Climate Change Impact Assessment and Disaster Risk Financing Strategies in Mali: A Comprehensive Analysis of Drought and Flood Events

Abstract

Climate change impact increasingly led to humanitarian assistance increase and needed. To better address climate change impacts mitigation, a suitable financing instrument is essential to facilitate government, humanitarian, and other stakeholders' finance mobilization. However, few studies have been done on disaster risk profiling to guide decision-makers in their choices. Disaster risk profile analysis has been conducted in Mali to facilitate financial resources mobilization and climate finance instrument choice by identifying Historical drought and flood events. To do so, published papers; and some international institution websites dealing with climate hazard events such as Reliefweb, Hazard/risk, climate information services, Relief Web; CRED- EM-DAT; World Bank Climate Knowledge Portal, World Bank- UNDRR - ThinkHazard, WFP ARC/GeoNode/VAM/DataViz addressing Mali country have been assimilated for evidence accumulation and synthesis and presented in a database. Furthermore, national statistics and national reports on hazards have been also reviewed. Before starting the reading exercise, a reading/analytical framework has been elaborated. In Mali the year 1984 to 2019, 21 flood events occurred in Mali and the most exposed regions to floods are Koulikoro, Bamako and Gao. From 1969 to 2020, 21 drought events were registered in in Mali and the most affected regions are Koulikoro, Mopti, Gao, Kayes. The time return period of drought has been estimated to 3 years while the time return of flood has been estimated to be about 2 years. Drought events are less frequent than flood events, however, drought events affect more population than floods. Also, Also, the yearly response cost for drought events is USD million 277.46 with an average US USD 204.37 cost per affected population. For the flood, even the yearly response cost is USD 11.107 million With USD 261.82 per affected population. Macro-insurance and CAT bonds are more suitable disaster risk financing instruments and are recommended to better address drought events while Anticipatory action and government contingency funds are more suitable climate disaster risk financing instruments to better address flood events in Mali.

Keys words: Drought, Floods, climate Insurance, Disaster risk management, climate adaptation

Introduction

Climate change is becoming more and more a major development challenge for humanity. Atmospheric carbon dioxide (CO2) rising is cited as the main factor and cause of global warming and is attributed, in large part, to human activities (Lindzen, 2009; Neya et al,. 2020; Neya et al,. 2023). To address these global challenges, the United Nations Framework Convention on Climate Change (UNFCCC) was created in 1993 by the international community in order to find an inclusive and holistic solution involving countries worldwide. Therefore, UNFCCC recommended its member countries to develop and implement local policies to cope with climate change impacts and to contribute to reducing greenhouse gas emissions to stabilize temperature increases at 2°C, through their National Adaptation Plan (NAP) and their Nationally Determined Contribution (NDC) in the application of Kyoto Protocol 2007, Paris Agreement 2015, Sendai Framework 2015 and Katowice climate package 2018. Despite Africa's limited contribution to global greenhouse gas emissions, it remains the most vulnerable Continent to the adverse effects of climate change. Climate change poses challenges to African countries' on-going efforts to combat poverty, food insecurity and sustainably manage natural resources because standards of living remain low. Droughts and floods have increased in frequency and intensity over the last two decades and adversely impacted food and water security, energy generation and livelihoods. In response to these challenges, African Countries through the African Union adopted the agenda 2063 in 2013 during the 50th Anniversary Solemn Declaration. The main vision of AU Agenda 2063 is "to build an integrated, prosperous and peaceful Africa, driven and managed by its own citizens and representing a dynamic in the international arena" in order to tackle collectively the main impact of climate change.

Mali which is part of African Union, and a member of UNFCCC since 1992, ratified the Kyoto Protocol in 1999, developed and implemented its first adaptation plan in 2007. It developed its first NDC in 2015 to implement AU Agenda 2063 and to contribute to international efforts to overcome climate change effects and to build its resilience through the adoption of social protection policies in the application of Sendai framework. To mainstream climate change in its development policies, Mali adopted a National Policy on Climate Change in 2011, accompanied by the National Climate Change Strategy in 2011. A National Drought Plan 2021-2025 was adopted in 2020 to tackle water scarcity. However, a suitable climate disaster risk financing instrument is essential to mitigate efficiently the climate impact.

