shocks instrumented by rainfall, found that, in highly unequal municipalities, negative income shocks cause twice as many land invasions as municipalities with average land inequality. According to Detges (2016), civic conflict events in connection with drought are more likely in administrative areas with poorly developed road infrastructures and in regions where an important part of the

population lacks access to an improved water source. A local drought is found to increase the likelihood of sustained violence for agriculturally dependent groups as well as politically excluded groups in very poor countries (Von Uexkull et al., 2016).

Undoubtedly, there have been a significant number of studies devoted to assessing the potential link between climate change and violent conflict. Indeed, from the simplest direct evaluation to the indirect assessment design, researchers have strived to convincingly probe the causal effect linking climate change to conflict. Particularly, the later change regarding the approach (from a direct association to search for indirect connection) has allowed a better understanding of the relationship. However, there are still significant gaps in the understanding of causal mechanisms and variations at the micro level (von Uexkull et al., 2020). Our knowledge of whether and how climate is related to conflict so far uncertain (J. Busby, 2018).

1.2 Problem statement:

Despite the important number of studies devoted to investigate the relationship between climate change and conflict, results remain so far inconclusive and even contradictory. Indeed, while a group of studies argue that climatic events especially warming and drier (scarcity in other words) are a strong predictors of violent conflict (see for instace, Burke et al., 2009; Eastin, 2018; Hsiang et al., 2013), another group of studies claimed the opposite as they found no relationship between climate change and violent conflict (see Buhaug, 2010; Theisen et al., 2011). A third group arrives at even contradictory conclusions. Indeed, rather than scarcity (induced by bad climatic conditions), it is found that, on average conflict is more prevalent in periods of favorable agro-climatic conditions (period of abundance) with water abundance and higher yields (see Aksoy & Palma, 2019; Koren, 2018, 2019; Raleigh & Kniveton, 2012; Salehyan & Hendrix, 2014). However, this lack of consensus may not be sufficient enough to conclude the absence of links between climate change and conflict. Instead, since livelihood is heavily undermined by climate change, the affected people would naturally struggle to maintain livelihood by coping and adapting to climate change. This is done either by developing new livelihood strategies or by adjusting the existing livelihood strategies. Hence, we believe that if climate change might affect conflict patterns, it would likely be related to how those affected people manage to adapt and compensate the livelihood losses induced by environmental change as a result of antagonistic and incompatible local adaptation practices developed. Accordingly, the causal mechanism linking climate change

to conflict outcomes is likely related to weak local capacity in adapting livelihood strategies to climate change. This ultimately rises and gives room to the research question guiding this dissertation.

In assessing the relationship between climate change and violent conflict, the area of investigation is of great importance and Central Mali offers an interesting case study because of several characteristics. Indeed, located in the center between the North (the Sahara) and the south (the Sahel), the region is a climate change hotspot plagued by growing insecurity and violent conflicts. Climate trends for Mopti show an overall increase in temperature associated with significant interannual variability in precipitation (Tor A. Benjaminsen et al., 2012). In addition to being densely populated, food insecurity is particularly prevalent in the study area with 47% of the population facing food insecurity (CGIAR, 2022). The economy is essentially agro-pastoral and halieutic (Maiga & Fall, 2023). The most important resources are those coming from agriculture (land), livestock (pasture land) and fishing (rivers, lakes, ponds and channels). The exploitation of these resources is mainly based on three production systems: the agricultural production system, the livestock production system and the fishing production system. The agricultural production system is mostly dominated by rice production and produces 40% of the Mali's rice and 20% of its millet and sorghum (International Crisis Group, 2016). The livestock production system is dominated by the breeding of cattle. Due to the diversity and richness of its natural pastures, the region is a breeding area par excellence and ranks first in number of cattle and sheep/goats in Mali. Mopti is the largest source of livestock in the country, the region alone holds 22.10% of the country's national cattle population and 26.5% of the sheep-goat population (International Crisis Group, 2016). The fishing production system is the third economic activity of the region after agriculture and pastoralism and represents 80% of the national fish trade (Brown et al., 2022) with an important hydrographic network. All of these production systems co-exist and, at times, overlap, depending on the season. However, climate change has made the actors of those different production systems competing, moving into new areas in search of land, water and grass for grazing and frequently fighting over natural resources.

In central Mali, violent conflicts between the different resource (land, water, pasture etc.) user groups (specially farmers and herders) are very common (International Crisis Group, 2016). For example between 1992 and 2009, Tor A. Benjaminsen et al. (2012), identified 820 land use

conflicts in the region. These conflicts most of time result in several deaths (human and animal) and cereal damage. For example, a clash between two Fulani villages the Soosoobé and Salsalbé in December 1993 has led to death of 29 and 42 injured people (Remi et al., 2018). In 2002, a Dogon (farmers) attack on the Fulani (herders) village of Mbana, killed around five people, including the village chief. Similarly, in a dispute over a cattle corridor blocked by agriculture in May 2012, the Dogon (famers) attack on the village of Sari in Seno (a Fulani village in the Koro circle) resulted in the burning of 350 huts with 774 cattle taken and 21 villagers killed in addition to several injured (Tor A. Benjaminsen & Ba, 2019; Remi et al., 2018). According to a 2018 Human Rights Watch report on central Mali[2], communal violence has in 2018 led to the death of over 200 civilians and driven thousands from their homes.

1.3 Research questions:

The main research question guiding the present dissertation is this: How do climate change-induced deterioration of livelihood and the resulting coping responses affect support for violence in Central Mali?

The sub-questions are:

1. What are the changes in climate as perceived by local communities in central Mali and associated economic impacts on livelihoods (agricultural production and income)?
2. Do livelihoods as affected by climate change, influence people support for violence?
3. Does increase in farm size as exacerbated by climate change and related livelihoods loss deteriorates people intergroup relations?

1.4 Objectives of the study

The main objective of this dissertation is to analyze the effect of climate change-induced deterioration of livelihood and the resulting adaptation measures on individual support for violence.

Specifically, the dissertation aimed at:

[2] https://www.hrw.org/report/2018/12/07/we-used-be-brothers/self-defense-group-abuses-central-mali accessed 18 February 2023.

i. Evaluate the perceptions of local communities on climate change and associated economic impacts on livelihoods in the study area;
ii. Ascertain the influence of livelihoods as affected by climate change on people's support for violence in Central Mali;
iii. Estimate the effect of increase in farm size as exacerbated by climate change and related livelihoods loss on people intergroup relations.

1.5 Hypotheses:

The following null hypotheses would be tested:

a. There is a significant perception of climate change and related impact on livelihoods in the study area;
b. Climate change and the resulting deterioration of livelihood significantly affect support for violence in Central Mali;
c. Increase in farm size as exacerbated by climate change significantly affects people intergroup relations.

1.6 Theoretical framework on the mechanism linking climate change to conflict

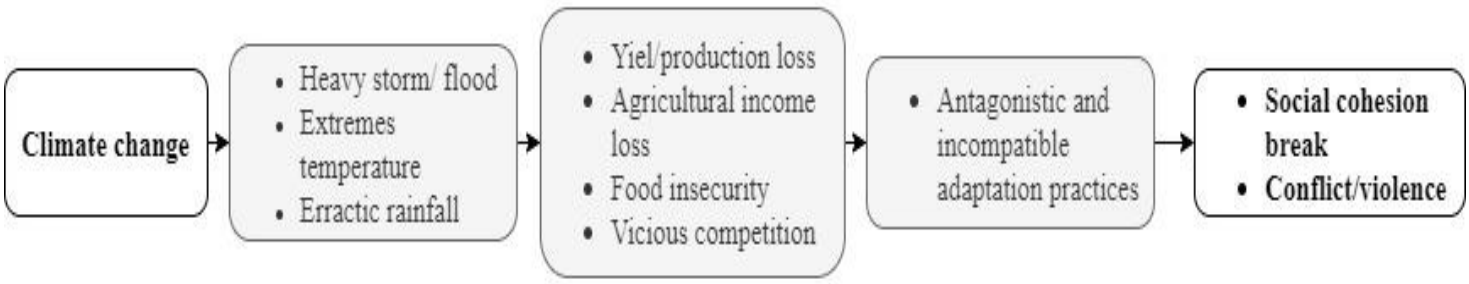
In this dissertation, we investigate the plausibility of a prominent mechanism according to which climate change can foster violent conflict through antagonistic and incompatible adaptation practices. Indeed, as climate change strikes, rainfed crops yields drops as a result of rising temperatures, and high rainfall variability. In parallel livestock productivity and production decline as well due to heat stress, reduced availability of water and pasture resulting from desertification and drought (Hegazi et al., 2021). This places a severe economic pressure on livelihoods and livelihood groups in the rural area due to the heavy reliance on rain-fed agriculture and natural resources (Detges, 2017). Consequently, it raises the awareness of local communities regarding climate change and relative adverse impact on livelihoods and gives room to our first hypothesis.

To compensate the mentioned losses induced by climate change, the affected people will naturally strive to cope and adapt. This is somehow done mainly through three main approaches. (i) The opportunity cost theory approach, indeed due to recruitment prospects facilitated by the current context, some affected may be willing to join one the numerous non-state armed groups presents in the study area (Hegazi et al., 2021). This led to the formulation of the second hypothesis being

explored in this dissertation: Climate change and the resulting deterioration of livelihood significantly affect support for violence in Central Mali. (ii) The second approach referred to the Common Pool Resource Theory (CPR theory). Indeed, while some affected people joined non-state armed groups motivated by financial incentives (Tora A. Benjaminsen & Ba, 2009) others may engage as a means of adaptation in a process of appropriation of common resources (land, water sources) hence creating negative externalities for others. Accordingly, we argue that climate change might affect conflict through these weak adaptation practices developed at the individual level in order to sustain living. This is likely because of antagonistic, incompatible and overlapping adaptation practices developed. Indeed, since livelihoods are heavily undermined by climate change each party would be interested by getting the most that it can (Hardin, 1968). Therefore, the behaviors and emotions of each party are ultimately directed toward maximizing its own gain regardless other parties (the Common Pool Resource Theory). One scenario is that farmers and herders as well as Farmers and Fisherman can increasingly come into conflict during rainfall shortages/drought because of failing harvest. In some cases, this means that farmers have to expand their crop lands to areas occupied by herders (either for pasture of transhumance route/passage) and fisherman (shallow parts of rivers and streams) in order to meet the growing food insecurity and income loss (Hegazi et al., 2021; Winters and Jeffrey, 2021). Another practice, is that herders because of suitable pasture areas shrinking would have to move their livestock to areas occupied by farmers. These situations will significantly affect people intergroup relations and social cohesion in the region (this has led to the third hypothesis formulated in this dissertation).

(iii) The third approach referred to Elinor Ostrom's theory. Indeed, in a context of free access to natural resources this disruption in inter-group relation area would be alleviated if instead of acting independently and uncoordinatedly local communities arrive at effectively design ways to govern the local resources. Indeed, Elinor Ostrom in 1990, developed eight (8) design principles for how commons can be governed sustainably and equitably in a community (See Cox et al., 2010).

Figure 1.1: Causal mechanism linking climate change to violent conflict



Source: Author's own construction

To sum up, climate change adverse chocks contribute to livelihood reduction, to which groups adapt differently in times of crisis. One strategy is to expand the harvested area through crop land expansion and livestock displacements. Other practices include migration, irrigation as well as livelihood diversification which, due to the convergence of the livelihoods of communal groups, increases the challenges of controlling common resources and in turn increases the likelihood of communal violence and conflicts. This has led to the formulation of the above associations in form of hypotheses.

1.7 Justification

With this case study, we hope to contribute understanding the complex interconnections linking climate change to conflict outcomes. We aim to do so by focusing on Mali, particularly the central region of the country. Indeed, regarding the country's high exposure to climate change, the heavy reliance of the population and livelihoods on climate-sensitive activities and the country's long history with communal conflict, this research should allow taking into account context specificity and understanding how climate hazards, livelihoods strategies and conflict are inter-related at the local level. This is important in the sense that, one of the arguments pointed out by scholars to explain the inconstancy and the contradiction found in the climate-conflict analyses, is that extant studies have paid too little attention to the context-specificity that condition the manifestation as well as the effect of climate hazards (Koubi, 2019; Von Uexkull, 2014). Next, investigating mediating factors susceptible to connect climate change to conflict outcomes is also of great interest and considered as research priority (De Juan & Hänze, 2021; Theisen et al., 2013). This study aims to explore such contexts-specificity argument by focusing on the mediating

mechanisms through which climate change is likely to contributes to communal conflict in Mali. The mechanisms that are explored are deterioration in livelihoods (specifically in living conditions), willingness to adapt livelihoods strategies to climate change, anarchical cropland expansion as coping strategies. Accordingly, the mechanism suppose that climate change first negatively affects livelihoods conditions. With a limited livelihoods alternative, the affected population would obviously strive to compensate losses induced by climate change mostly by adjusting the extant livelihoods strategies while motivated by the goal of gaining the maximum. This is likely to increase the likelihood of conflict if the individual coping practices developed are antagonistic and incompatible. We believe that investigating this mechanism should allow for a more accurate mapping of the climate-conflict nexus in the case of Mali.

1.8 Analytical approach and Methods of the dissertation

This study employs two main analytical techniques to achieve the formulated objectives. It uses for the first and second objectives a two-step instrumental variable procedure. Specifically, a recursive bivariate probit model to determine the interaction between climate change induced deterioration in livelihoods, increase in farm size (anarchical cropland land expansion) and support for violence. Contrary to the standard two-step instrumental variable, the recursive bivariate probit model account for sample selection (endogeneity) bias. Next, the study employs the standard binary probit model to probe the effect of willingness of adapting livelihoods strategies to climate change on support for violence.

1.9 Organization of the thesis

Above this introductory section, this dissertation is structured around 5 chapters. Chapter 1 presents the theoretical and empirical studies related the climate-conflict nexus including the conceptual framework of the study. The background of the study area which includes the socio-economic and bio-physical description of the study area is presented in chapter 2 in addition to a description of the data collection methods. It also provides the socio-economic and demographic characteristic of the sample households. In chapter 3, chapter 4, chapter 5 are respectively presented the analysis on climate-induced deterioration in livelihoods effect on support for violence, the analysis on the impact of willingness of adapting livelihoods strategies to climate change on support for violence and the analysis on anarchical cropland expansion and support for violence. A section dealing presenting the general conclusion finally ends this dissertation.

2 CHAPTER ONE: LITERATURE REVIEW

2.1 Introduction:

Investigating the relationship between climate change and conflict outcomes is ongoing since 1960 (see Busby, 2016). Substantive number of studies have been carried out accordingly. These includes theoretical analyses as well as quantitative and empirical assessments. In order to have an insightful view of what have been so far done regarding the climate-conflict nexus and finding out the gaps and limitations, this chapter reviews those theoretical and empirical studies. Consequently, the chapter is organized in two sections. The first section provides an overview and definitions of key concepts being used in this dissertation for then to give some clarification and precision. Thereafter, the theoretical and empirical literature across the world on the link between climate change and armed conflict are presented in the second section.

2.2 Conceptual framework:

The field of climate-conflict nexus analysis is bogged down with so many different definitions and approaches of same concepts. Hence, it is sometimes singled out that, the failure of precising the nature of the used concepts could be one of the potential sources of the discrepancy found in the literature. To avoid falling in the same pitfall, we recall in the following lines some major definitions and then precise the nature of the concepts being used in this dissertation.

2.2.1 The concept of climate change:

Climate change refers to a statistically significant change in the average state of the climate or its variability that persists over a long period (usually decades or more), for example, an increase in temperature and a rise in the level of the sea. While, Climate change is commonly defined as long-term weather patterns. Climate variability, on the other hand, is defined as changes in the mean state and other statistics of climate at all temporal and spatial scales, beyond individual weather events (Koubi, 2017). According to the World Meteorological Organization (2019), "The term 'Climate Variability' is often used to denote deviations of climatic statistics over a given period of time (e.g. a month, season or year) when compared to long-term statistics for the same calendar period. Climate variability is measured by these deviations, which are usually termed anomalies"

2.2.2 Climate change proxy:

As defined above, climate change is reported as a less useful explanatory variable when it comes to the occurrence of a conflict-related event. This is particularly due to the fact that changes in the climate occurred too slowly, they often take decades or more to manifest themselves (Hendrix & Glaser, 2007). While the weather is also argued to change too quickly (day-to-day variations), climate variability remains the candidate with the greatest explanatory power in matters of climate conflict. This motivates the use of climate variability as a proxy for climate change in this essay. Variables such as precipitation and temperature, or indices combining different climatic statistics, would be used alongside our dependent variables of interest.

2.2.3 Environmental change:

"Environmental change is a broader form of transformation of natural settings including the natural variability in the climate, anthropogenic climate change, and other anthropogenic activities that transform the environment" (Cabot, 2016).

Note: Environmental migration is defined as the displacement of people due to climatic changes.

2.2.4 The concept of resilience:

In the economic environment, resilience is referred to as "a capacity that ensures stressors and shocks do not have long-lasting adverse development consequences"(FAO, 2013). It is the ability (capacity) of a household to regain a previous level of well-being after a shock. Resilience is a multi-faceted concept that emphasizes the capacity of the individual or household to absorb, adapt and transform livelihoods (von Uexkull et al., 2020). These stressors and shocks can be shared by a large community (large group of people) or experienced only within a given community or household. They can occur naturally such as environmental shocks (droughts, floods. cyclones) or triggered by man such as those related to markets, conflict etc.

2.2.5 The concept of livelihood:

Livelihood is a multi-facetted concept which means both: what people do (for example: farming, animal breeding, fishing, trading etc.) and what they accomplish by doing that (for example, income, food etc). in that regard, it refers to outcomes as well as activities (Niehof, 2004). However, a multitude of definitions can be found in the literature. Importantly, each authors attempt to define the concept regarding his focus and objective. For example, Chambers and

Conway (1992) defined livelihood as "the capabilities, assets (stores, resources, claims and access) and activities required for a means of living". According to Ellis (2000), a livelihood includes the assets (natural, physical, human, financial and social capital), activities and access to them (mediated by institutions and social relationships) which together determine the living earned by the individual or household. In Long's (1997) terms, livelihoods best express the idea of individuals and groups struggling to earn a living, trying to meet their various consumer and economic needs, facing uncertainties, responding to new opportunities and choosing between different value positions. For Bakhtsiyarava et al. (2018), livelihood means the strategy by where people get income or food. The livelihood portfolio is the set of activities in which households engage to generate livelihoods and achieve a certain level of livelihood security (Niehof, 2004). In this dissertation, we follow Niehof (2004) and refer to livelihood as both the activities and outcomes required to secure the necessities of life.

2.2.6 Conflict:

There are various definitions and approaches of the concept of conflict whose nature generally differs according to the research field, the view point or emphasis provided by researchers, groups of researchers or institutions. The use of various definition of conflict is exactly one of the reasons pointed out by scholars to explain the inconclusiveness and the divergence related to the literature on the climate-conflict nexus. However, in general term, conflict means a violent opposition of interests, ideas or actions. It encompasses a large phenomenon ranging from interpersonal disputes to wars between states. In the words of Coser (1956), it is defined as "the struggle over values or claims to status, power, and scarce resources, in which the aims of the groups or individuals involved are to neutralize, injure or eliminate rivals". For the Uppsala Conflict Data Program (UCDP) [3] conflict referred to "an incident where armed force was used by an organized actor against another organized actor, or against civilians, resulting in at least 1 direct death at a specific location and a specific date". Some authors prefer to add certain specifications based on the damage resulting from the conflict in order to classify it as violent or non-violent. For instance, Wallensteen & Axell (1994) distinguish conflict from violent conflict and defines the latter as "a conflict between two or more parties, of which at least one is the government of a state and an anti-

[3] A data collection program on organized violence and armed conflict based at Uppsala University in Sweden

state group or groups using weapons on a sustained basis, that often results in at least 25 battle-related deaths per year". Others prefer to put the specification according to the cause and origin of the conflict (Environmental or Climate Conflicts, Political conflicts, Economic conflicts/ Economic war, Ethnic conflicts, religious conflicts or Territorial conflicts). As we are more interested by things related to climate and environment in this work, the Environmental or Climate Conflicts, will be developed a bit in the following line in order to give more insight about this concept.

2.2.7 Climate-conflict/ environmental conflict:

In the environmental and climate change field, conflict referred generally to competition over scarce resources resulting from climate change or environmental degradation, implying the use of forces. However, this scarcity of resources should not be considered as a sufficient condition for conflict to occur. It must have been caused by changes in the physical environment induce by climate change (Denis, 2019). According to Libiszewski (1992) land disputes can only be viewed as climate conflicts if, when affected by climate change, land becomes a matter of contention. However, ordinary land-conflict coming from unequal distribution, overusing and so cannot be considered as environmental conflict. In the same line Gleditsch (2015) indicate that environmental degradation such as soil erosion, gully erosion, drought, water pollution, desertification and so on, may exacerbate environmental conflicts because it stress more the scarcity by reducing the quantity and quality of resources in question.

In practice, empirical studies on the climate-conflict nexus focus generally on civil conflict (as proxy of conflict) when quantitatively examining the link between climate change and conflict. However, there is recently a growing argument that climate-induced conflicts are more likely to be in the form of local communal conflict (Nordkvelle et al., 2017). This is based on the argument that this local-level conflict is more likely consequence of climate change. In fact, it is argued that the threshold for engaging in civil conflict is higher than the threshold to challenge another group. Following the trend in the recent literature, the focus of this dissertation is on communal conflict (inter-communal violence). This later form as it is one of the types of conflict that is widespread in Mali region. We define communal conflict as a phenomenon at a communal scale that must involve at least one group (organization) with a contested claim against another group, where at least one of these groups is using violent force. However, along with this dissertation, we will be

using the words violence, conflict, violent conflict, armed conflict interchangeably to mean communal conflict.

Note: Political violence is defined in the broad sense as recourse to violence to achieve political goals. It can manifest itself in many ways, ranging from violent protests and property damage to community clashes and civil unrest.

2.2.8 Conflict-measurement techniques: Support for conflict/violence a microlevel approach

The traditional and most used conflict-measurement techniques in the academic and research domain is the consideration (recording) of the contestation (confrontation) or its incidence (number of deaths, of injured, the extent of the damage etc.) after it took place. Information regarding those events is generally collected from secondary source of information (reports, newspapers, newswires, publications by NGOs etc.), then revised, aggregated, completed and arranged in database.

Multiple databases and research project regularly collect and give access to such type of conflict data. The most known among these include, the Armed Conflict Location & Event Data Project (ACLED) which collects and gives information on the dates, actors, locations, fatalities, and types of all reported political violence and protest events around the world. The Political Instability Task Force (PITF) Worldwide Atrocities Dataset, compiles data on major domestic political conflicts leading to state failures. The Uppsala Conflict Data Program (UCDP) offers a number of datasets on organized violence and armed conflict. The Social Conflict Analysis Database (SCAD) includes protests, riots, strikes, inter-communal conflict, government violence against civilians, and other forms of social conflict not tracked in other conflict datasets. The SCAD covers all of Africa, Mexico, Central America, and the Caribbean. Overall data of that nature are remotely measured and essentially macrolevel (country-level). Due to the heterogeneous definition of the concept of conflict, data vary from one database or project to another, and hence affecting the conclusions from conflict analysis.

Beyond the macro-level approach, the micro-level measurement technique involves targeting and directly interviewing the people involved in the violence (victims or perpetrators). The main objective guiding this approach is to understand of the motivations and attitudes of populations

where conflict emanates. It involves in the first-time selecting individuals (respondents) using relevant, systematic and appropriate sampling techniques. Structured questionnaires are then administered in the second-time. The questionnaires include not only questions on conflict or violence, but also questions on other individual characteristics, such as the demographic and socio-economic characteristics of the respondents. In the literature, researchers have used several fairly similar questions to capture people's attitudes and motivations towards conflict and violence. The differences are generally found in the way each question attempts to minimize the sensitivity and social desirability biases associated with the nature of that questions. Regarding our objectives, this second approach is used in this thesis. Specifically, we collected survey data in the study area that explicitly asked individuals about their willingness to support the use of violence and changes climate that had recently occurred. For the exact formulations of the question measuring support for violence and other questions see section (3.4.1) variables definitions and design.

2.3 Theoretical and empirical literature review

Understanding the human security implications of environmental changes has been a major focus of social science researchers. Indeed, climatic changes characterized by recurrent droughts, flooding, higher temperature, storms, etc. are reported to have significant potential implications for the living conditions of people all over the world. One of the most threatening potential implications for mankind, remains the potential impact of environmental changes on human security. However, this security risks of environmental changes appears to be very complex. Theories and empirical assessments have been proposed by scholars in the literature to help understanding the relationship between climate change and conflict outbreak. Although, no consensus has emerged so far, those works constitute a useful guidance about the potential climate-conflict nexus.

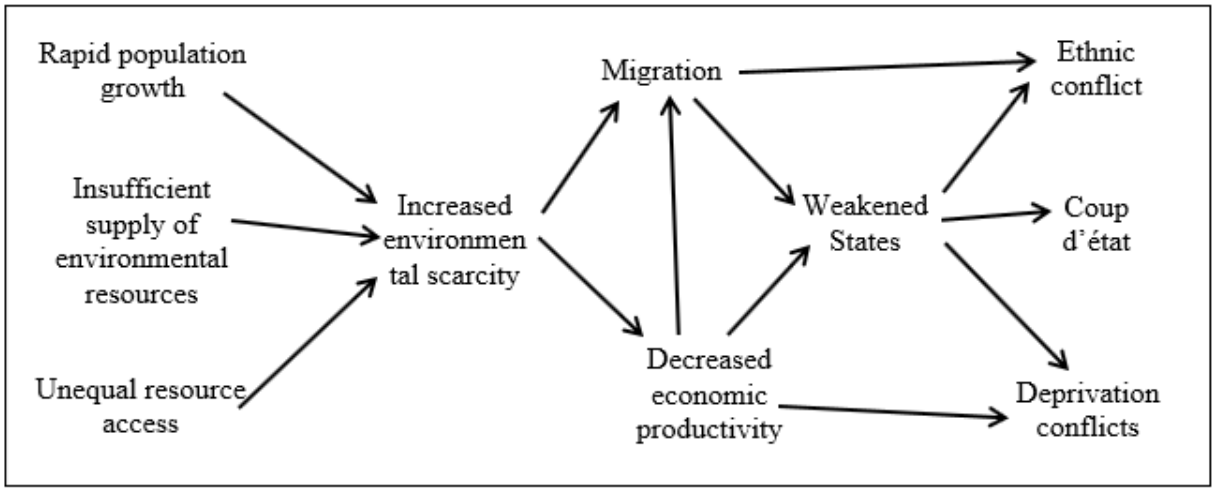
2.3.1 Theoretical literature review

Theoretical studies on the link between climate change and violent conflict is definitely incorporated into the general theoretical literature on the environmental security agenda. In what follows, I will review the most influential theories dealing with the climate-conflict nexus.

2.3.1.1 The Neo-Malthusian theory:

Also called “eco-violence-theory”, the neo-Malthusian theory tried to draw a connection between population growth, environmental scarcity and violent conflict. The fundamental assumption is that, rapid population growth (as it is observed in developing countries) combined to increasing environmental scarcity (especially those crucial to food production) will trigger off violence and conflict in those countries (T. Homer-Dixon, 1994). It is argued that, too much demand coming from the rapid population growth associated to insufficient supply (decrease in quality and quantity of natural resources) and/or unequal resource access both as result of environmental hazards will force certain people and societies into a severe condition of deprivation. The affected people may either migrate (for those who are able to); either to fall in violence (most powerful groups generally) for then to get control of the scarce resource (deprivation conflicts). Migrants’ groups also often trigger ethnic conflicts when they move to new places.

Figure 2.1: Illustration of the Neo-Malthusian Theory



Source: (Gleditsch & Urdal, 2002)

According to Homer-Dixon from the Toronto School, there are three forms of scarcity which in combination could cause violence: “Supply-induced scarcity” this form of scarcity arises from misuse, overuse and degradation generally imposed by human being and environmental shocks. Indeed, as climate change hits, the quality and the quantity of renewable resources such as fresh water, cropland, forest and so on will decrease and shrink. This could heavily undermine people livelihood and put them in a situation of high vulnerability especially in developing countries where agriculture constitute the main source of food. The second form is “Demand-induced scarcity” resulting from either rapid population growth either from the increase in demand per

capita. As Malthus the father of the Malthusianism theory indicate it in the early 1790s[4], population always grow exponentially while natural resources which generally drive economic growth especially food supply growth follow an arithmetic progression. In that regard, the food per capita will decrease as the number of people increases, and could further undermine people living conditions. The last form of scarcity is called "Structural scarcity". This scarcity derives from unequal social distribution of resource such as uneven allocation of land among land users (farmers and herders). For example, Mali's 1960s government basing their economic development policy on agriculture have given more priority to crop production in the detriment of livestock husbandry. This situation has favored farmers and give them more access to land while herders are neglected and herding land more and more transformed in cropping land. These three forms of scarcity are identified in the neo-Malthusian as the main sources of environmental scarcity which in turn exacerbate certain stresses within countries and affect the livelihood of conflict through, deprivation (decreased economic productivity) and/or, migration.

2.3.1.2 The opportunity-cost theory:

In the opportunity cost theory, focus is made mainly on the economic adverse effects of environmental changes. For instance, it is argued that, in the face of adverse climatic chocks, the individuals experiencing high economic losses will be more willing to join violent groups than if they had not experienced such losses (Vestby, 2019). This is explained by the fact that, as climate change increasingly favors economic losses, the opportunity cost of joining an armed group will decrease. Since, the expected outcome from engaging in violence outweigh the expected outcome from ordinary economic activities (such as farming, fishing or herding), individual's motivation and willingness to engage in violence will then increase.

From the literature, the opportunity cost theory appears as the most widely cited model to sustain the argument that climate change and violent conflict are indirectly linked. For instance, in line with the opportunity cost model, Vestby (2019) using Afrobaromter data, show that individual who reported to have experienced deterioration of living condition is more likely to participate in political violence than if it had not. In a similar way Dube & Vargas (2013) assess the opportunity cost theory in focusing on Columbia's two largest exports: coffee and oil. Two groups of

[4] In Malthus' famous Essay on the principle of population (1798).

municipalities are in interest. The first group is specialized in agricultural goods production (coffee) which is known of being labor intense, while the second group is based on natural resources exportation (oil) which are not as labor intense as the coffee production. They report that, a fall in coffee prices (coffee shock) occurred in the 1990s has lowered wages consequently translate into violence among the municipality cultivating more coffee.

2.3.1.3 Common Pool Resource (CPR) theory, the Tragedy of the Commons (TC) and Environmental conflict:

The link between both theories (CPR and TC) lies in their subject of analysis. In fact, both CPR and TC deal with questions of resource exploitation and collective action. A common pool resources are defined as systems that generate finite amounts of resource units so that one person's use subtracts from the amount of resource units available to others. Indeed, based on the principle of excludability and rivalry in consumption, the CPR theory has identified four kinds of goods which are, first, the Common goods, are considered as open-access (non-excludable) and rivals such as pastures or fish stocks in international waters; second, the public goods are open-access but non rivals for example military defense or public spot light; third, the Private goods are excludable and rival. Examples of private goods include food and clothes; and, finally, the Club goods which are excludable but non rival, cable television is an example.

According to the CPR theory, the deterioration of the commons (such as pastures, water basins, irrigation systems, etc.) induced by climate change will not only aggravate the competition among the different group of users, but also will lead to the overexploitation and even to the destruction of the commons (the tragedy). In the absence of a central authority for the management of those commons, this vicious competition could lead to violent conflicts between different user groups since the appropriations made by an individual are likely to create negative externalities for others. Particularly, if each individual is only interested in maximizing personal utility rather than conservation for general interest. That process of maximizing individual utility to the detriment of the general interest gives rise to what is commonly called the “tragedy of the commons”. Indeed, the tragedy of the commons occurs when it is difficult and costly to exclude potential users of common-pool resources that generate finite flows of benefits, as a result of which those resources

will be depleted by rational, utility maximizing individuals rather than conserved for the benefit of all (Ostrom, 2008).

The notion of "the tragedy of the commons" was first introduced by Hardin (1968) to describe the problem of resource over-exploitation. He illustrates that by taking the example of an open to all pasture. As indicates Hardin (1968), every herder have total benefits from his own over-use of the pasture (when selling or exchanging his animals) while the cost of overgrazing is shared by all herders using the site. As all rational individual (self-interested), each herder would be motivated to add more and more animals without caring about exceeding the capacity of the pasture, guided only by maximizing individual benefits. Therein lies the "tragedy", in fact, pasture being a finite resource (like all common-pool resources), ruin is the destination of all pastoralists (all men in general), since a cumulative over-use of the resource leads to an eventual depletion of the resource in question.

The tragedy of commons theory became a very known and cited theory in the field of economics and ecology. However, it has also been heavily criticized and Elinor Ostrom[5] was able to oppose this popular theory by showing how local communities could effectively design ways to govern the commons (local resources) to ensure its survival for their needs and future generations. The theory of Elinor Ostrom is based on conditions. Indeed, instead of acting independently and uncoordinatedly (as in the tragedy of commons), it suggests a collective and coordinated action. It also requires the involvement of local communities in the management of local resources (commons) and that a need for a central authority is not necessary. In that regard, Elinor Ostrom in 1990, developed eight (8) design principles for how commons can be governed sustainably and equitably in a community (See Cox et al., 2010). The first principle is to well-defined boundaries (it stipulates the presence of well-defined boundaries around a community of users and boundaries around the resource system this community uses); The second principle is to "match rules governing use of common goods to local needs and conditions"; the third principle is to "ensure that those affected by the rules can participate in modifying the rules"; the forth is to "make sure the rule-making rights of community members are respected by outside authorities"; the fifth is to "develop a system, carried out by community members, for monitoring members' behavior"; the

[5] Elinor Ostrom's theory asserts that local communities are best placed to manage their natural resources because they are the ones who use them and that any regulation of resource use must be done at the local level, as opposed to a higher, central authority that does not have direct interaction with the resources.

sixth is to “use graduated sanctions for rule violators”; the seventh s to “provide accessible, low-cost means for dispute resolution” and the eight is to “build responsibility for governing the common resource in nested tiers from the lowest level up to the entire interconnected system”.

2.3.2 Empirical literature review

Before reviewing the empirical works on the relationship between climate change and conflict outcomes, this section starts by discussing climate change as it is perceived by the local communities and related negative impacts.

2.3.2.1 Perception of climate change and related impacts on livelihoods

This sub-section is an attempt to understand local people’s perceptions of climate change and related impacts. Indeed, The affected people responses to climate change likely depend on their perceptions of climate change (Babatolu & Akinnubi, 2016; Sekelemani et al., 2020). More interestingly, the manifestation of climate change and its impacts are expected to vary across localities. Some areas are expected to get drier while other parts are expected to be much wetter (Collier et al., 2008). By implication, individuals from different regions and localities are likely to have different experiences of climate change and it impacts. For instance, Asrat & Simane (2018), in a study on North-West Ethiopia have analyzed the local communities’ perception and adaptation to climate change. The study employed the Heckman sample selection model. The Heckman selection model is used to analyze the two-step process of adaptation to climate change which initially requires the perception that climate is changing prior to responding to the changes through adaptation measures. Using data collected from 734 randomly selected farm household heads, the authors found that educational attainment, the age, the number of crop failures in the past, farming experience, climate information, duration of food shortage determined farmers’ perception of climate change.

In Nigeria, smallholder Farmers’ Perception of Climate Change was evaluated by (Babatolu & Akinnubi (2016). The study revealed that there is high level of climate change awareness in the study area. According to respondents, increasing temperatures, unpredictable, erratic, heavy and increasing rainfall, late onset and early retreat of rains are the major changes intervening in climate in their localities. In another study conducted in Nigeria (more specifically in the agricultural zone of Oyo State), respondents have identified delayed rainfall, higher temperature, unusual heavy

rainfall and flood as their perception of climate change (Kuponiyi et al., 2010). Similar findings in made in South Ethiopia. Indeed, using survey data collected from 20 pastoral/agropastoral associations and 480 farm households, Debela et al. (2015) found that most participants in the sample perceived climatic change and its negative impact on agricultural. This perception was significantly influenced by factors including age, education level, livestock holding, access to climate information and extension services.

