ADAPTING TO CLIMATE RISKS IN THE SAHEL: STRATEGIES FOR SMALLHOLDER FARMERS IN NIGER

A Project Paper

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Master of Professional Studies in Global Development

by

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ABSTRACT

This project discusses the impacts of climate change on agriculture in Niger, a country highly vulnerable to climate risks. Agriculture, which significantly contributes 40% to Niger's GDP and employs over 80% of the population, faces severe challenges from recurring droughts, floods, and rising temperatures. These climate risks jeopardize crop yields, livestock productivity, and food security, exacerbating existing issues of malnutrition and poverty. The project reviews current adaptation practices, such as land restoration and crop diversification, and finds them insufficient for the scale of challenges. It proposes strategies including improving cropping systems with climate-resilient varieties, enhancing water management through rainwater harvesting and small-scale irrigation, and implementing conservation agriculture. The project also advocates adopting agroecological approaches and strengthening livestock systems through diversification, transhumance, breed improvement, and climate risk insurance. To build more climate-resilient agriculture, it highlights the need for increased investment, better climate information access, and stronger institutional support and partnerships.

BIOGRAPHICAL SKETCH

Oumar Issoufou Adamou is an MPS (Master of Professional Studies) candidate in Global Development at Cornell University, specializing in climate change and food security within the Sahel region. Hailing from the Republic of Niger, Oumar has focused on addressing the impact of climate change on food production systems for underserved communities in his home region. Before joining Cornell, Oumar gained considerable experience with government newspapers *Le Sahel* and *Sahel Dimanche*. He played a key role in data collection for a World Bank-funded initiative on social safety net programs in rural Niger, which sharpened his analytical skills and strengthened his commitment to socio-economic improvement. Oumar's passion for international development began in early childhood and was further fueled by his volunteer work with Population Services International (PSI). There, he engaged with communities on health issues, mobilized youth on sexual and reproductive health, and collaborated with local leaders to turn knowledge into impactful projects. His article, "Maternal and Child Health: Low Awareness of Danger Signs during Pregnancy," earned recognition in UNICEF's Neonatal and Child Health Media Competition in November 2022. Oumar participated in a Climate Change Journalism Fellowship Program in Accra, Ghana that enriched his understanding of vulnerabilities and adaptive strategies in sub-Saharan Africa's agricultural systems. As the 2023–24 Bouriez Family Fellow, Oumar is committed to advancing research and solutions that address climate change and food security challenges in the Sahel. His capstone project focuses on innovative strategies to enhance food production systems amidst climate variability. Oumar's vision extends beyond academia. He aims to empower communities, promote socio-economic growth through climate adaptation, and contribute to sustainable development in Africa and beyond.

To my family, whose unwavering support and belief in my dreams have been my greatest strength. Your encouragement has been the fuel of my journey.

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TABLE OF CONTENTS

LIST OF ABBREVIATION

3N	Nigerien Nourish Nigerien (Initiative)
ANADIA	Niger Flood Database
CA	Conservation Agriculture
CILSS	Permanent Inter-State Committee for Drought Control in the Sahel
CNEDD	National Environmental Council for Sustainable Development
EPER	Crop Forecasting and Estimation Survey
FAO	Food and Agriculture Organization
FEWS NET	Famine Early Warning Systems Network
FMNR	Farmer-Managed Natural Regeneration
GDP	Gross Domestic Product
IBLI	Index-based Livestock Insurance
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
ILRI	International Livestock Research Institute
INRAN	National Institute of Agronomic Research of Niger
INS	National Institute of Statistics
IPC:	Integrated Food Security Phase Classification
IPCC	Intergovernmental Panel on Climate Change
IPDR	Practical Institute of Rural Development
MAGEL	Ministry of Agriculture and Livestock
OCHA	United Nations Office for the Coordination of Humanitarian Affairs
PNA	National Plan of Adaptation
RWH	Rainwater Harvesting
SAC	Specialized Support Services
SPIN	Small-scale Irrigation Strategy in Niger
SPN2A	National Strategy and Plan for Adaptation to Climate Change in the Agricultural Sector
UBT	Tropical Livestock Units
UNDP	United Nations Development Program
USAID	United States Agency for International Development

Chapter I: The Sahel Region and its Vulnerabilities

1.0 Introduction

The Sahel region is increasingly vulnerable to the impacts of climate change, facing unprecedented challenges that exacerbate existing environmental and economic pressures in this vast semi-arid belt stretching from Senegal to Sudan. This chapter aims to provide a comprehensive understanding of the climate-related challenges in the Sahel by analyzing current trends and future projections. Such understanding is essential for guiding discussions on adaptive strategies and resilience-building measures in subsequent sections.