2. Method

2.1Country Overview

2.1.1 Geography

Mali is located in western Africa at latitudes of 10 to 25°N, straddling the sub- tropical band called the Sahel with a total land area estimated at about 1.2 million Km^2. The northern parts of Mali reach well into the dry Sahara Desert, while the southern regions experience a wetter, more tropical climate. Seasonal rainfall in Mali is controlled by the movement of the tropical rain belt

(also known as the Inter-Tropical Conversion Zone, ITCZ) which oscillates between the northern and southern tropics over the course of a year and brings rainfall to the southern regions of Mali when it is in its northern position between June and October, peaking in August. The average rainfall in the wettest (southernmost) regions at this time is on average 300mm per year, but rainfall totals diminish rapidly with increasing latitude. In the dry months between November and March, almost no rain falls at all. Variation in the latitudinal movements of the ITCZ from one year to another causes large inter-annual variability in wet season rainfall, which means that Mali suffers from recurring rainfall deficits. The northern, desert regions of Mali receive very little rainfall all year round (Figure 1).

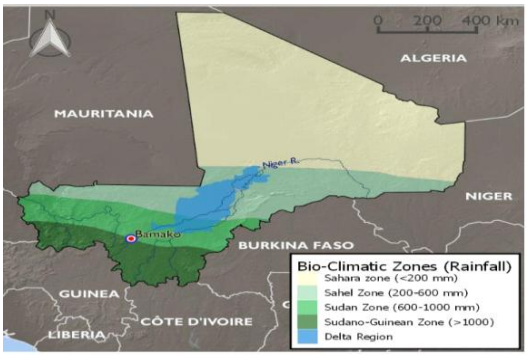

Figure 1: Bio- Climatic zone of Mali Sources USAID 2018

- **Population and Demographics**

The population of Mali was estimated at more than 20 million (20,251,000) in 2020 and is expected to double by 2035, given the current annual demographic growth rate of 3% (World Bank 2019, CIA World 2020; UNFPA 2020). The majority of the inhabitants live in the southern part of the country, mainly due to a hotter and drier climate in the northern Sahel and Sahara region [CIA World 2020]. The average population density is estimated to 16 inhabitants per square kilometer and the fecundity rate has been estimated at 5.8. The population is predominantly young, and the proportion of youth under 25 in the total population more than doubled between 1960 and 2020, from 59.18% in 1960 to 66.89% in 2020. The proportion of youth aged between 5 to 20 increased from 34% in 1960 to 40.31% in 2020. The proportion of

youth aged 15-34 varied between 31% and 33% between 1960 and 2020 (UNFPA 2020). As developing One in eight primary school-aged children do not attend school. Of those enrolled in schools, only one-third are girls (WFP 2021).

- **Economic and Social Prosperity**

Mali is a low-income country with a poorly diversified economy that is highly vulnerable to external shocks and natural disasters. Human Development Index (HDI) in 2018 has been estimated at 0.427 and the country is ranked 184 out of 189 countries (UNDP 2018; FAO et al 2019). The extreme poverty rate declined slightly from 43.4 percent to 41.3 percent between 2017 and 2019 (UNFPA 2020). Since independence, its economic growth has been mostly weak, fragile and erratic. With a real GDP per capita of 794 USD, Mali is one of the poorest countries in the world, counting as a Least Developed Country (LDC) (World Bank 2019). The real GDP growth has remained at almost the same trend before and after the 2012 crisis. Between 2015 and 2017, real GDP growth averaged 5.7 percent. On the other hand, the household consumer price index (base 100 in 2008) increased from 112.2 in 2016 to 114.7 in 2017, representing an annual inflation rate of 1.8% compared to -1.8% in 2016, below the WAEMU standard (3.0% maximum). In the area of public financial management, the budget balance stood at -1.4 percent of GDP in 2017 compared to -2.4 percent in 2016 and -0.90 percent in 2015 (UNFPA 2020). Mali's economy is dominated by the agricultural sector, contributing 38.7% to the country's GDP in 2018, followed by services with 36.9% and industry with 19.1% (World Bank 2018).

- **Food and nutrition security**

The food insecurity situation is still acute in Mali (Table 1). In 201621.9% of households were categorized as moderately food insecure and 3.1% were severely food insecure. These proportions increase to 23.6 and 3.3 percent respectively if Bamako is excluded from the national picture. Food insecurity is much more prevalent in the Gao and Mopti regions, with 35.8% and 27.3% of households moderately food insecure and 6.3% and 3.8% severely food insecure, respectively. The number of food insecure people was estimated at 3.6 million (NUPI 2021; WFP 2021) and 30.4% of children under 5 are stunted (UNFPA 2020; WFP 2021).