In southern Mali, the analyze of a data collected form 400 smallholder farmers revealed an increase in the frequency of strong wind, dust, drought, high temperatures and number of hot days as the main climate change-related indicators (Sanogo et al., 2017). The key factors shaping this perception were age, educational level, farm size and gender. Households are aware of climate variability and identify wind and occasional excess rainfall as the most destructive climate factors. The study of Mertz et al. (2009), has shown that, households in the savanna zone of central Senegal are aware of climate variability and has identified wind and occasional excess rainfall as the most destructive climate factors in the area. The perceptions of cocoa farmers on climate change in rural Ghana were analyzed by Codjoe et al. (2013). The study has shown that all the cocoa growing regions in Ghana are aware of climate change and its impact on livelihoods. Using the Heckman sample selection model Deressa et al. (2011) found that farmers' perception of climate change in the Nile basin of Ethiopia was significantly related to the age of the head of the household, wealth, knowledge of climate change, social capital and agroecological settings. In Togo, evidence has shown that 85% of respondents out of 320 households (the sample) have perceived increase in temperature while 85.58% of the respondents observed decrease in rainfall amount and distribution. These perceptions were influenced by the gender, the fact of owing the farm land and being located in the plateau region or savannah region of Togo. Farmers in northwestern Bangladesh have indicated that drought, groundwater depletion, lack of canal and river dragging are the most prevalent disaster in the area because of rainfall and temperature variation (Habiba et al., 2012). As can be seen from the above literature, each communities seems to have its own perception of climate change manifestation and different factors are found to be associated with those perceptions. The following lines discussed the economic impact of climate change on livelihoods.

Although climate change is a global phenomenon, its impacts vary across locality and may also depend on the structure of economies. For instance, in a comparison study, Barrios et al. (2008) found that climate change is more detrimental for Sub-Saharan Africa (SSA) developing countries than non- Sub-Sahara Africa (NSSA). This is probably due to the important role of agriculture (which is a very sensitive sector to climate change) in these economies. Indeed, rainfed agriculture is the engine of most SSA developing country economies. Its average contribution to the Gross Domestic Product (GDP) of these countries is around 40% and remains the job provider par excellence. (Barrios et al., 2008). This feature associated to the geographical exposition of SSA developing countries make them particularly sensitive to environmental change. For instance, the production of millet in Niger is expected to be about 13% lower (in 2025) as a result of decreasing rainfall amount associated to an increasing temperature (Ben Mohamed et al., 2002). In Burkina Faso, evidence shows that a 1% increase in temperature is likely to reduce farm income by 3.6% (i.e., -19.9 USD per hectare) and is expected to reach 93% if the temperature increases by 5 degrees Celsius. Regarding precipitation, it is found that one percent decrease in rainfall amount will result in a decrease of the agricultural income by 14.7% (i.e., -2.7 $ USD per hectare), a decrease of 14% of rainfall will translate in 100% decrease in the agricultural income (Ouédraogo, 2012). These results are confirmed in a more recent study by Sossou et al. (2020). Their results show that a decrease in rainfall of 1 millimeter would decrease cereal production in Burkina Faso by 385 tons in the long term and 252 tons in the short term. This equates to a 9 kg increase in crop yield per hectare in the long term. In Mali, Kouyate (2020) found that decrease in average rainfall over the period June-September negatively affects crop production while. With regard to temperature, he shows that an increase in mean temperature during the month August and September, negatively affect the performance of crop production. In an attempt to estimate the potential negative effect of climate change in Malaysia, Vaghefi et al. (2011) found that an increase of temperature by 2°C is likely to reduce rice yield by 0.36 ton per hectare. The economic loss induced by this reduction in rice yield to the Malaysian rice industry is estimated to be 162.531 million per year. Using the Bayesian approach Abidoye and Odusola (2015) evaluated the empirical linkage between economic growth and climate change in Africa. Annual data for 34 countries from 1961 to 2009 was used. The Bayesian approach employed allowed them to take into account country specificity and permit the effect of climate change to vary across countries. The results show a negative impact of climate change on economic growth. More specifically, they found that that a 1°C increase in

temperature reduces gross domestic product (GDP) growth by 0.67 percentage point. In sensitive analyses, they further realized that this impact of temperature on GDP is even worse if Nigeria and South Africa are removed from the full sample.

While the above studies together provide evidence for a detrimental economic effect of increase in temperature on agricultural production, Hossain et al. (2019) found a more optimistic and beneficial impact of rising temperature. Indeed, the authors found that 10-degree Celsius increase in temperature (associated to 1 millimeter / month increase in rainfall) will lead to about US $ 4-15 increase in net crop income per hectare in Bangladesh. This contrasting effect of temperature may probably be attributed to the feature of the climatic zones being investigated. That ultimately call for caution regarding the characteristics of the climatic area while designing and implementing the adaptation policies. In sum, despite this broad scientific debate on the perception of climate change and associated impacts, not much is known about the perceptions of rural households in central Mali regarding climate change and the impacts on their livelihoods.

2.3.2.2 Empirical evidence on the climate-conflict nexus

Certainly, empirical investigations on the link between climate change and conflict began since the early 1970. However, it was not until the 1990s that more convincing causal design started to emerge and continue to generate a growing interest up to these days. Overall, there are four main research groups/schools working on the empirical environment and the security agenda as indicated by Wilner (2007). These include the Toronto group led by Thomas Homer-Dixon, the Zurich group around Bächler and Spillmann, the Oslo group around Gleditsch and the Irvine group around Matthew. In what follows, we will review the main idea and findings from these influential groups before moving to the individual studies done on the climate conflict nexus.

2.3.2.2.1 The Toronto group around Homer-Dixon

The Toronto group is the most dominant and ambitious project of all those listed. The group's main goal was to construct a "causal-path analysis" linking environmental change and violent conflict. They strive to answer two fundamental questions. First, "Does environmental scarcity contribute to violence?" second, "if yes, then how does it contribute?" Quantifiable environmental variables and traditional conflict (insecurity, war) indicators are used in order to approximate reliable answer to the questions. This further help them to establish several plausible causal links

which they evaluate through in-depth analysis of 16 cases of suspected environmental conflict (See Homer-Dixon, 1999).

The key model resulted from this evaluation is that “environmental scarcity leads to the social effects which in turn lead to social conflict”. Out of the model, three general hypotheses have emerged. The hypotheses are (i) the decrease in the supply of environmental resources will lead to “simple-scarcity” conflict or resource wars such as conflicts between territorial groups for the control of the remaining resources; (ii) large population movements caused by environmental degradation will create “group identity” conflicts such as ethnic clashes between groups that are not unusually in contact or religious conflicts; (iii) A severe environmental scarcity will simultaneously increase "economic deprivation" and disrupt "key social institutions" which in turn will lead to "deprivation" conflicts such as civil unrest between the rich and the poor.

The results coming from their analysis show that, the first hypothesis is empirically invalid. So, environmental scarcity is not directly related to violent conflict. However, they found empirical support for the second and third hypotheses. Accordingly, environmental scarcity can lead to organized and generalized violence, but this very rarely occurs between States (Wilner, 2007).

2.3.2.2.2 The Zurich group around Bächler and Spillmann

The Zurich group, also known as the Environmental Conflict Management and Sustainability Group, is the second most dominant group after the Toronto group which has been instrumental in advancing the empirical agenda on the climate-conflict nexus. It grew out of the Environment and Conflicts Project (ENCOP) set up by Bächler and Spillmann at the Swiss Federal Institute of Technology (ETH) in Zurich. The project main objective was to design a typology of conflicts linking a particular type of environmental degradation to its socio-economic consequences and to the parties affected by the conflict. Thus, by analyzing 40 environmental conflicts, six typologies of conflicts emerge. These include: centre-periphery conflicts, ethnoecological conflicts, regional, cross-border and demographically-induced migration conflicts, international water conflicts and conflicts arising from distant sources.

In its conclusions, the Zurich group indicates that certain socio-economic factors such as, “a lack of societal mechanisms for regulating conflict, an instrumentalization of environmental degradation for group-specific interests, group identities, the organization and arming of parties to

a conflict, and the influence of past conflict" in combination with environmental scarcity are more likely to lead to environmental-induced conflict (Schubert et al., 2008).

Although, these two above groups have made significant empirical advances and produced several interesting conclusions which have had resounding consequences for the field they are not free from critics. Indeed, from the mid-1990s, two other approaches have been developed on the basis of critics formulated towards the work done by the Toronto and Zurich groups. These include, the groups from Oslo and Irvine which we will present in the following lines.

2.3.2.2.3 The Oslo group around Gleditsch

The Oslo group was born out of an independent quantitative research approach developed by Gleditsch at the International Peace Research Institute in Oslo (PRIO). The approach is based on a process of critical engagement with studies from the Toronto and Zurich groups. The main objective was to decomplex existing qualitative models and correct their shortcomings in the selection of case studies, particularly the tendency to study countries with serious resource conflicts. For example, in criticizing the Toronto group, the Oslo group refuted the second assumption formulated by this group that environmental scarcity, combined with growing population pressure, leads to violent conflict. According to the Oslo group, rather than scarcity, it is the abundance of resources that is more likely to lead to violence, as violent groups typically derive their funding from the exploitation of natural resources.

The group's findings come to confirm the results reached by the first two groups (the Toronto and Zurich groups). Indeed, the Oslo group also come out to the conclusion that, environmental change alone is less likely to translate into violence. According to the group, environmental degradation is just one of several variables that may contribute to the escalation of conflict. Arguably, Environmental stress would only increase the risk of conflict in countries, whereas, for the outbreak and intensity of this conflict economic and political factors are necessary (Hauge & Ellingsen, 1998).

2.3.2.2.4 The Irvine group around Matthew:

The Irvine group has grown out of the Global Environmental Change and Human Security project (GECHS) headed by Matthew. It was set up at the Center for Unconventional Security Affairs at the University of California in Irvine. Like the previous group, the Irvine group's analysis is also

built upon critics with the aim of promoting a new theoretical orientation more centered on the long-term adaptability of human beings and societies. In that regards, they first, underlined the absence of qualitative frames of access to the issue of environment and conflicts (Schubert et al., 2008). The lack of empirical study was also pointed out in second position. In their view, the literature ultimately lacks quantifiable empirical research on three important aspects: firstly, on the relevance of demography as a factor; secondly, on whether it is the abundance or scarcity of resources that poses the greatest risk of conflict; and finally on the question of whether environmental degradation might actually promote cooperation rather than fueling conflict.

Matthew and his colleagues, concludes their analysis by giving some guidelines in order to better understand the interconnections and the impacts of environmental change and conflict. According to them, it would be useful to broaden the range of methods and instruments used when investigating the link between environmental change and violence. Arguably, this could be done by engaging in interdisciplinary cooperation, using conflict research and cooperation and carrying out micro-analyses.

Defensibly, each of these four groups has sought, over the past decade, to quantitatively assess the link between environmental change and social conflict by pursuing a general program of studying observable cases of environmental conflict. Although, each research group diverges from the others in terms of focus and methodology, there is convergence when it comes to the obtained results. For instance, all the group have come to the conclusion that environmental degradation alone is less likely to trigger off conflict. Environmental change is just one of several mechanisms through which conflict happens. There is also a consensus regarding the locality of environmental conflicts. These are mainly intra-state conflicts. In addition, it is interesting to note that criticisms have also been leveled at these works. Moreover, the group of Oslo and Irvine was even born on the basis of criticisms formulated in place of the first two groups.

It is evident that, results and conclusions from those groups remains very informative and constitutes a great advance in the field of climate-conflict quantitative analysis. However, beyond these groups, there are also several other scholars who individually or in collaboration have worked to quantitatively assess the link between climate change and conflict. They have also come out with very interesting methodologies and results which deserve to be reviewed in this dissertation.

Based on the research design employed, those works can easily be divided in two main groups (or even phases, chronologically speaking) of study which assess in two different ways the link between climate change and conflict. The first group of study focuses on direct effects of climatic conditions on conflict while the second group concentrates on indirect effects of climatic events on conflict and mediating factors. The next section will be devoted to shedding light on this work and results produced.

2.3.2.2.5 Direct effect of climatic events on conflict onset

When researchers first began to question the link between climate change and violent conflict, all efforts were directed toward a direct linkage. Indeed, this body of literature have essentially tested the climate conflict nexus by running climatic and conflict variables together in a same and unique model based on the argument of climate change-induced resource scarcity leading to conflict outcomes. For instance, Burke et al. (2009), carried out a panel regression of climate variation and conflict events between 1981 and 2002. The aim was to assess the impact of global climate change on armed conflict in Sub-Saharan Africa. Time series of temperature and precipitation were used as climatic variables (for the exogenous variables). For the dependent variable, country- and year-specific civil war incidence is taken. The results pointed out a large direct role of temperature in shaping conflict risk. They found that, one-degree centigrade increase in temperature lead to 4.5% increase in civil war in the same year and 0.9% increase in conflict incidence in the following year. Similar approaches have been employed by, Theisen (2012). However, contrary to Burke et al. (2009), he used subnational data on Kenya between 1989-2004 to test the link between climate change and conflict. Although the results of Theisen's (2012) analysis are not very similar to those of Burke et al. (2009), support is found for a strong link between climatic variables and conflict outcomes. The difference is in the nature of the links between variables. While, Burke et al. (2009) argued that warming fuel conflict, Theisen (2012) indicates a peaceful effect of a drier year over the following year. He also found a little support for the idea that scarcity of farmland fuels violence per se or during election years, but an election in itself just increases the risk.

Another contribution searching for a direct links between climate change come from Tol and Wagner (2010) study which used both various reconstruction of temperature and precipitation to investigate the relationship between violent conflict and climate change. The study was carried on European countries. They also give support for a robust link between climatic variables and violent events. However, contrary to the African continent, conflict is more intense during colder period in Europe as showed in Tol and Wagner's results.

The effect of climate change on conflict was also assessed in the study of Hendrix and Salehyan (2012). However, they took a step further in the sense that, instead of using temperature as proxy for climate variability, Hendrix and Salehyan (2012) used deviation from normal rainfall patterns to question the link between climate change and conflict in Sub-Sahara Africa. In that regard, three hypotheses were formulated. First, extreme deviations from normal rainfall patterns will increase the frequency of social conflict. Second extreme deviations from normal rainfall patterns will increase the frequency of violent conflict more than the frequency of nonviolent protest. And finally, extreme deviations from normal rainfall patterns will increase the frequency of nongovernment targeted action more than the frequency of actions targeting the state. The dependent variables of interest were social conflict and armed conflict. For running the estimation, a logistic regression model is employed. The first and second hypotheses are confirmed while less support in favor of the third hypothesis is found. In conclusion of Hendrix and Salehyan's work, rainfall variability has a significant effect on conflict events.

Similar finding is observed in the study of Hsiang et al. (2013) in which they further indicate that: each one standard deviation change in climate, specifically in terms of warmer temperatures or more extreme rainfall lead to 4% increase in the frequency of interpersonal violence and 14% in the frequency of intergroup conflict. In a more recent study, Eastin (2018) employs a micro-level data from Philippines to question the link between climate change and conflict. He finds that precipitation shocks increase violence in armed intrastate conflict in the Philippines.

According to these studies, climatic events especially warming and drier do influence the risk of conflicts and violent events. Considering that findings, one could already suspect an interaction between climate change and the continuous conflict ongoing in country such as Mali. Indeed, the IPCC have provided evidence of accelerated global warming and climate change all across the world since the early 1990s. According to IPCC (2013) the globally average temperature has

increased by 0.85 [0.65 to 1.06] degree centigrade over the period 1880 – 2012. In Mali, temperature indices showed a general warming trend throughout the region during the period 1960-2014 (Touré Halimatou et al., 2017). In terms of variability in rainfall patterns, it is reported an overall reduction in rainfall in most part of Africa, particularly in the Sahel regions (Biasutti, 2013). In Mali, the annual rainfall is highly variable ranging from less than 200 mm to 1100 mm with uneven distribution between north and south (Touré Halimatou et al., 2017).

To summarize, there are a substantial body of the literature that have focused on identifying a direct link between climatic conditions and conflict. Although the results often seem contradictory, all authors have reached the same general conclusion. Climatic variables do influence conflict events. However, on the basis of the research design (methodology) employed, several critics have been formulated toward those works as their results differ from those reached by numerous other authors (Buhaug, 2010; Hsiang and Burke, 2014; Klomp and Bulte, 2013). In addition, Buhaug (2010), when investing the empirical foundation for the claimed relationship between environmental change and violence, demonstrate that Burke et al. (2009) findings are quite fragile. In a similar way, Theisen et al. (2011), use data on subnational units for Africa and find no relationship between drought and civil conflict onset. Arguably, this growing inconclusion ultimately have led to a shift in perspective on the part of researchers. Indeed, the search for direct links being inconclusive, scholars have productively turned to assessing causal mechanisms (indirect pathway) and mediating factors between climate change and conflict outcomes.

2.3.2.2.6 Indirect effect of climatic events on conflict and mediating factors

The change in perspective has led to a wave of excellent research exploring the indirect route and mediating factors linking climate factors to conflict. Miguel et al.'s (2004) work remains a reference in that regard. They implemented the first study which employ an instrumental variable approach to deal with climatic, economic and conflict variables. Specifically, Economic growth is taken as mediating variable between climate and civil conflict. The analysis is run over 41 African countries during 1981-1999. Africa is suited for such a study since only one percent of the cropland is irrigated in the median African country according to the World Development Indicator database. Africa's economy is therefore fueled by rain-fed agriculture. This makes the variation in rainfall a plausible instrument for growth in Gross Domestic Product. The first-stage regression further confirmed that, as they found rainfall variation closely related to income growth. Miguel et al.

(2004), concluded that a negative growth shock of 5% points (due to negative weather shocks) increase the likelihood of conflict by one-half the following year in Africa. However, this result has later been the subject of severe dispute from Ciccone (2011).

In a study aimed at re-evaluating Miguel et al.'s (2004), Ciccone (2011), have come out with a different result. According to him, the use of year-on-year rainfall growth may be misleading since it reflects either a positive as rainfall shock or a reversal to normal conditions. However, the main difference between both approaches is that Ciccone (2011) does not use the current and lagged rainfall levels as instruments for economic growth, instead he focuses directly on the regression of conflict variable on measures of rainfall level. Miguel & Satyanath (2011) reply to that, and show that even when using rainfall level instead of rainfall growth as instrument, Miguel et al. (2004) findings hold.

Another contribution, using instrumental variable technique in the line of Miguel et al., was Koubi et al. (2012). However, contrarily to Miguel et al. who choose this approach merely as a technical solution for addressing endogeneity and omitted variables problems[6]. Koubi et al. (2012), "theoretical considerations suggest that climate variability may indirectly affect the probability of intrastate conflict via its effect on economic growth". Two stages were built for the model. In the first stage, Koubi et al. use measures of precipitation and temperature to estimate per capita economic growth. Then this is further used to generate an interaction term (to be introduced in the second-stage equation) between economic growth and a country's political system in order to capture potentials contingent effect of factors such as political stability. In the second-stage of the model the effects of predicted income growth and the predicted interaction term on intrastate conflict are estimated. The result indicates that there is no statistically significant impact of climate variability on violent intrastate conflict through economic growth. In short, no support is found for a climate change–economic growth–conflict pathway. However, the study just provides a weak support for a mediating effect of political system characteristics.

In a similar process, Caruso et al. (2016), used an instrumental approach to investigate the effect of variations in temperature on the emergence of violence. However, by a way of improving the

[6] Miguel et al. (2004) main goal was just to assess the effect of Economics shocks on civil conflict. Their focus, was not really directed toward studying the relation between climatic conditions and conflict.

operational variability of key variables, they narrowed down the geographical scope choosing Indonesia as the study area over the period 1993-2003. As rice representing the staple food in that country, the aim was to investigate whether its scarcity (induced by climate change) can be blamed for fueling violence. Another major improvement made in this study is based on using the agronomic specificities of paddy rice as well as its growing calendar in order to select the best instrument. Indeed, their argument was such, studies focusing on several countries with different crops and using changes in average temperature as climate change proxy miss the biological mechanism that underlies the relationship between environmental change and violence. This motivates them toward developing a model taking into account the biological process. The results suggest that an increase of the minimum temperature in December (which is the core month of the rice growing season in Indonesia), determines an increase in violence. Likewise, Jun (2017), found that, a high temperature during maize growing season reduced the crop's yield, which in turn increased the incidence of civil conflict in Sub-Saharan Africa. Taken together, these studies argue that climate change influence agricultural production, and that subsequent climate change-induced food scarcity increase the likelihood of conflict.

The absence of alternative coping strategies to climate change is also pointed out to increase the likelihood of conflict outcomes. The argument is such that individuals resort to conflict and violence in the face of environmental induced hardship when loosing alternative coping mechanisms (Fjelde & von Uexkull, 2012). This suggest that the effect of environmental changes on conflict outbreak would probably depend on certain factors such as country's economic vulnerability, political regimes, ineffective institutions, inequality etc. For instance, Koubi et al. (2012), have examined the causal pathway linking climate change to economic growth and to armed conflict using a global data set for 1980-2004. Their results suggest no evidence that climate variability affects economic growth. Instead, they found that non-democratic countries are more likely to experience civil conflict under deteriorate economic conditions when facing climatic shocks. In a study carried out on land invasion in Brazil, Hidalgo et al. (2010), using adverse economic shocks instrumented by rainfall, found that, in highly unequal municipalities, negative income shocks cause twice as many land invasions as municipalities with average land inequality. According to Detges (2016), civic conflict events in connection with drought are more likely in administrative areas with poorly developed road infrastructures and in regions where an important part of the population lacks access to an improved water source.

As it is highlighted above, the majority of studies addressing the climate-conflict relationship are empirically based on the exploitation of aggregated data for administrative areas, towns or villages as well as geographic grids. Consequently, scholars rarely draw their interest in investigating social, economic and political processes that might condition the link between climate variability and violent attitudes at the individuals or households level (Linke et al., 2015). The following section shed light on the recent wave in survey-based research on climate change and violent conflict.

2.3.2.2.7 Climate change and the micro-level investigations of support for violence: A step further

The recent wave in survey-based research on environmental change and armed conflict is significantly improving our understanding of the climate-conflict nexus. Indeed, central propositions from the macro-oriented literature are now being been put to the test on the individual and household level, where they conceptually belong. One major contribution of those studies is the use of survey data that explicitly asks respondents about violence and changes in climate that have taken place in recent periods. This approach undoubtedly provides a better understanding of the micro-level dynamics that unfold in countries exposed to difficult environmental conditions.

For instance, Linke et al. (2015) collected primary data from three Kenyan counties in November 2013 in order to probe people's attitudes concerning perceived climate variability, their belief and economic activities. 504 respondents were administrated questionnaires for that purpose. Although, they found no support that reported worsening drought conditions is associated with increased support for the use of violence. The analysis further revealed a pacifying conditional effect of inter-community dialogue between ethnic groups on support for the use of violence. In contrast to the existence of formal, institutionalized, governmental rules for which they found no evidence of any conditional negative effect of reported drought conditions on support for violence.

The relationship between peoples and their government can play an important role in shaping their attitudes toward violence when experiencing adverse climatic shocks. For instance, contrary to those who enjoy good relations with the government, marginalized or politically neglected peoples would be more likely to endorse violent attitudes in response to climatic shocks. Indeed, the first

group have more access to public goods and are more likely to overcome the shock. While, the second group have more difficulties and fewer resources in coping with shocks. Roads and transport facilities that allow the transportation of supplies including food relief or feed for livestock in times of drought are more often absent or of poor quality in areas where marginalized people live.

Such an association between marginalization and the climate-violence nexus has been suggested and tested in micro-level analysis by Detges (2017) using data from the Afrobarometer survey. Interestingly, he found that, male, younger respondents as well respondents who were previously victims of violence, respondents who do not trust their head of state and respondents who feel that their ethnic group is being treated unfairly are more likely to support the use of violence. Paradoxically, proof was also found for a positive effect of respondent's self-reported economic status and their support for violence. Arguably, the more comfortable the economic situation, the more likely to approve of violent action. This stands in contrast to the opportunity cost theory, which suggest that the individuals who have less, are more likely to support violence than those in more comfortable economic situation.

Contrarily to those mentioned above, no evidence was found for a significant effect of exposure to drought on respondents' attitudes toward violence. Supporting the argument that severe climatic shocks are unlikely to influence attitudes towards violence on their own. This also holds true for an effect of the educational achievement on respondent's support for violence. Detges's (2017) results also come to confirm the need for paying attention to the context specificity when dealing with the climate-conflict association. Indeed, his results show significant differences between sub-regions of the African continent. In particular, "effects in West Africa are opposite to those observed in East and Southern Africa".

Rather than focusing on the relationship between peoples and the sitting government like Detges (2017), De Juan & Hänze (2021) instead focused on the relationship between the people themselves. More precisely, their work investigated the mechanism according to which environmental change can foster violent conflict by deteriorating intergroup relations. Thus, the main outcome of interest is intra-ethnic and inter- ethnic trust. By trust, they refer to the expectation of benevolence of someone or a group as well as one's own willingness to also act benevolently upon this expectation. Accordingly, a high level of trust and solidarity may allow for cooperation,

collective action and mass organization/mobilization. While, a low level of trust may foster more competition and conflict between individuals. Moreover, having high level of in-group/ intra-ethnic trust alongside a low level of inter-group/ inter-ethnic trust could increase the likelihood of violent conflict. In order to assess the merit of their argument, De Juan & Hänze (2021) make use of individual-level survey data provided by the Afrobarometer project. This dataset specially includes questions that allow to gauge respondents' trust in members of their own and other ethnic groups.

However, the results show no evidence for a negative effects of climate change on intra and inter-ethnic trust. Rather, the analysis reveals a positive effect of environmental scarcity on inter/intra group attitudes. This is to say that drought affected individuals hold the higher levels of self-reported trust in both members of their own and of other ethnic groups. Although this article does not focus directly on the effects of environmental change on conflict, it nonetheless enlightens us about the plausible conditional effects of inter/intra group relationship. Importantly, the study shows that, if drought increases the likelihood of violence, it does so, through other channels than deteriorating intergroup relations.

The afrobarometer survey was once again used to assess the association between climate change and violent conflict. Indeed, Vestby's (2019b) uses two rounds in Afrobarometer and offer an instrumental variables approach. The outcome variable of interest studied here is individual's perception of changes in living conditions. In order to get around endogeneity problems, theses perceived changes are instrumented using a standardized precipitation-evapotranspiration index (SPEI). For the subsample whose living conditions are affected by droughts, the analysis showed that participation in violence would, on average, have been more likely if an individual experienced a deterioration than if it had not. However, more cautious should be paid considering this result given the size of the subsample who reported a worse living condition and which comply with participation in violence. Indeed, the bivariate relation have shown that most of the respondents surveyed did not report participating in violence and that more people reported having same or better living conditions than they had 12 months earlier.

Using micro-level survey data, Koubi et al. (2020) examine whether and how climate-induced rural-to-urban migration (called environmental migration) contributes to social-movement participation. They defend the argument according to which the forceful nature of relocation shape

migrant's attitudes toward participation in social movements which tend to promote their rights in urban areas. Migrants from three urban centers have been surveyed. Is classified as migrants, a respondent who is born in rural area with an age comprises between 16 to 65 years. She or he came to live in the survey site after living a minimum of one year in the rural area. The respondent must have also stayed or intends to stay in the survey site for a least of 6 months. However, to determine whether that migrant belongs to the category of environmental migrant, the authors further relied on migrant's perception of environmental changes. Interestingly, the analysis shows that climate-induce migration may in fact lead to increased support for violence. Accordingly, the results show that both migrants who have experienced sudden and gradual climatic events at their place of origin are likely to approve of more violent attitudes.

Taking advantage of a novel household survey data collected from two conflict-affected regions in Eastern Democratic Republic of the Congo, von Uexkull et al. (2020) study variation in support for violence related to reported exposure to drought and household's resilience. As expected, the results show that less resilient respondent who have been exposed to drought conditions are the one more likely to be supportive of violence. However, no evidence is found for a general association between exposure to drought and support for violence.

In the Niger Delta for example, Rustad (2016) make use of a new survey data collected and show that support for violence is highest in the districts and ethnic groups where people's self-reported living conditions compare least favorably to the richest district or largest group in their state.

2.4 Conclusion:

Although there is no evidence for a universal link associating climate change to conflict yet. This literature review overall shows that there is a dynamic process underway that attempts to uncover the link between climate change and violent conflict. The conclusion is such that the relationship that may link climate/environmental change to violent conflict is far from being straightforward. That is arguably the reason why the first strand of the literature is being inconclusive and remain heavily contested. By implication, researchers have recognized the need to investigate the climate-conflict nexus by probing mediating factors likely to facilitate the connection. This has raised a new wave of research exploring the indirect route and mediating factors linking climate factors to conflict in which this dissertation aims at contributing. The causal mechanism being evaluated in this dissertation is the mechanism related to livelihood adaptation practices, climate change and

its resulting livelihoods deterioration and support for violence. While bulk of the studies on climate change and conflict focus on broad and aggregated levels of analysis, researchers have also recognized the need for narrowing down units of analysis and taking into account context specificity when evaluating the interconnection between environmental change and conflict. This study aims to explore such contexts-specificity argument by focusing on mediating mechanisms through which climate change is likely to contributes to communal conflict in Mali.

The literature further shows that, the vast majority of research on climate change and conflict outcomes so far focus generally on evaluating whether environmental change contributes to conflict dynamic somehow. They are rarely interested in the process undermining the potential relationship between the two phenomena. A main contribution of this dissertation is its engagement with the investigation of the causal mechanism and process that can give us better indications on how climate change would translate into conflict and violence at communal level.

3 CHAPTER TWO: BACKGROUND OF THE STUDY AREA (THE MOPTI REGION), DATA COLLECTION METHODS AND CHARACTERISTICS OF SAMPLE HOUSEHOLDS

3.1 Introduction:

Mali is the largest landlocked country in the Sahel region of Sub-Saharan West Africa. The country has an area of 1,241,238 square kilometers and shares a total of 7,243 kilometers (4,500 miles) of land boundaries with seven (7) states. The Niger Republic is located on the East; Ivory Coast on the South; Burkina Faso on the Southeast; Guinea on the Southwest; Senegal and Mauritania on the West. In terms of natural zones, the country is divided in three natural areas: at south the Sudanese zone, in the middle the Sahelian or semi-desert zone, and at the north the Saharan desert zone.

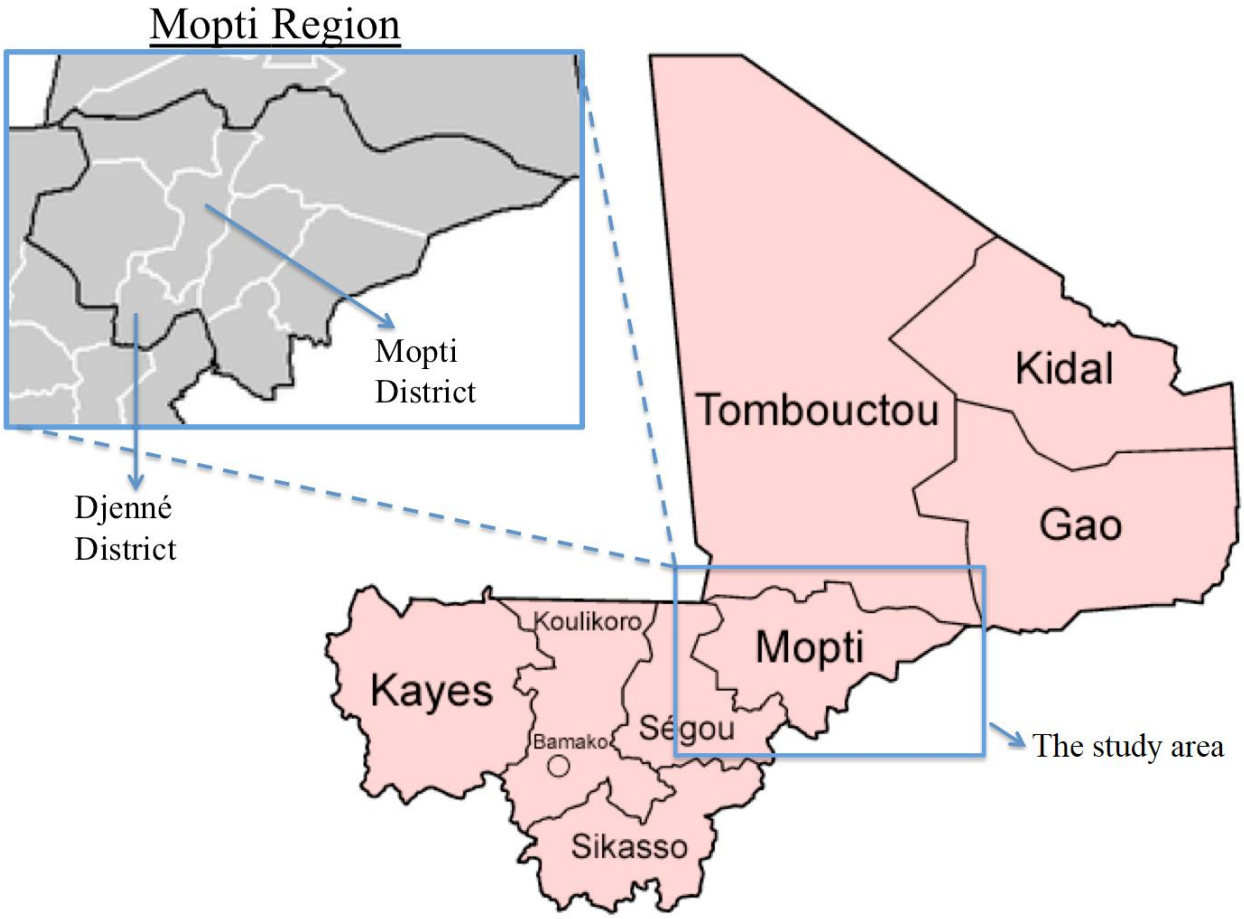
Economically, Mali is one of the poorest countries in the world with a Gross Domestic Product (GDP) of 10.9 billion of dollars and a population of 15.3 million (World Bank, 2015). Agriculture including livestock production is the dominant sector of the Malian Economy about 45% of the country GDP (Ebi et al., 2011; Montaud, 2019). The livestock portion account itself for approximately 30% of agricultural GDP (USAID, 2012). The Agricultural sector is the main source of livelihood of the majority of the people living in the area. More than 80 % of the country's workforce is employed in this sector (Ng'ang'a et al., 2012). Regarding this context, there is no doubt that climate change with its different manifestations (specifically, increases in temperature and/or modifications of rainfall quantities and distribution) would ultimately and directly affect people's livelihood in the country. Thus, making them more vulnerable and poorer.

Figure 3.1: The Map of Mali

Source: United Nations Map no 4231, September 2022.

The country administrative structure consists of eight (8) regions including Mopti region (the field being studied in this dissertation) at the highest level. To that is added one capital region notably the district of Bamako. The regions are divided into second level administrative divisions called Cercles (the country count officially 56 cercles). That administrative cercle are further divided into 703 communes which is the third level administrative division of the regions and capital region.

Figure 3.2: Location of Mopti Region in Mali



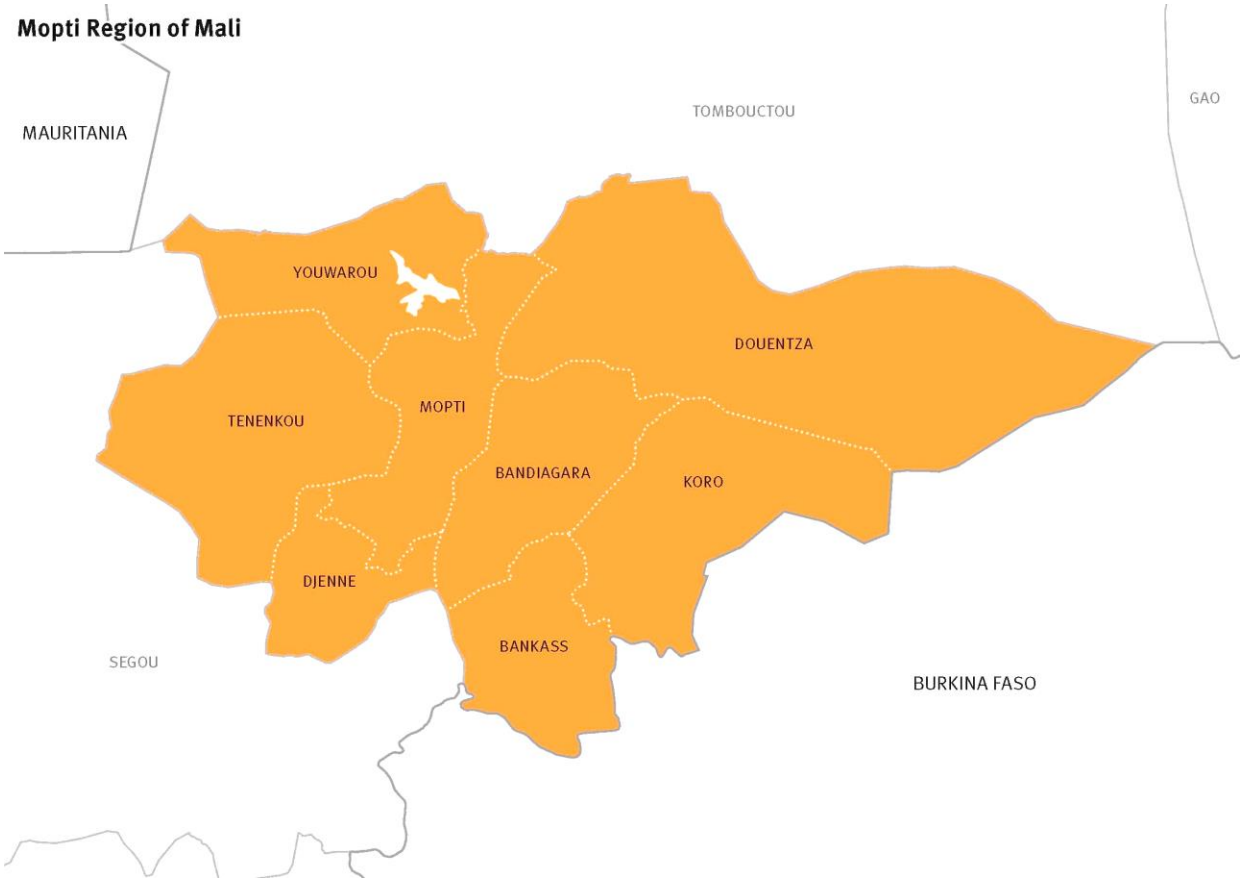
Source : https://nataliegagne.wordpress.com/where-im-working-2/

The remainder of the chapter is organized in two main sections. The first section presents the soci-economic characteristics of the study area while the second section is devoted to the Sampling procedure, Data collection Methodology including the Descriptive Statistics.