Table 1: Food insecurity Rate per region in Mali

Regions	Moderate food insecurity	Severe food insecurity	Vulnerability to food insecurity
Bamako	7.1	1.0	35.4
Gao	35.8	6.3	54.1
Kayes	19.4	1.9	55.0
Kidal	14.5	1.8	69.6
Koulikoro	22.5	2.6	48.1

Mopti	27.3	3.8	53.2
Ségou	22.3	2.9	53.3
Sikasso	21.5	2.2	43.2
Tombouctou	19.4	5.1	65.8
Mean	21,9	3,1	51,0

Sources UNFPA 2020

- **Livelihood strategies used by vulnerable populations**

Mali is physically exposed to adverse weather events resulting from climate change and smallholder farmers and herders are heavily dependent on seasonal rainfall. Smallholder farmers in Mali are increasingly challenged by the uncertainty and variability of weather that climate change causes (Sultan 2013; Traore et al., 2013). The main crops cropped are maize, millet, sorghum and rice (FAO 2020). The main animal species bred are cattle, goats and sheep. Since crops are predominantly rain fed, crop yields depend on water availability from precipitation and are prone to drought. Moreover, the length and intensity of the rainy season is becoming increasingly unpredictable and making smallholder farmers' production more unpredictable FAO 2016). To cope with climate effects, the following coping systems have been developed and implemented by vulnerable population:

- **Pastoral migration**

Agro-pastoralist households in the Sahel often use short-term migration as a livelihood adaptation strategy, but women are less likely than men to travel for short periods. Although women assume household leadership roles, they have limited access to services and alternative livelihood strategies available to men, making them doubly exposed to climate change, food insecurity and malnutrition (NUPI 2021). According to NUPI (2021), pastoral migration seems to be an important adaptation strategy in Mali and the Sahel region, requiring climate-sensitive policy responses that consider the needs of pastoralists and farmers alike – particularly in areas experiencing increasing in-migration and intensive resource use. Malian government and its partners are trying to develop policy frameworks for responding to changing migration and mobility patterns, to support climate mitigation and adaptation strategies that reinforce the resilience of farming and herding communities and prevent violent conflict.

- **Climate Smart Agriculture Practices**

The most Climate Smart Agricultures practices developed in Mali are : (i) introduction of new cropping systems; (ii) strengthening early warning systems to help farmers make use of agro-meteorological information;(iii) increasing the use of improved varieties that are adapted to local conditions, (iv) using new agricultural technologies (soil and water conservation), (v) diversifying agricultural production, (vi) improving access to credit for agricultural activities; and securing water for agriculture through the building and maintenance of wells, (vii) digging

of canals to irrigate more land and cleaning of canals that have been filled with sand, and (viii) constructing new irrigation schemes based on water (NAPA 2007; GFDRR 2011). According to FAO 2017 the use of irrigation facilities remains limited despite Mali's considerable irrigation potential of approximately 566 000 ha (1.4 % of the national crop land) and, only 30 % of that potential is irrigated. However to cope with energy issue, improved stoves, replacing charcoal with gas for cooking, improving coal production efficiency, and regulating charcoal markets are promoted (NAPA 2007; GFDRR 2011).

- **Support to food-insecure vulnerable households**

The venerable are something supported to cope with food insecurity through the development or rehabilitation of productive, natural or social assets, the intensification and diversification of livelihood activities and improved access to markets, using an integrated, gender equitable and participatory community approaches (WFP 2021).

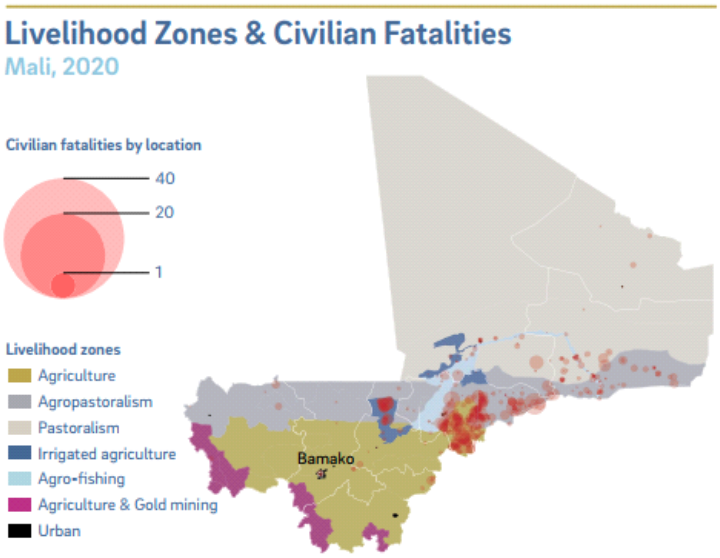

Figure 2: livelihood zone and civilian fatalities

2.2 Historical drought events identification

For Drought event identification, published papers; and some international institution website dealing with climate events such as OCHA through Relief Web, Hazard/risk, climate information services, Relief Web; CRED- EM-DAT; World Bank Climate Knowledge Portal, World Bank-UNDRR -ThinkHazard, WFP ARC/GeoNode/VAM/DataViz website addressing Mali country have been assimilated for evidence accumulation and synthesis and presented in a database. Furthermore, national statistics and national reports on hazards have been also being reviewed.