3.2 Socio-economic structure of the Mopti Region, the study area

This section presents the soci-economic characteristics of the study area which includes the demographic configuration, household structure, climatic characterization and an overview conflict history in Mali.

Figure 3.3: Map of the Mopti Region



Source : https://www.hrw.org/report/2018/12/07/we-used-be-brothers/self-defense-group-abuses-central-mali

3.2.1 Demographic configuration and household structure

Ranked as the fifth administrative region of Mali, the Mopti region is located in the central part of the country between the North (the Sahara) and the southern part (the Sahel) and extends between the parallels 15°45' and 13°45' north latitude on the one hand, and the meridians 5°30' and 6°45' west longitude on the other hand. It is bordered by the Tombouctou region in the north, the Ségou region in the southwest, and Burkina Faso in the southeast. The region covers an area of 79,017 km² which represents about 6% of the national territory and count around 2,037,330 of inhabitants (in 2009 during the last general population and housing census). Currently it is projected at 2 878 285 inhabitants (According to the 2020's modular and permanent survey of households [EMOP]

run by the National Institute of Statistic [INSTAT-MALI]). The region is divided in eight (8) administrative circles also divided into two natural zones. The exposed zone which corresponds in particular to the Dogon plateau zone includes Douentza, Bandiagara, Bankass and Koro. The flooded area corresponds to part of the Inner Niger Delta and encompasses Mopti, Youwarou, Djenne and Tenenkou. Moreover, the region is a zone of mixed population composed of Peuls (the fulani), Bozos, Somonos, Dogons, Bambaras and Sonrhay. The population increased from 1,129,041 in 1976 to 2,037,330 in 2009 with an increase of 38% since 1998, i.e., an annual growth rate of 3%. This demographic weight confers the rank of 4th region at the national level.

3.2.2 Livelihood systems in Central Mali

The Mopti region is essentially agro-pastoral and halieutic, the most important resources are those coming from agriculture (land), livestock (pasture land) and fishing (rivers, lakes, ponds and channels). The exploitation of these resources is mainly based on three "Traditional" production systems: the agricultural production system, the livestock production system and the fishing production system.

The agricultural production system is mostly dominated by rice production. Specifically, the region has 40% of the national area cultivated in rice and 20% of the national area cultivated in millet and sorghum[7]. Overall, cultivable lands are estimated at 1,500,000 hectares of which 910,000 ha are irrigable, especially in flooded areas. Moreover, the agricultural production system is divided according to the location zone. Indeed, dry crops such as cereals predominate in dry areas it is associated with a sedentary mode of living. Rice cultivation in the flooded zone.

The livestock production system in the region is dominated by the breeding of cattle. Due to the diversity and richness of its natural pastures, the region is a breeding area par excellence and ranks first in number of cattle and sheep/goats in Mali. The region alone holds 22.10% of the country's national cattle population and 26.5% of the sheep-goat population. Pastoralism is practiced in the Mopti region according to 3 modes: the semi-sedentary and sedentary breeding mode with radius of movement limited around towns and villages; transhumant herding mode which is the most widespread in the region which very often involves a double transhumance: internal transhumance

[7] Rice, millet and sorghum are traditionally the principal staple food in Mali (Aman et al., 2019).

in the Delta (from Diafarabé and Sofara to the pastures of Lake Débo) and a longer transhumance from the Delta to pastures located on land where floods have receded (Seno, Plateau, Gourma). And lastly the nomadic herding mode in the arid and semi-arid areas of the north.

The fishing production system is by far the third economic activity of the region after agriculture and pastoralism due to the importance of the hydrographic network. This system can be divided into three categories: fishing carried out together with farming; full-time traditional dam fishing; and specialized river fishing. Fishing systems are associated with both nomadic and sedentary ways of life. Fish marketing is an important aspect of fishing products and makes the fishing port of Mopti the hub of fish marketing in Mali. The fish is sold fresh, dried or smoked.

The socio-professional groups involved in those production systems largely overlap with the ethnic groups resident in the Mopti region. For instance, the Dogon, the Bambara and the Sonhray are usually associated with a sedentary agricultural mode of subsistence, and cultivate millet, sorghum and rice, as well as onions, tobacco and peanuts. The Fulani and the Tuareg are known as a nomadic ethnic group of pastoralists who move their herds across the regions they inhabit in search of better grazing and watering for their animals. The Bozo ethnic group is associated with fishing activities and with both sedentary and nomadic ways of life as indicated above, depending on the availability and access to waters rich in fish.

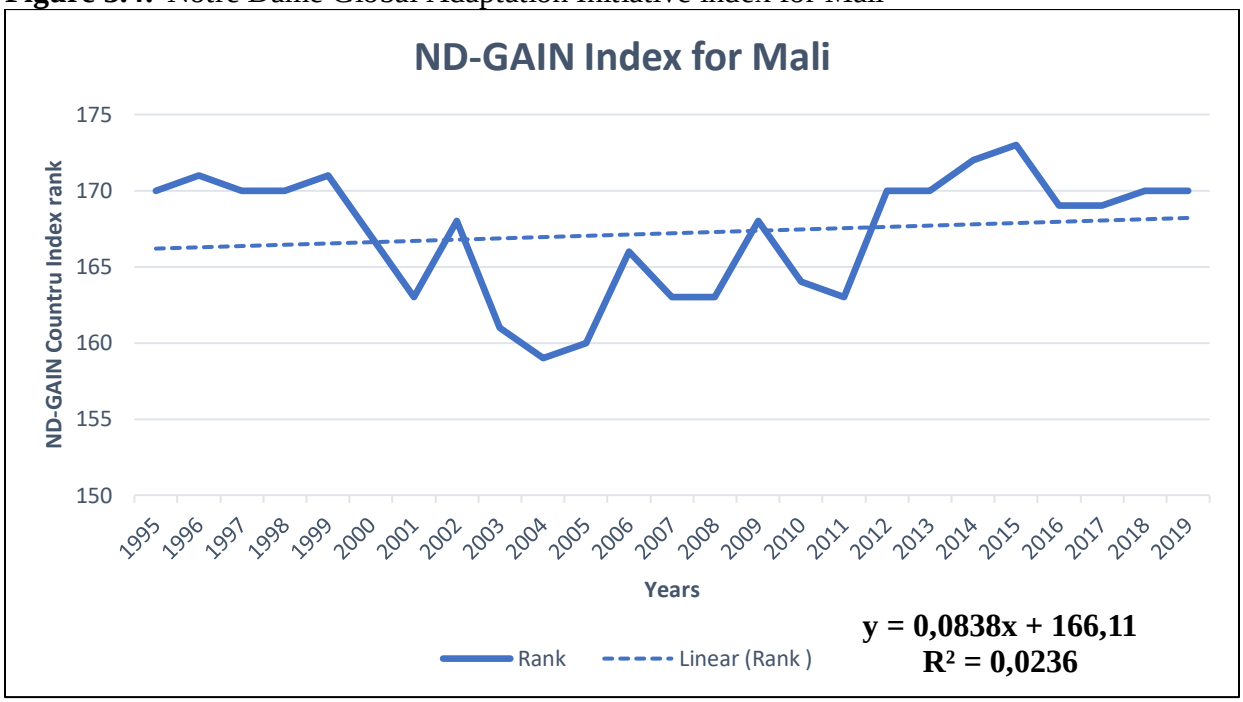
All of these production systems co-exist and, at times, overlap, depending on the season. For instance, during the rainy season usually between June and September up to October sometimes the inner Delta is flooded. While the inner Delta is being flooded gradually, pastoralists move their cattle to dry lands towards the south or east of the region. Agriculturalists start cultivating millet, sorghum, peanut and rice and harvest them between September and December. The fishermen at that moment place their nets on the channels (ponds) flooded by the Niger River and abundant in fish. Pastoralists start returning their cattle in the Delta once the water recedes based on a well-established calendar and order normally.

3.2.3 Climate characterization, variability and change

Climate in the central region of Mali as well as in the rest of the country (in general) is characterized by three main seasons. These include a pronounced dry season from March to June, a rainy or wintering season from June to September and an off-season or cold season from October

to February with a drying Saharan wind called the harmattan. However, as the other Sahelian countries, Mali is highly vulnerable to climate change with an increasing trend (see Figure III-3). This is illustrated by the data from Notre Dame Global Adaption Initiative[8] (ND-GAIN, 2019) which ranked the country the 7th most vulnerable country over 188 countries and the 37th least ready country to face climate change.

Figure 3.4: Notre Dame Global Adaptation Initiative index for Mali



Source: Author's construction using ND-GAIN index data

This growing vulnerability is the result of two main climatic hazards: increasing temperature and strong variation (spatially and temporally) in rainfall quantity as well as distribution.

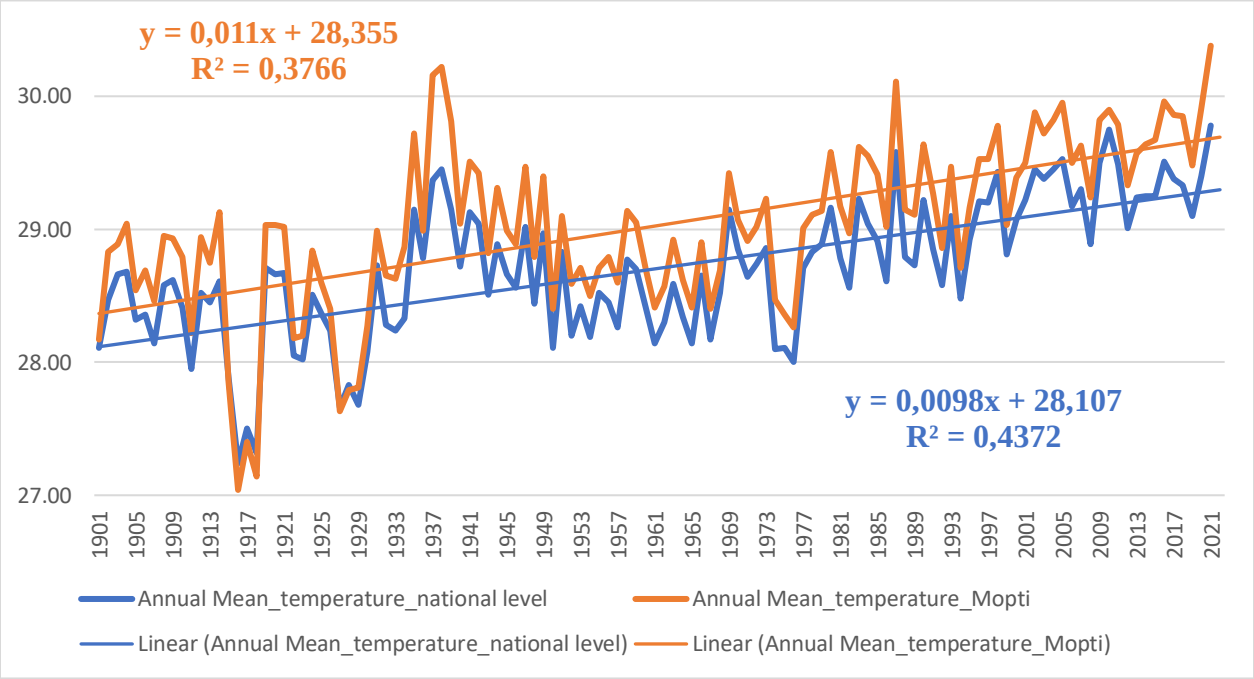
3.2.3.1 Temperature trend in central Mali

From 1901 to 2021, temperature in central Mali and in the whole country depicts an increasing trend. Although Figure III-4 shows a similar trend, the average annual temperature in the center is slightly above the national average. the average annual temperature in central Mali is 29.38˚C (Aman et al., 2019). Since the vast majority of population in central heavily relied on agriculture

[8] The ND-GAIN Country Index summarizes a country's vulnerability to climate change and other global challenges in combination with its readiness to improve its resilience.

including livestock breeding, this rising temperature is likely to have a direct and devastating effect on livelihoods and food security in the region. Indeed, temperature influences most plant processes, including photosynthesis, transpiration, respiration, germination and flowering. When the temperature increases, photosynthesis, transpiration and respiration increase as well, thus disrupting the normal development of the plant. Additionally, increasing temperature is also likely to affect the transition from vegetative growth (leaves) to reproductive growth (flowering) when combined with day length. The overall economic impacts of the above-mentioned disturbances in plant process resulting from temperature increase are ultimately reduction in crop yields, loss of farm income and increase in food stress (Gornall et al., 2010). Indeed, It is reported that each °C of warming could reduce crop yields by 10-30 percent (Mbaye, 2020). Sultan et al. (2013) is even greater than that. Accordingly, they found that higher temperature inducing increase in both evapotranspiration and respiration while reducing the crop-cycle length is likely to decrease crop (especially millet and sorghum) yields by up to 41 percent regardless whether rainfall increases or decreases. In Burkina Faso, Sossou et al. (2020) found that a 1°C increase in temperature would result in a decrease in crop production of 134748 tons and 72 kg per hectare in terms of crop yield in the short term. In the long term, the amount of loss is 154 634 tons in crop production and 1074 kg per hectare in terms of yield. In Mali, evidence has shown that an increase in mean temperature during the month August and September, negatively affect the performance of crop production (Kouyate, 2020).

Figure 3.5: Times series of mean temperature trend at both regional (Mopti) and national level



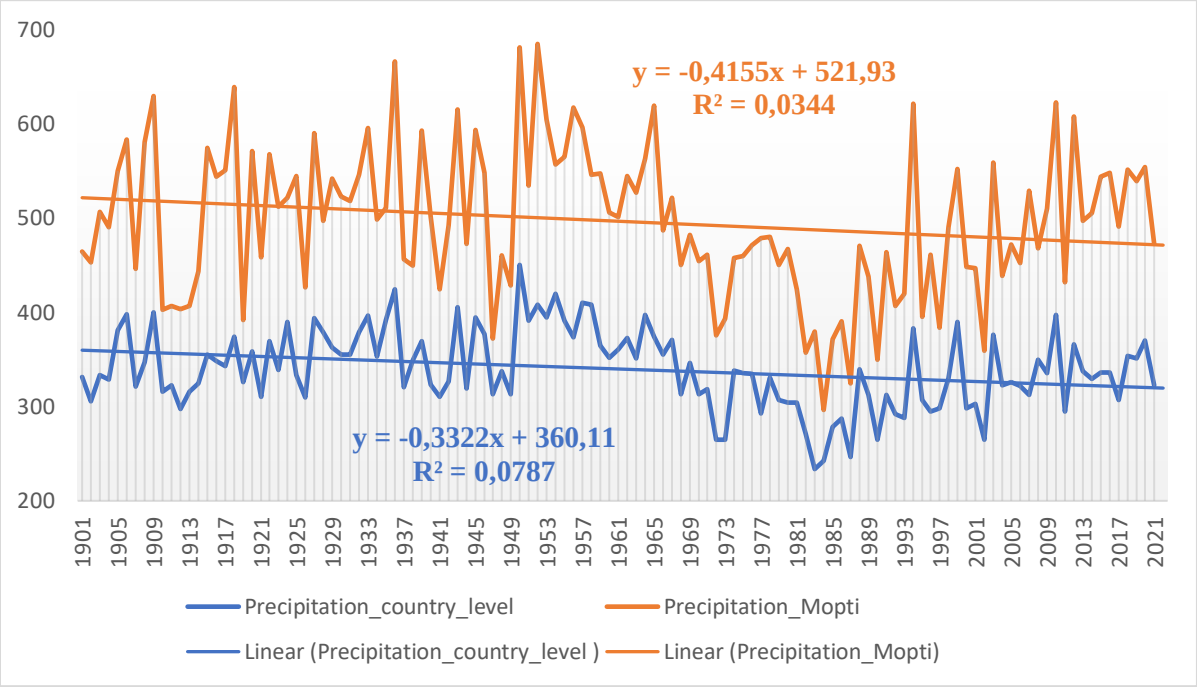
Source: Author's construction using the data from World Bank Climate Change Knowledge portal (CCKP)

3.2.3.2 Rainfall patterns in Mali

Annual and decadal rainfall quantity and distribution vary greatly at both regional and country scale. Rainfall data for the period 1901-2021 show a dramatic declining trend in average precipitation and characterized by strong variability in central Mali as well as at the national level. Like the rest of the country, the Mopti region has only one rainy season which lasts four months (June to September), the weather and climate are hot and dry for much of the rest of the year. The average amount of annual rainfall in the region is 510 mm. The month of August is the wettest month with 166 mm of precipitation with November and December being the driest months with respectively 0 mm of precipitation. With this only one rainy season per year, the period of June to September remains the planting time par excellence in the region. Consequently, the rainfall amount and distribution during this time is extremely important since changes in rainfall patterns increase the likelihood of short-term crop failures and long-term production declines. However, due to climate change, this feature is shifting and severely disrupting crop life cycles and planting schedules in the region. Indeed, the area faces a more erratic rainfall pattern and frequent dry spells during the planting periods of June to September. Moreover, the amount of soil moisture available to plants is greatly reduced by high runoff during the period of June - September and high

evapotranspiration. As shown in Fig. III-5, the precipitation regime in central Mali is irregular and associated to a downward trend. The immediate impacts of this variability in rainfall amount and distribution is a reduction in crop productivity in central Mali (Kane et al., 2018). Sossou et al. (2020) found in Burkina Faso that each 1 millimeter decrease in rainfall amount would decrease crop production by 252 tons in the short term and 385 tons in the long term. In Mali, Kouyate (2020) found that decrease in average rainfall over the period June-September negatively affects the performance of crop production to a certain threshold.

Figure 3.6: Times series of mean rainfall trend at both regional (Mopti) and national level



Source: Author's construction using the data from World Bank Climate Change Knowledge portal (CCKP)

3.3 Conflict dynamic in central Mali:

The Mopti region is located in the interior delta of the Niger. It is an area known as "le Macina" which is home to a network of lakes, swamps and canals. Also known as one of the most fertile areas in Africa, the Inner Delta encompasses a watershed that covers up to 30,000 km2 in good years and is mainly dependent on annual rainfall (See Tora A. Benjaminsen & Ba, 2009). In this area a variety of socio-professional groups such as herders, farmers and fishermen coexist and carry out different forms of livelihoods activities which very often overlap and further translate to communal conflicts over natural resources (land and water in particular). For instance, between

1895 and 1960, tensions due to access to land and the sharing of natural resources were reported between farmers (Dogon) and herders (Peuhl) in the locality of Koro. Generally, these tensions were short-lived and subsided after the intervention of local notables and religious authorities (traditional local management mechanisms). New tensions and disputes have soon emerged between 1960 and 1998 resulting from the overexploitation of natural resources (land and water), due to the recurrent droughts series and the drop in rainfall (amount and distribution) observed during this period. For example, a clash between two Fulani villages the Soosoobé and Salsalbé in December 1993 has led to death of 29 and 42 injured people (Remi et al., 2018). To ease those tensions and disputes, the traditional tension management mechanisms were complemented by new modern mechanisms. These modern mechanisms were essentially constituted of conflict management commissions headed by the administrative authorities. After 1998, the conflicts resumed with renewed vigor. For instance, in the north of Koro, a conflict has pitted the Dogons of Gondogourou against the Fulani of Mbana for decades. In 2002, these tensions escalated, prompting the Dogon to attack the Fulani village of Mbana, killing around five people, including the village chief[9]. After 1998, in a context of continued environmental degradation with climate change negatively impacting the two dominant region's livelihoods systems (cropping and pastoralism) with the decrease arable land and pasture, conflicts in the region take on new dimensions. For instance, in a dispute over a cattle corridor blocked by agriculture in May 2012, the Dogon (famers) attack on the village of Sari in Seno (a Fulani village) resulted in the burning of 350 huts with 774 cattle taken and 21 villagers killed in addition to several injured (Tor A. Benjaminsen & Ba, 2019; Remi et al., 2018). Indeed, from that time the communities started to organize in group and constituting local militias and communal armed groups. This has further paved the way and facilitated the installation (and expansion) of local militias, terrorist and jihadist groups in Central Mali (Winters & Jeffrey, 2021).

[9] https://www.crisisgroup.org/fr/africa/sahel/mali/293-enrayer-la-communautarisation-de-la-violence-au-centre-du-mali.

3.4 Sampling procedure, Data collection Methodology and Descriptive Statistics

Before going through the sampling procedure employed in this dissertation, the section begins by introducing and defining the main variables being collected in the survey. Then, the presentation of descriptive statistic ends the section.

3.4.1 Variables definitions and design:

In this dissertation, our main variables of interest remain naturally those related to climate change, livelihood sources and individual's conflicting attitudes or support for violence. Accordingly, variables gauging individual's perception of climate change in the study area; the adaptation strategies developed to cope with climate change adverse effects as well as attitudes regarding violence and conflict. In addition to that, the literature has identified several other variables necessary when analyzing climate change impact on a community. Accordingly, our questionnaire is organized in eight (8) main sections. Section A records the demographic information; Section B records the information regarding livelihoods and livelihoods sources; Section C deal with information on household food security status; Section D, records information regarding access to extension, markets, credit, food consumption, and social capital; Section E includes the questions designed to gauge climate change perception and shocks; In section F are found questions identifying the adaptation strategies employed; Section G includes questions capturing people's attitudes towards violence. And finally, Section H records household assets, and access to basic services. In what follows we describe the key variables employed in the survey.

3.4.1.1 Support for violence

Sensitivity is a key element when it comes to designing questions in order to capture respondents' willingness and attitude toward the use of violence. Importantly, the risk for admitting participation in violence may be high or low depending on the relationship (ethnically for instance) between the enumerator and the respondent because of social desirability (von Uexkull et al., 2020). Social desirability is referred to as the tendency of some respondents to answer questions in a way they consider more socially acceptable than their real response would be. This is done in order to provide a favorable image of themselves and to avoid receiving negative evaluations from enumerators. In order to get over of that issues, we follow previous studies on climate change and conflict (see for instance: Linke et al., 2015; Vestby, 2019b; von Uexkull et al., 2020). Thus, we

make use of a standard approach to measure support for violence adapted from the Afrobarometer[10] survey carried out routinely in many African countries. More precisely, each respondent was asked "which of the following statements is closest to your view? Choose statement one or two. Statement one: The use of violence is never justified in Malian politics. Statement two: In this country, it is sometimes necessary to use violence in support of a just cause". In addition, respondents may also choose among a set of other responses that they agree, strongly agree or not agree with either statement with even a possibility to refuse to answer. We then create a binary variable which is coded "0" for individuals who agree to the first statement (not supportive of violence) and "1" for individuals who agree, or strongly agree, to the second statement (supportive of violence).

3.4.1.2 Climate change's perception variables:

To capture people perception of climate change, we focus on individual's experience of changes regarding climate and weather patterns. Hence, we introduced 15 questions to ask respondents about all forms of changes in weather condition they have noticed over the past 10 to 20 years.

3.4.1.3 Adaptation strategies variables:

The climate change literature has identified several adaptation strategies. Adaptation methods for this dissertation are based on asking respondents about the different actions employed to counteract the negative impact of climate change on their livelihoods. A specific adaptation method will take the value of 1 if it is adopted and 0 otherwise. This means that adaptation is measured by a dummy variable.

3.4.1.4 Intra-ethnic and inter-ethnic attitudes

Furthermore, we also introduced variables intended to gauge people's intra-ethnic and inter-ethnic attitudes. For that we adopted two straightforward survey questions from the Afrobarometer to measure these variables: (1)"How much do you trust people from your own ethnic group?" (2)"How much do you trust people from the other ethnic group?" The response

[10] The Afrobarometer is a non-partisan pan-African research institution that conducts repeated rounds of surveys of public attitudes on democracy, governance, economy and society across dozens of countries.

3.4.2 Sampling procedure and data collection method:

At the time of the 2009 census (the last national demographic census called RGPH "Recensement General de la Population et de l'Habitat") the population of the Mopti region was 2 037 330 inhabitants. Currently it is projected at 2 878 285 inhabitants (According to the 2020's modular and permanent survey of households [EMOP] run by the National Institute of Statistic [INSTAT-MALI]). Collecting data from every person of such a large population is though and rarely possible. First of all, it necessitates a relatively long time to realize such a collect, moreover, it implies building a consistent budget. Therefore, a sample is needed to be drawn from the entire population. Accordingly, a sample is a specific group of individuals to whom will be administrated the questionnaires. It is the group of individuals who will actually participate in the survey, the research.

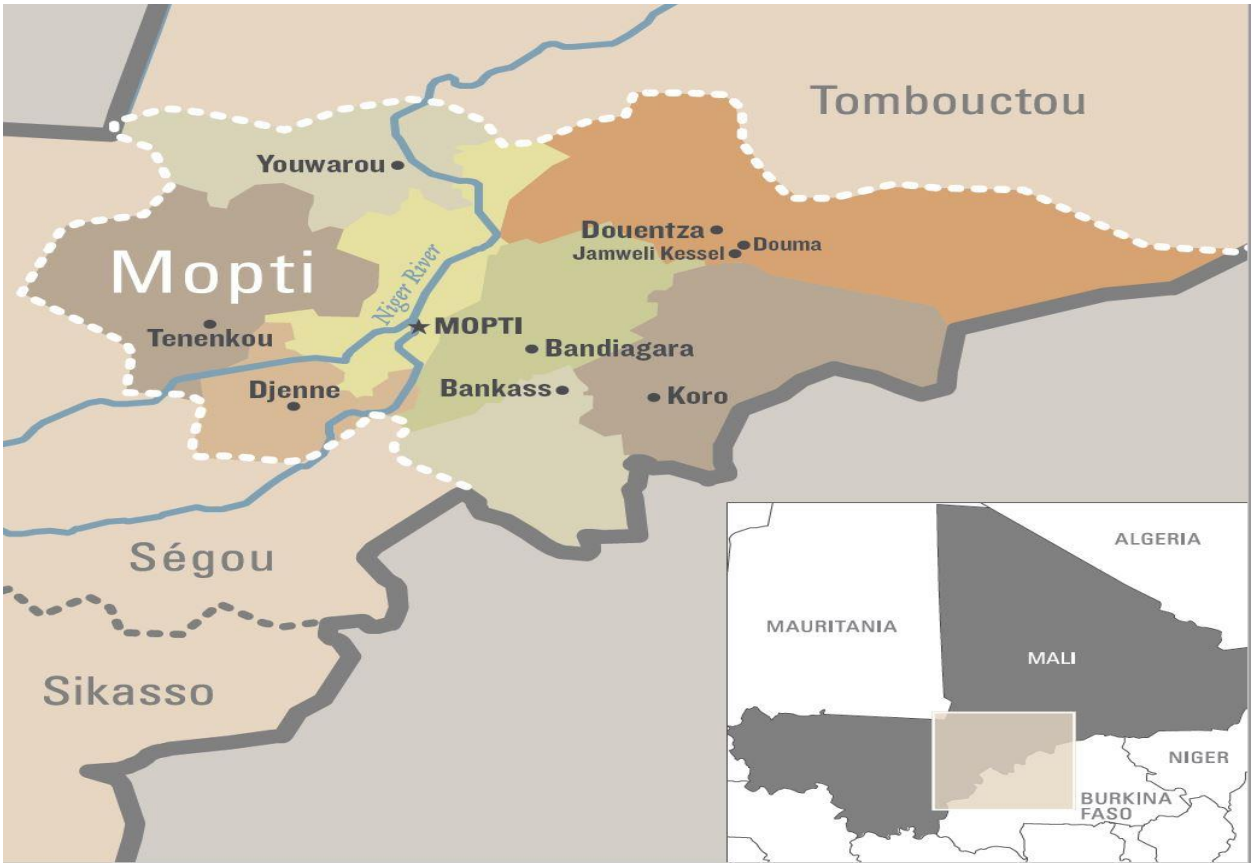
Sampling comes in two forms: probability sampling and non-probability sampling. The first one involves random selection, allowing to make strong statistical inferences about the entire population. The last one in contrast, implies non-random selection, very often based on convenience, accessibility or other similar criteria. The Non-probability sampling generally allows to easily collect data however its most notable disadvantage is that it does not allow statistical inferences to be made concerning the entire population. Regarding this shortcoming, the probability sampling methods is chosen in this dissertation.

There are mainly five forms of probability sampling technique: the Simple Random Sampling, the Systematic Random Sampling, the Stratified random Sampling, the Cluster Sampling and the Multi-Stage Sampling technique. In a Simple Random Sampling, every member of the population has an equal chance of being selected, accordingly, it creates samples that are highly representative of the population. In that case the sampling frame should include the entire population. The Systematic Sampling technique is quite similar to the Simple Random sampling, but it is usually slightly easier to conduct. In the Systematic Sampling procedure every member of the population is listed with a number, but instead of randomly generating numbers, individuals are chosen at regular intervals. The Stratified Sampling implies dividing the population into subpopulations/subgroups (called strata) based on relevant characteristic (e.g., gender, age range, income bracket, job role). Based on the overall proportions of the population, you calculate how many people should be sampled from each subgroup. Then you use simple random or systematic

sampling method to select a sample from each subgroup. This form of probability sampling particularly allows to draw more precise conclusions by ensuring that every subgroup is properly represented in the sample. Similarly, to the Stratified Sampling method, the Cluster Sampling technique also involves dividing the population into subgroups, however, each subgroup should have similar characteristics to the whole sample. Instead of sampling individuals from each subgroup, you randomly select entire subgroups. Finally, the Multi-stage sampling technique involves a combination of two or more of the probability sampling methods outlined above in one survey data collection.

Regarding the configuration of our study area (the Mopti region) the most suitable sampling strategy would be a multi-stage sampling procedure which enables the combination of several probability sampling techniques. At the first level we made use of the Stratified Random Sampling method. Indeed, as the Mopti region is made of two different natural zones (flooded zone and exposed zone) we divided the region into two strata. The flooded zone (the Inner Niger Delta) constitutes one stratum and is comprises of four administrative cercles: Mopti, Djenne, Tenenkou and Youwarou. While, the second stratum is the exposed zone (the Dogon plateau) which is also made of four administrative cercles: Bandiagra, Bankass, Douentza and Koro. The rationale behind this stratification per natural zones is both: first we want to make sure that every subgroup is properly represented in the sample. Second, we expect the adaptation strategies to vary in number and type depending on the location. From each type of natural zone both villages and respondents are randomly chosen. However, before getting to that step the number of households to be included in the sample is needed.

Figure 3.7: The Map of the study area "Map of Mopti, central Mali"



Source: USHMM/Early Warning Project

To calculate an adequate sample size there are a multiple of methods, calculators and formulas. Interestingly, one method of determining sample size is to specify the sample frame (the targeted population size regarding the sample unit), the desired margin error and degree of confidence. However, in our case the sample frame (the complete list or enumeration of all of the households) is not available. In such case, scholars usually resort to the use of the expected prevalence (P) of the studied population. This should be found from previous studies published in the study domain. However, when there is no previous studies to help estimating P as in our case (no study so far, which collected survey data on climate change and conflict issues in central Mali), scholars recommend that the sample size (n) may calculated using P = 0.5 (See for instance Lwanga & Lemeshow, 1991; Naing et al., 2006). Within ±5% margin of error (ℓ), 95% confidence level gives us Z values of 1.96 (2-tailed test). Hence, by applying the most used sample size formula (especially, when dealing with larger population) accordingly, Cochran's (1977) sample size formula which figure the sample size (n) as equal to :

$$n = \frac{\left[Z^2(1-P)P\right]}{e^2} = \frac{\left[(1,96)^2(1-0.5)(0.5)\right]}{(0,05)^2} = 384.16 \approx 384$$

We obtained a sample size (n) in the range of 384 households. However, this was adjusted to 450 respondents, explicitly we added 17.4% of 384.16 to 384.16 (the initial sample size) i.e $[384.16 + (384.16 * 17.14\%) = 450.00]$ to account for non-respondents' biases. Indeed, as we are dealing with sensitive questions (gauging attitude toward violence) in this survey, it is recommended to be more cautious with regard to non-respondents' biases. To take that in to account, authors suggested to take a random sample of about 10-20% of non-respondents to use in non- respondent follow-up analyses (Bartlett II et al., 2001).

Then, from the two types of zones (flooded and exposed), a total of 450 randomly selected households, equally distributed is drawn. Accordingly, 225 households have been randomly chosen from each zone. With regard to the relative size of villages in the Mopti region, we choose to limit the number of households per villages at 25. Thus, we randomly selected 18 villages to build up: nine (9) villages from each stratum/zone. Then from each village, 25 households are interviewed. The following table shows the selected villages and related commune and administrative cercles for the survey.

Table 1.1: List of Survey Cercles, Communes and villages in the central region of Mali (Mopti)

Stratum/zone	Villages	Commune	Administrative cercle	Number of households
Exposed zone	Dounali	Kendie	Bandiagara	25
	Dini	Sangha	Bandiagara	25
	Ireli nattaye	Sangha	Bandiagara	25
	Kanibonzon	Kanibonzon	Bankass	25
	Bankass	Bankass	Bankass	25
	Seni-Doh	Deberé	Douentza	25
	Koubewel	Koubewel koundia	Douentza	25
	Fonbori	Douentza	Douentza	25
	Togo-Tina	Koro	Koro	25

Flooded zone	Tongorongo	Socoura	Mopti	25
	Diodiori	Socoura	Mopti	25
	Sampara	Bassirou	Mopti	25
	Welingara	Djenne	Djenne	25
	Mansaba	Fakala	Djenne	25
	Dia	Diaka	Tenenkou	25
	Diafarabé	Diafarabé	Tenenkou	25
	Hombolore	Youwarou	Youwarou	25
	Ouro	Youwarou	Youwarou	25
Total	**18**	**16**	**8**	**450**

***Source**: Author's own construction*

The Surveys was administered by eight (8) different but commonly-trained research assistants (one per administrative district/ cercles). They were selected based on their knowledge of the study area and survey experience from similar data collection undertakings. The enumerators were provided one day of training. This was done, in order to prepare them for an efficient usage of the data collection tool (ODK COLLECT on tablet). In addition to the structured data from the household survey, the data collection includes informal discussions with some resource people (focus group discussion).

3.4.3 Descriptive Statistics (Characteristics of the sample)

The descriptive statistics of our sample carry out some of the most important characteristics of the central region of Mopti. In the following lines are discussed those main characteristics.

3.4.3.1 Gender, age, household size and household head

The gender distribution in the sample household is such that 83.78 percent of respondents (377) are male while a minority (16.22 percent) are from the opposite sex (female). This could be explained by the fact the survey specifically focuses on household head who naturally tend to be male in the survey are and even in the whole country. The total average age in the whole sample is 49.41 years old with an average of 44 for the female and 50 for the male compared to an average household head age of 49 years old at the national level (INSTAT, 2021). The average household size turns out to be 4. 15 members with an average of 4.44 males and 2.64 female members. This

average household size is a bit under the national average which is 5.8 members (INSTAT, 2019). About 85.83 percent of the households had family sizes ranging between 2 and 9, while only 2.88 percent had more than 10 members. Over the 450 respondents, 54 percent declared belonging to a community association or organization with 53.11 actively participating in community activities. About 79.33 percent of them trusting the communitarian organization in a large extent. Only 11.33 percent of the household head in our sample are female compared to 14.7 percent at the national level (INSTAT, 2019).

Table 3.1: Distribution of the sample according to gender, age and household size

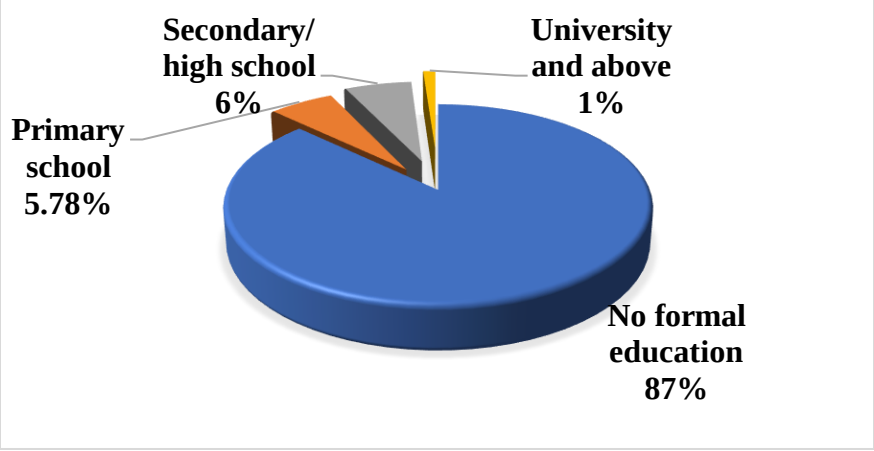
Variables	Obs	Mean	Std. Dev.	Min	Max	Skew.	Kurt.
Male	450	0.838	0.369	0	1	-1.832	4.358
age	450	49.409	14.168	20	85	0.247	2.269
Househol size	450	4.149	2.434	1	16	1.414	6.312

Source: Author's construction using the survey data

3.4.3.2 Education level:

In general, the education level is low in Central Mali as most of the households in the sample were headed by illiterate heads. Accordingly, about 87.11 percent of the sample had no formal education and were not neither able to read nor to write in French (the country official language). Hence, the proportion of individuals with no formal education is higher in the study area than the national level of 61.0% (INSTAT, 2021). About 7.11 percent of the respondents completed the secondary and high schools' degree against 4.0% at the national level. The remaining 5.78 were only primary completes compared to 33.3% for the national scale. Regarding the university level and above only 1.11% of the sample reached that level compared to 0.8% for the whole country.

Figure 3.8: Educational level in the sample



3.4.3.3 Marital status, ethnicity and religion:

The most dominants ethnic group found in the sample are the Dogon ethnic group which represents up to 48 percent of the respondents compared to the Fulani ethnic group corresponding to about 29.56 percent of the sample and followed by the Bozo ethnic group (about 10.44 percent). The remaining percentage of ethnic groups is shared between the Bambara, the Bobo, the Kassonke, the Malinke, the Samogo, the Sonrhay and the Soninke. Over the 450 respondents, out of 90.67 percent reported to be an adept of the Islamic religion against 93.7 percent at the national level (INSTAT, 2019). The marital status share is such that 90 percent of the sample is found married compared to 80.7 percent at the national level (INSTAT, 2019).

Table 3.2: Distribution of the sample according to marital status, ethnicity and religion

Variable	Obs	Mean	Std. Dev.	Min	Max
Married	450	0.900	0.300	0	1
Dogon	450	0.480	0.500	0	1
Peulh	450	0.296	0.457	0	1
Muslim	450	0.907	0.291	0	1

Source: Author's construction using the survey data

Table 3.3: Ethnic distribution of the sample

Ethnicity	Freq.	Percent	Cum.
Other	10	2.22	2.22
Bambara	16	3.56	5.78
Bobo	4	0.89	6.67
Bozo	47	10.44	17.11
Dogon	216	48.00	65.11
Kassonke	1	0.22	65.33
Malinke	3	0.67	66.00
Peulh	133	29.56	95.56
Samogo	1	0.22	95.78
Songhrai	18	4.00	99.78
Soninke	1	0.22	100.00
Total	450	100.00	

Source: Author's construction using the survey data

3.4.3.4 Intra-ethnic and inter-ethnic trust attitudes:

Those variables were administered to the respondents in order to capture the nature of intra and intergroup relations that exist between people in the study area. According to (De Juan & Hänze, 2021), high levels of intra-ethnic trust associated to low levels of inter-ethnic trust might increase the risk of conflict. We adapted the definition of the word trust following De Juan and Hänze's (2021) article in which they refer to "Trust" as in one hand the expectation of benevolence from someone or from a group and in the other hand, one's own willingness to act benevolently on those

expectations as well. As a result 76 percent of those polled reported to trust in a large share people from their own ethnic group while 52.44 percent reported to not trust enough people from other ethnic groups. However, regarding the State and govrenors about 59.33 percent reported to not trust at all the State.

3.4.3.5 Livelihood sources in the sample:

Managing multiple livelihood sources seem not to be a very common practice in the sample. Indeed, only 49.78 respondents reported to held more than one source of livelihood. The main source of livelihood and income in the sample is agriculture (about 71.56 percent) followed by livestock husbandry (about 8.67 percent). However, 70.67 respondents reported that the incomes made from those activities are not sufficient to sustain their living, with 49.56 percent reporting having had difficulty feeding in the past 12 months. In addition, 55.33 percent of the respondents affirmed there is no rule their locality managing natural resources.

3.4.3.6 Subjective living condition, poverty and food security:

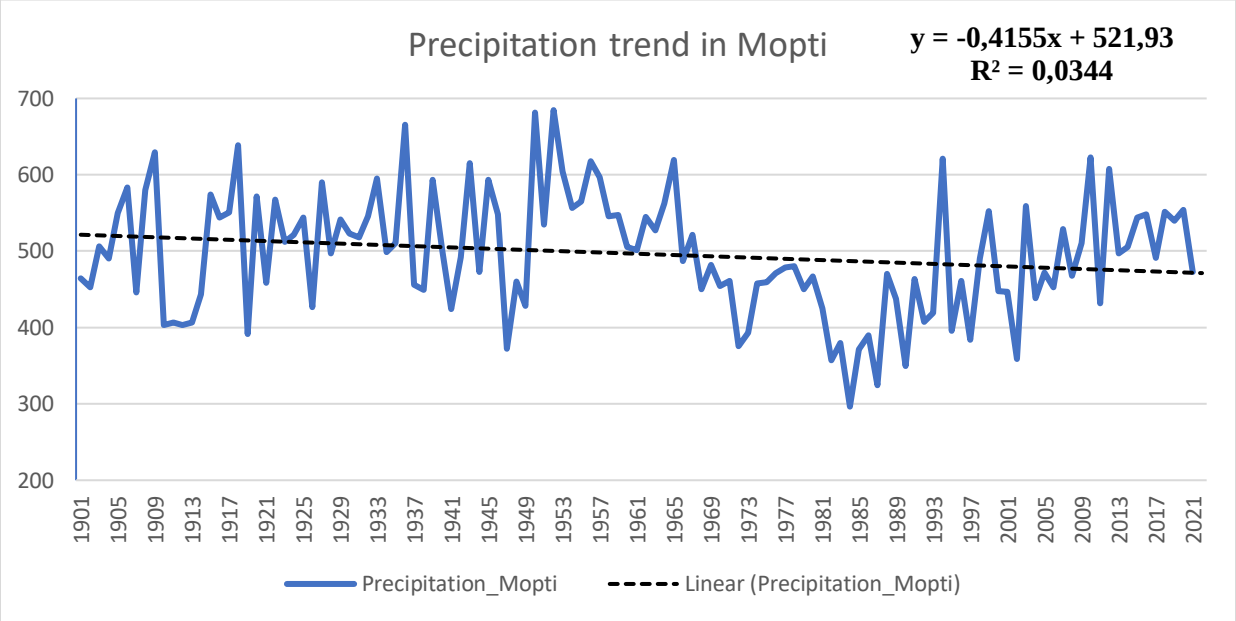
Relatively to their activities and incomes made from thosre activities, 86.44 percent of those consider they live decently. However relatively to others living in the same are only 63.56 percent reported to live convenably. About, only 32.44 consider themselves beings poor against 44,6 % at the national level (INSTAT, 2021) with 63.56 considering the State as not fighting enough poverty in the country. Relatively to the time, especially over the past 5 – 10 years, 66.44 reported experiencing a deterioration in their living conditions. 45.78 percent consider that the whole community is experiencing that deterioration. The data revealed that food insecurity is more prevalent in the region compared to the avreage national rate of 27.8% (INSTAT, 2021). Indeed, overall, 49.55% of households reported experiencing food difficulties during the last 12 months preceding the survey.

3.4.3.7 Climate change perception:

More than 90 percent (precisely 92.89 percent) of the respondents in both sites (flooded and exposed zones) have observed changes in the weather patterns. Accordingly, 58.44 percent of the respondents mentioned a decreasing and erratic rainfall amount. Figure 3.7 shows that this perception is somewhat in agreement with the observed meteorological data from meterological

stations concerning the Mopti region. Indeed, the figure highlights erratic rainfall with a downward trend.

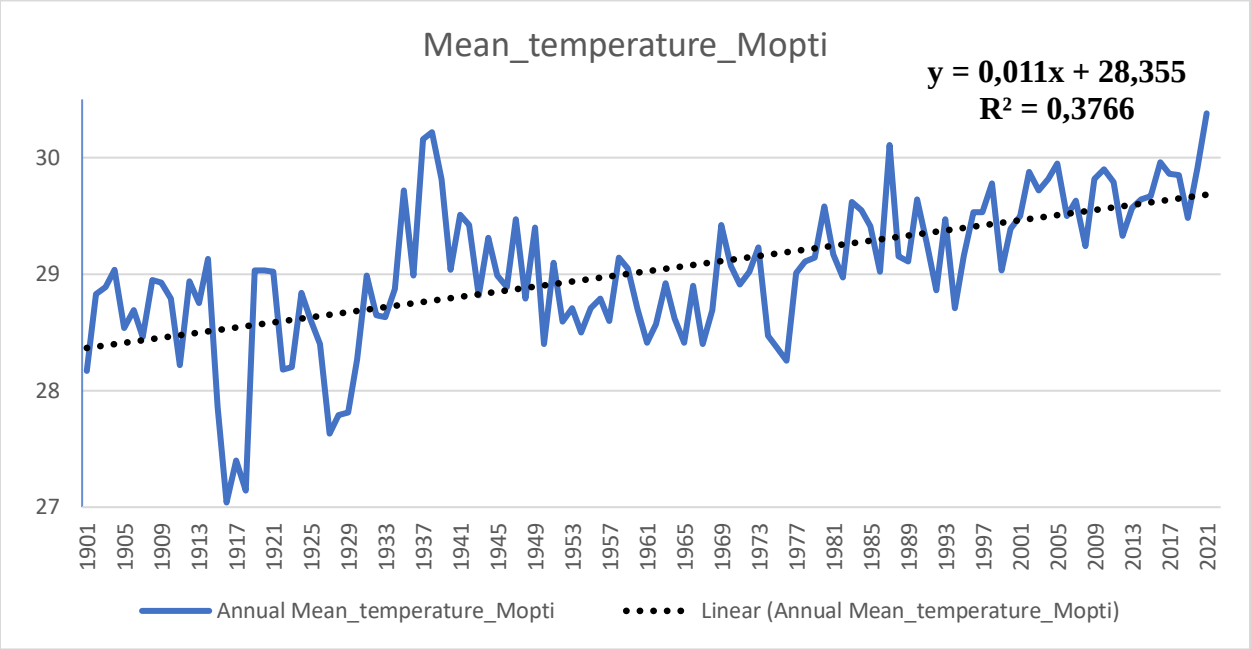
Figure 3.9: Precipitation pattern and trend in Mopti



Source: Author's construction using the data from World Bank Climate Change Knowledge portal (CCKP)

Regarding temperature patterns, 74.89 percent of the participants reported an increasing temperature trend in central Mali. Data from World Bank Climate Change Knowledge Portal (CCKP) depicts similar trend (Figure 3.8).

Figure 3.10: Mean temperature and trend in Mopti



Source: Author's construction using the data from World Bank Climate Change Knowledge portal (CCKP)

We further include in the questionnaire survey items designed to gauge respondents awarness regarding whether the changes obersed in weather impact their livelihoods or no. overall, 87.56 percent of the responded affirm that the reported changes in climate impacts people livelihoods in central Mali. According to 66.89 percent of the participants these changes are responsible for the decrease in crop and livestock production experienced. Specifically, 71.56 percent agreed that yield is decreasing with 57.10 percent pointing out the decrease in precipipation as the main of cause of that situation. We also added questions to investigate the different measures employed by the local communities to cope with climate change. About 80.44 percent of the sample indicated to adapt to climate change using less fertilizer (28.44 percent), planting short croping varieties (26.89 percent) and crop diversification (26.44), combining agriculture and livestock production (15.11 percent) appear in the sample as the main adaptation strategies implemented. The lack of funds (44.89 percent) and knowledge on adaptation techniques (16 percent) are the two main obstacles identified by the respondents for adapting to climate change.

3.4.3.8 Support for violence

The majority of respondents in the sample about 78 percent indicate to not approve the way the country is being managed. However, only 42.22 percent reported having used force and violence

to seek justice. Interestingly, 81.78 percent of respondents support the use of violence in the country whether it is morally, financially or physically and found it justified.

3.4.3.9 Access to basic services:

In terms of accessibility toward basic services, 94.44 percent of those polled reported to have access to market while 58.44 percent argued to not have access to vulgarization services. About 24.44 percent only have access to credit facilities. 55.56 percent indicate to be satisfied regarding health facilities while 59.33 percent affirmed to not have access to school facilities. Only 41.78 percent of the sample agreed to have access to electricity compared to 71.3% at the national level (INSTAT, 2021). In contrast, access to paved road seem to be the lowest one. Indeed, only 10.67 percent reported having access to paved road in the study area.

Table 3.4: Descriptive statistics over variables capturing people access to basic services

Variable	Obs	Mean	Std. Dev.	Min	Max
Acces to market	450	0.944	0.229	0	1
Acces to vulgaristion facilities	450	0.416	0.493	0	1
Access to credit	450	0.244	0.430	0	1
Access to electricity	450	0.093	0.291	0	1
Access to improved water sources	450	0.804	0.397	0	1
Access to improved sanitation	450	0.258	0.438	0	1
Access to health facilities	450	0.556	0.497	0	1
Access to school	450	0.407	0.492	0	1
Access to electricity	450	0.418	0.494	0	1
Access to paved road	450	0.107	0.309	0	1

Source: Author's construction using the survey data

3.4.4 Summary of main variables used in the different analyses

On the basis of previous micro-level analysis in the field of climate change and conflict (See De Juan & Hänze, 2021; Detges, 2017; Vestby, 2019a; von Uexkull et al., 2020) the following variables (Table 3.6) have identified and included in our analyses.

Table 3.5: Summary of main variables used in the different analyses

Variable	Explanation	Mean/ Freq	Std. Dev/percentage.
Support for violence	Unity if respondent support the use of violence; zero otherwise	0.422	0.494
Inter-ethnic trust	Unity if respondent trust members of other ethnic groups; zero otherwise	0.475	0.499
Intra-ethnic trust	Unity if respondent trust members of own ethnic groups; zero otherwise	0.760	0.427
Independent variables			
Age			
20-30	Unity if respondent is between 20 and 30 years; zero otherwise	0.111	0.314
31-50	Unity if respondent is between 31 and 50 years; zero otherwise	0.464	0.499
51 and above	Unity if respondent is between 51 and above; zero otherwise	0.424	0.494
Gender	Unity if respondent is male; zero otherwise	0.837	0.369
Educational status			
No formal education	Unity if respondent has no formal education; zero otherwise	392	87.11
Elementary/Primary school	Unity if respondent graduated elementary/primary school; zero otherwise	26	5.78
Secondary school	Unity if respondent graduated secondary school; zero otherwise	27	6.00
University, graduate school	Unity if respondent graduated university or graduate school; zero otherwise	5.00	01.11
Household size	Number of people living in the household	4.148	2.434
Drought perception	Unity if respondent indicate drought as the most serious climate hazard; zero otherwise	0.493	0.500
Deterioration in community living condition	Unity if respondent indicate deterioration in community living condition; zero otherwise	0.371	0.483
Trusting the sate	Unity if respondent trust the state; zero otherwise	0.406	0.491
Marital status	Unity if respondent is married; zero otherwise	0.900	0.300
Subjective poverty	Unity if respondent consider himself as poor; zero otherwise	0.324	0.468
Food security as priority	Unity if respondent consider food security as priority; zero otherwise	0.306	0.461
Access to credit	Unity if respondent has access to credit; zero otherwise	0.244	0.430
Access to improved water sources	Unity if respondent has access to improved water sources; zero otherwise	0.804	0.397

Source: *Author's construction using the survey data*

3.5 Conclusion:

In general, the survey has shown that people living in the central region of Mali accordingly the Mopti region are well aware of climate change, its different manifestations and the adverse effects on the community livelihood. The result revealed that drought and flood are the climatic shocks most observed by those living in the study area. An increase in temperature and decrease in rainfall amount where also mentioned by a vast majority of the respondents. The results also show that the main activity and source of livelihood in the study are is agriculture followed by livestock production and fishing. This naturally confirms why people are sufficiently aware of the negative impact of climate change expressed in terms of reduced yield and production. The survey further

indicate that the population is striving to adapt to climate change with crop diversification, using less fertilizer and combining agriculture and livestock husbandry being the most mentioned by respondents. However, they also face obstacles such us the lack of funds and lack of knowledge on coping techniques as mentioned. Almost all respondents in the study area do not approve the way the country is being managed and a large majority of them support the use of force violence to make one better off.

4 CHAPTER THREE: PERCEPTION OF CLIMATE VARIABILITY AND ASSOCIATED IMPACTS ON LIVELIHOODS IN CENTRAL MALI

4.1 Introduction

Climate variability constitutes an important threat to rural livelihoods in most West African Sahelian countries such as Mali (Sanogo et al., 2017). This is further exacerbated by factors including the geographical location, the large dependence on agriculture as well as the lack of adaptation capacity due to poverty. The resulting consequences are disastrous and may even translate into violence and communal conflict according to scholars (Detges, 2017; Vestby, 2019a; von Uexkull et al., 2020). For instance von Uexkull et al. (2020) found that experiencing drought and associated losses increase the likelihood of supporting the use of violence in the Democratic Republic of the Congo. According to Vestby (2019a) participation in violence would have been, on average, more likely if a person had been affected by climate change than if they had not. Similar findings are found in Caruso et al. (2016) and Koubi (2018). In short, these studies highlight a potential relationship between climate change and participation in violence at the individual level. However, we believe that participation in such violent and conflictual behaviors in response to climate change do not occur by default. This may necessarily involve as a precondition how local communities perceive climate change and their ability to appropriately cope. Hence, understanding the micro-level perception and management of climate change is therefore critical to inform policy makers especially for localities like Central Mali.

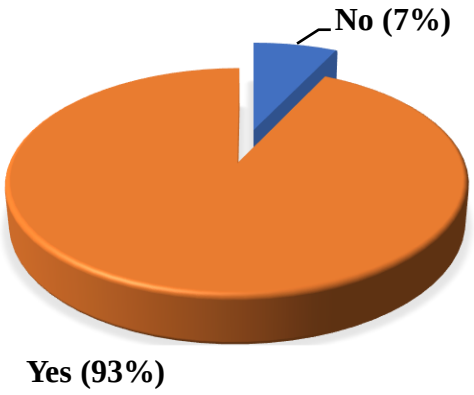
Located between the Sahara and the Sahel, Mali's Central region severely suffers from violence and communal conflict (see for instance, Tor A. Benjaminsen & Ba, 2019, 2021; Van Wieringen, 2020). In parallel, the region is exposed to extreme climatic shocks with agriculture and pastoralism being the main economic occupations of local communities (Aman et al., 2019). While it is argued that people tend to perceive climate change at local scale (Sanogo et al., 2017), little is known about how local communities in Central Mali perceive and cop with climate change. To address this pressing research need, this chapter is an attempt to documents the perceptions of climate change and related impacts on rural livelihoods using data from household interviews in the eight administrative cercles of Mopti. Overall, our objective is to analyze the perceptions of local communities on climate change and its impacts on livelihoods in Central region of Mali.

Beyond, this introductory section, the rest of the chapter is structured as follow: Section 2 discuss the changes in climate as perceived by the local communities in the study area followed by an analysis of factors explaining such perception in section 3. Section 4 and 5 describe respectively adaptation strategies as practiced in the study area and barriers to adaptation to climate change finally, in section 6 is discussed the perception of climate change effect on agricultural production and the conclusion.

4.2 Perception of Climate Change in Central Mali

Based on our household survey data collected in the Central region of Mali, this section presents summaries of individual's perceptions of climate change and what strategies they use for adapting to those changes. In our survey, respondents were asked questions about their perceptions of long-term climate changes, as well as measures and options they have typically adopted in order to cope with such changes over the years. Those questions range from a general perception of changes in weather patterns to specific changes such as drought, erratic rainfall and so, "During the past 10 - 20 years, have you noticed any changes in the weather conditions?" this is a "Yes" or "No" question.

Figure 4.1: Respondent's perception of changes in Climate conditions over the past 10-20 years

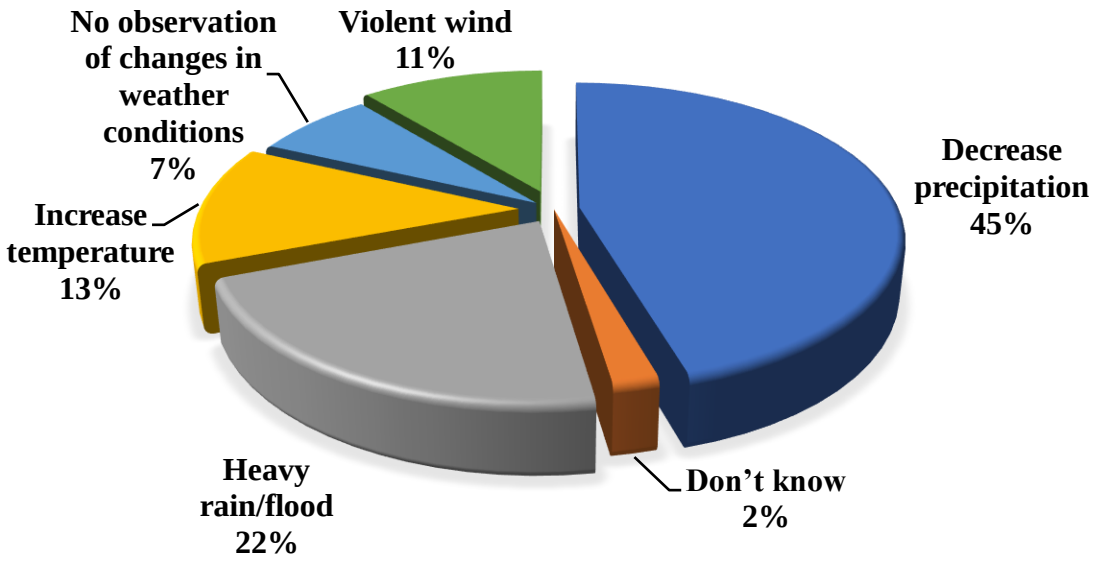


Source: *Author's construction using the survey data*

The results (See Figure 4.1) show that the majority of respondents have perceived that climate has been changing over the last 10-20 years in Central Mali (92.89 percent). Those who replied "Yes" meaning they noticed changes in weather patterns are then invited to describe the changes they observed. Enumerators had a not exhaustive list of some possible changes in weather patterns, a

list that was establish after the pilot survey. However, to avoid the risk of framing bias, they did not present the list to the respondents. Instead, the respondents verbally described the changes noticed and the interviewers checked the corresponding changes from the list.

Figure 4.2: Description of respondents' observed changes in weather



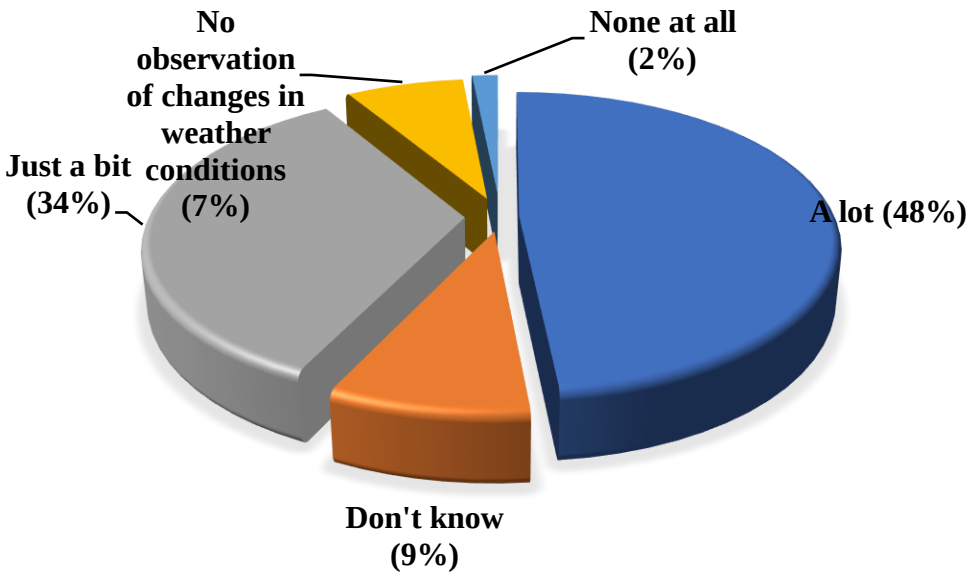
Source: *Author's construction using the survey data*

Among those households who perceived changes in climate, a significant proportion of the households reported (45.33 percent of respondents) noticed a decrease in precipitation/rainfall (in amount and frequency) in their area while 21.56 percent record heavy storms which most of time turn out to flood. Taken together irregularities in precipitation patterns (whether it is scarcity or abundance) were observed by almost 67 percent of the respondents. This represents 72 percent of those who have observed changes in weather conditions. Moreover, 12.67 percent observed an increasing temperature. Recurrent violent wind has also been identified among changes occurring in climate (10.89 percent). These findings are consistent with previous studies including Hussain et al. (2016) in the Hindu-Kush Himalayan region; Kawadia and Tiwari (2017) in Madhya Pradesh; Opiyo et al. (2016) in in northwestern Kenya; Debela et al. (2015) in South Ethiopia; (Sanogo et al., 2017) in southern Mali; Babatolu and Akinnubi, (2016) in Nigeria.

In addition, we also administrated questions to respondents in order to check whether the changes observed in the weather conditions affect they livelihood. Hence, they were asked the following questions: "In your opinion, how much did these changes affect the livelihood of peoples in your

community within the last five years?" the potential responses ranging from "None at all" to "A lot". Results in Figure 4.3 show that 48.44 percent of respondents noticed that weather changes affect livelihood "a lot" (in a great extent). 34.22 percent observed that livelihood is affected but "just a bit" while 1.56 percent consider that climate change do not affect livelihood.

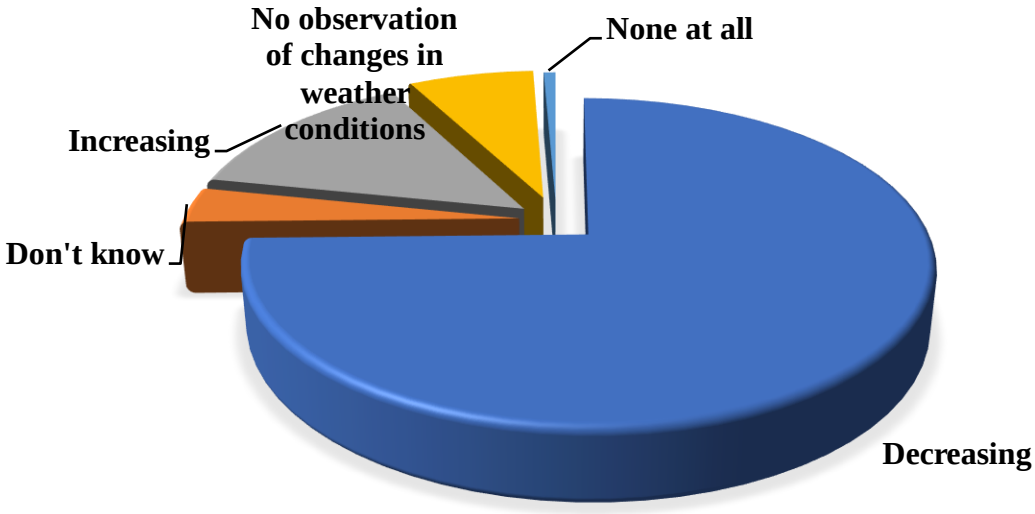
Figure 4.3: Perception of climate change impact level



Source: *Author's construction using the survey data*

To determine the nature of the impact (whether it is negative or positive) respondents were further asked in which sense weather change is impacting their livelihoods. "Based on your opinion, it is this impact positive or negative? Meaning that livelihood (crop and livestock) yield are: "1. increasing" "2.decreasing" "3.don't know". Hence, 74.67 percent of respondents consider that the impact of climate change on livelihood is negative, accordingly crop and livestock yield are decreasing while 14 percent think the opposite (see Figure 4.4).

Figure 4.4: The nature of climate change's effect livelihood in Central Mali



Source: *Author's construction using the survey data*

4.3 Socio-economics and demographics characteristics influencing climate change perception in Central Mali

Based on the results of our survey, this section analyzes the socio-economic characteristics likely to influence climate change (temperature changes, rainfall changes, flood and violent wind) perception in the study area. Our outcome variable of interest is categorical (nominal) with five levels/modalities representing each a climate attributes. In such situations, both Multinomial Logit (MNL) or Multinomial Probit (MNP) regression model can be employed as appropriate econometric model to estimate the parameters (Kemal et al., 2022). However, since the modalities in our outcome variable are not excludable, the use of MNL seems inappropriate as the MNL model relies on the assumption of the Independence of Irrelevant Alternatives (IIA). Although, computationally intensive[11] (see Greene, 2012), the MNP seem more appropriate since it does not assume the IIA. Nevertheless, little evidence exists, which shows that MNP will yield more accurate results than MNL even when the IIA assumption is not met (violated). Hence, to avoid

[11] The main obstacle to the implementation of the MNP model has been the difficulty in calculating the multivariate normal probabilities for any dimension greater than two (2).

falling into the trap of advocating one at the expense of the other, both MNP and MNL are estimated to compare the signs and assessing the assumption of the IIA.

The outcome variable used for both the MNL and the MNP in this analysis is the perception level of climate change which in this case has five levels/modalities (see Table 4.1). The first level coded "0" meaning "perception of no change" is used as the reference outcome (the baseline or base outcome); in the second, third, fourth and fifth level are respectively found perception of changes in precipitation amount, perception of changes in temperature patterns, perception of changes in flood patterns and perception of changes in violent wind frequency. To econometrically illustrate that, let Y_i for instance denote our random outcome variable taking on the modalities $\{0,1,...4\}$ that indicates the choice made by the respondent (i). X is a set of conditioning variables. Specifically, Y_i represents the changes in climate as indicated by respondents in the study area and X the vector of respondents' socio-economic and demographic characteristics (such as: gender, age, education level, household size, farm size, marital status…). Our goal is therefore to evaluate all other things being equal, how changes in the variables of X (vector of individual' characteristics such as gender, age, education…) affect the response probabilities (perception of climate attributes):

$$P(Y_i = j \mid X_i) = F_{ij}(X_{ij}\beta), \quad \text{with } i = 1,2,...,N \text{ and } j = 0,...,4 \tag{4.1}$$

Where $P(Y_i = j \mid X_i)$ is the probability for an individual i to perceive the change j and X_i a vector of individual' characteristics.

4.3.1 The Multinomial Logit Model

According to Greene (2012), If the 5 disturbances (in Eq 4.1) related to modalities are independent and identically distributed, we obtain the MNL model written as follow:

$$P(Y_i = j \mid X_i) = \frac{\exp(X_i\beta_j)}{\sum_{j=0}^{5}\exp(X_i\beta_j)} = \frac{1}{1+\sum_{\substack{k=0 \\ k\neq j}}^{5}\exp[X_i(\beta_k - \beta_j)]} \tag{4.2}$$

Where β_j is a characteristic vector of modality j.

Following Eq. 4.2 The log likelihood can be specified as:

$$\ln L = \sum_{i=1}^{N} \sum_{j=0}^{5} y_{ij} \ln P_{ij} \tag{4.3}$$

The coefficients coming from the estimation of the MNL do not directly represent neither the magnitude of the effects of the exogenous variables on the dependent variable nor the probabilities, they only give the direction of the relationship (positive or negative/ decreases or increases). However, it is possible to measure the magnitude of the effects by determining the marginal effects (or marginal probabilities) of the explanatory variables. This can be obtained by differentiating Eq. (4.2) with respect to the exogenous variables as displayed in Eq. (4.4).

$$\frac{\partial P_j}{\partial X_i} = P_j \left(\beta_j - \sum_{j=0}^{5} P_j \beta_j \right) \tag{4.4}$$

Therefore, being functions of the probability itself, marginal probabilities measure the expected change in the probability of a particular choice being made relative to a unit change in an independent variable. The estimation of the model's parameters is done using the maximum likelihood method.

4.3.2 The Multinomial Probit Model

If we assume that the 5 disturbances (in Eq 4.1) related to modalities follows a normal distribution with zero mean and variance-covariance matrix $\sum$ (unlike the multinomial logit, this assumption implies that the error terms are not independent) and if we assume that the alternative i is chosen as the first alternative in C_n (set of modalities corresponding here to the climate attributes) we will obtain the corresponding probit formulation which is much more complicated than in the case of the logit model:

$$P_n(1) = \int_{-\infty}^{+\infty} d\varepsilon_{1n} \int_{-\infty}^{X_i \overline{\beta} - X_j \overline{\beta} + e_i} d\varepsilon_{2n} \ldots \int_{-\infty}^{X_i \overline{\beta} - X_n \overline{\beta} + e_i} \phi(\varepsilon_{1n}, \ldots \varepsilon_{j_n n}; \sum) \, d\varepsilon_{j_n n} \tag{4.5}$$

Where ϕ a is the multiple normal density function of the zero mean and the variance-covariance matrix $\sum$, to solve this function , it is necessary to estimate a multiple integral of order $J_n - 1$(

J_n as number of modalities/alternatives); n is the number of individuals in the sample; β denotes the vector of the k unknown parameters; $\varepsilon_{jn}(\varepsilon_{1n},...\varepsilon_{j_n n})$ is the set of disturbances related to modalities.

The explanatory variables included in the model are age and gender of the household head, education level, household size, wealth in terms of non-productive asset, whether the respondents is a farmer, whether the respondents have multiple livelihood, whether the respondents has gone without food over the past two years, access to extension services and access to credit (Kawadia and Tiwari, 2017). Results are presented in the Table 4.1 (for the coefficients) and Table 4.2 (for the odds ratios).

4.3.3 Results and discussion:

Parameter estimates of the MNP model and the MNL model are displayed in "Table A-1 and Table A-2" (see appendix A). Both the MNP and MNL yielded almost similar results in terms of signs with only some few differences regarding the statistical significance of variables. For instance, the variables access to vulgarization and age are found statistically significant respectively in outcome 3 and 4 using the MNP and statistically not significant in the MNL regression. The variable related to the use of multiple livelihoods sources is also found statistically significant in the outcome using the MNL and statistically not significant in the MNP. Except these differences, the remaining of the results are similar in terms of signs and statistical significance.