Before starting the reading exercise, a reading/analytical framework has been elaborated. The analytical framework provides a means to incorporate key information pertaining to the drought Risk Profile such as drought year, drought manifestation weather is meteorological, agricultural or hydrological, drought frequency, drought covered area or zone, Socio-economic impacts and Response cost if applicable.

In addition to a literature review, rainfall data per given drought event year were collected for a better understanding of drought events and have been analysed in order to sustain the information's recorded through literature review using country rainfall data if available or using recent advances in open data, remote sensing and geospatial cloud-based processing solutions such as Google Earth Engine (GEE) that provides a number of benefits for the processing of high resolution, temporal big climatic, environmental and demographic spatial data.

For impact modeling purpose, Africa RiskView model was also used to model the impacts of drought, and the outputs are presented in terms of annual averages rather than absolute modelled estimates to compare with found results. Thematic maps are also presented showing the impacts of the specific drought at the administrative level such as province, district, county, and department, as applicable. Also, a stocktaking of key data and information derived from national agriculture statistics have been carried out as a means to highlight the impacts of drought on agriculture production over time in order to sustain the information's found with Africa RiskView.

For risk metric purposes, Average Annual Population (AAP) affected and Average Annual Losses (AAL) for Mali have been estimated and presented in graphic format for comparative purposes using Africa RiskView model. To highlight gender, population affected has been disagreed by gender (male/female).

Country technical experts of Mali in different sectors within the government, UN, academia, non-state actors, among others have been involved to collate and harmonize information and data. Finally, countries Technical Working Groups have been involved to validate the DRP.

2.3. Historical Flood Events Identification

For Flood event identification, published papers; and some international institution websites dealing with climate events such as OCHA through reliefweb, Hazard/risk, climate information services, CRED- EM-DAT; World Bank Climate Knowledge Portal, World Bank- UNDRR - ThinkHazard, WFP ARC/GeoNode/VAM/DataViz website addressing Mali country has been assimilated for evidence accumulation and synthesis and presented in a database. Furthermore, national statistics and national reports on climate hazards have been also reviewed. Before starting the reading exercise, a reading/analytical framework has been elaborated. The analytical framework provides a means to incorporate key information pertaining to the flood Risk Profile

such as flood year flood manifestation whether is river flood, flash flood or urban flood, flood frequency, flood-covered area or zone,

In addition to literature review, rainfall data per given flood event year were performed for a better understanding of flood events and have been analysed in order to sustain the information's recorded through literature review using country rainfall data if they are available or using recent advances in open data, remote sensing and geospatial cloud-based processing solutions such as Google Earth Engine (GEE) that provides a number of benefits for the processing of high resolution, temporal big climatic, environmental and demographic spatial data.

For flood hazard impact and risk metric assessment purposes, the damages and losses value method has been used using local price value and if there is a lack of information about those values similar values used from other countries have been applied in order to estimate the damage or losses value. For instance, the number of populations affected, homeless, injury, deaths, livelihood affected (loss of animal, crops area per type of crop), and habitat losses caused by flood have been recorded and estimated their monetary value.

Country technical experts of Mali in different sectors within the government, UN, academia, and non-state actors, among others have been involved to collate and harmonize information and data. Finally, country Technical Working Groups have been involved to validate the DRP.

2.4. Climate disaster Risk financing Instrument choice

For suitable climate disaster risk financing instrument choices the time return of each has been estimated and compared. Also, the population affected per hazard has been estimated and compared. The hazard which had time return less than two years and less affected population will fil within Anticipatory Action and contingency plan. Those hazards with time returns greater than three years and highly affected populations suited to macro-insurance mechanism.

3.RESULTS AND DISCUSSION

- **Drought Hazard**

- **Exposure**

Drought hazard event analysis shows that from the year 1969 to 2020, 21 drought events have been registered in in Mali. The least exposed regions to drought are Bamako and Sikasso with six drought events registered while the most affected regions are Koulikoro, Mopti, Gao, Kayes with over 21 drought events registered (Figure 3). The main drought events are meteorological

and agricultural drought (Early Warning System).