Overall, in the analyses, access to credit, access to extension services, having multiple livelihood sources and experiencing food insecurity over the past two years were found to influence households' perception of climate change in the Central region of Mopti. Hence, from the socio-economic characteristics examined, the results suggest that those who access to credit are less likely to perceive a change in climate. This is likely because, access to credit and other financial facilities in general would enhance people adaptive capacity and help mitigating the adverse effects of climate change. The analysis also revealed that access to extension services in the study area significantly increases the likelihood that households perceive climate change. This is probably due the fact that extension services provide information and create a greater awareness of climate change. These results are consistent with those found in similar studies conducted in different countries (see for instance, Debela et al., 2015; Opiyo et al., 2016). The findings furthermore

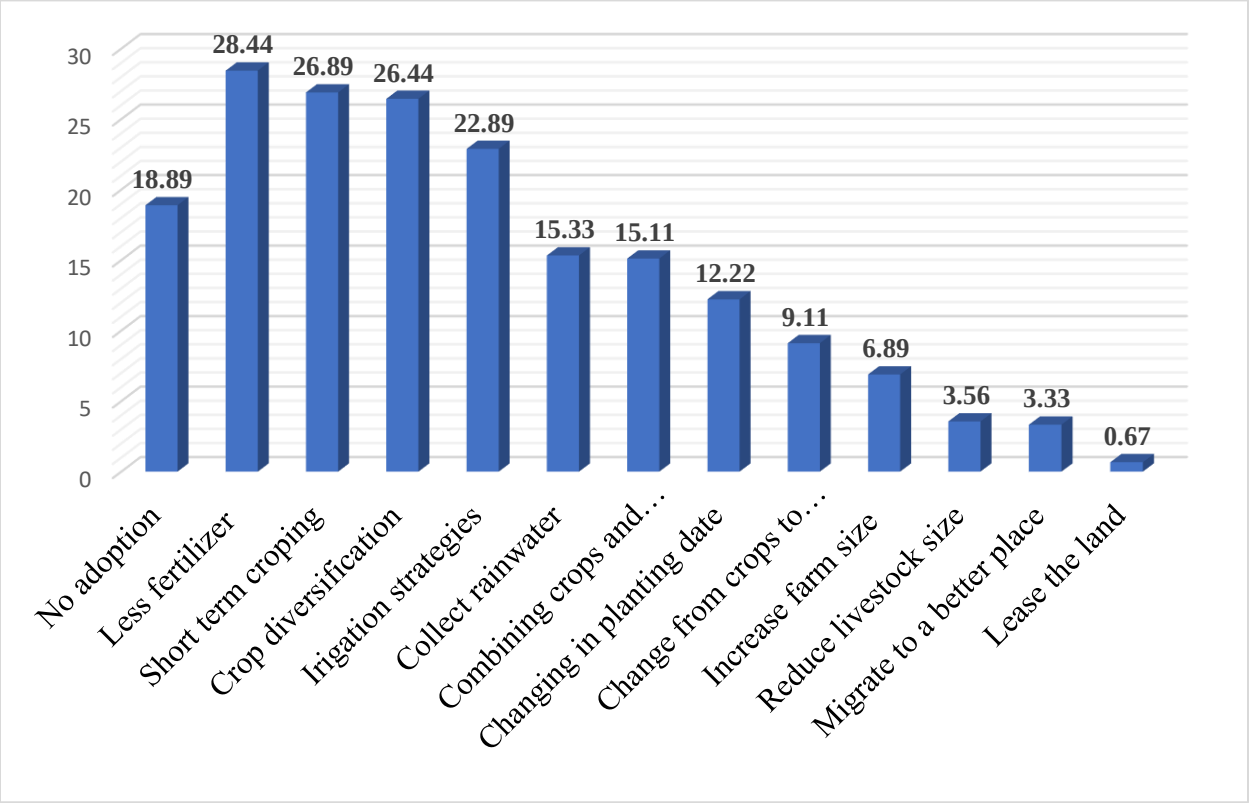
suggest that, the more the individual is food insecure the more he perceived climate change. This is likely because most of households in central Mali draw directly (through agriculture, livestock breeding, fishing) or indirectly (through the processing and selling product from agriculture, livestock breeding) their livelihoods from climate-sensitive activities. The reliance on such climate-sensitive activities builds the affected people awareness regarding climate which the production depends upon. Overall, the analysis confirms the hypothesis according to which different household characteristics and socio-economic factors affect the abilities of individual to perceive climate change. Additionally, the results also suggest that individuals involved in multiple livelihood activities are more likely to perceive climate change. However, this is likely a consequence of climate change. Indeed, as the traditional livelihood activities (agriculture, livestock production and fishing) are no more capable of sustaining living, people may naturally try to associate other activities in order to complete the gap. Our results are consistent with previous study which analysis of the determinants of climate change perception. For instance, in northwestern Kenya Opiyo et al. (2016) found that perception of climate change was significantly ($p<.05$) associated with access to extension services. Similar finding is made the study of Debela et al. (2015) on South Ethiopia. In India, Kawadia and Tiwari, (2017) have found that household size is significantly related to climate perception. Age is also found to be a key factor influencing perception of climate change in southern Mali (Sanogo et al., 2017), and in South Ethiopia (Debela et al., 2015). Moreover, Asrat & Simane (2018), found that age and food shortage are among the determinants of farmer's perception of climate change in North-West Ethiopia.

4.4 Adaptation practices in the Central region of Mali

The same methodology was applied to adaptation practices as well. Those who responded to have noticed changes in weather patterns, were asked ones more whether they have managed to adjust and cope with the changes they face. Then enumerators invite those who indicate to adjust to describe their adoption options which will be checked on a list the interviewer hold. Figure 4.5 displays the share of respondents that have managed to employ specifics strategies. The results have revealed that many households in the central region of Mali are struggling in one way or another to cope with climate change adverse effects (almost 82 percent of the respondents). Specifically, 28.44 percent of the respondents are applying less fertilizer as a means of adapting to the adverse climatic conditions. 26.89 percent are using short term crops and varieties. Crop

diversification is implemented by up to 26.44 percent of the respondents. 15.33 percent are applying water conservation. In addition, the results have also shed light on certain behaviors developed by affected populations as means of adapting to climate change that we yet suspect to be the potential mechanisms linking climate change to violent conflict. Those practices are, "increasing farm size" practicing by around 7 percent of the survey respondents; "migrating to better and resilient places" practicing by 3.33 percent of the respondents and developing "irrigation strategies" actually practicing by up to 22.89 percent of the respondents. These are in line with previous study including Sanogo et al. (2017) who have found that crop varieties, diversification of crops and seasonal migration are key adaptation strategies implemented by the affected people in southern Mali.

Figure 4.5: Adaptation strategies used in the Mopti region (% of respondents)



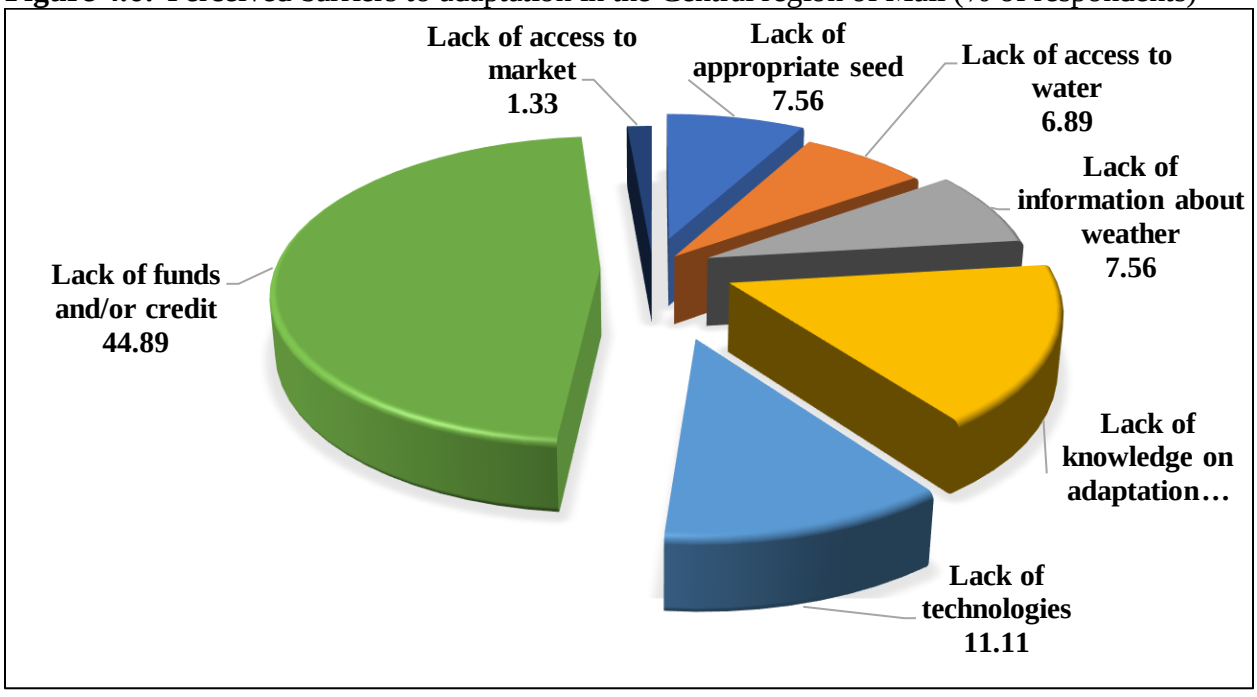
Source: *Author's construction using the survey data*

4.5 Perceived barriers to adaptation to climate change in the central region of Mopti

Results on barriers to the use of adaptation practices are presented in Figure 4.6. According to the results lack of funds and credit facilities, lack of access to timely weather information, lack of

technologies (physical infrastructure, technical material and equipment), lack of knowledge regarding adaptation technics (required human skills, e.g., applying specific planning and management approaches and methods), lack of appropriate seeds is identified as the major critical barriers to adoption in the central region of Mali. However, the most important constraint indicated was the lack of funds and credit facilities (mentioned by almost 50 percent of the survey respondents). This probably limits the ability of actors to provide the necessary technologies required to adjust to the adverse climatic condition faced. It may also explain the lack of appropriate seed regarding the high cost of farm inputs in the region. The lack of knowledge about adaptation technics and methods as well as the lack of information related to weather conditions are likely due to the poor access to extension services in the study area. These are consistent with the recent findings by Diallo et al. (2020) and Sanga et al. (2021). They are also in line with the study of Sekelemani et al. (2020) who have found that lack of funds and financial resources and lack of appropriate skills are among the main challenges to adapt to climate change in Botswana.

Figure 4.6: Perceived barriers to adaptation in the Central region of Mali (% of respondents)



Source: *Author's construction using the survey data*

4.6 Perception of climate change effect on agricultural production in the region

In order to check in which extent, the perception of climate change would affect the likelihood of indicating (experiencing) a decrease in livelihoods in the study area, a binary logit analysis was

performed. The correlation is found to be statistically significant. As displayed in "Table 4.1", the perception of erratic rainfall increases the likelihood of experiencing bad agricultural production by 22,20%, perception of decreasing rainfall amount increases it by 19.19% while perception of drought increases it by 12.60%. Suitable weather conditions are absolutely necessary to agricultural production specially in Central Mali where irrigation is less practiced due to the high cost it implies. The adverse meteorological conditions are very detrimental to crops and animal production. Erratic rainfall completely disrupts the agricultural calendar and is likely to mislead farmers regarding favorable periods for planting, for applying pesticides, for applying fertilizer and so on. The decrease in rainfall amount as well as drought considerably affect plants' growth and development hence preventing them of giving their full potential. These findings give evidence that climate change seriously undermined livelihoods in Central Mali. Similar findings are found in the studies of (Ouédraogo, 2012) and (Sossou et al., 2020) in Burkina Faso. They are also in line with results from (Ben Mohamed et al., 2002) in Niger and (Kouyate, 2020) in the administrative cercle of Koutiala in Mali.

No statistically significant relationship was found between perception of increasing temperature and experiencing bad agricultural production. This may likely be related to rural community weak knowledge regarding the role of temperature in growing crops. Indeed, temperature intervene mostly in the photosynthesis process and plant pollination which are not straightforward and require a minimum formal training.

Table 4.1: Parameter estimates of the of the binary logistic model, displaying the Odds ratio

Variables	Drop in agricultural production		
	Odds ratio	dy/dx	Std. Err.
Drought	1.976***	0.127***	0.263
Decreasing precipitation	2.805***	0.199***	0.246
Erratic rainfall	6.277***	0.222***	0.664
Increasing temperature	1.110	0.198	0.298
Gender	1.186	0.033	0.404
Age			
[20-30] Ref			
[31-51]	1.064	0.012	0.443
[51- over[	0.755	-0.053	0.456
Education			
No formal education [Ref]			
Primary	0.841	-0.033	0.552
Secondary	0.797	-0.044	0.432
University	0.100**	-0.518**	0.985
Married	2.182*	0.166*	0.470
Household size	0.948	-0.009	0.0548
Access to electricity	0.228***	-0.334***	0.412
Access to health facilities	0.618*	-0.087*	0.252
Access to credit	1.695*	0.092*	0.278
Log pseudolikelihood			-225.498
Pseudo R^2 de Mcfadden (en %)			16.08
Prob > chi2			0.000
Number of observations			450

Source: *Author's construction using the survey data*

*Note: ***, **,* and Ref denote respectively the threshold of 1%, 5%, 10% and reference modality.*

4.7 Conclusion

The analysis provided in this chapter aimed at investing changes in climate as perceived by the local communities, the socio-economic and demographic factors shaping that perception as well as the effect of climate change on agricultural production. The multinomial logit analysis, shows that households in the Mopti region are well aware of climate change, its different manifestations and the adverse effects on their livelihood. However, they face considerable challenges in adapting to those changes in climate. Lack of funds and credit facilities, lack of access to timely weather information, lack of technologies (physical infrastructure, technical material and equipment), lack

of knowledge regarding adaptation technics (required human skills, e.g., applying specific planning and management approaches and methods), lack of appropriate seeds is identified as the major critical barriers to adoption in the central region of Mali. These constraints generally explain why individuals often resort to options which are more affordable in terms of cost but which also on the other hand affect the sensitivities of other actors in the rural area and fuel tensions. The analysis further shows that climate change perception in the area is most shaped by socio-economic factors such as access to credit, access to extension services and experiencing food insecurity over the past two years.

the results obtained in this work imply the formulation of certain economic policies. Indeed, implementing policies that aim at improving the effectiveness of extension services in supporting households to adapt to climate change could also be of great importance. It could help actors to develop more effective coping strategies without affecting others interest. The policy makers can also focus on food support policies to help households improving their livelihood. Together, we believe that these policies may increase adaption capacity in the area, thereby reducing competition and potential conflicts resulting from their behavioral responses to climate change.

5 CHAPTER FOUR: EFFECT OF CLIMATE CHANGE ON SUPPORT FOR VIOLENCE: EVIDENCE FROM CENTRAL MALI

5.1 Introduction

Climate change imposes serious pressures on people and livelihoods all around the globe. Particularly in Sahelian countries such as Mali where the livelihoods system is mainly based on rain-fed agriculture (see Detges, 2017) coupled to a limited alternatives. The consequences are disastrous as livelihoods and related living conditions in the region continuously deteriorate. More interestingly, livelihoods activities such as agriculture and animal breeding known as cohesion factors in rural areas are no more than source of vicious competition and tensions under climate change adverse shocks. As results, social cohesion and complementarity that existed in those areas for several centuries are disrupting, making way to more frequent inter and intra communal conflicts and violence. Although, there is no consensus yet on whether environmental change affects conflict outcomes, it may not be sufficient enough to conclude the absence of relationship between climate change and disruption in social cohesion. As we found evidence of a negative impacts of climate change on livelihoods in the previous analysis, we therefore ask the question of whether livelihoods, as affected by climate change, influence people's support for violence. More specifically, the aim of this chapter is to analyze the effect of climate change-induced livelihoods deterioration on support for violence in Central Mali.

In fact, due to the associated recurrent drought, floods, heavy storms etc., climate change constitutes a major threat to rural actor's livelihoods (see Sanogo et al., 2017). The manifestation is such that in one hand, increased temperature and severe shortages of rainfall (drought) lead to failing harvest, in the other hand, heavy rains (which usually lead to flooding) and high winds destroy crops, lead to soil erosion as well as massif animal death. Due to these implications, climate change adverse shock has devastating effects on local populations and their livelihoods. Especially subsistence farmers and pastoralists, who mainly rely on rainfall for crop production and livestock breeding (see von Uexkull et al., 2020). The next section presents the empirical strategy employed to test our hypotheses. Section three presents the results and discussions.

5.2 Empirical Strategy and main results

5.2.1 Empirical Strategy

To reach the objectives set in this chapter, two econometrical models are used. A binary logit model is used first to show the negative effect of deterioration in agricultural production on income. Then for the second and third objectives a recursive bivariate probit model is employed.

5.2.1.1 Binary logistic regression model

We used the survey question "Is your income currently sufficient to support your living?" which response goes from (a) More than enough; (b) Quite sufficient; (c) Not so much enough; (d) Far from sufficient; to (e) Don't know/Refused to answer, to draw our variable called insufficient income. This variable is coded "1" if respondent chooses response (d) "Far from sufficient" and "0" otherwise. A binary regression was used to investigate the effect of drop in agricultural production on the probability of having an income far from being sufficient to support living[12]. The specified estimated model is:

$$\begin{aligned}\text{Insuffucient income}_i = {} & \alpha_0 + \alpha_1 \text{Drop in agricultural production}_i \\ & + \alpha_2 \text{Age}_i + \alpha_3 \text{Education}_i + \alpha_4 \text{Gender}_i \\ & + \alpha_5 \text{Married}_i + \alpha_6 \text{Household size}_i \\ & + \alpha_7 \text{M liv sources}_i + \gamma \text{Access to basic services}_i \\ & + \lambda \text{Wealth indicators}_i + \varepsilon\end{aligned} \tag{5.1}$$

Where γ and λ are respectively vectors of basic services factors (such as access to electricity, health facilities, paved road etc.) and wealth indicators (such as owning car, television, laptop etc.); M liv sources is specifically multiple livelihood sources. ε is the error term.

5.2.1.2 Bivariate probit regression model

The chapter uses a recursive bivariate probit model to analyze the effect of climate change and the resulting livelihood deterioration on individual support for violence. The bivariate probit model is

[12] For a detailed presentation of the logistic regression model see chapter three.

a two equations model which allows the modeling of two decisions (two dichotomous variables) simultaneously and explore their potential relationship (Tesfaye and Gebremariam, 2020). It thus makes it possible to calculate the probability of two simultaneous events. Moreover, the model also allows to take into account endogeneity biases (Komlagan et al., 2020). The general model is made of a framework of structural latent variables with two equations: an "outcome equation" and a "selection equation". The later one determines in the first stage whether the treatment is received or not (1 or 0 / yes or no) while in the second stage, the outcome equation describes the outcome variable (y_1) as a function of the binary treatment (y_2) with a latent error ε_{1i}. Let for instance y_1 (Support for violence$_i$) and y_2 (Inter-ethnic trust$_i$) denote the two equations mentioned earlier respectively the willingness to support the use of violence and the perception of deterioration in individual living condition. Indeed, perception of deterioration in living condition is used to capture the negative impact of worsening livelihood on people's life. Hence, each response is generated by a probit equation (Meng & Schmidt, 1985) and are respectively given by the following latent variables:

$$\text{Support for violence}_i^* = X_{1i}\beta + \gamma \, Inter-ethnic\ trust_i^* + \varepsilon_{1i} \tag{5.2}$$

$$\text{Inter-ethinc trust}_i^* = X_{2i}\alpha + \varepsilon_{2i} \tag{5.3}$$

Where $\text{Support for violence}_i^*$ and Deterioratoin in living condition$_i^*$ [13] are unobservable and are related to the binary dependent variables $(\text{Support for violence}_i, \text{Inter-ethnic trust}_i)$ by the rule (Meng & Schmidt, 1985) as it follows:

$$\text{Support for violence}_i = \begin{cases} 1, & \text{if the individual support the use of violence}_i^* > 0 \\ 0, & \text{otherwise} \end{cases} \tag{5.4}$$

[13] $\text{Support for violence}_i^*$ and $\text{Cropland expansion}_i^*$ are latent continuous variables determining their observable Counterparts $(\text{Support for violence}_i, \text{Cropland expansion}_i)$

$$\text{Inter-ethnic trust}_i = \begin{cases} 1, & \text{if the individual report trusting} \\ & \text{the other ethnic groups}_i^* > 0 \\ 0, & \text{otherwise} \end{cases} \tag{5.5}$$

X_{1i} and X_{2i} are the vectors of the explanatory variables linked to the individual characteristics of the respondents and his household as well as perception of climate change and its impact on production. β, α and γ are the parameters to be estimated (β and α are vectors).

The error terns (ε_{1i} and ε_{2i}) are assume to be i.i.d (independent and identically distributed) as a bivariate normal with zero means (Marra, 2013). That is,

$$E[\varepsilon_{1i} | X_{1i}, X_{2i}] = E[\varepsilon_{2i} | X_{1i}, X_{2i}] = 0 \tag{5.6}$$

$$Var[\varepsilon_{1i} | X_{1i}, X_{2i}] = Var[\varepsilon_{2i} | X_{1i}, X_{2i}] = 1 \tag{5.7}$$

$$Cov[\varepsilon_{1i}, \varepsilon_{2i} | X_{1i}, X_{2i}] = \rho \tag{5.8}$$

$$\begin{pmatrix} \varepsilon_{1i} \\ \varepsilon_{2i} \end{pmatrix} \overset{i.i.d}{\rightarrow} \mathrm{N}\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} 1 & \rho \\ \rho & 1 \end{bmatrix} \right) \tag{5.9}$$

Where ρ is the correlation coefficient, and the error variances are normalized to unity (see equation 6.4), which is a conventional normalization required to identify the parameters in the model. The correlation between ε_{1i} and ε_{2i} (ρ) as defined above actually induces the endogeneity of $\text{Inter-ethnic trust}_i$ in the outcome equation $(\text{Support for violence}_i)$. Thus, in this analysis, it is supposed that inter-ethnic trust and support for violence are jointly determined. Therefore, the two equations need to be estimated jointly using the recursive bivariate probit model whenever the null hypothesis that $(\rho = 0)$ is rejected (Komlagan et al., 2020). Indeed, for the recursive bivariate probit model to be validated as the appropriate model in this analysis we will be interested in testing the following null and alternative hypotheses:

$$\begin{cases} H_0 : \rho = 0 \\ H_1 : \rho \neq 0 \end{cases} \tag{5.10}$$

A failure of rejecting the null hypothesis that $(\rho = 0)$ will imply the use of separate, standard probit models which in that particular case will fits the data better than a recursive bivariate probit model.

With everything considered, the following specified model is finally estimated in this analysis:

$$\begin{aligned}\text{Support for violence}_i = {} & \beta_0 + \beta_1 \text{Inter-ethnic trust}_i + \beta_2 \text{Age}_i + \beta_3 \text{Education}_i + \beta_4 \text{Gender}_i \\ & + \beta_5 \text{Married}_i + \beta_6 \text{Household size}_i + \beta_7 \text{Trusting the state}_i \\ & + \beta_8 \text{Intra-ethnic trust}_i + \varepsilon_1\end{aligned} \tag{5.11}$$

$$\begin{aligned}\text{Inter-ethnic trust}_i = {} & \beta_0 + \beta_1 \text{Insufficient income}_i + \beta_2 \text{Education}_i \\ & + \beta_3 \text{Gender}_i + \beta_4 \text{Household size}_i + \beta_5 \text{Age}_i \\ & + \beta_6 \text{Poor}_i + \beta_7 \text{Food insecurity}_i + \varepsilon_2\end{aligned} \tag{5.12}$$

Where: $\text{Support for violence}_i$ is a dummy variable taking unity if respondent support the use of violence and zero otherwise; $\text{Inter-ethnic trust}_i$ is also a dummy variable taking unity if respondent reports trusting the other ethnic groups living in central. The estimation of parameters of the model is performed using the maximum likelihood technique.

5.2.2 Measuring main variables of the model

5.2.2.1 Endogenous variables

The endogenous variables of the model are support for violence and Inter-ethnic trust. Support for violence is measured using the following question adapted from the Afrobarometer survey: "which of the following statements is closest to your view? Choose statement one or two. Statement one: The use of violence is never justified in Malian politics. Statement two: In this country, it is sometimes necessary to use violence in support of a just cause". In addition, respondents may also choose among a set of other responses that they agree, strongly agree or not agree with either statement with even a possibility to refuse to answer. We then create a binary variable which is coded "0" for individuals who agree to the first statement (not supportive of violence) and "1" for individuals who agree, or strongly agree, to the second statement (supportive of violence). Similarly, the survey question we used to gauge participants' trust in members of other ethnic groups is also adapted from the Afrobarometer survey (2016). The exact wording of the question

is “How much do you trust people from other ethnic groups or tribes? Response options range from ‘Not at all’ to ‘I trust them a lot’. The answers are then recoded into 1“trust them” and zero otherwise.

5.2.2.2 Explanatory variables

The chapter relies on previous micro-level analysis in the field of climate change and conflict to select the explanatory variables (for both the selection and outcome equation) (See De Juan & Hänze, 2021; Detges, 2017; Vestby, 2019a; von Uexkull et al., 2020). These include mainly socio-economic, demographic variables and climate related information variables.

Education level: the educational level is likely to influence both attitudes towards violence and the susceptibility of experiencing deterioration in living condition induced by climate change. Indeed, more educated individuals are less likely to experience deterioration in living condition caused by climate change. This is because, they are generally involved in activities less sensitive to climate change such as working in public or private services. Hence, further lowering their likelihood to engage in climate related conflict. To measure education, the chapter considers a categorical variable coded into “no formal education,” “primary education,” “secondary education,” and “university.” The study also includes **age of respondent**. It is measured as respondent’s age in number of years at the time of data collection. We expect younger respondents to be more supportive of violence as well as more likely to experience deterioration in living condition due to climate change. **Household size** is also included in our explanatory variables to the analysis and is expected to positively affect both the likelihood of experiencing deterioration in living condition and the willingness to support the use of violence. In fact, regarding the per capita needs of the household, any negative shock of climate change is likely to translate into a greater experience of livelihood deterioration.

To account for ethnic cleavages, the paper includes another variable related to intragroup relations designed to gauge **intra-ethic** in the study area. In this regard, we make use of straightforward survey item adapted from the Afrobarometer survey to measure this variable: “How much do you trust people from your own ethnic or tribe?” Response options range from ‘Not at all’ to ‘I trust them a lot’. The answers are then recoded into 0 “Don’t trust them”, 1“trust them”. This variable

is expected to negatively influence support for violence, the more people trust each other (those from their own ethnic) the less likely they might be willing to fight or to engage in violence against each other. Beyond the relationship between people and its effect, we further, included another quite similar variable (State trust) to capture people's relationship with their state/government and how it influences willingness to support the use of violence.

The exogenous variable also includes climate change mediating factors "insufficient income". This is drawn from a survey question worded as "Is your income currently sufficient to support your living?" which response goes from (a) More than enough; (b) Quite sufficient; (c) Not so much enough; (d) Far from sufficient; to (e) Don't know/Refused to answer, to draw our variable called insufficient income. This variable is coded "1" if respondent chooses response (d) "Far from sufficient" and "0" otherwise. Specifically, we used that variable to instrument participants' trust in members of other ethnic groups and then to estimate the causal effect of the instrumented inter-ethnic trust variable on the likelihood of supporting the use of violence.

Individual reported poverty state (subjective poverty), perception of the community living conditions and perception of food insecurity were also included in the analysis. To inform the variable "subjective poverty" respondents were invited to answer the following question "Considering your living conditions and that of the households in your locality, how do you consider yourself?" response varies between "Poor"; "Rich" "Neither poor or rich". The variable was then converted into a binary structure taking the value "1" if the answer is "poor" and "0" otherwise. The expected sign of this variable effect on individual's perception of their own living condition is positive. The more an individual consider himself as poor compared to others, the most likely he is to report a deterioration in its own living condition. Perception of own living conditions and of the community living conditions is informed respectively by these questions: "Compared to last year, how would you describe: (a) Your own present living conditions? (b) Your community present living conditions?" Respondents may choose between "Much worse", "Worse", "Same", "Better", "Much better", "Don't know". The variable was given the value "1" for those reporting a "Much worse" or "Worse" community living conditions and "0" otherwise. To inform the perception of food insecurity variable, a list of actions among which "Ensure food security" were presented to respondents to identify the main and most urgent action that the

authorities should take to improve living conditions. Responses giving “Ensure food security” as priority are coded “1” and “0” for the others.

Finally, the paper includes Extension services such access to credit and access to improved water sources. Both are expected to decrease vulnerability regarding climate change negative impacts hence lowering the likelihood to be supportive of the use of violence. Indeed, access to credit facilities may help increasing investment in coping strategies such as irrigation infrastructure, crop varieties, fertilizer etc. and hence increasing people resilience regarding climate change negative chocks. Improved water sources such as tap, piped water, water pump are good indicators of the wealthiest (in average) of the household as well as the locality hence their likelihood to be less likely vulnerable to climate change adverse effects.

5.2.3 Data source and descriptive statistics

To probe the hypotheses set in this chapter primary data collected from the field was used. The survey was conducted in the central region of Mali in September 2021. All the eight (8) administrative cercles of the Mopti region were considered in the survey. Probabilistic sampling method was applied at the regional level to generate a sample that is representative of all communities living in the central region of Mali. At the final stage, a total of 450 participants aged 18 and more were interviewed in their local languages. Table V-1 presents the descriptive statistics of the main variables included in the analysis. Overall 35.77 percent of the participants are found to be supportive of the use of violence in the sample, while 37.11 percent report deterioration in their living condition over the past 10 to 20 years. More than half about 66.89 percent of the sample indicate to have observed over the past decade a decrease in production with 49.33 percent indicating more recurrent dry seasons. Overall, the average age in the sample is 49.41 percent and is distributed as 11.11 percent of the respondents were between the ages of 20 and 30, 46.44 between the ages of 31 and 50, 42.44 percent were 51 years old or above. 83.78 percent of the participants were male, 87.11 percent of the respondents have no formal education, 5.78 percent were elementary school graduates, 6 percent were secondary school graduates with only 1.11 percent of postgraduates. 71.76 percent of the respondent use farming as primary livelihood source. In the sample, 32.44 percent of participants consider themselves as poor regarding their living conditions and that of the households in the locality. 30. 66 percent of the sample identified ensuring food security as the main and most urgent action that the authorities should take to

improve living conditions in the central region of Mopti. Credit facilities are accessible to around 24.44 of the participants while only 9.33 percent have access to improved water sources.

Table 5.1: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Support for violence	450	.357	.479	0	1
Deterioration in living conditions	450	.371	.483	0	1
Insufficient income to sustain living	450	.706	.455	0	1
Intra-ethnic trust	450	.760	.427	0	1
Inter-ethnic trust	450	.475	.499	0	1
Age	450	49.4	14.1	20	85
Male	450	.838	.369	0	1
No formal education	450	.871	.335	0	1
Elementary school graduates	450	.057	.233	0	1
Secondary school graduates	450	.060	.237	0	1
Postgraduates	450	.011	.104	0	1
Househol size	450	4.14	2.43	1	16
Farmer (y/n)	450	.716	.452	0	1
Subjective poverty	450	.324	.468	0	1
Deterioration in community LC	450	.457	.498	0	1
Food security as priority	450	.306	.461	0	1
Access to credit facilities	450	.244	.430	0	1
Access to improved water sources	450	.093	.291	0	1

Source: Author's construction using the survey data

To check for multicollinearity issues a variance inflation factor (VIF) analysis was applied to make sure the model does not suffer from any multicollinearity problem. This is important in the sense that the presence of multicollinearity in the model could adversely affect the validity of the regression's results. The VIF test is one of the widely used methods to detect the multicollinearity presence. This method estimates how much the variance of a regression coefficient is inflated because of multicollinearity. The calculation is performed by regressing one independent variable against all other independent variables used in the model. The resulting R-squared values are then inserted into the following formula to obtain the VIF:

$$\mathrm{VIF} = \frac{1}{1 - R_i^2} \tag{5.13}$$

The VIF values range from 1 upwards and indicate (in decimal form) what percentage the variance (the standard error squared) is inflated for each coefficient. Hence, a VIF value of 1 indicates no multicollinearity. A VIF value between 1 and 5 cause a moderate degree of multicollinearity problems, while those with a value greater than 5 cause a high degree of multicollinearity issues (Alkan et al., 2021). As displayed in Table V-2 bellow, none the explanatory variables used in this analysis had a VIF value of 5 or greater. This gives the evidence that there were no independent variables that caused multicollinearity issues between the variables used in the analysis.

Table 5.2: Variance Inflation Factor results

Variable	Explanation	VIF	1/VIF
Dependent variables			
Support for violence	Unity if respondent support the use of violence; zero otherwise		
Inter-ethnic trust	Unity if respondent trust members of other ethnic groups; zero otherwise		
Independent variables			
Age			
20-30	Unity if respondent is between 20 and 30 years; zero otherwise	1.22	0.819
31-50	Unity if respondent is between 31 and 50 years; zero otherwise	1.25	0.803
51 and above	Unity if respondent is between 51 and above; zero otherwise	Ref	Ref
Gender	Unity if respondent is male; zero otherwise	1.53	0.655
Educational status			
No formal education	Unity if respondent has no formal education; zero otherwise	Ref	Ref
Elementary/Primary school	Unity if respondent graduated elementary/primary school; zero otherwise	1.05	0.956
Secondary school	Unity if respondent graduated secondary school; zero otherwise	1.16	0.859
University, graduate school	Unity if respondent graduated university or graduate school; zero otherwise	1.07	0.932
Household size	Number of people living in the household	1.27	0.788
Drought perception	Unity if respondent indicate drought as the most serious climate hazard; zero otherwise	1.25	0.801
Deterioration in community living condition	Unity if respondent indicate deterioration in community living condition; zero otherwise	1.64	0.609
Intra-ethnic trust	Unity if respondent trust members from its own ethnic group; zero otherwise	1.22	0.819
Inter-ethnic trust	Unity if respondent trust members from the other ethnic groups; zero otherwise	1.22	0.819
Trusting the sate	Unity if respondent trust the state; zero otherwise	1.11	0.900
Marital status	Unity if respondent is married; zero otherwise	1.50	0.668
Subjective poverty	Unity if respondent consider himself as poor; zero otherwise	1.48	0.677
Food security as priority	Unity if respondent consider food security as priority; zero otherwise	1.30	0.768
Access to credit	Unity if respondent has access to credit; zero otherwise	1.14	0.874
Access to improved water sources	Unity if respondent has access to improved water sources; zero otherwise	1.19	0.837

Source: *Author's construction using the survey data*

5.2.4 Main Results:

In this section we started by presenting and discussing results from the binary logistic regression first before moving to the bivariate probit regression model.

5.2.4.1 Binary logistic regression

Table 5.3 shows the binary logit results of how drop of agricultural production as a result of changes in climate affect people's capacity of sustaining living regarding their income. As hypothesized it appears that drop in agriculture production increases the household's likelihood of being in a situation of having income insufficient to sustain living by 15%. This is likely because in the rural part of central Mali, income and livelihood in general are made generally from agricultural activities such as cropping and animal breeding. The drop in agricultural production is mainly caused by changes in climate such erratic rainfall, decreasing rainfall amount and recurrent drought as shown in the analysis we carried out in the previous chapter.

Above drop in agricultural production, that seven out of eleven the logit analysis revealed that variables such as gender, household size, having multiple livelihood sources, access to basic service and wealth indicators are other factors significantly influencing people's capacity of sustaining living in central Mali. Considering the gender of respondents, the results show that being man decreases the likelihood of having income insufficient to sustain living by 17%. This reveal how vulnerable are women in central Mali. In the rural area of central women are generally denied access to land and economic activities which have more income making potential such as animal breeding. In the same line, the fact of being involved in multiple livelihood activities reduces by 10% the probability of being in situation of insufficient income for sustaining living as a consequence of changing climate. The multiple activities help the household making money from different sources and being less vulnerable to climate change and drop in agricultural production. In the same way having access to basic services such as electricity, improved water sources and owning television, laptop and so on yield the same effect lowering the influence of climate change and related drop in agricultural production on household's likelihood of not making enough income for sustaining living.

Table 5.3: Logistic regression results

Variables	Coefficient	dy/dx	Odds ratio
Drop of agricultural production	0.726***	0.148***	2.066***
Gender	-1.090**	-0.174**	0.336**
Age			
[20-30] Ref			
[31-51]	-0.417	-0.087	0.659
[51- over[	-0.126	-0.024	0.881
Education			
No formal education [Ref]			
Primary	-0.068	-0.013	0.934
Secondary	-0.322	-0.067	0.725
University	0.517	0.088	1.677
Married	0.609	0.130	1.838
Household size	0.104**	0.020**	1.109**
Multiple livelihood sources	-0.510**	-0.099**	0.601**
Access to improved water sources	-1.053***	-0.173***	0.345***
Access to electricity	-0.643***	-0.128***	0.526***
Access to paved road	-0.363	-0.075	0.696
Owning television	-0.494*	-0.102*	0.610*
Owning laptop	-1.820*	-0.424*	0.162*
Owning fridge	0.473	0.082	1.604

Source: *Author's construction using the survey data*

*Note: ***, **,* and Ref denote respectively the threshold of 1%, 5%, 10% and reference modality.*

Having highlighted the negative correlation between drop in agricultural production as a consequence of climate change and the likelihood of making enough money to sustain living, the next section presents and discuss the bivariate probit regression results.