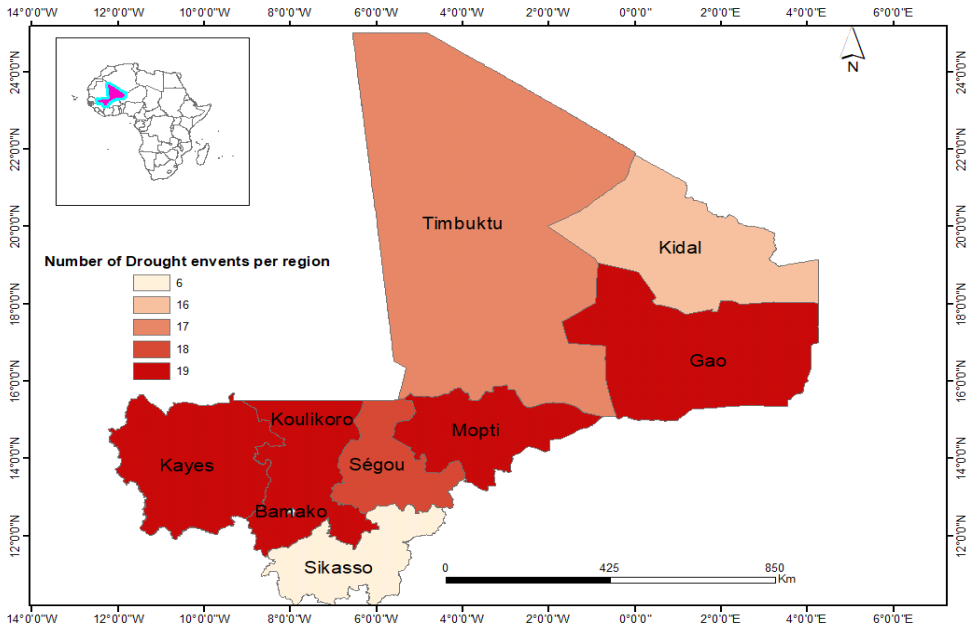

Figure 3: Number of drought events by region in Mali from 1969 to 2020

Analysis of the occurrence of drought events in Mali reveals that the time of return of drought events is around 2.4 to 3 years. This implies that Mali is exposed to a drought event every three years and it faces around three drought events each decade. However, the most exposed regions are Koulikoro, Mopti, Gao, Kayes with 90.47 % to be affected by drought events respectively, Segou with 85.71% Tombouctou with 80.95% chance; Bamako and Sikasso with only 28.57 % chance that drought occurred respectively.