5.2.4.2 Bivariate probit regression

The regression's results of the bivariate probit model are presented in Table V-4. To check the relevance of the model, a Wald test[14] for independence of residuals (ε_{1i} and ε_{2i}) is performed. As can be seen in the table below, the test rejected the null hypothesis $(\rho = 0)$ at a 1% significance level hence giving evidence for a correlation between the error terms (Wald test of rho=0: chi2(1) = 8.24186, with Prob > chi2 = 0.0041). As implication, this finding definitely gives room for employing the simultaneous estimation approach, the bivariate probit model. Indeed, As the error terms are found to be correlated, even if the two dependent variables (support for violence and inter-ethnic trust) were observed, a univariate approach model such as the standard logit or probit regression would have been inefficient. According to Morais et al., (2020), the bivariate logit model is more appropriate in such context and would yield efficiency gains compared to standard logit and probit model. In conclusion, the above discussion regarding the Wald test of independence shows that the bivariate probit model is globally applicable in this chapter and the exogenous variables have strong explanatory power. The positive sign of the correlation coefficient (0.932) indicates a positive correlation between the error terms of the two equations. Consequently, it means that the household's decision of not trusting people from other ethnic groups and supporting the use of violence are made simultaneously and they are complementary decisions[15] (Tesfaye and Gebremariam, 2020)

Table 5.4: Parameter estimates of the bivariate regression model

	Support for violence equation		**Inter-ethnic trust equation**	
Variables	**Coefficient**	**Std. Err.**	**Coefficient**	**Std. Err.**
Inter-ethnic trust	**-0.964*** **	**0.243**		
Age	0.718**	0.387	0.120	0.406
Age square	-0.761**	0.385	-0.129	0.403
Education	0.062	0.068	-0.131*	0.071
Gender **(Ref: Female)**	0.143	0.205	0.125	0.208
Marital status **(Ref: Married)**	-1.054***	0.262	-1.045***	0.274

[14] The Wald test measures the significance of the rho coefficient and conclude concerning the correlation between the residuals for the equations established for both dependent variables (Alkan et al., 2021).
[15] A negative correlation would indicate the mutual exclusiveness of the decisions.

Trusting the state	-0.077	0.107		
Intra-ethnic trust	0.143	0.123		
Access to credit	0.195	0.143		
Access to basic services	-0.007	0.061		
Asset index	-0.041	0.054		
Insufficient income			-0.481***	0.128
Intercept	0.996***	0.284	1.114***	0.245
rho	0.932***	0.325		
Wald test of rho=0 chi2(1) = 8.24186	Prob > chi2 = 0.0041			
Log likelihood			= -581.38311	
Number of observations			= 450	
Wal chi2(19)			= 86.42	
Prob > chi2			= 0.0000	

Source: *Author's construction using the survey data*
Note: *** Significance at 1% level; ** significance at 5% level; * significance at 10% level.

The results showed at the first stage that, insufficient income to sustain living, the educational status and the marital status have a statistically significant influence on peoples' attitudes towards members of other ethnic groups. Support for violence in the second stage is significantly affected by inter-ethnic relations of peoples, age and age square, the marital status and household size. Gender, education, access to credit and basic services as well as wealth situation are found not to play much statistically roles in explaining support for violence. The marginal effects measuring the change in probability implied by independent variables on dependents variables after estimations are given in Table 5.5.

Table 5.5: Marginal effects of independent variables on dependents variables after estimations

	Support for violence equation		**Inter-ethnic trust equation**	
Variables	**dy/dx**	**Std. Err.**	**dy/dx**	**Std. Err.**
Inter-ethnic trust	**-0.333*** **	**0.071**		
Age	0.248**	0.134	0.044	0.150
Age square	-0.263**	0.133	-0.047	0.149
Education	0.021	0.023	-0.048*	0.025
Gender **(Ref: Female)**	0.049	0.070	0.046	0.077
Marital status **(Ref: Married)**	-0.364***	0.086	-0.388***	0.096
Trusting the state	-0.026	0.037		

Intra-ethnic trust	0.049	0.042		
Access to credit	0.067	0.050		
Access to basic services	-0.002	0.021		
Asset index	-0.014	0.018		
Insufficient income			-0.178***	0.045

Source: *Author's construction using the survey data*
Note: *** Significance at 1% level; ** significance at 5% level; * significance at 10% level.

Marginal effects of exogenous variables on dependents variables are presented in table 5.5 above. We found initial evidence that a further decline in income is likely to deteriorate intergroup relations by 17% which in turn increases the likelihood that people approve of violence by 33% (from the outcome equation). This result may be explained by the fact that, the affected people in order to compensate the economic losses induced by climate change will naturally strive to cope and adjust. If the various coping responses initiated at the individual level turn out to be weak, antagonistic and uncoordinated, this could create negative externalities which are likely to deteriorate intergroup relations and further increase individual support for violence. Central Mali is a region with strong ethnic diversity and the socio-economic activities generally overlap with the ethnic groups. For instance, the Dogon, the Bambara and the Sonhray are usually associated with a sedentary agricultural mode of subsistence. The Fulani and the Tuareg are known as a nomadic ethnic group of pastoralists who move their herds across the regions they inhabit in search of better grazing and watering for their animals. The Bozo ethnic group is associated with fishing activities. All of these activities are based on two main production factors which are land and water. In times of favorable climatic conditions these (land and water) used to be cooperation and cohesion factors (Hegazi et al., 2021). However, as climatic conditions worsen it undermined the affected people way of making income to sustain living. This further promote competition for land and water and likely to deteriorate intergroup relations (through antagonistic and uncoordinated coping responses) in the region to the detriment of cooperation and cohesion. In the second stage of the analysis (from the outcome equation), the results further show that this deterioration in intergroup relations increases the likelihood that people approve of violence by 33%. This finding is intuitive since degradation in intergroups relations is likely to compromise the different possibilities of engaging in inter-community dialogues and negotiations which have been shown (in previous studies) to have a moderating power to decrease support for the use of violence in

times of crisis (See Linke et al., 2015). Taken together, these results are line with our expectations (the second hypothesis set in this chapter) and with previous micro-level studies supporting the underlying argument that climate change and related resource scarcity is likely to foster competitions and pave the way for more anti-cohesion behavior (See Grossman & Mendoza, 2003; Linke et al., 2015; Prediger et al., 2014; Vestby, 2019b). In addition, these results may give support to the opportunity cost theory since lower incomes would increase the prospects of recruitment by non-state armed groups in the study area (Hegazi et al., 2021). However, our results are quite different from De Juan & Hänze (2021)' findings. Indeed, De Juan & Hänze (2021) found that the relationship between environmental conditions specifically drought and social trust is conditioned by the intergroup inequality politically and in terms of exposure to climatic chocks.

The analysis also includes alternative explanations of support for violence such as age and age square, gender, educational status, state trust, intra-ethnic trust, marital status, household size and access to basic services which have been linked to people participation in and support for the use of violence in previous studies (Claassen, 2014; Detges, 2017; Prediger et al., 2014; Vestby, 2019b). Regarding age and age square which allows to test for a curvilinear relationship between age and supporting the use of violence we have similar findings as Claassen (2014). Both age and age square are statistically significant and depict a non-linear relationship between the age and supporting the use of violence. Indeed, we have a positive effect of age and a negative effect of age squared which means that as people get older their likelihood to be supportive of the use of violence decreases. The result shows that a unit increase in age leads to 0.24 increase in the probability of supporting the use of violence however, in the long run, a unit increase in age would yield to 0.26 decrease in the probability of supporting the use of violence. This is consistent with our expectations. Generally, as people get older, they lose their force and energy while gaining more knowledge and wisdom. Hence, they became less supportive of engaging in violent conflict.

Although, no evidence was found for a correlation between educational status and individual propensity to use violence in times of crises, evidence is found for an interaction between intergroups relations and educational status. The finding shows that the educated respondents are less likely to trust members of other ethnic groups compared to respondents with no formal education. However, a closer examination of the data reveals that this result is only valid for respondents with intermediate levels of education (secondary school achievement). As supported

by Detges (2017), we believe that these individuals might be more "politicized without being part of the beneficiaries of the political status quo.

The results further show that being married reduces both the propensity of supporting the use of violence and the probability of trusting members of other ethnic groups. Specifically, the married individuals are 36 percent less likely to support the use of violence than single individuals. These people might have a different view on the meaning of life and staying for from violence. Indeed, they might be aware of the fact that being involved in violence and conflict not only expose them but above all expose their families (parents, wife and children) to different forms of risks and danger. Regarding its negative effect on intergroup relations, we believe that this is linked to the fact that interethnic marriage is still very uncommon in the Mopti region. Some tribes like the Fulani are still not comfortable by giving one of them in marriage with another ethnic group. This added to the fact that some tribes consider themselves as more noble than others generally exacerbate the inter-ethnic polarization in central Mali.

5.3 Copula Bivariate Probit model to perform robustness check of alternative specifications

In order to ensure robustness in estimation and inference, we allow the latent errors (ε_{1i} and ε_{2i}) in Eq. 5.11 and Eq.12 to be correlated without imposing the assumption of normal joint distribution as in the bivariate probit model (Rainer, 2011). Indeed, the bivariate probit model strongly relied on the assumption that the latent errors ε_{1i} and ε_{2i} have a bivariate standard normal joint distribution with correlation ρ (the latent errors are not correlated). A failure to maintain this assumption for one reason or another would ultimately invalidate the results of the standard bivariate probit model. Interestingly, the copula bivariate probit model CBP model provides a convenient approach for generating a flexible non-normal distribution for the errors. Moreover, the CBP model has two specificities, not only does it maintain the probit assumption for marginal distributions but allows the correlation between latent errors (ε_{1i} and ε_{2i}) without imposing the assumption of normal joint distribution (see Rainer, 2011). Additionally, like the standard bivariate probit, CBP also uses maximum likelihood framework for estimations and inferences.

Overall, our goal in this section is to evaluate the sensitivity of our results regarding the normal distribution assumption of latent errors. As displayed in "Table 5.6", the copula bivariate probit yielded similar results (in terms of statistical significance and signs) compared to those from the standard bivariate probit model. Concludingly, the particular findings made in the section give evidence that the results obtained in this analysis are robust and holds even if the normal joint distribution of error terms hypothesis happen to be rejected.

Table 5.6: Parameter estimates of the Copula Bivariate Probit model

	Support for violence equation		**Inter-ethnic trust equation**	
Variables	**Coefficient**	**Std. Err.**	**Coefficient**	**Std. Err.**
Inter-ethnic trust	**-0.964*** **	**0.243**		
Age	0.718**	0.387	0.120	0.406
Age square	-0.761**	0.385	-0.129	0.403
Education	0.062	0.068	-0.131*	0.071
Gender **(Ref: Female)**	0.143	0.205	0.125	0.208
Marital status **(Ref: Married)**	-1.054***	0.262	-1.045***	0.274
Trusting the state	-0.077	0.107		
Intra-ethnic trust	0.143	0.123		
Access to credit	0.195	0.143		
Access to basic services	-0.007	0.061		
Asset index	-0.041	0.054		
Insufficient income			-0.481***	0.128

Source: *Author's construction using the survey data*
Note: *** Significance at 1% level; ** significance at 5% level; * significance at 10% level.

5.4 Conclusion

The main objective of this chapter was to investigate the effect of climate change and the associated livelihood deterioration on support for violence. Two econometrical strategies were employed. A standard binary logit regression and an instrumental variable approach using bivariate probit model. We find evidence for a plausible mechanism linking climate change and violence. The mechanism has been probed in detail. We first presented an argument that climate change negatively affects people living conditions through income. Evidence is then given for a negative effect of this deterioration in living condition on individual intergroups relations which is directly related the propensity of supporting the use of violence in times of crises. As contribution to the climate-conflict nexus, our study contributes to an explanation that has not been clearly identified

in previous studies. The particular intergroups relations context help determine social outcomes related to climate change. We find that both age and age square are statistically significant with different sign. This depicts a non-linear relationship between the age and supporting the use of violence meaning that as people get older, their propensity of supporting the use of violence decreases. These findings are in line with our expectations and previous studies in this topic. We conclude that approaches that combat the negative effect of climate variability on livelihoods and strengthen intergroup relations would be of great help in preventing violent uprisings. To further our analysis in this dissertation, the next chapter attempt to uncover the underling process between climate change and intergroup relations.

6 CHAPTER FIVE: COPING WITH CLIMATE CHANGE: ASSESSING THE EFFECT OF ANARCHIC EXPANSION OF CULTIVATED LAND ON SUPPORT FOR VIOLENCE IN CENTRAL MALI

6.1 Introduction:

Human as well as livestock populations are now experiencing an ever faster growht in terms of number and densities, furhter increasing the need for food and pasture requirement. However, land especially arable land which is the main source of livelihood to sustain such a growth is limited and even declining (in terms of fertility) under the adverse effects of climate change. As a result, this limited available land which used to be more than sufficient to sustain living in earlier times is now being less capable of feeding peoples and animals in the face of a harsh climatic conditions. Consequently, people (especially in the rural areas) who used to carry out their activities in the same spaces and terroirs and had been complementary for several centuries (Hegazi et al., 2021) are now mired in vicious competition and struggle over scarce resources (especially over land and fresh water). Interestingly, the analyses in the previous chapter indicated that climate change has a significant impact on disrupting inter-group relations and exacerbating conflicts. However, the underlying mechanisms responsible for linking these two phenomena are not straightforward and require further investigations. This chapter therefore aims to fill that gap by evaluating a particular route through which climate change may affect conflict patterns in Central Mali. Specifically, it explores the effect of climate change and the associated increase in farm size on intergroup relations.

In contrast to the opportunity cost theory according to which, individuals generally engage in conflict only because it became more economically beneficial (and provides more economical advantages) compared to ordinary livelihood activities (such as farming, fishing and herding) in the face of climate change. We expect the existent intergroup relations to disrupt and further increasing people willingness to support the use of violence when the affected people engage in inappropriate coping processes which overlap such as cropland expansion. Indeed, expansion of cropland when improperly managed can easily take on other dimensions, including agricultural encroachments, the non-recognition of traditional rights, contestation over borders, the obstructions of pastoral routes, disagreements over herders' grazing rights, land theft (Hegazi et al., 2021; Winters and Jeffrey, 2021). Such issues may pave the way for violent confrontations

between farmers, as well as between farmers, herders, and fishermen. This is particularly likely in West African Salehian countries such as Mali, where crop production constitutes a key component of agricultural activities and plays an important role in the country's food security strategy (Diamoutene & Jatoe, 2020). For instance, it is reported that, only between the year 2016 to 2020, up to 25 percent of lands in Mali changed from other land use to cropland (Traore et al., 2021). Between 1992 and 2009, Tor A. Benjaminsen et al. (2012), identified 820 land use conflicts in Central Mali. The reality could be far beyond that since reporting conflict to the judiciary court is uncommon in the region (Winters and Jeffrey, 2021). According to Winters and Jeffrey (2021), approximately 21% of respondents in a survey data collected from 187 villages in Mali indicated that they or a family member had recently been involved in a dispute over land theft. In Central Mali, the area devoted to crops has increased by 82% while the area covered by pasture has decreased by 29% (International Crisis Group, 2016).

Overall, the subsequent section details the applied empirical method employed to examine our hypotheses. Finally, the third section presents the results and discussions in detail.

6.2 Empirical Strategy and main results

6.2.1 Empirical Strategy

Our main hypothesis is that using the expansion in cropland as climate change adaption means has a positive causal effect on people's support for violence. To probe that, this chapter uses two survey items that tap into inter-ethnic trust and the expansion in cropland as climate change adaptation means. Since respondents are asked to list the adjustments made or that would be made to reduce the negative effect of climate change, the core idea of the chapter is to instrument[16] reported usage of crop land expansion as adaptation means through climate change related deterioration of production, and then estimate the causal effect of the instrumented crop land expansion variable on the likelihood of trusting members of other ethnic groups. Specifically, the paper argues that climate change related deterioration of agricultural production can act as such an instrument. However, as we are dealing with two categorically dependent variables accordingly the effect of a

[16] The instrumental variable method "relies on the existence of one or more instruments that induce substantial variation in the endogenous covariate, are independent of unmeasured confounders, and have no direct effect on the outcome (Marra & Radice, 2011).

binary endogenous variable (cropland expansion) has on a binary outcome (inter-ethnic trust), the simultaneous likelihood estimation methods prove to be more appropriate than the conventional two-stage instrumental variable procedures (Marra and Radice, 2011). Hence following Vestby (2019b), this chapter employs (uses) the simultaneous recursive bivariate probit model introduced by (Heckman, 2016) as developed in the following section.

The Bivariate probit model:

The recursive bivariate probit model is an econometric approach that allows to estimate the treatment effect (the impact) that a binary endogenous variable (the predictor of interest) has on a binary outcome (the response variable) in the presence of unobservable confounders (Marra & Radice, 2011). In short, it allows to estimate the effect of a treatment on a binary outcome. This model is relevant not only because it makes it possible to take into account endogeneity biases in the analysis of binary choices, but also to analyze the effect of climate change and cropland expansion as climate change adaptation means on individual's inter-ethnic trust (Komlagan et al., 2020). Econometrically, the bivariate probit model consists of a framework of structural latent variables with two equations: the first equation called "outcome equation" describes the outcome variable (y_1) as a function of a binary treatment (y_2) and latent error ε_{1i} while the second equation named "selection equation" determines whether the treatment is received or not (1 or 0 / yes or no). Let y_1 $(\text{Inter-ethnic trust}_i)$ and y_2 $(\text{Cropland expansion}_i)$ denote these two equations respectively the probability of trusting members of other ethnic groups and the probability to use cropland expansion as adaptation means aiming at compensating the loss of yield induced by climate chocks. Each decision is generated by a probit equation (Meng & Schmidt, 1985) and are respectively given by the following latent variables:

$$\text{Inter-ethnic trust}_i^* = X_{1i}\beta + \gamma\text{Cropland expansion}_i^* + \varepsilon_{1i} \quad (6.1)$$

$$\text{Cropland expansion}_i^* = X_{2i}\alpha + \varepsilon_{2i} \quad (6.2)$$

Where $\text{Inter-ethnic trust}_i^*$ and $\text{Cropland expansion}_i^*$ [17] are unobservable and are related to the binary dependent variables $(\text{Inter-ethnic trust}_i, \text{Cropland expansion}_i)$ by the rule (Meng & Schmidt, 1985) as it follows:

$$\text{Inter-ethnic trust}_i = \begin{cases} 1, & \text{if the individual trust members of other ethinc groups} > 0 \\ 0, & \text{otherwise} \end{cases} \tag{6.3}$$

$$\text{Cropland expansion}_i = \begin{cases} 1, & \text{if the individual resort to cropland expansion}_i^* > 0 \\ 0, & \text{otherwise} \end{cases} \tag{6.4}$$

X_{1i} and X_{2i} are the vectors of the explanatory variables linked to the individual characteristics of the respondents and his household. β, α and γ are the parameters to be estimated (β and α are vectors).

The error terns (ε_{1i} and ε_{2i}) are assume to be i.i.d (independent and identically distributed) as a bivariate normal with zero means (Marra, 2013). That is,

$$E[\varepsilon_{1i} | X_{1i}, X_{2i}] = E[\varepsilon_{2i} | X_{1i}, X_{2i}] = 0 \tag{6.5}$$

$$Var[\varepsilon_{1i} | X_{1i}, X_{2i}] = Var[\varepsilon_{2i} | X_{1i}, X_{2i}] = 1 \tag{6.6}$$

$$Cov[\varepsilon_{1i}, \varepsilon_{2i} | X_{1i}, X_{2i}] = \rho \tag{6.7}$$

$$\begin{pmatrix} \varepsilon_{1i} \\ \varepsilon_{2i} \end{pmatrix} \overset{i.i.d}{\rightarrow} \mathrm{N}\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} 1 & \rho \\ \rho & 1 \end{bmatrix} \right) \tag{6.8}$$

Where ρ is the correlation coefficient, and the error variances are normalized to unity (Eq. 6.6), which is a conventional normalization required to identify the parameters in the model. The correlation between ε_{1i} and ε_{2i} (ρ) as defined above actually induces the endogeneity of

[17] $\text{Inter-ethnic trust}_i^*$ and $\text{Cropland expansion}_i^*$ are latent continuous variables determining their observable Counterparts $(\text{Inter-ethnic trust}_i, \text{Cropland expansion}_i)$

$\text{Cropland expansion}_i$ in the equation for $\text{Inter-ethnic trust}_i$. Thus, in this analysis, it is supposed that cropland expansion and inter-ethnic trust are jointly determined. Therefore, the two equations need to be estimated jointly using the recursive bivariate probit model whenever the null hypothesis that $(\rho = 0)$ is rejected (Komlagan et al., 2020). Indeed, for the recursive bivariate probit model to be validated as the appropriate model in this analysis we will be interested in testing the following null and alternative hypotheses:

$$\begin{cases} H_0 : \rho = 0 \\ H_1 : \rho \neq 0 \end{cases} \tag{6.9}$$

A failure of rejecting the null hypothesis that $(\rho = 0)$ will imply the use of separate, standard probit models which in that particular case will fits the data better than a recursive bivariate probit model.

With everything considered, the following specified model is finally estimated in this analysis:

$$\begin{aligned} \text{Inter-ethnic trust}_i = {} & \beta_0 + \beta_1 \text{Crop land expansion}_i + \beta_2 \text{Age}_i + \beta_3 \text{Education}_i \\ & + \beta_4 \text{Gender}_i + \beta_5 \textit{Married}_i + \varepsilon_1 \end{aligned} \tag{6.10}$$

$$\begin{aligned} \text{Cropland expansion}_i = {} & \beta_0 + \beta_1 \text{Deteriration in agricultural production}_i + \beta_2 \text{Age}_i \\ & + \beta_3 \text{ Education}_i + \beta_4 \text{Household size}_i + \varepsilon_2 \end{aligned} \tag{6.11}$$

The estimation of parameters of the model is performed using the maximum likelihood technique.

6.2.2 Data source and descriptive statistics

The data used in this paper are extracted from a survey we conducted in the central region of Mali in September 2021. The survey was conducted in the eight (8) administrative cercles of the region and participants aged 18 and more were interviewed in their local languages. A probabilistic sampling method was applied at the regional level to generate a sample that is representative of all communities living in the Mopti region. Table (6.1) summarizes descriptive statistics of the main variables of the bivariate probit analysis. It shows that 47.57 percent of the participants are trust members other ethnic groups, while 6.89 percent used cropland expansion as adaptation means. Overall, the average age in the sample is 49.41 percent and is distributed as 11.11 percent of the

respondents were between the ages of 20 and 30, 46.44 between the ages of 31 and 50, 42.44 percent were 51 years old or above. 83.78 percent of the participants were male, 87.11 percent of the respondents have no formal education, 5.78 percent were elementary school graduates, 6 percent were secondary school graduates with only 1.11 percent of postgraduates. 71.76 percent of the respondent use farming as primary livelihood source.

Table 6.1: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Age	450	49.409	14.168	20	85
Male	450	.838	.369	0	1
No formal education	450	.8711	.3354	0	1
Elementary school graduates	450	.0577	.2336	0	1
Secondary school graduates	450	.06	.2378	0	1
Postgraduates	450	.0111	.1049	0	1
Househol size	450	4.149	2.434	1	16
Farmer (y/n)	450	.716	.452	0	1
Decrease in agri production	450	.715	.451	0	1
Appliede less fertilizer	450	.284	.452	0	1
Planting short croping varieties	450	.269	.444	0	1
Crop Diversification	450	.264	.442	0	1
Reducing the livestock size	450	.036	.185	0	1
Increasing the harvested area	450	.069	.254	0	1
Migrating	450	.033	.18	0	1
No adaptation strategy	450	.196	.397	0	1
Inter-ethnic trust	450	.475	.499	0	1

Source: Author's construction using the survey data

Before the estimation of the model, a variance inflation factor (VIF) analysis was run in order to make sure the model does not suffer from multicollinearity problem which could adversely affect the validity of the regression's results. Indeed, multicollinearity is the presence of correlation between the independent variables in a model, the VIF is one of the widely used methods to detect its presence. This method estimates how much the variance of a regression coefficient is inflated because of multicollinearity. The calculation is performed by regressing one independent variable against all other independent variables used in the model. The resulting R-squared values are then inserted into the following formula to obtain the VIF:

$$\mathrm{VIF} = \frac{1}{1 - R_i^2} \tag{6.12}$$

The VIF values range from 1 upwards and indicate (in decimal form) what percentage the variance (the standard error squared) is inflated for each coefficient. Hence, a VIF value of 1 indicates no multicollinearity. A VIF value between 1 and 5 cause a moderate degree of multicollinearity

problems, while those with a value greater than 5 cause a high degree of multicollinearity issues (Alkan et al., 2021). As displayed in Table 6.2 bellow, none of our independent variables used in the paper had a VIF value of 5 or greater. As a result, there were no independent variables that caused multicollinearity issues between the variables used in the model.

Table 6.2: Variance Inflation Factor's results

Variable	Explanation	VIF	1/VIF
Dependent variables			
Inter-ethnic trust	Unity if respondent trust members of other ethnic groups; zero otherwise		
Cropland expansion	Unity if respondent uses cropland expansion to cope with climate change; zero otherwise		
Independent variables			
Age			
20-30	Unity if respondent is between 20 and 30 years; zero otherwise	1.17	0.852
31-50	Unity if respondent is between 31 and 50 years; zero otherwise	1.14	0.810
51 and above	Unity if respondent is between 51 and above; zero otherwise	Ref	Ref
Gender	Unity if respondent is male; zero otherwise	1.35	0.738
Educational status			
No formal education	Unity if respondent has no formal education; zero otherwise	Ref	Ref
Elementary/Primary school	Unity if respondent graduated elementary/primary school; zero otherwise	1.01	0.992
Secondary school	Unity if respondent graduated secondary school; zero otherwise	1.02	0.977
University, graduate school	Unity if respondent graduated university or graduate school; zero otherwise	1.02	0.980
Household size	Number of people living in the household	1.017	0.937
Deterioration in A P	Unity if respondent indicate decrease in yield; zero otherwise	1.04	0.958
Marital status	Unity if respondent is married; zero otherwise	1.31	0.763
Flooded zone	Unity if respondent is located in the flooded area; zero otherwise	1.43	0.701

Source: *Author's construction using the survey data*

6.3 Main Results:

Table 6.3 presents the main results of the econometric bivariate probit model. The Wald test[18] (rho=0) for independence of residuals (ε_{1i} and ε_{2i}) rejects the null hypothesis $(\rho = 0)$ at a 1% significance level. This shows in one hand the correlation of the error terms and in the other hand gives credit to the use of a simultaneous estimation using bivariate probit model. Indeed, since the error terms are found to be correlated, even if our two dependent variables (inter-ethnic trust and cropland expansion) were observed, a univariate decision model (separate standard probit

[18] The Wald test measures the significance of the rho coefficient and conclude concerning the correlation between the residuals for the equations established for both dependent variables (Alkan et al., 2021).

regression) would have been inefficient. In such context, the bivariate probit model is more appropriate, fits the data better and would yield efficiency gains (Morais et al., 2020).

Table 6.3: Regression results of the bivariate probit model

	Inter-ethnic trust equation		**Cropland expansion equation**	
Variables	**Coefficient**	**Std. Err.**	**Coefficient**	**Std. Err.**
Cropland expansion	**-1.673*** **	**0.157**		
Age (Ref: above 51)				
[20-30]	-0.025	0.201	-0.056	0.279
[31- 50]	-0.147	0.125	-0.135	0.172
Education (Ref: No formal educa)				
Primary	-0.024	0.245	0.280	0.334
Secondary	-0.697***	0.269	-0.053	0.435
University	0.325	0.576	-4.376***	0.216
Gender **(Ref: Female)**	0.166	0.181		
Marital status **(Ref: Married)**	-0.931***	0.243		
Household size			0.074**	0.029
Deterioration of agric production			0.771***	0.234
Intercept	0.840***	0.219	-2.699***	0.431
rho	1.726***	0.412		
Wald test of rho=0 chi2(1) = 17.5718	Prob > chi2 = 0.0000			
Log likelihood			= -399.10456	
Number of observations			= 450	
Wal chi2(19)			= 1921.42	
Prob > chi2			= 0.0000	

Source: *Author's construction using the survey data*
Note: *** Significance at 1% level; ** significance at 5% level; * significance at 10% level.

The marginal effects of the independent variables on dependents variables after estimations are given in Table 6.4. From the right panel of the table, the selection model shows that the variable used to capture climate change related deterioration in agricultural production positively and significantly affects at one percent level people probability of resorting to cropland expansion to meet the subsistence food needs. This finding is in line with our expectation and reject the first hypothesis set in this chapter. Specifically, it indicates that climate change related deterioration in agricultural production increases the probability of expanding the cropping land by 2.9 percent.

Indeed, the deterioration of production as a result of climate change (decreased rainfall and soil depletion) is likely to motivate (increasing the likelihood of) farmers willingness to expand the cropping land in the search of more suitable cropping areas (especially land not yet under cultivation such as grazing lands or fallow lands) in order to meet their subsistence food needs. The finding made here may in some parts explain the shift in land use patterns observed in the study area where the cultivated area increased by 82% in the detriment of the pasture land which decreased by 29% (International Crisis Group, 2016). Between 2016 and 2020 Traore et al. (2021) found that up to 25 percent of the national lands changed from other land use to cropland.

The results also show that for each additional individual in the household, the likelihood of increasing the cropping area increases by 0.8 percent. This is intuitive, since the additional individual in the household will increase the household's food requirement. Thus, to meet the growing food needs of the household and the losses induced by climate change in a context of shortage of alternatives, the famers is likely to increase the cropping land which is available to him. In contrast to those variables influencing positively the probability of increasing cropland, education specifically the superior schooling level is negatively correlated our climatic variable. This is likely because the more educated a person is, the more likely they are to find employment in the formal public and private sector, which reduces vulnerability to climate change and its negative impact.

Table 6.4: Marginal effects of independent variables on dependents variables

	Inter-ethnic trust equation		**Cropland expansion equation**	
Variables	**Coefficient**	**Std. Err.**	**Coefficient**	**Std. Err.**
Cropland expansion	**-0.603*** **	**0.157**		
Age (Ref: Above 51)				
[20-30]	-0.009	0.072	-0.006	0.033
[31-50]	-0.052	0.044	-0.016	0.021
Education (Ref: No formal educa)				
Primary	-0.008	0.088	0.033	0.040
Secondary	-0.251***	0.094	-0.006	0.052
University	0.117	0.207	-0.530***	0.085
Gender **(Ref: Female)**	0.059	0.064		
Marital status **(Ref: Married)**	-0.335***	0.083		
Household size			0.008**	0.003

Deterioration of agric production	0.093***	0.029

Source: *Author's construction using the survey data*
Note: *** Significance at 1% level; ** significance at 5% level; * significance at 10% level.

Results from the left panel of the table show that anarchical expansion in cropland has a statistically significant and negative effect on people intergroup relations in the study area. Specifically, expansion in cropland is likely to deteriorate people inter-ethnic trust by 60 percent (see Table 6.4). This finding is likely because expansion in cropland as it is referred in this analysis is generally initiated at the individual level and usually take the form of agricultural encroachments, the non-recognition of traditional rights, land theft, contestation over boundaries, disputes over property rights, the obstructions of pastoral routes etc. Since arable lands are limited, these different forms of expansion in croplands are generally done at the detriment of the other land users and likely to disrupt the social cohesion in the rural areas. In line with this finding, Skidmore et al., (2016) show that localities with less land per person in Mali tend to experience more land related conflict compared to localities endowed with enough land per person. Similarly, Winters and Jeffrey (2021) found that 21% of respondents to a survey conducted in 187 villages in Mali had been involved at least once in a dispute over land theft. Supporting those results, Tor A. Benjaminsen et al.,(2012) and Froese & Schilling (2019), show that land and land use could be affected by climate mitigation and adaptation measures which in turn may increase the risk of conflict. For the discussion regarding the negative effect of education and marital status see previous chapter.

6.4 Robustness check: A Copula-Based Approach to account for non-normal distribution of error terms

The bivariate probit model is strongly based on the assumption that the latent errors ε_{1i} and ε_{2i} have a bivariate standard normal joint distribution with correlation ρ. A failure to maintain this assumption for one reason or another would ultimately invalidate results of the standard bivariate probit model. Fortunately, there is an alternative approach: the copula bivariate probit model (CBP) which, in one hand maintains the probit assumption for the marginal distributions and, in the other side allows correlation between latent errors (ε_{1i} and ε_{2i}) without imposing the assumption of normal joint distribution (Rainer, 2011). Moreover, like the standard bivariate probit, CBP also uses maximum likelihood framework for estimations and inferences. Hence, our

goal in this section is to evaluate the sensitivity of our results regarding the normal distribution assumption of latent errors. As displayed in table 6.5, the copula bivariate probit yields similar results (in terms of statistical significance and sign) compared to those from the standard bivariate probit model. In sum, this particular finding shows that the results obtained in this paper are robust and holds even if the normal joint distribution of error terms hypothesis happen to be rejected.

Table 6.5: Regression results using the Copula bivariate probit model

	Inter-ethnic trust equation		**Cropland expansion equation**	
Variables	**Coefficient**	**Std. Err.**	**Coefficient**	**Std. Err.**
Cropland expansion	**-1.673*** **	**0.157**		
Age (Ref: above 51)				
[20-30]	-0.025	0.201	-0.056	0.279
[31- 50]	-0.147	0.125	-0.135	0.172
Education (Ref: No formal educa)				
Primary	-0.024	0.245	0.280	0.334
Secondary	-0.697***	0.269	-0.053	0.435
University	0.325	0.576	-4.376***	0.216
Gender **(Ref: Female)**	0.166	0.181		
Marital status **(Ref: Married)**	-0.931***	0.243		
Household size			0.074**	0.029
Deterioration of agric production			0.771***	0.234
Intercept	0.840***	0.219	-2.699***	0.431

Wald test of equality of coefficients chi2(df = 5) = 66.002	Prob > chi2 = 0.0000
Wald test of equality of independence chi2(df = 1) = 366.458	Prob > chi2 = 0.0000

Source: *Author's construction using the survey data*
Note: *** Significance at 1% level; ** significance at 5% level; * significance at 10% level.

6.5 Conclusion:

The main goal of this chapter was to examine the underlying process linking climate change to people intergroup relations. Hence, based on data from the household survey conducted in the Mopti Region in central Mali, we employed a bivariate probit model using instrumental variable as our econometrical strategy. The findings are in line with our expectation and confirm our hypotheses. Indeed, the empirical results have shown that climate change related deterioration in production increases the probability that farmers try to expand their cropland. This in turn is likely to break people intergroup relations (specially through encroachment). The chapter thus provides some of the first evidence in assessing the positive correlation between anarchical cropland expansion as adaptation practice aiming at reducing the negative effect of climate change on farm yield and support for violence. In line with these results, the chapter concluded that conflict and violence among communities in the central region of Mali could be minimized by promoting policies aiming at reducing climate change adverse impact on farm yield and enhancing farmers resilience. Additionally, the promotion of extension projects designed to improve farmer's knowledge in terms of adaptation practices thus offering them alternatives should also be of great help.

7 GENERAL CONCLUSION:

The main objective of this dissertation was to analyze the effect of climate change-induced deterioration of livelihoods and the resulting adaptation measures on individual support for violence in central Mali. To that ends, primary data have been collected. The survey was conducted in the central region of Mali in September 2021. All the eight (8) administrative cercles of the Mopti region were considered in the survey. Probabilistic sampling method was applied at the regional level to generate a sample that is representative of all communities living in the central region of Mali. At the final stage, a total of 450 participants aged 18 and more were interviewed in their local languages.

Three specific objectives were then drawn from the general objective which constitute each a chapter of dissertation. The first chapter is an analysis of climate change as perceived by the local community in central Mali, the socio-economic and demographic factors shaping that perception and the perception of climate change effect on agricultural production. The multinomial logit analysis, has shown that households in central Mali are well aware of climate change, its different manifestations and the adverse effects on their livelihood. For instance, the analysis revealed that 92 percent of the sample reported that the climate is changing. 45.33 percent of respondents noticed a decrease in rainfall amount over the past 10-20 years while 12.67 report an increasing temperature. The findings also shows that the affected people faced considerable challenges in adapting to those changes in climate. Lack of funds and credit facilities, lack of access to timely weather information, lack of technologies (physical infrastructure, technical material and equipment), lack of knowledge regarding adaptation technics (required human skills, e.g., applying specific planning and management approaches and methods), lack of appropriate seeds hare identified by respondents as the major critical barriers to climate change adaptation in the central Mali. We believe that these constraints generally explain why individuals often resort to inappropriate options which are more affordable in terms of cost but which on the other hand are likely to affect the sensitivities of other actors in the rural area and fuel tensions. The analysis further shows that climate change perception in the area is most shaped by socio-economic factors such as access to credit, access to extension services and experiencing food insecurity over the past two years.

The second chapter has evaluated the effect of climate change and the associated livelihood deterioration on support for violence. Two econometrical strategies were employed to that ends. A standard binary logit regression and an instrumental variable approach using bivariate probit model. We find evidence for a plausible mechanism linking climate change and violence. The mechanism has been probed in detail. We first presented an argument that climate change negatively affects people living conditions through income. Evidence is then given for a negative effect of this deterioration in living condition on individual intergroups relations which is directly related the propensity of supporting the use of violence in times of crises. The third chapter has been designed to further the findings from the second chapter. Hence it was dealing with investigating the underlying process linking climate change to people intergroup relations. This chapter uses a bivariate probit model using instrumental variable as econometrical strategy. The findings have shown that climate change related deterioration in production increases the probability that farmers try to expand their cropland. This in turn is likely to break people intergroup relations hence fueling violence and conflict.