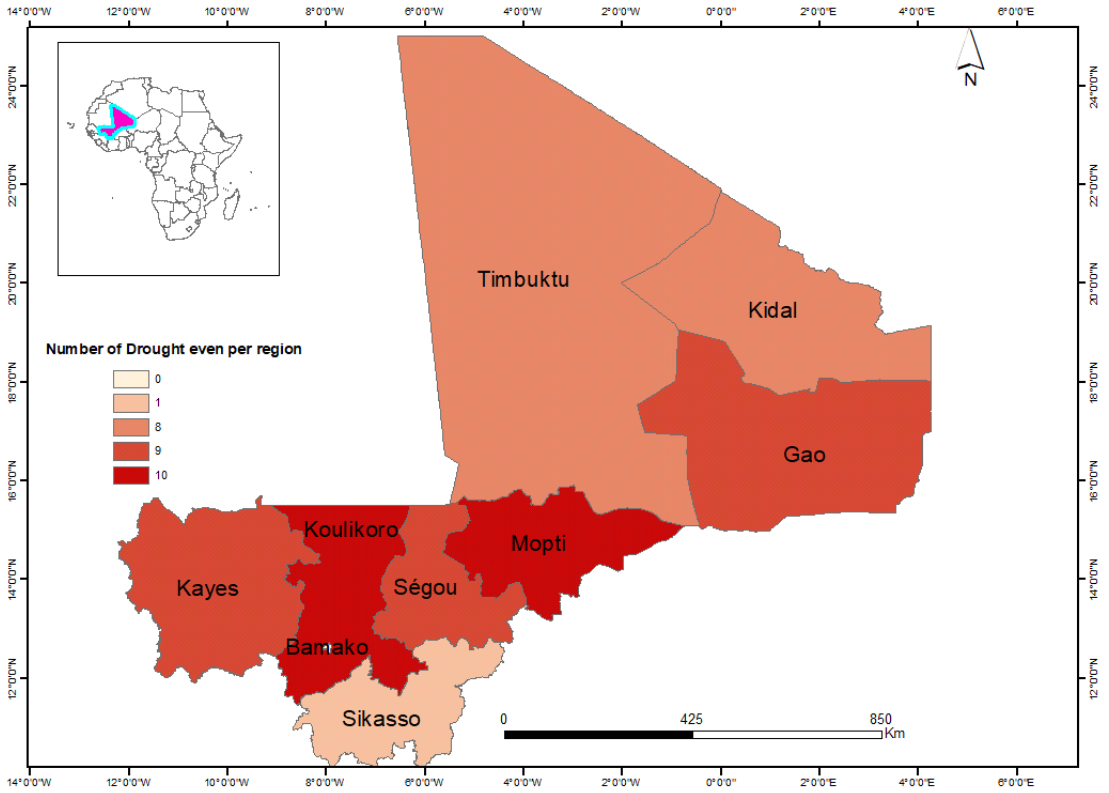

Figure 4: Number of drought event/frequency per Region from 2010 to 2020 in Mali

- **Vulnerability to drought**

The return period of drought in Mali of 1 in every 3 years implies that Mali is extremely vulnerable to drought. Also, the last decade year's drought event analysis in Mali from 2010 to 2020 revealed 11 drought events meaning that for each year drought event has occurred and the most exposed regions still remain the same (Figure 4). These frequent droughts affect food production and make Mali very vulnerable to food insecurity given that most of the active populations are small farmers, herders and their farming is predominantly rain fed.

- **Historical affected Population**

From 1969 to 2020, twenty one drought events have been recorded and affected an estimated population of 21 million, with an average of close to one million people affected yearly (Figure 5).

Figure 5: Affected population of Drought events from 1969 to 2020 in Mali

However, from 2010 to 2020 eleven droughts even are been recorded and affected around 14.9 million people in total with an average affected population of 1357630 yearly (Figure 6).

Figure 6: Affected population of Drought events from 2010 to 2020 in Mali

- **Risk Matrix and modeled cost of drought impact**

The total yearly average affected populations by drought is 1357630 and according to Mali country meter consulted in 18/2/2021 the population is composed to half percent of men and women so mathematically 678815 men and 678815 women were affected. This mean that Mali should be prepared yearly to assisted 1357630 peoples that will be exposed to food insecurity. According to Mali government the yearly need in Cereal per inhabitant is estimated to 327kg in 2016 and cereal price per kg has been estimated by FAO 2020 at 312.5 CFA/ USD 0.625 given the cost of response per drought event synthesis by Figure 7.

Figure 7: Cost response per drought event cereal acquisition without logistic costs

The risk Matrix analysis reveals a yearly response cost of US million 277.46 so an average US 204.37 cost per affected population. That means Mali will spend each year more than USD 277.46 million yearly to assist affected populations by drought events when taking into account other costs such as logistic costs, staff costs and stored cost

3.2. Flood Hazard

- **Exposure**

Flood hazard event analysis shows that from the year 1984 to 2019, 21 flood events have occurred in Mali and the most exposed regions to floods are Koulikoro, Bamako and Gao with 12, 11 and 10 flood events experienced respectively, over the 21 year period (Figure 8)