Overall, three major conclusions should be retained from this research work. The analyses carried out in this dissertation show: that violence and conflict are not default responses to climate change; that people in central Mali do not engage in violence and conflict because it became more economically beneficial compared to ordinary livelihoods activities (cropping, herding, fishing etc.) as portrayed in the climate-conflict literature; that the inappropriate individual adaptation measures developed by the affected people to sustain livelihoods (which often result in agricultural encroachment) are blamable for breaking intergroup relations and fueling conflict. These findings are consistent with previous studies that have shown that climate change is not directly linked to conflict outcomes, but exacerbates existing rivalries and fuels violence, consequently it plays as a "threat multiplier" (Detges, 2017; Froese and Schilling, 2019; Koubi, 2019; Mbaye, 2020; Vestby, 2019b; von Uexkull et al., 2020). In summary, we have shown that livelihoods (which includes agricultural production and farming income) deterioration and resulting weak (and individual) adaptation practices is the mechanism through which climate change influences conflict outcomes. In other words, climate change indirectly fuel violence by adversely affecting livelihoods.

POLICY IMPLICATIONS

From the aforementioned findings, it is possible to draw certain conclusions with respect to economic policies. Overall, this thesis emphasizes the importance for policy makers to consider the consequences of climate change and the potential hazards of adaptation measures when designing peacebuilding policies in the study area. Besides this general policy implication, it is noteworthy that particular outcomes have notable implications. Indeed, the analysis showed that populations in central Mali affected by climate change struggle to adapt due to several challenges. These challenges include a lack of funds and credit facilities. Therefore, implementing policies that facilitate access to credit and promote financial inclusion is critical. By enabling access to credit, local communities' financial and resilience capabilities are likely to improve. The financial support would assist the affected populations in covering the acquisition cost of most adaptation technologies. This could involve investing in irrigation technologies to combat water shortages, purchasing improved seeds to cope with changes in rainfall patterns, or diversifying their livelihood sources by investing in sectors less vulnerable to climate.

Other barriers to climate change adaptation identified in this work include both lack of timely weather information and lack knowledge of adaptation technics, such as the use of specific planning and sustainable land management approaches. To address these issues, there is a need to develop and implementing early warning systems that involve affected populations and effectively disseminate information and warnings. This indicates the need to promote strategies that enhance both access and effectiveness of extension services in supporting households to increase their awareness of weather changes and adaptation practices. Extension services are, indeed, powerful mechanisms for disseminating information on climate and major upcoming meteorological events. On the other hand, they are invaluable tools for providing local communities with knowledge on sustainable management practices, such as the restoration of degraded land through conservation tillage, cover cropping, crop rotation and other techniques. Overall, facilitating access to these services may offer two benefits. Firstly, it would reduce the local community's vulnerability to environmental change. Secondly, the local community is likely to be better equipped to cope with climate change and related shocks.

The findings also show that income and livelihoods in Central Mali are negatively affected by climate change and related drop in agricultural production. To address this issue, there is pressing

need to develop livelihoods restoration programs in order to enable the affected households to maintain securing their livings from one rainy season to another. Indeed, in Central Mali, the rainy season barely lats three months while the vast majority of the populations mainly rely on agriculture for food and income. When climate change hits, food and income for the whole year are ultimately threatened and become less likely to be sustained until the next season. This situation can significantly impact living conditions and pre-seasonal preparations for the next rainy season. In addition, providing food support may also help the local community sustaining living and empowering them to be in a better state of preparedness for upcoming seasons. The findings additionally, highlight the need to reinforce the local economy by creating more economic opportunities and decent jobs in order to reduce the pressure on natural resources.

Another major conclusion reached in this study is that climate change significantly deteriorates people's intergroup relations and further fueling individuals' support for violence in the study are. This outcome highlights the requirement for promoting both inter and intra communal dialogues as well as collective action to address the negative impacts of climate change. The inter and intra communal dialogue may help the local communities developing large scale adaptations strategies by investing in collective actions likely to benefit the entire community. The dialogue may also facilitate the likelihood of finding consensus while defining cropping and harvesting calendars, herding periods as well as pastoral routes. Overall, we believe that the policies proposed in this thesis could enhance the adaptive capacity of households in Central Mali and ameliorate their livelihoods. They may foster stronger inter-group relationships, promote social cohesion, thereby reducing competition and the likelihood of violent conflict.

LIMITATION AND AREA FOR FURTHER RESEARCH

The conclusions thus drawn from our findings should be interpreted in light of the main limitations of the analyses. Indeed, caution is warranted regarding the way we used to capture people's attitude toward violence. In fact, we adapted a survey item from the Afrobarometer survey questionnaire with which, respondents were asked if they considered the use of violence in Mali to be justifiable and necessary in today's politics. Although similar questions have been used in previous analyzes and are meant to provide good insight into support for violence and conflict, yet there is disagreement that simply asking people if they found the use of violence justifiable can capture their participation in violence. Indeed, given the sensitivity of the question, respondents may

probably be reluctant to give sincere answers especially when they are pro-violence for fear of repercussions (and problems with the judiciary system) or fear of being seen differently by enumerators (social desirability bias).

Another limitation of this study may be related to our data. Indeed, the dissertation relied on only one single survey round that invites respondents to share experiences of changes observed in weather over the past and observed changes in living conditions as well as income. While climate change itself is a long turn phenomenon, we couldn't capture its impacts on changes in attitudes and livelihoods in the same individuals over time with the available data. Future research should evaluate the robustness of the mechanism we outline here using panel data. A third shortcoming in this thesis concerns the inaccessibility of certain localities in central Mali. Indeed, though all the eight administrative cercles and communes of the Mopti region were sampled, important villages were not accessible due to insecurity and had to be excluded from the sample. Future research, instead of focusing only on central Mali, could extend the study area to consider not only the northern parts of the country but also the southern parts. like the center, the north of Mali, an entirely desert zone with difficult climatic conditions, has also been plagued by conflicts since the independence.

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APPENDICES

Appendix A : Multinomial logistic regression results

Table A- 1: Parameter estimates of the of the MNL model, displaying the coefficients

Independents variables	**Outcome1 Coefficient**	**Outcome2 Coefficient**	**Outcome3 Coefficient**	**Outcome4 Coefficient**
Age	-0.011	0.005	-0.006	-0.025*
	(0.352)	(0.630)	(0.641)	(0.090)
Education	-0.287	-0.207	-0.311	-0.126
	(0.347)	(0.558)	(0.330)	(0.720)
Gender (Male)	0.191	0.288	0.541	0.515
	(0.707)	(0.630)	(0.320)	(0.439)
Household size	-0.059	-0.221**	-0.051	-0.000
	(0.423)	(0.025)	(0.535)	(0.998)
Farmers	-0.265	-0.974	0.460	0.316
	(0.618)	(0.107)	(0.396)	(0.665)
Multiple sources of livelihood	**1.153*** **	**0.884***	**0.891****	**0.347**
	(0.006)	**(0.068)**	**(0.049)**	**(0.503)**
Gone without food/ the past 2 yrs	**1.014****	**1.140****	**0.948****	**0.854***
	(0.014)	**(0.016)**	**(0.034)**	**(0.082)**
Flooded zone	-0.609	-0.846*	1.498***	1.145
	(0.169)	(0.096)	(0.002)	(0.790)
Access to credit	**-1.026****	**-1.318*****	**-1.556*****	**-1.137****
	(0.011)	**(0.008)**	**(0.001)**	**(0.031)**
Access to extension services	**1.480*****	**1.226*****	**0.818***	**1.190****
	(0.000)	**(0.007)**	**(0.051)**	**(0.010)**
Wealth index	0.178	0.309	-0.014	-0.310
	(0.432)	(0.228)	(0.956)	(0.377)
Intercept	1.607*	0.949	-1.094	0.026
	(0.096)	(0.411)	(0.299)	(0.983)
Log pseudo likelihood	= -565.53058			
Number of observations	= 450			
Prob > chi2	= 0.0000			
Pseudo R2	= 0.1131			

Source: *Author's construction using the survey data*

Note: *** Significance at 1% level; ** significance at 5% level; * significance at 10% level. Between parentheses are assigned (two-tailed tests)

Table A- 2: Parameter estimates of the of the MNL model, displaying the Odds ratio

Independents variables	**Outcome1 Odds ratio**	**Outcome2 Odds ratio**	**Outcome3 Odds ratio**	**Outcome4 Odds ratio**
Age	0.989	1.005	0.993	0.975*
	(0.352)	(0.630)	(0.641)	(0.090)
Education	0.750	0.813	0.732	0.881
	(0.347)	(0.558)	(0.330)	(0.720)
Gender (Male)	1.210	1.334	1.717	1.673
	(0.707)	(0.630)	(0.320)	(0.439)
Household size	0.942	0.802**	0.951	1.000
	(0.423)	(0.025)	(0.535)	(0.998)
Farmers	0.767	0.377	1.585	1.372
	(0.618)	(0.107)	(0.396)	(0.665)
Multiple sources of livelihood	**3.167*** **	**2.419***	**2.437****	**1.414**
	(0.006)	**(0.068)**	**(0.049)**	**(0.503)**
Gone without food/ the past 2 yrs	**2.757****	**3.128****	**2.582****	**2.349***
	(0.014)	**(0.016)**	**(0.034)**	**(0.082)**
Flooded zone	0.544	0.429*	4.474***	1.145
	(0.169)	(0.096)	(0.002)	(0.790)
Access to credit	**0.358****	**0.267*** **	**0.211*** **	**0.320****
	(0.011)	**(0.008)**	**(0.001)**	**(0.031)**
Access to extension	**4.394*** **	**3.408*** **	**2.267***	**3.288****
	(0.000)	**(0.007)**	**(0.051)**	**(0.010)**
Wealth index	1.194	1.362	0.986	0.733
	(0.432)	(0.228)	(0.956)	(0.377)
Intercept	4.989*	2.583	0.335	1.026
	(0.096)	(0.411)	(0.299)	(0.983)
Log pseudo likelihood	= -565.53058			
Number of observations	= 450			
Prob > chi2	= 0.0000			
Pseudo R2	= 0.1131			

Source: *Author's construction using the survey data*

Note: *** Significance at 1% level; ** significance at 5% level; * significance at 10% level.

Between parentheses are assigned (two-tailed tests)

Table A- 3: Parameter estimates of the of the MNP model, displaying the coefficients

Independents variables	**Outcome1 Coefficient**	**Outcome2 Coefficient**	**Outcome3 Coefficient**	**Outcome4 Coefficient**
Age	-0.008	0.001	-0.005	-0.016*
	(0.354)	(0.906)	(0.583)	(0.097)
Education	-0.138	-0.046	-0.208	-0.125
	(0.482)	(0.838)	(0.350)	(0.592)
Gender (Male)	-0.009	0.321	0.286	0.319
	(0.981)	(0.492)	(0.504)	(0.494)
Household size	-0.029	-0.120*	-0.034	-0.006
	(0.589)	(0.071)	(0.556)	(0.920)
Farmers	-0.305	-0.805**	0.299	0.240
	(0.371)	(0.034)	(0.418)	(0.541)
Multiple sources of livelihood	**0.703*** **	**0.484**	**0.500***	**0.210**
	(0.007)	**(0.108)**	**(0.073)**	**(0.478)**
Gone without food/ the past 2 yrs	**0.587****	**0.614****	**0.581****	**0.532***
	(0.016)	**(0.026)**	**(0.026)**	**(0.055)**
Flooded zone	-0.555**	-0.645**	0.964***	0.166
	(0.028)	(0.027)	(0.001)	(0.954)
Access to credit	**-.635****	**-.811****	**-1.022*****	**-0.714****
	(0.029)	**(0.014)**	**(0.002)**	**(0.037)**
Access to extension services	**1.032*****	**0.780****	**0.542***	**0.803****
	(0.000)	**(0.014)**	**(0.087)**	**(0.014)**
Wealth index	0.378	0.109	-0.034	-0.023
	(0.532)	(0.328)	(0.632)	(0.563)
Intercept	1.179*	0.987	-0.847	0.099
	(0.066)	(0.169)	(0.230)	(0.895)
Log pseudo likelihood			= -565.53058	
Number of observations			= 450	
Prob > chi2			= 0.0000	
Pseudo R2			= 0.1131	

Source: *Author's construction using the survey data*

Note: *** Significance at 1% level; ** significance at 5% level; * significance at 10% level. Between parentheses are assigned (two-tailed tests)

Table A- 4: Multinomial logistic regression result (chapter one)

Multinomial logistic regression — Number of obs = 450
Wald chi2(48) = 146.27
Prob > chi2 = 0.0000
Log pseudolikelihood = -565.53058 — Pseudo R2 = 0.1131

New_perception	RRR	Robust std. err.	z	P>|z|	[95% conf.	interval]
0	(base outcome)					
1						
Flooded_zone	.5440109	.2407557	-1.38	0.169	.2285086	1.295128
age	.9890405	.0117074	-0.93	0.352	.9663585	1.012255
Sexe	1.210621	.6161849	0.38	0.707	.4464385	3.282879
Diplome_obtenu	.7501906	.2294201	-0.94	0.347	.4119654	1.3661
Farmer	.7674294	.4069311	-0.50	0.618	.2714482	2.169651
Herders	.404188	.2942335	-1.24	0.213	.0970378	1.683549
Househol_size	.9429681	.0691403	-0.80	0.423	.8167425	1.088702
Access_to_credit	.3583583	.145167	-2.53	0.011	.1619963	.7927383
Acces_to_vulgaristion	4.394429	1.647466	3.95	0.000	2.107599	9.162559
Multiple_livelihood_sources	3.166805	1.328545	2.75	0.006	1.391628	7.206415
Difficulties_to_feed_the_last_tw	2.756705	1.143263	2.45	0.014	1.222867	6.214432
Wealth_index	1.194378	.269868	0.79	0.432	.7670327	1.859814
_cons	4.988508	4.814278	1.67	0.096	.7524863	33.07066
2						
Flooded_zone	.4290258	.2183598	-1.66	0.096	.158216	1.163366
age	1.004528	.0142356	0.32	0.750	.9770105	1.03282
Sexe	1.333927	.797229	0.48	0.630	.4134345	4.303854
Diplome_obtenu	.8126893	.2880771	-0.59	0.558	.4056914	1.627996
Farmer	.3774847	.2281345	-1.61	0.107	.1154707	1.234033
Herders	.2041647	.1867718	-1.74	0.082	.0339855	1.226501
Househol_size	.801656	.0792646	-2.24	0.025	.6604266	.9730866
Access_to_credit	.2676321	.1326526	-2.66	0.008	.1013066	.7070313
Acces_to_vulgaristion	3.408419	1.539497	2.71	0.007	1.406328	8.260745
Multiple_livelihood_sources	2.419651	1.169793	1.83	0.068	.9380698	6.241234
Difficulties_to_feed_the_last_tw	3.128218	1.483278	2.41	0.016	1.235068	7.923249
Wealth_index	1.362651	.3498322	1.21	0.228	.8238656	2.253787
_cons	2.583067	2.984632	0.82	0.411	.2682909	24.86941

3						
Flooded_zone	4.474162	2.195591	3.05	0.002	1.710033	11.70628
age	.9937882	.0132789	-0.47	0.641	.9680999	1.020158
Sexe	1.716999	.9340085	0.99	0.320	.5912014	4.986598
Diplome_obt~u	.732488	.2340584	-0.97	0.330	.3915692	1.370227
Farmer	1.584683	.8595812	0.85	0.396	.5472983	4.588392
Herders	1.559662	1.122586	0.62	0.537	.3805112	6.392836
Househol_size	.9506746	.0774773	-0.62	0.535	.8103289	1.115328
Access_to_c~t	.2109609	.1017613	-3.23	0.001	.0819611	.5429957
Acces_to_vu~n	2.266831	.9519919	1.95	0.051	.9952754	5.162913
Multiple_li~s	2.437083	1.105115	1.96	0.049	1.002042	5.92727
Difficultie~w	2.581565	1.152404	2.12	0.034	1.076239	6.192377
Wealth_index	.9858755	.2562008	-0.05	0.956	.5924057	1.640684
_cons	.3349903	.3527625	-1.04	0.299	.0425277	2.638715
4						
Flooded_zone	1.14517	.5817372	0.27	0.790	.4231231	3.099371
age	.9751817	.0144636	-1.69	0.090	.9472418	1.003946
Sexe	1.673411	1.113107	0.77	0.439	.454367	6.163089
Diplome_obt~u	.8812926	.3104879	-0.36	0.720	.4418081	1.75795
Farmer	1.371791	1.000318	0.43	0.665	.3285389	5.727815
Herders	1.219827	1.072115	0.23	0.821	.2178565	6.83008
Househol_size	.9998193	.0806147	-0.00	0.998	.8536695	1.17099
Access_to_c~t	.3206875	.1691884	-2.16	0.031	.1140262	.9019018
Acces_to_vu~n	3.288352	1.524779	2.57	0.010	1.325207	8.159674
Multiple_li~s	1.414455	.7324822	0.67	0.503	.5126138	3.902904
Difficultie~w	2.349473	1.152381	1.74	0.082	.8983984	6.144296
Wealth_index	.7331148	.2575901	-0.88	0.377	.3682056	1.459666
_cons	1.025906	1.223633	0.02	0.983	.0990492	10.62586

Source: Authors using STATA 17

Appendix B: **Perception of climate change effect on agricultural production in Central Mali**

Empirical strategy

In this section we provide an analysis of the perception of climate change on crop and livestock in the study area. A binary regression model was used to analyze the perception of climate change's effect on agricultural production. This because our dependent variable of interest has a binary form and is coded "1" when the respondents reported to experience a decrease in agricultural production and "0" otherwise. Indeed, this variable is the response to a survey question which is worded as: "Over the past 10-20 years, have you noticed any change in the production of animals and crops in terms of quantity and yield? If yes, respondents may also choose among a set of other responses (is this change?): (i) an increase; (ii) a decrease; (iii) don't know. This specificity of our dependent variable necessitates the use of an adequate and specific econometric tool.

Indeed, the well-known linear regression models generally fail when the dependent variable is qualitative or categorical as the conditional expectation $E(Y/X) = X_i\beta$ can lie outside $[0,1]$ and does not represent a probability. In such case, the binary regression models appear to be the most appropriate. In contrast to linear remodels, the particularity of binary regression models is that, the probability of observing the modality 1 (called the event) is studied in those models. Let's consider for instance Y_i as this dichotomous dependent variable being studied in this dissertation. Y_i is designed as follows:

$$Y_i = \begin{cases} 1, & \text{if the respondent i observed a decrease in agricultural production} \\ 0, & \text{Otherwise} \end{cases} \quad \text{(B.1)}$$

To analyze the probability that Y_i takes the value 1, we use a set of k explanatory variables $x_{i1}, x_{i2}, ..., x_{ik}$ that can be gathered into a vector X_i. The probability model could be then presented as follows:

$$P(Y_i = 1/X_i) = F(\beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + ... + \beta_k x_{ik}) = F(X_i\beta) \quad \text{(B.2)}$$

Where $P(Y_i = 1/X_i)$ represents the probability that Y_i is equal to 1 conditionally to the characteristics $x_{i1}, x_{i2}, ..., x_{ik}$. β is a vector made of $k+1$ parameters: $\beta_0, \beta_1, \beta_2, ...\beta_k$. $F(.)$ is

the distribution function of the quantity $\beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + ... + \beta_k x_{ik}$ ($X_i\beta$ in matrix form). The properties of the function $F(.)$ are such that for any variable z, $\lim_{z\to-\infty} F(z) = 0$ and $\lim_{z\to+\infty} F(z) = 1$. $F(.)$ is therefore a positive, continuous function and comprises between 0 and 1.

On the basis of the previous properties, our discrete choice model can be written as follows:

$$\begin{cases} P(Y_i = 1) = F(X_i\beta) \\ P(Y_i = 0) = 1 - F(X_i\beta) \end{cases} \quad \text{(B.3)}$$

Hence, the general form of the model can finally be written as:

$$Y_i = F(X_i\beta) + \varepsilon_i \quad \text{(B.4)}$$

Where ε_i is the error term.

The probability $P(Y_i = 1)$ depends thus on the distribution of the error term ε_i. If the error term is assumed to follow the standard normal distribution, then the Probit model is required. In contrast if the error term is assumed to follow the cumulative distribution function of the logistic distribution, the Logit model is required. Both Probit and Logit models are widely used in the literature. The following section gives more details on these models and indicates the one being used in this dissertation.

Model choice

As mentioned above, Probit and Logit models are the most commonly used to deal with binary outcomes (Cakmakyapan & Goktas, 2013). More interestingly, these two models can be used to analyze the same data sets for the same purpose. However, they differ in the form of the distribution function F(.). indeed, The Probit model uses the cumulative distribution function of the standard normal distribution and can be specified as follow:

$$P(Y_i = 1/X_i) = F(X_i\beta) = \Phi(X_i\beta) = \int_{-\infty}^{X_i\beta} \left(\frac{1}{\sqrt{2\pi}} e^{\frac{-t^2}{2}} \right) dt \quad \text{(B.5)}$$

Φ represents the standard normal cumulative distribution.

While the Logit model make use of the cumulative distribution function of the logistic distribution specified as follow:

$$P(Y_i = 1 / X_i) = F(X_i\beta) = \frac{1}{1+e^{-X_i\beta}} \quad \text{(B.6)}$$

It is worth noting that, from a historical point of view, the Logit model was just introduced as an approximation of the Probit model allowing simpler calculations. Therefore, there is no fundamental differences between the two models. Both methods produce similar (although not identical) inferences. Moreover, there are no econometric tests (in the best of our knowledge) to discriminate and choose between the two models. However, the choice usually comes down to interpretation needs. Indeed, the Logit model offers the advantage of several alternative interpretations of the results (including marginal effects and odds ratios). Additionally, it allows to attribute to "extreme" events a higher probability than the normal distribution.

The Logit regression is finally chosen in this dissertation regarding the advantages mentioned above and based on a conclusion made from a recent research analysis. Indeed, Jose et al. (2020) recently conducted a research purposively to make a comparison between the Probit and Logit models. The models were compared using indices of AIC/AICc, BIC, sensitivity, specificity, correct prediction percentage, RMSEs, null deviance, residual deviance as well as LR tests. Additionally, the comparison was made under various conditions of varying correlation structures, different prevalence and different sample sizes. Some results have shown that both models fitted equally well in all the situations (this is actually the results coming from the indices AIC/AICc, BIC, LR test, and pseudo R2s comparisons). However, in the other side, results from the sensitivity, specificity, correct prediction percentage as well as RMSEs analysis, have shown that the Logit model fits better than Probit model in most of the situations. Hence, having indicated the model chosen in this study and the reasons guiding that choice, the following section gives the specification of this model.

Model specification

Latent[19] or unobserved variables are a the most common response to the problems associated with the use of ordinary least squares in a model in which the dependent variable is binary. By definition a latent variable is a continuous variable that reflects an unobservable process that governs the realization of the observed dichotomous variable (Jose et al., 2020). For instance, in our case this latent variable could actually be the difference between the unobserved utility provided by reporting a decrease in crops and animals' production and that provided by the opposite situation. Hence, for an individual i, the unobserved utilities associated with the choice of reporting a decrease in crops and animals' production and the choice not reporting a decrease in crops and animals' production can be written as a linear function of the explanatory variables X_{iD} and X_{iI} :

$$\begin{cases} U_{iD} = \beta X_{iD} + \varepsilon_{iD} \\ U_{iI} = \delta X_{iI} + \varepsilon_{iI} \end{cases} \quad \text{(B.7)}$$

Where ε_{iD} and ε_{iI} are random variables representing the error terms, β and δ are unknown parameters. With D = decrease in agricultural production and I = increase in agricultural production.

We then define the latent variable Y_i^* as the difference between the utility provided by reporting a decrease in crops and animals' production and that provided by not reporting a decrease in crops and animals' production:

$$Y_i^* = \beta X_{iD} - \delta X_{iI} + (\varepsilon_{iD} - \varepsilon_{iI}) \Leftrightarrow Y_i^* = \beta X_{iD} + \lambda X_{iI} + \upsilon_i \quad \text{(B.8)}$$

The choice of reporting a decrease in crops and animals' production is made when Y_i^* is positive. In that case, when we define the probability for an individual to report a decrease in crops and animals' production given his characteristics we obtain:

[19]The latent approach is convenient because it can be used to derive both Probit and Logit models.

$$
\begin{aligned}
P_i &= \Pr ob(Y_i = D) = \Pr ob(Y_i^* \geq 0) \\
&= \Pr ob\left[\beta X_{iD} + \lambda X_{iI} + \upsilon_i \geq 0\right] \\
&= \Pr ob\left[\upsilon_i \geq -(\beta X_{iD} + \lambda X_{iI})\right]
\end{aligned}
\tag{B.10}
$$

As the distribution of the random variable υ_i is symmetrical therefore we can write:

$$
\Pr ob(Y_i = D) = \Pr ob\left[\upsilon_i \prec (\beta X_{iD} + \lambda X_{iI})\right] \tag{B.11}
$$

Finally, we obtain $P_i = \Pr ob(Y_i = D) = \Pr ob(\upsilon_i = \beta X_{iD} - \lambda X_{iI}) = F(\beta X_{iD} - \lambda X_{iI})$

Where F is the distribution function of the random variable υ_i.

As mentioned above, the Logit model uses the distribution function of the logistics function. More specifically, it is assumed that the random variable υ_i follows a logistic law defined by the following distribution function:

$$
\Lambda(t) = \frac{1}{1+e^1} = \frac{e^t}{1+e^t} \quad \text{with } t \in IR \tag{B.12}
$$

The density of the logistic law is $\Lambda'(t) = \frac{e^{-t}}{(1+e^{-t})^2}$ with $t \in IR$, the following relationship can therefore be deduced between the density and the distribution function:

$$
\Lambda(t) = \Lambda'(t)\left[1 - \Lambda'(t)\right] \tag{B.13}
$$

Logistics distribution is symmetrical [$\Lambda(-t) = 1 - \Lambda(t)$] with a null mean and a variance equal to $\frac{\pi^2}{3}$. We can then write P_i as follows

$$
P_i = \Pr ob(Y_i = 1) = \phi(\beta X_i + \lambda X_{iI}) \tag{B.14}
$$

$$
\text{Where } \phi(\beta X_i + \lambda X_{iI}) = \frac{\exp(\beta X_i + \lambda X_{iI})}{1 + \exp(\beta X_i + \lambda X_{iI})} = \frac{1}{1 + \exp\left[-(\beta X_i + \lambda X_{iI})\right]} \tag{B.15}
$$

Therefore $P_i = \Pr ob(Y_i = 1) = \frac{1}{1+\exp\left[-(\beta X_i + \lambda X_{iI})\right]}$ (B.16)

In this particular case of analysis, we are only interested by individuals who report a decrease in agricultural production, therefore P_i will be equal to:

$$P_i = \Pr ob(y_i = 1) = \frac{1}{1+\exp(-\beta X_i)} \quad \text{(B.17)}$$

It is important to note that, in the logistic model, the modeled quantity is made up of the ratio of two distinct groups of populations. In this dissertation these groups are: the group of individuals reporting a decrease in agricultural production which probability of belonging is P_i and of the group of those not reporting a decrease in agricultural production with the probability ($1-P_i$).

Let's pose for instance $\delta = \frac{P_i}{1-P_i}$ the relative probability, better known as the odds ratio. Using equation (IV-16) we can determine δ as follows:

$$\delta = \frac{P_i}{1-P_i} = \frac{\frac{1}{1+\exp(-\beta X_i)}}{\frac{\exp(-\beta X_i)}{1+\exp(-\beta X_i)}} = \frac{1}{1+\exp(-\beta X_i)} * \frac{1+\exp(-\beta X_i)}{\exp(-\beta X_i)}$$

We obtained $\Rightarrow \delta = \frac{1}{\exp(-\beta X_i)} = \exp(\beta X_i)$ (B.18)

By taking the natural logarithm of δ, we finally obtain the Logit function defined as follows:

$L = \ln(\frac{P_i}{1-P_i}) = \beta X_i$ where $\frac{P_i}{1-P_i}$ represents the relative probability of choosing $Y_i = 1$ and L varies from $-\infty$ (when $P_i = 0$) to $+\infty$ (when $P_i = 1$).

Hence, in the main analysis, we estimate logistic regression model. For each survey respondent, experiencing decrease in agricultural production is modeled as:

$$\begin{aligned}\text{Decrease in production}_i = {} & \beta_0 + \beta_1 \text{Drought}_i + \beta_2 \text{Decreasing precipitation}_i \\ & + \beta_3 \text{Erratic rainfall}_i + \beta_4 \text{Increasing temperature}_i \\ & + \beta_5 \text{Gender}_i + \beta_6 \text{Age}_i + \beta_7 \text{Education}_i + \beta_8 \text{Household size}_i \\ & + \beta_9 \text{Electricity}_i + \beta_{10} \text{I-Sanitation}_i + \beta_{11} \text{Health}_i + \beta_{11} \text{Credit}_i + \varepsilon_i\end{aligned} \quad \text{(B.19)}$$

Before proceeding with estimation of the specified model, the following section present a brief overview of the appropriate estimation method when dealing with logistic regression model and binary regression models in general.

Estimation method

The structure of the Logit model and all categorical models in general is such that the relationship between the conditional expectation $E(Y/X)$ and parameters β is not linear. Since the dependent variable is binary, linear regression methods which use ordinary least squares for estimation cannot be applied. Instead, a maximum likelihood estimate that assumes a specific distribution of errors should be used(Jose et al., 2020). Hence, in this dissertation the maximum likelihood method to estimate the Logit model. Several raisons sustain that choice. First, the estimators obtained with the maximum likelihood method are asymptotically unbiased with a minimum of variance; the second raison is that, the maximum likelihood estimator is consistent. In other words, if $\hat{\theta}$ represents the maximum likelihood estimator of the vector of parameters θ therefore $\hat{\theta} \xrightarrow{P} \theta$; another raison is such the maximum likelihood estimator is asymptotically normal.

In practice, the estimation of the Logit model by the maximum likelihood method consists in choosing the vector of parameters β as to maximize the likelihood of Y_i. Thus, the probability to observe Y_i for an individual can be written as:

$$P(y_i / X_i) = \left[P(y_i = 1/ X_i)\right]^{y_i} \left[1 - P(y_i = 1/ X_i)\right]^{1-y_i} \quad \text{(B.20)}$$

$$P(y_i / X_i) = \left[F(X_i\beta)\right]^{y_i} \left[1 - F(X_i\beta)\right]^{1-y_i} \quad \text{(B.21)}$$

The likelihood function of Y_i will therefore look like this:

$$L(\beta) = \prod_{i=1}^{n} \left(\left[F(X_i \beta) \right]^{y_i} \left[1 - F(X_i \beta) \right]^{1-y_i} \right) \tag{B.22}$$

Maximizing the likelihood function is also equivalent to maximizing the logarithm of the likelihood function. Therefore, we prefer to first calculate the function $\log L(\beta)$:

$$\log L(\beta) = \sum_{i=1}^{n} \left\{ y_i \log \left[F(X_i \beta) \right] + (1 - y_i) \log \left[1 - F(X_i \beta) \right] \right\} \tag{B.23}$$

The maximum of this function is obtained by differentiating with respect to the vector of parameters β. However, the log likelihood being nonlinear (due in particular to the expressions of $f(X_i \beta)$ and $F(X_i \beta)$), it is not possible to give a simple analytical expression of these estimators, and their computation is generally done through the implementation of an optimization algorithm. Several algorithms have been developed for this purpose among which are the algorithm of Newton Raphson, the algorithm of Berndt-Hall-Hall-Hausman, the algorithm of Davidom-Fletcher-Powell, the algorithm Broyden-Fletcher-Goldfarb-Shanno. But whatever the optimization algorithm employed, the resolution approach always consists in maximizing the log likelihood function starting from the first order conditions. Hence, in table 4.3 is reported the results coming from the estimation of our Logit model using the Maximum likelihood estimation method.

Table A- 5: Estimation of the Logit model (results)

Variables	Coefficient	Std. Err.
Drought	0.681***	0.263
Decreasing precipitation	1.031***	0.246
Erratic rainfall	1.837***	0.664
Increasing temperature	0.105	0.298
Gender	0.171	0.404
Age		
[20-30] Ref		
[31-51]	0.0621	0.443
[51- over[	-0.281	0.456
Education		
No formal education [Ref]		
Primary	-0.173	0.552
Secondary	-0.226	0.432
University	-2.294**	0.985
Married	0.780*	0.470
Household size	-0.0529	0.0548
Access to electricity	-1.477***	0.412
Access to health facilities	-0.481*	0.252
Access to credit	0.528*	0.278
Intercept	-0.288	0.636
Log pseudolikelihood		-225.498
Pseudo R^2 de Mcfadden (en %)		16.08
Prob > chi2		0.000
Number of observations		450

Source: *Author's construction using the survey data*

*Note: ***, **,* and Ref denote respectively the threshold of 1%, 5%, 10% and reference modality.*

Contrarily to the linear regression models, in binary regression models parameters (β) do not represent neither the magnitude of the effects of independents variables on dependent variable nor probabilities. The coefficients are meaningful only in giving the direction of the relationship. The following section discusses the interpretation procedure of parameters in binary regression models in general and specifically in Logit regression model.

Interpretation procedure of parameters

In econometrics, the procedure for interpreting estimated coefficients does not always remain the same. This is actually the case of categorical outcomes regressions. Indeed, in dichotomous dependent variable models, the estimated coefficients do not neither represent the partial effect of

explanatory variables on dependent variables nor probabilities as it is the case in linear regression models. Therefore, they cannot be interpreted directly. Only signs and statistical significance of coefficients are meaningful and interpretable. Hence, when the coefficient associated with an explanatory variable x_{ik} (statistically significant) is positive, it said that the increase of this variable favors the probability of occurrence of the event $Y_i = 1$. In contrast, when the coefficient of that variable x_{ik} is negative, it means that the increase is detrimental to the occurrence of the event $Y_i = 1$. However, the magnitude of this influence that x_{ik} exerts on the probability $P(y_i = 1)$ cannot be measured by the coefficient β_k as discussed above. However, two possibilities the "marginal effects" and the "odds ratios", help to capture that magnitude for the dichotomous regression models (especially for the Logit model). The marginal effect of an explanatory variable on the probability of the event $Y_i = 1$ is the change in that probability following an increase in the independent variable of a unit while the odds ratio refers to the ratio of the probabilities of two mutually exclusive outcomes. In this dissertation, both, odds ratios and marginal effects are being displayed in order to appreciate the magnitude of the influence of climate change effect on agricultural production according to local community's perception and experience.

Table A- 6: Odds Ratio resulting from the logistic regression

Variables	Odds ratio	dy/dx	Std. Err.
Drought	1.976***	0.127***	0.263
Decreasing precipitation	2.805***	0.199***	0.246
Erratic rainfall	6.277***	0.222***	0.664
Increasing temperature	1.110	0.198	0.298
Gender	1.186	0.033	0.404
Age			
[20-30] Ref			
[31-51]	1.064	0.012	0.443
[51- over[	0.755	-0.053	0.456
Education			
No formal education [Ref]			
Primary	0.841	-0.033	0.552
Secondary	0.797	-0.044	0.432
University	0.100**	-0.518**	0.985
Married	2.182*	0.166*	0.470
Household size	0.948	-0.009	0.0548
Access to electricity	0.228***	-0.334***	0.412
Access to health facilities	0.618*	-0.087*	0.252
Access to credit	1.695*	0.092*	0.278
Log pseudolikelihood			-225.498
Pseudo R^2 de Mcfadden (en %)			16.08
Prob > chi2			0.000
Number of observations			450

Source: *Author's construction using the survey data*

*Note: ***, **,* and Ref denote respectively the threshold of 1%, 5%, 10% and reference modality.*

Before proceeding with interpretations of the above obtained results from the estimation of the Logit model, it is important to judge the precision and the validity of the estimated model. Hence, in the following section will be presented the different validation tests available for binary models before discussing the validity of the estimated model.

Model validation tests

In order to judge the accuracy of an estimated binary model, a number of measurements have been proposed. This is the Pseudo R^2 (defined according to the principle of the coefficient of determination R^2 studied in the linear model) and the proportion of correct predictions (measure of the power of prediction).