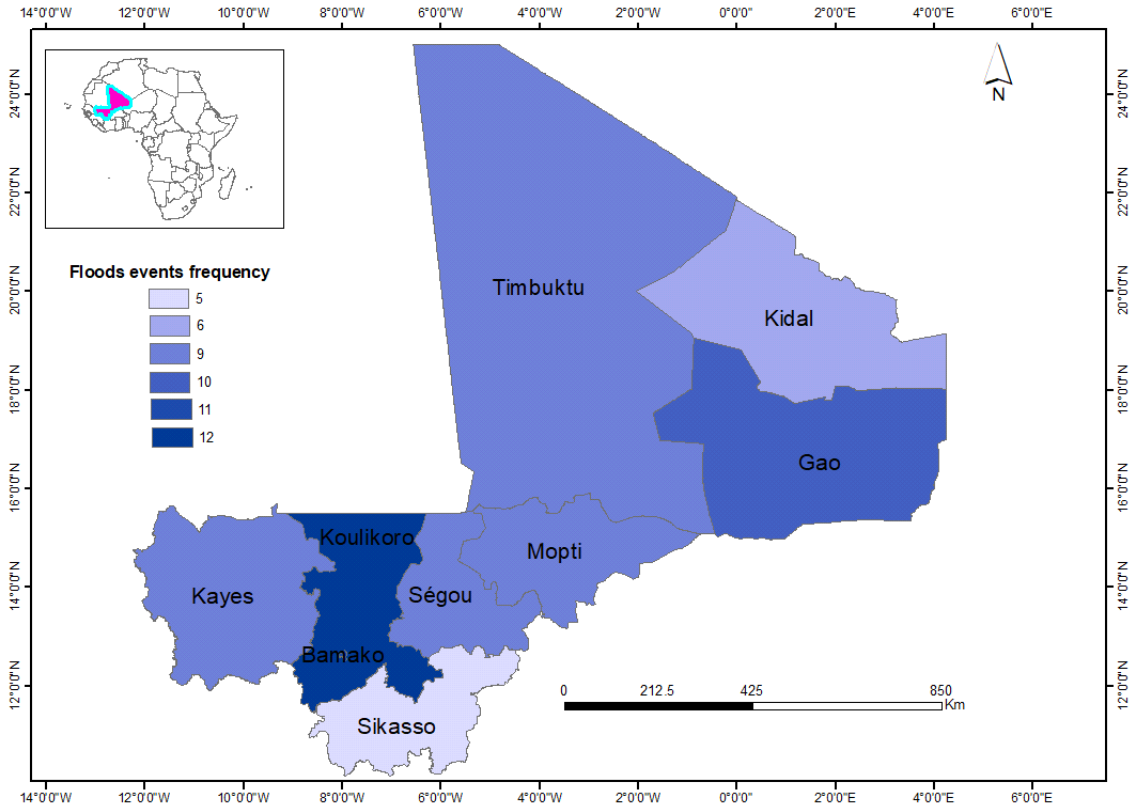

Figure 8: Number of flood year event occurred per Region in Mali from 1988 to 2019

Flood event analysis reveals that Mali experiences a flood every 1.4 to 2 years. It means that, every two (2) year Mali is exposed to flooding events. However, the most exposed region are Gao, Bamako and Tombouctou, with 47% ; 52% and 57 % respectively of chance being affected by occurred flood events. However, the last decade year's flood event analysis in Mali from 2010 to 2020 revealed 9 flood events meaning that for each year flood event has occurred and the most exposed regions are Bamako, Tombouctou, Kidal Gao, and Mopti, with 55.55 % to be affected by occurred flood (Figure 9).