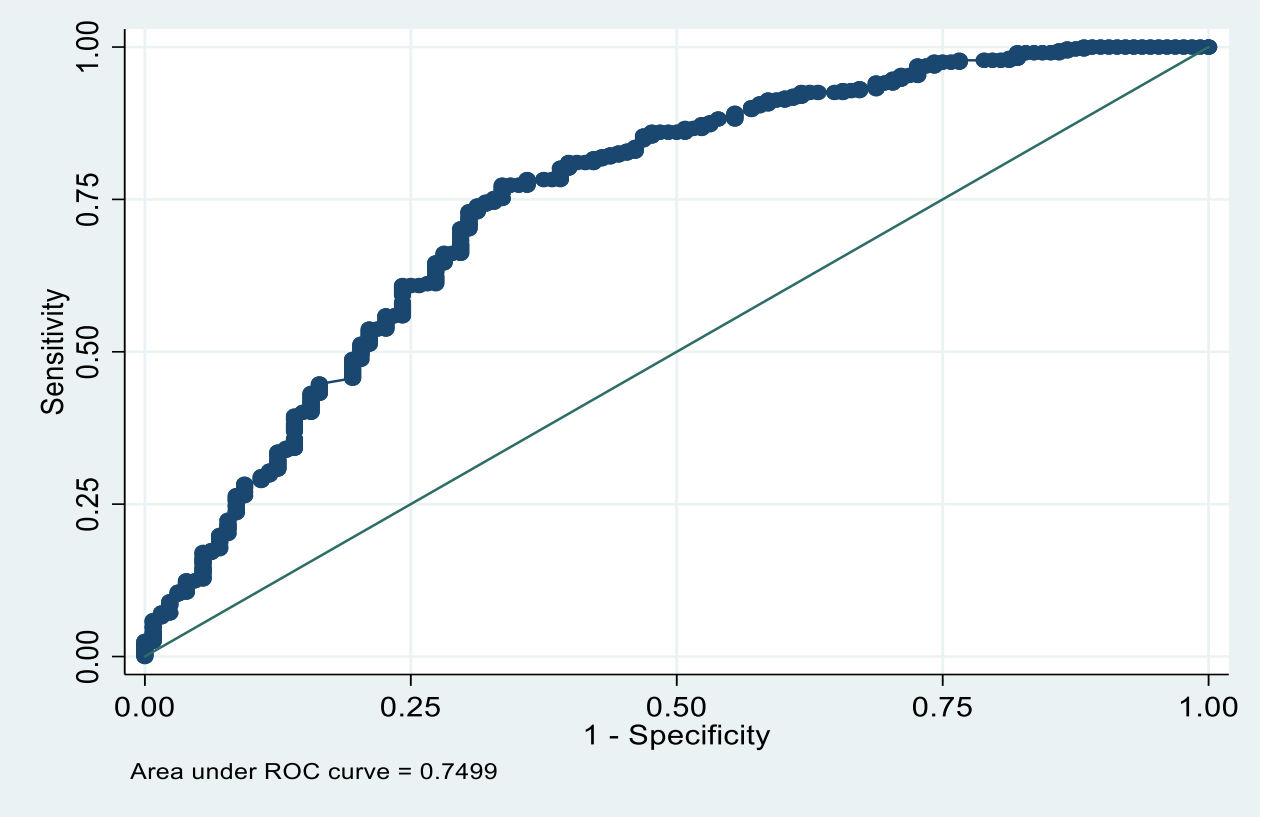
To test the overall significance of the model, the following hypothesis is formulated: $H_0 : \beta_1 = \beta_2 = ... = \beta_k = 0$. Given the characteristic of the dependent variable coded in 0 or 1, the coefficient of determination (R^2)\ cannot be interpreted in terms of the fit of the model. In that case, it is necessary to resort to the statistic of Macfadden called pseudo-R square and given by $R^2 = 1 - \frac{Log(L_U)}{Log(L_R)}$ in order to conclude on the overall significance of the model.

Another way to measure goodness of fit is to examine the predictive power of the estimated model. The idea here is to calculate the proportion of correct predictions of the model. The model is then considered to be of good quality when the percentage of correct predictions is close to 1.

The overall significance test of the model estimated in this chapter shows that the model is significant at the 1% level (Prob > Chi2 = 0.000). The chi2 LR value is 76.55. McFadden's Pseudo R^2 or R^2 is 16.08%. Additionally, the prediction table (prediction quality) shows that for individuals supporting the use of violence ($Y_i = 1$), 81 out of 128 cases (0.63) were well predicted (probability greater than 0.5) in the other hand, for individuals not supporting the use of violence ($Y_i = 0$), 298 out of 322 cases were well predicted. The overall prediction rate of the estimated model is equal to 76.67% (see appendixes). These evaluation criteria globally show that the model estimated here is adequate. This reflects the existence of at least one exogenous variable in the model which makes it possible to explain and predict the behavior of individuals experiencing decrease in agricultural production.

Another way of evaluating the accuracy of the model is yet to analyze its discriminating power. The discriminating power of a model reflects the capacity of that model to describe, explain and predict membership in predefined groups (classes, modalities of the variable to be predicted, etc.) of a set of observations (individuals) from a series of predictive variables (descriptors, exogenous variables, etc.). In order to appreciate the discriminating power of the model estimated in this chapter, we use the ROC curve which allows to measure the predictive power of binary models in general. The visualization of the fit of the model to the data through the ROC curve, indicates an acceptable discrimination of the model since the value of the area below the ROC curve is between 0.7 and 0.8, which in terms of interpretation indicates an acceptable discrimination power of the model.

Graphic A- 1: ROC curve



Source: *Author's construction using the survey data*

One more way of probing the accuracy of the model is to use the "global fit test or global goodness test". This is done through the "Hosmer and Lemeshow's goodness-of-fit test". The idea behind this test is that the predicted frequency and observed frequency should match closely, and that the more closely they match, the better the fit. In practice, the Hosmer-Lemeshow goodness-of-fit statistic is computed as the Pearson chi-square from the contingency table of observed frequencies and expected frequencies. Similar to a test of association of a two-way table, a good fit as measured by Hosmer and Lemeshow's test will yield a large p-value. With a p-value of 0.66 (p-value > 0.05), the Hosmer and Lemeshow's goodness-of-fit test (see appendixes) indicates that our model fits the data well.

The synthesis of the results from the various suitability and adjustment tests carried out allows to conclude overall that the model used to analyze the impact of climate change effect on agricultural production is adequate, discriminating and predictive. The results from the iterations of the model can thus be analyzed and interpreted.

Results and discussion

The modeling carried out in this analysis shows that the perception of changes in climatic conditions is likely to shape people experience of bad agricultural campaign. Indeed, the relationship between climate change perception and experiencing bad harvest is found to be statistically significant. Specifically, table IV-8 shows that the perception of erratic rainfall increases the probability of reporting bad agricultural production by 22,20%, perception of decreasing rainfall amount increases it by 19.19% while perception of drought increases it by 12.60%. These results confirm our third hypothesis (H3) formulated in this chapter. As 80.22% of respondents in our sample are involved in agricultural production (both crops and animals' production), the more an individual face bad climatic conditions, the more likely he is to experience bad agricultural production since in the study area agricultural production largely depends on meteorological conditions. Indeed, good meteorological conditions are necessary to agricultural production. Environmental variability such as erratic rainfall completely disrupts the agricultural calendar and is likely to mislead farmers regarding favorable periods for planting, for applying pesticides, for applying fertilizer and so on. The decrease in rainfall amount as well as drought considerably affect plants' growth and development hence preventing them of giving their full potential. Our results are in line with Ouédraogo (2012) and Sossou et al. (2020) findings in Burkina Faso. They are also in line with results from Ben Mohamed et al. (2002) in Niger and Kouyate (2020) in the administrative cercle of Koutiala in Mali.

However, we found no statistically significant relationship between perception increasing temperature and experiencing bad agricultural harvest. This may likely be related to rural community poor knowledge regarding the role of temperature in crop production. Indeed, temperature intervene mostly in the photosynthesis process and plant pollination which are not straightforward and require a certain level of deep training. In contrast, being married increases the probability of reporting a decrease agricultural production. This is probably due to the family charge and responsibility in terms of food and income that marriage bring.

Besides the climatic factors, the analysis also highlights the detrimental effect of education on climatic vulnerability. Indeed, a statically significant negative effect is found between having a college education higher than the secondary level and the likelihood of experiencing bad harvest. The result shows that having a college education higher than the secondary level decreases the

probability of experiencing bad harvest with up to 51.8%. this is likely because those having college degree are mostly involved in public and formal private jobs hence making them less dependent to agricultural activities and climatic issues. In the other hand, even when involved in agriculture those individuals are more informed on weather conditions and are more likely to implement strategies helping them to reduce the negative impact of climate change. Similarly, we found access to electricity and health facilities also negatively related to the likelihood of experiencing bad agricultural production. Indeed, individuals having access to those facilities are somehow less vulnerable to climate change and less likely to experienced bad economic situation due to environmental change. This is likely because, these facilities show that the respondents are not based in rural areas since in the study area electricity is found only in some big urban areas. In those areas people are more likely to be involved in different activities hence do not rely solely on agricultural. However, access to credit facilities is positively and significantly correlated to experiencing unfavorable agricultural production. Generally, the majority of individual living in the study area are involved in subsistence farming or breeding which in most cases do not require higher financial investment and credit. However, being experiencing losses in production people tend to develop adaptation strategies. Adaptation whether it is adopting improved crop varieties, using fertilizer or doing other activities always require funds and lead people to subscribe to credit facilities. Hence, those using credit are generally the affected people lacking adaptation capacity and which are more likely to share their experience of bad harvest.

Appendix C: Hosmer-Lemeshow's test (chapter one)

Table A- 7: Hosmer-Lemeshow's test result

```
Goodness-of-fit test after logistic model
Variable: Decreasing_yield
```

Table collapsed on quantiles of estimated probabilities

Group	Prob	Obs_1	Exp_1	Obs_0	Exp_0	Total
1	0.4203	10	13.1	35	31.9	45
2	0.5360	25	23.0	22	24.0	47
3	0.6499	26	25.8	17	17.2	43
4	0.7290	30	30.9	15	14.1	45
5	0.7768	37	34.0	8	11.0	45
6	0.8257	39	36.1	6	8.9	45
7	0.8559	40	39.5	7	7.5	47
8	0.8833	36	37.4	7	5.6	43
9	0.9086	39	40.3	6	4.7	45
10	0.9789	40	42.0	5	3.0	45

```
 Number of observations =    450
       Number of groups =     10
Hosmer–Lemeshow chi2(8) =   5.91
           Prob > chi2 = 0.6568
```

Source: Authors using STATA 17

Comment: As can be seen above, the Hosmer-Lemeshow's test led us not to reject the null hypothesis of a goodness of fit since the critical probability (Prob > chi2) is greater than the significance threshold of 5%.

Appendix D: the prediction power of the logit model (chapter one)

Table A- 8: model prediction's power test

Logistic model for Decreasing_yield

Classified	True D	True ~D	Total
+	298	81	379
-	24	47	71
Total	322	128	450

Classified + if predicted Pr(D) >= .5
True D defined as Decreasing_yield != 0

Sensitivity	Pr(+| D)	92.55%
Specificity	Pr(-|~D)	36.72%
Positive predictive value	Pr(D| +)	78.63%
Negative predictive value	Pr(~D| -)	66.20%
False + rate for true ~D	Pr(+|~D)	63.28%
False - rate for true D	Pr(-| D)	7.45%
False + rate for classified +	Pr(~D| +)	21.37%
False - rate for classified -	Pr(D| -)	33.80%
Correctly classified		76.67%

Source: Authors using STATA 17

Comment: the test shows that our model has a good prediction power (76.67%)

Appendix E: Logistic estimation results

Table A- 9: Logistic estimation results using coefficients

Logistic regression — Number of obs = 450
Wald chi2(16) = 76.55
Prob > chi2 = 0.0000
Log pseudolikelihood = -225.49756 — Pseudo R2 = 0.1608

Decreasing_yield	Coefficient	Robust std. err.	z	P>|z|	[95% conf.	interval]
Drought_perception	.6810164	.2625146	2.59	0.009	.1664973	1.195536
M	.0620993	.4434461	0.14	0.889	-.807039	.9312377
_above	-.2808307	.4559138	-0.62	0.538	-1.174405	.6127439
Sexe	.1706148	.4041981	0.42	0.673	-.621599	.9628285
Etat_civil	.7803357	.4700243	1.66	0.097	-.140895	1.701567
Primary_degree	-.1731025	.5519808	-0.31	0.754	-1.254965	.9087599
Secondary_degree	-.2264498	.4320835	-0.52	0.600	-1.073318	.6204182
Postseondary_level	-2.293969	.984809	-2.33	0.020	-4.224159	-.3637787
Househol_size	-.0528867	.0548489	-0.96	0.335	-.1603886	.0546151
Access_to_electricity	-1.476538	.4122122	-3.58	0.000	-2.284459	-.668617
Access_to_improved_sanitation	.0070795	.2950877	0.02	0.981	-.5712818	.5854407
Access_to_health_facilities	-.4811174	.2524329	-1.91	0.057	-.9758767	.0136419
Increasing_temperature	.1045269	.2984519	0.35	0.726	-.4804281	.6894819
Decreased_precipitation	1.031262	.2458674	4.19	0.000	.5493708	1.513153
erratic_rainfall_perception	1.836867	.6635358	2.77	0.006	.5363607	3.137373
Access_to_credit	.527602	.2784631	1.89	0.058	-.0181756	1.07338
_cons	-.2875628	.6359246	-0.45	0.651	-1.533952	.9588266

Source: Authors using STATA 17

Table A- 10: Logistic regression results using the odds ratio

Logistic regression — Number of obs = 450
Wald chi2(16) = 76.55
Prob > chi2 = 0.0000
Log pseudolikelihood = -225.49756 — Pseudo R2 = 0.1608

Decreasing_yield	Odds ratio	Robust std. err.	z	P>|z|	[95% conf.	interval]
Drought_perception	1.975885	.5186987	2.59	0.009	1.18116	3.305328
M	1.064068	.4718568	0.14	0.889	.4461772	2.537648
_above	.7551562	.3442861	-0.62	0.538	.3090027	1.845488
Sexe	1.186034	.4793926	0.42	0.673	.537085	2.619094
Etat_civil	2.182205	1.025689	1.66	0.097	.8685805	5.482529
Primary_degree	.8410514	.4642442	-0.31	0.754	.2850858	2.481244
Secondary_degree	.7973594	.3445258	-0.52	0.600	.3418724	1.859706
Postseondary_level	.1008654	.0993331	-2.33	0.020	.0146376	.695045
Househol_size	.9484875	.0520235	-0.96	0.335	.8518127	1.056134
Access_to_electricity	.2284271	.0941604	-3.58	0.000	.1018291	.5124167
Access_to_improved_sanitation	1.007105	.2971842	0.02	0.981	.564801	1.795782
Access_to_health_facilities	.6180923	.1560268	-1.91	0.057	.3768618	1.013735
Increasing_temperature	1.110185	.3313369	0.35	0.726	.6185185	1.992683
Decreased_precipitation	2.804603	.6895603	4.19	0.000	1.732163	4.541027
erratic_rainfall_perception	6.276842	4.164909	2.77	0.006	1.709773	23.04326
Access_to_credit	1.694863	.4719568	1.89	0.058	.9819886	2.925249
_cons	.7500895	.4770004	-0.45	0.651	.2156816	2.608634

Source: Authors using STATA 17

Appendix F: Survey Questionnaire

Section 0 [to be filled out prior to interview]

Date : ____/____/_____
Interviewer ID _____

Cercle : _____ Commune : _____ Village : _____

Number of households (HH) in the village: _____

GPS Coordinates (of the household): _____

Section A: Demographic information

A1. Respondent's name: .....

A2. Age: /_____/

A3. Sex: 1. Male 2. Female /_____/

A4. Marital status: /_____/

(Choose the number corresponding to the answer given by the respondent)

1. Married	2. Separated	3. Widowed	4. Single	5. Divorced

A5. What is your religion? /_____/

1. Muslim	2. Catholic	3. Protestant	4. Animist

A6. Which ethnic group do you belong to? _____

1.Bambara	2.Dogon	3.Bozo	4.Mianka	5.Peulh
6.Kassonke	7.Senoufou	8.Malinke	9.Kassonke	10.Bobo
11.Sonrhay	12.Touareg	13.Soninke	14.Senoufo	15.Other

A6a. Specify other _____

(A7-8). Intra-ethnic and inter-ethnic attitudes

A7. How much do you trust people from your own ethnic group [or tribe] /___/
(Choose the number corresponding to the answer given by the respondent)

1. Not at all	2. Just a little	3. Somewhat	4. A lot	99. Don't Know/Refused to Answer

A8. How much do you trust people from other ethnic groups? /____/
(Choose the number corresponding to the answer given by the respondent)

1. Not at all	2. Just a little	3. Somewhat	4. A lot	99. Don't Know/Refused to Answer

A9. Educational Background

A9a. What is the highest level of education you have completed (finished)? /____/

(Choose the number corresponding to the answer given by the respondent)

Note: If A9a is equal to 0 go to A9b. On the other hand, if A9a is greater than 0, go directly to A10.

No formal schooling	0	
CEP (Primary school completed)	1	
DEF/BEPC (Secondary school completed/)	2	
CAP (DEF +2)	3	
BT (DEF +4)	4	
BAC	5	
DEUG, DUT, BTS (BAC+2)	6	
Licence (BAC + 3)	7	
Maitrise, Master 1 (BAC + 4)	8	
DEA, Master 2 (BAC + 5)	9	
Doctorat	10	
Don't know or cannot say	99	

A9b. Alphabetization (For those that have no formal schooling): /____/

(Choose the number corresponding to the answer given by the respondent)

1. Can read	2. Can write	3. Can read and write	4. None

A10. Respondent status: 1. Household head 0. Others (Specify)..... /_____/

(The four following questions should be asked in the case the respondent is not the household head if A10=0):

A11. Household head sex: 1. Male 2. Female /_____/

A12. Household head age: /_____/

A13. Household head marital status: /_____/

(Choose the number corresponding to the answer given by the respondent)

1. Married	2. Separated	3. Widowed	4. Single	5. Divorced

A14. Educational Background of the household head

A13a. What is the highest level of education the household head have completed (finished)? /____/

(Choose the number corresponding to the answer given by the respondent)

Note: If A13a is equal to 0 go to A13b. On the other hand, if A13a is greater than 0, go directly to

A14.

No formal schooling	0	
CEP (Primary school completed)	1	
DEF/BEPC (Secondary school completed/)	2	
CAP (DEF +2)	3	
BT (DEF +4)	4	
BAC	5	
DEUG, DUT, BTS (BAC+2)	6	
Licence (BAC + 3)	7	
Maitrise, Master 1 (BAC + 4)	8	
DEA, Master 2 (BAC + 5)	9	
Doctorat	10	
Don't know or cannot say	99	

A13b. Alphabetization (For those that have no formal schooling): /____/

(Choose the number corresponding to the answer given by the respondent)

1. Can read	2. Can write	3. Can read and write	4. None

A14. How many are you in the household: /_____/

A14a. Children (under 15) /_____/ A11b. Men /_____/ A11c. Women /_____/

A15. To which ethnic group the household head belong to? _____

1.Bambara	2.Dogon	3.Bozo	4.Mianka	5.Peulh
6.Kassonke	7.Senoufou	8.Malinke	9.Kassonke	10.Bobo
11.Sonrhay	12.Touareg	13.Soninke	14.Senoufo	15.Other

A15a. Specify other _____

A16. Information regarding the remaining members of the household: *[Choose the number corresponding to the respondent's answer for each line (member)]*

First name	A16a.Sex 1=Male 2=Female	A16b.Age	A16c1 Education (highest school completion)	A16c2. Alphabetization 1. Can read 2. Can write 3. Can read and write 4. None	A16d. Relationship to the head of the household head 1. Wife 2. Child 3. Others (specify)
1.					
2.					

3.					
4.					
5.					
6.					
7.					
8.					
9.					
10.					

Section B: Information regarding livelihoods and livelihoods sources

B1. How many livelihood sources do your household depend upon? :_____

1.One livelihoods source	2.Multiple livelihoods sources	99.Dont know or can't say it

B2. What livelihoods activity do you PRIMARILY depend upon for your livelihoods? /___/
(Choose the number corresponding to the answer given by the respondent)

Livestock keeping	1	
Trade in livestock and livestock goods	2	
Crop Farming	3	
Trade in harvested crops and agricultural goods	4	
fishing	5	
Small business (non-agriculture or livestock goods)	6	
Day Labor-Temporary	7	
Remittances	8	
Tourism	9	
Salaried and/or wage d labor	10	
Other (Specify) _____	95	

B3. Is the income you made from your primary livelihoods activity currently enough to ensure your livelihoods? /___/

1.More than enough	2.quite enough	3. Not really enough	4.far from being enough	99.don't know/ can't say

B4. Given your income, how much do you value your life? /___/

1.Good	2.Fairly good	3.Quite a bit good	4. With difficulty

B5. In general, how would you describe: Your own present living conditions? /___/
(Choose the number corresponding to the answer given by the respondent)

1.Very bad	2.Fairly bad	3. Neither good nor bad	4. Fairly good	5. Very good	99. Don't Know/Refused to Answer

B6. In general, how do you rate your wealthiness compared to those of your own locality? /____/
(Choose the number corresponding to the answer given by the respondent)

1.Rich	2.Poor	3. Neither rich nor poor	99. Don't Know/Refused to Answer

B7. How much do you estimate the minimum amount monthly necessary for your household to sustain living? _____

B8. Over the past year, has your household's living condition? /____/

1.Declined	2.Improved	3.Unchanged

B9. Over the past year, has your community's living condition? /____/

1.Declined	2.Improved	3.Unchanged

B10. In general, how do you rate your living conditions compared to those of other Malian? /____/
(Choose the number corresponding to the answer given by the respondent)

1.Very bad	2.Fairly bad	3. Neither good nor bad	4. Fairly good	5. Very good	99. Don't Know/Refused to Answer

B11. Looking back, how do you rate your living condition compared to five years ago? /_____/
(Choose the number corresponding to the answer given by the respondent)

1.Very bad	2.Fairly bad	3. Neither good nor bad	4. Fairly good	5. Very good	99. Don't Know/Refused to Answer

B12. How much do you trust the farmers in your community? /____/

(Choose the number corresponding to the answer given by the respondent)

1. Not at all	2. Just a little	3. Somewhat	4. A lot	99. Don't Know/Refused to Answer

B13. How much do you trust the herders in your community? /____/
(Choose the number corresponding to the answer given by the respondent)

1. Not at all	2. Just a little	3. Somewhat	4. A lot	99. Don't Know/Refused to Answer

B14. How much do you trust the fishermen in your community? /____/
(Choose the number corresponding to the answer given by the respondent)

1. Not at all	2. Just a little	3. Somewhat	4. A lot	99. Don't Know/Refused to Answer

B15. How much do you trust government officials? /____/
(Choose the number corresponding to the answer given by the respondent)

1. Not at all	2. Just a little	3. Somewhat	4. A lot	99. Don't Know/Refused to Answer

B16. How much do you trust traders in your community? /____/
(Choose the number corresponding to the answer given by the respondent)

1. Not at all	2. Just a little	3. Somewhat	4. A lot	99. Don't Know/Refused to Answer

B17. Do you think that the authorities fight effectively against poverty? 1. Yes 2. No /____/

B18. Do LOCAL OFFICIAL (GOVERNMENTAL) rules regulate the use of natural resources in your area? (Choose all that apply): /____/
(Choose the number corresponding to the answer given by the respondent)

Yes (land for grazing)	1
Yes (water for livestock)	2
Yes (land for agriculture)	3
Yes (water for agriculture)	4
There are no LOCAL OFFICIAL (GOVERNMENTAL) rules in place in this area	5
Refused to answer	98
Don't know or cannot say	99

B19. In your opinion, what is the main measure that the authorities should take to improve the living conditions of the population? /___/

1.Creating jobs	7. Guarantee commodity prices
2.Building road	8. Raising wages
3.Facilitate access to water and electricity	9.Fighting corruption
4.Ensure food security	10.Facilitate access to health
5.Facilitate access to school	11.Facilitate access to credit
6.Facilitate access to housing	12. Other (specify)

Section C: Food security

C1. Do you usually eat the three daily meals every day? 1. Yes 2. No /____/

C2. Over the past year, has the household had difficulty obtaining food? 1. Yes 2. No /____/
(If C2 is equal to 1, go to C3, otherwise go to next section)

C3. If yes, what recourse did you adopt to overcome this difficulty?

1. Livestock sale	6.Aid from the State
2. Sale of good	7. Take a loan
3. Sale of its capital	8. Aid from NGOs
4. Use of savings	9. Aid from parents/friends
5. Migration of a family member	10. No aid/recourse

Section D. Access to extension, markets, credit, food consumption, and social capital

D1. Do you sell some of your produce? 1. Yes 2. No /___/

D2. Do you have access to market? 1. Yes 2. No /___/

D3. How far is the nearest market from your house? D3a. /_____/Km D3b. /_____/Min

D4. Do you have access to extension services? 1. Yes 2. No /_____/

D5. If yes, how many times per year? /_____/

D6. If no, why? .....

D6. Do you have access to credit facilities? 1. Yes 2. No /____/

D7. If yes, where (source of credit)? 1. Commercial bank 2. Microfinance agency 3. Relatives 4. Friends 5. My children 6. Others (specify)..... /_____/

D8. If no, why? .....

D9. What is the amount of credit do you have this year?

D10. Are you a member of any community organizations/associations? 1. Yes 2. No /___/

D11. If no, why? ……

D12. Do you participate in community activities? 1. Yes 2. No /___/

D13. If no, why? ……

D14. What is the probability that people who do not participate in community activities are criticized or sanctioned? /____/

1.Very likely	2. Quite unlikely	3. Very unlikely
4. More or less likely	5. Neither probable nor improbable	

D15. [if D10 is equal to 1] How much do you trust those community organizations? /___/

1.To a very large extent	2. To a large extent	3. To a very weak extent
4. To a weak extent	5. To a degree neither great nor small	

Section E. Climate change perception and shocks

E1. In the last 10 - 20 years have you notice any change in the weather pattern so far? 1. Yes 2. No /___/

E2. If so, could you describe the main weather event(s) that have happened here during the last 10 -20 years? /____/

(Choose the number corresponding to the answer given by the respondent)

[If respondent is unable to answer freely, read the list. For each reported event follow up with questions in the following table].

1. Heavy Rains/Floods	1
2. Drought/Desertification	2
3. Storm/heavy winds	3
4. Extreme temperatures (extremely hot, extremely cold)	4
5. Other specify: ……..	5
6. None	6
99. Don't Know/Refused to Answer	99

E3. Has there been a change in rainfall pattern in the last 20 years? /____/

(Choose the number corresponding to the answer given by the respondent)

1. Yes	2. No	3. I don't know

E4. If yes, has the rainfall period: /____/

(Choose the number corresponding to the answer given by the respondent)

1. Increased?	2. Decreased?	3. Neither increased nor decreased	4. I don't know

E5. Has the intensity of rainfall increased over the years? /___/

(Choose the number corresponding to the answer given by the respondent)

1. Yes	2. No	3. decreased	4. I don't know

E6. In your opinion, do you think that the FREQUENCY of flood is changing since approximately 10 years ago? (For Example: Has the time between flooding become shorter?) /____/

(Choose the number corresponding to the answer given by the respondent)

Yes, there are more floods than there were before	1
Yes, there are fewer floods than there were before	2
No, there has been no change in the frequency of floods	3
I am not sure, there is no way to tell if there has been a change	4
Refused to answer	98
Don't know or cannot say	99

E7. In your opinion, do you think that the SEVERITY of floods is changing? (For Example: When a flood comes, is it longer?)

Yes, floods are more severe than 10 years ago	1
Yes, floods are less severe than before	2
No, there has been no change in the severity of floods	3
I am not sure, there is no way to tell if there has been a change	4
Refused to answer	98
Don't know or cannot say	99

E8. Has the length of dry spells during the rainy season increased? /____/

(Choose the number corresponding to the answer given by the respondent)

1. Yes	2. No	3. I don't know

E9. In your opinion, do you think that the FREQUENCY of drought is changing since approximately 10 years ago? (For Example: Has the time between droughts become shorter?) /____/

(Choose the number corresponding to the answer given by the respondent)

Yes, there are more droughts than there were before	1
Yes, there are fewer droughts than there were before	2
No, there has been no change in the frequency of drought	3
I am not sure, there is no way to tell if there has been a change	4
Refused to answer	98
Don't know or cannot say	99

E10. Has there been a change in temperature in the last 20 years? /____/

(Choose the number corresponding to the answer given by the respondent)

1. Yes	2. No	3. I don't know

E11. Is the temperature for the past 20 years: /____/

(Choose the number corresponding to the answer given by the respondent)

1. Increasing?	2. Decreasing?	3. Neither one nor the other	4. I don't know

E12. Have you noticed the occurrence of climatic shocks during the five last years?

1. Floods	
2. Droughts	
3. Strong winds	
4. Erratic rainfalls	
5. Heavy rainfalls	
6. Others (Specify).....	

E13. In your opinion, how much did these changes affect the livelihood of peoples in your community within the last five years? /____/

(Choose the number corresponding to the answer given by the respondent)

1. None at all	**2.** A little	3**.** A lot	4.Don't know

E14. In your experience, would you say climate conditions for agricultural and livestock production in your area have gotten better, gotten worse, or stayed about the same over the last 5 years?
(Choose the number corresponding to the answer given by the respondent)

No experience	1
Much worse	2
Worse	3
About the same	4
Better	5
Much better	6
Don't know	7
Don't Know/Refused to Answer	99

E15. Have you seen a change in grain/animal yield or produce over the past 20 years? /___/
(Choose the number corresponding to the answer given by the respondent)

1. Yes	2. No	3. I don't know

E16. I yes what change is it in yield? /____/
(Choose the number corresponding to the answer given by the respondent)

1. Increased in crop/animal yield	2. Decreased in crop/animal yield	3. I don't know

E17. If there is a decrease in yield, what could be the reason? /___/
(Choose the number corresponding to the answer given by the respondent)

1. Less rainfall	2. High temperature	3. Low soil fertility	4. I don't know

Others (Specify).....

E18. What are the other kinds of risk apart from climatic ones have you faced so far? /____/
(Choose the number corresponding to the answer given by the respondent)

E18a.	E18b.	E19c.	E20d.

Section F: Adaptation Strategies

F1. What adjustments have you made or will you do to reduce the impact of the changes on weather patterns on your livelihoods?

Let the respondent give his own option. Check and tick the answers below for F1 and then ask for the ones not yet cited. 1: Yes 2: No

F1a. Apply less fertilizer /__/	F1b. Plant short season varieties /__/	F1c. Stone bunds /__/	F1d.Crop diversification /__/	F1e.Change from crops to livestock /___/
F1f. Rainwater harvesting /__/	F1g.Change from crops to livestock /___/	F1h.Change in crop /__/	F1i.Change in planting date /__/	F1j. Reduce farm size /__/
F1k.Increase farm size /__/	F1l.Migrate to a big city /__/	F1m. Lease your land /__/	F1n. Plant different crops /__/	F1o. Develop irrigation strategies /__/
F1p.Find off-farm /__/	F1r.No adoption /__/			

F1s.Others (specify) …….

F2. If no adoption, why? /__/

1. Lack of means	2. Lack of technology	3. Lack of time	4. Lack of timely weather information	5. Other (specify)

F3. What are the possible barriers/difficulties to adapt to climate change or long-term change in weather?

F3a.Lack of funds or credit facilities/Poverty /__/	F3b. Lack of technology /__/	F3b. Increase in population /__/	F3b. Lack of access to water /__/
F3c.Lack of access to market /__/	F3d. Lack of appropriate seed /__/	F3e. Lack of knowledge on adaptations technics /__/	F3f. Lack of timely weather information /__/

F3g. Other (specify).....

Section G: attitude toward violence

G1. Are you satisfied with the management of the country by the various government officials? /__/ (*if Yes go to G3 otherwise go to G2)*

1. Yes	2. No	3. I don't know

G2. If no why? /__/

1.Bad governance	2. Corruption	3. Favoritism	4. Mismanagement of public funds

5.Other (specify) ……

G3. Here is a kind of action that people some-times take as citizens. Please tell me whether you, personally, have done such a thing during the past year. If not, would you do this if you had the chance: Used force or violence to win a case or obtain justice: /__/

(Choose the number corresponding to the answer given by the respondent)

1.No, would never do this	2.No, but would do if had the chance	3. Yes, once or twice	4.Yes, several times
5. Yes, often	6. Don't know	99. Refused to answer	

G4. Now! Among the following two statements, please tell me which statement is closest to your view? Choose Statement 1 or Statement 2:

Statement 1: The use of violence is never justified in Malian politics today.

Statement 2: In this country, it is sometimes necessary to use violence IN SUPPORT OF A JUST CAUSE: /___/

(Choose the number corresponding to the answer given by the respondent)

1. Agree very strongly with Statement 1	2. Agree with Statement 1	3. Agree very strongly with Statement 2	4. Agree with Statement 2
5. Agree with neither	6. Refused to answer	99. Don't know or cannot say	

G5. Imagine there is a group of individuals living in your locality who feel that they are being treated differently in various areas which is affecting their overall quality of life in the locality in a negative way. They have formed as a group with the aim to eliminate discrimination and organize various activities to help further their goals. Please tell us for each of the following activities how willing you are to engage in these activities in order to support the group's goal.

G5a. Peaceful protest: Participate in peaceful protest rallies organized by group/____/			
1.Strongly willing to	2.Willing to	3.Not willing to	4.Refused to answer

/___/	/___/	/___/	/___/
G5b. Violent protest: Participate in violent protest rallies organized by group even if these may cause violent clashes /____/			
1.Strongly willing to /___/	2.Willing to /___/	3.Not willing to /___/	4.Refused to answer /___/
G5c. Join group: Become a member of groups /____/			
1.Strongly willing to /___/	2.Willing to /___/	3.Not willing to /___/	4.Refused to answer /___/

Section H. Household assets, and basic services

H1. What materials is the roof of the main building made of? /____/	H2. Main material of the floor /____/	H3. What is the material of the walls of the house? /___/	H4. How many separate rooms do members of your household occupy?	H5. What is the main source of drinking water for members of your household? /___/
1. Mud	1. Earth/mud/mud bricks	1. Mud/mud bricks	(Count living rooms, dining rooms but no bathrooms, toilets, garage and kitchens)	1. Piped into dwelling or compound
2. Thatch	2. Cement/concrete stone	2. Stone	/_____/	2. Public outdoor tap
3. Wood	3. Burnt bricks	3. Burnt bricks		3. Borehole
4. Metal sheets	4. Wood	4. Cement/sandcrete		4. Protected well
5. Cement/Concrete	5. Ceramic/marble tiles	5. Wood/bamboo		5. Unprotected well, rain water
6. Roofing tiles	6. Carpet	6. Iron sheets		6. River, lake, pond
7. Others	7. Others	7. Others		7. Others

H6. How long does it take you to go to the nearest hospital/clinic? /___/Km /___/Min	H7. What kind of toilet facility does your household have? /__/	H8. Do your household share these facilities with other households? 1=Yes 2=No /___/	H9. How many households do you share these facilities with? /__/	H10. What type of fuels does your household mainly use for cooking? /__/
	1. Flush toilet		1. 1-2	1. Charcoal/firewood
	2. Covered Pit Latrine		2. 3-4	2. Crop residue/saw dust
	3. Uncovered Pit Latrine		3. 5-9	3. Animal waste
	4. KVIP		4. 10+	4. Others
	5. Bucket/Pan			
	6. No facility/Bush/Field/Beach			
	7. Others			

H11. Does any member of your household own any means of transport? /___/	H12. How long (average) does it take to reach other nearest facilities by kilometres and minutes	H13. Does your household have electricity? 1=Yes 2=No /___/
1. A bicycle	1. Public transportation /____/Km /____/Min	
2. A motorbike	2. Telecommunication facility /____/Km /____/Min	
3. A car	3. Supply of drinking water /____/Km /____/Minsss	
4. A tractor	4. Distance to food market /____/Km /____/Min	
5. A horse/cart	5. Distance to vaccination center/hospital /____/Km /____/Min	

Do you currently own any of the following assets?	a. 1=Yes 2=No	b. Quantity owned	c. Current resale value
H14a. Motor car			
H14b. Motorbike			
H14c. Bicycle			
H14d. Truck			
H14e. Tractor			
H14f. Furniture/Sofa			
H14g. Sewing machine			
H14h. Radio			
H14i. Television			
H14j. Mobile phone			
H14k. Electric fan			
H14l. House made of blocks			
H14m. Generator			
H14n. Water well			
H14o. Water pump			
H14p. Others (specify)			
H14q.			
H14r.			

H15. How happy are you with the access to health facilities in your locality? /___/

(Choose the number corresponding to the answer given by the respondent)

1.Very happy	2.Happy	3.Okay	4.Unhappy	5.Very unhappy

H16. How happy are you with the access to education facilities in your locality? /_____/
(Choose the number corresponding to the answer given by the respondent)

1.Very happy	2.Happy	3.Okay	4.Unhappy	5.Very unhappy

H17. How happy are you with the access to electricity facilities in your locality? /_____/
(Choose the number corresponding to the answer given by the respondent)

1.Very happy	2.Happy	3.Okay	4.Unhappy	5.Very unhappy

H18. How happy are you with the access to paved road facilities in your locality? /_____/
(Choose the number corresponding to the answer given by the respondent)

1.Very happy	2.Happy	3.Okay	4.Unhappy	5.Very unhappy