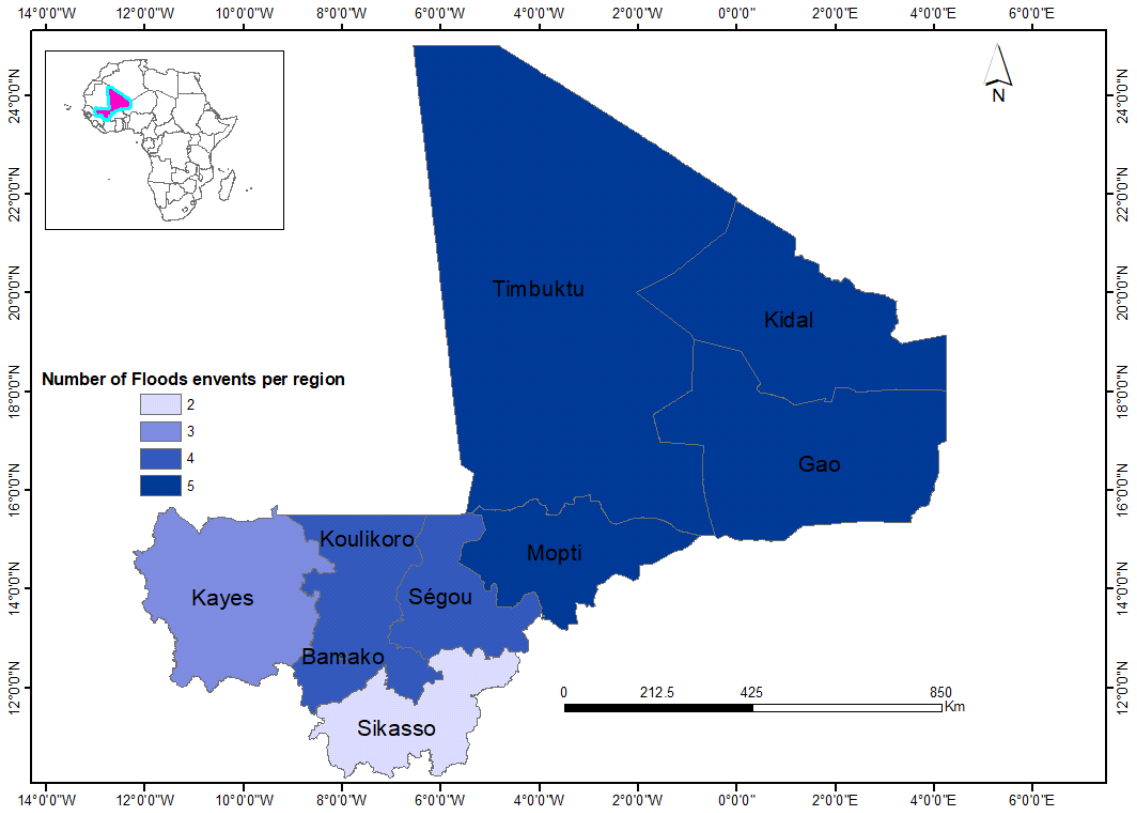

Figure 9: Number of flood event per Region from 2010 to 2019 in Mali

- **Vulnerability**

The time of return/frequency of flood year events is estimated about 2 year is less than 10 years of return time making Mali more vulnerable to flood events. That will affect more people and making their livelihood more vulnerable given that most of the active populations are small farmers and herders. According to GFDRR /ThinkHazard 2020 floods events are expected to occur at least once in the next 10 years and will increase in the future due to the effects of climate change.

- **Historical affected population and type of impacts**

From 1988 to 2019 flood events in Mali affected an average of 42423 populations, with 5689 homeless, 15 death, 2615 animals' loss and 2104 ha cropping area (Figure 10). While the most flood events with the most impacts are the flooding from year 2013 year 2018 and 2007 with 458475 affected populations; 137000 affected populations and 88858 affected populations respectively (Figure 10 , 11)

Figure 10: Affected population and type of damage occurred from 1988 to 2019 by flood event in Mali

From 2010 to 2019 the nine (09) flood events recorded affected in total 706965 people and caused an average of 5766 homeless and 27 deaths with high animal loss in 2016 (Figure 11)

Figure 11: Affected population and type of damage occurred from 2010 to 2019 by flood event in Mali

- **Risk Matrix and modeled cost of drought impact**

The total yearly average affected populations by flood are 42423 and the total yearly average homeless is 5689. According to Mali country meter consulted in 18/2/2021 the population is composed of 50% men and women so mathematically 21211 men and 21212 women were affected, and 2844 men and 2845 women are homeless. This mean that Mali should be prepared yearly to assist 42423 people who will be exposed to food insecurity and 5689 homeless to be assisted with shelters. Also According to the Mali government, the yearly need for Cereal per inhabitant was estimated to 327kg in 2016 and cereal price per kg has been estimated by FAO 2020 at 312.5 CFA/ USD 0.625 given the cost of response per flood event including the other damages cost (animal , deaths, shelters crop area loss) in the Figure 12.

Figure 12: Response Cost per flood event without logistic cost

The risk Matrix analysis reveals a yearly response cost of US million 11.107 so an average US$ 261.82 cost per affected population. That means the Government of Mali will spend each year more than US million 11.107 each year to assist the population affected by flood events when taking into account other costs such as logistics cost, staff cost and other costs.

CONCLUSION

Between the year 1984 to 2019, 21 flood events have occurred in Mali and the most exposed regions to floods are Koulikoro, Bamako and Gao. From 1969 to 2020, 21 drought events were registered in Mali and the most affected regions are Koulikoro, Mopti, Gao, Kayes . Time return period of drought has been estimated to be 3 years while the time return of flood has been estimated to be about 2 years. Meaning that flood events are more frequent in Mali than drought. The total yearly average affected populations by drought is 1 357 630 people while the total yearly average affected populations by flood events is estimated at 42 423 people. Drought

events are less frequent than flood events, however, drought event affect more populations than floods. Also, the yearly response cost for drought events is US D million 277.46 with an average US USD 204.37 cost per affected population. For floods, the yearly response cost is USD 11.107 million, with USD 261.82 per affected population. That means the Mali government will spend each year more than US D million 288.567 to assist the population affected by drought and flood events when taking into account, other costs such as logistics cost, staff cost and storage costs. Given that drought occurs every four years and flood occurs every two years enables us to state that Macro-insurance and CAT bonds are more suitable for drought and Anticipatory action is more suitable for floods in Mali.

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