Changes in the atmosphere, including higher carbon dioxide levels, rising temperatures, and increased tropospheric ozone, pose significant challenges to agricultural practices. These changes threaten global food production, heighten concerns about food security, and affect long-term sustainability (Deryng, 2020). According to the Intergovernmental Panel on Climate Change (IPCC), the Sahel region is particularly vulnerable to climate change impacts. Over the last six decades, this semi-arid region in Africa has experienced rising temperatures and shifting rainfall patterns (Nassah et al., 2022). Devastating droughts in 1973-1974 and 1984 resulted in famines in the Sahel, underscoring the region's susceptibility to climate-induced crises. Since then, varying rainfall patterns have continued to challenge agricultural activities. Projections suggest that rainfall variability in the Sahel will increase; exacerbating existing difficulties in farming practices (Bacci et al., 2020). The Sahel encompasses nine countries: Mauritania, Senegal, The Gambia, Guinea-Bissau, Mali, Burkina Faso, Niger, Chad, and Cabo Verde. However, the boundaries of the Sahel are not strictly defined and may include additional countries such as Sudan or northern parts of Ethiopia, depending on the source or context (Sissoko et al., 2011).

1.1.Research Objectives

The primary goal of this project is to comprehensively assess the climatic risks to agriculture and livestock in Niger, with a focus on both crop production and animal husbandry by smallholder farmers. The project will explore the coping mechanisms employed by smallholders to mitigate the impacts of climate variability on both crops and livestock and investigate alternative strategies from other Sahelian regions or similar agroecological contexts that could be adapted to Niger. Specifically, the project aims to develop adaptation strategies tailored to the needs of smallholder farmers, who are particularly vulnerable to climate variability due to limited access to resources, technology, and information. By equipping farmers with effective adaptation approaches, the project seeks to improve agricultural output and livestock productivity, strengthen resilience against persistent climate change, and contribute to Niger's food security goals.

Addressing food insecurity in Niger, where a significant portion of the population faces chronic malnutrition, is a daunting task. The project will provide resources and guidance for both crop and livestock management while formulating policy recommendations to tackle the complex challenges encountered. Effective strategies may include improved pasture management, veterinary care, and climate-resilient animal breeds. By advocating for evidence-based policymaking and providing targeted adaptation strategies, the project aims to enhance resilience in both the agricultural and livestock sectors and improve overall food security.

This effort will benefit various stakeholders, including the Government of Niger, public sector agencies, non-governmental organizations (NGOs), and development partners working with smallholder farmers. The following chapters will discuss climate risks affecting both agriculture and livestock in Niger, analyzing challenges such as erratic rainfall patterns, prolonged droughts,

soil degradation, and the impacts on pasture and animal health. Drawing on existing literature, the project will explore context-specific adaptation strategies, highlighting successful practices such as water harvesting techniques, drought-resistant crop varieties, sustainable land management practices, improved livestock management, and climate-resilient animal breeds. By integrating scientific research, local knowledge, and policy analysis, the project aims to establish a comprehensive framework for enhancing the resilience of both crop and livestock production in the face of a rapidly changing climate.

1.2. Geography of the Sahel Region

The term "Sahel" comes from the Arabic word "Sahil," meaning "border of the desert." It refers to a region covering approximately 5.4 million square kilometers (Sissoko et al., 2011). The Sahel lies between the arid Sahara Desert to the north and the humid savanna to the south. It stretches from the Atlantic Ocean in the west through northern Senegal, southern Mauritania, the Great Bend of the Niger River in Mali, Burkina Faso, southern Niger, northeastern Nigeria, south-central Chad, and Sudan (Sahel - New World Encyclopedia Britannica Inc., 2024). Geographically, the Sahel spans between latitudes 10° and 20° north. It also encompasses northern Cameroon, the Central African Republic, central and southern Sudan, northern Eritrea, and the far north of Ethiopia, reaching Somalia in the east (Epule et al., 2022). Figure 1 illustrates the Sahel region's boundaries.

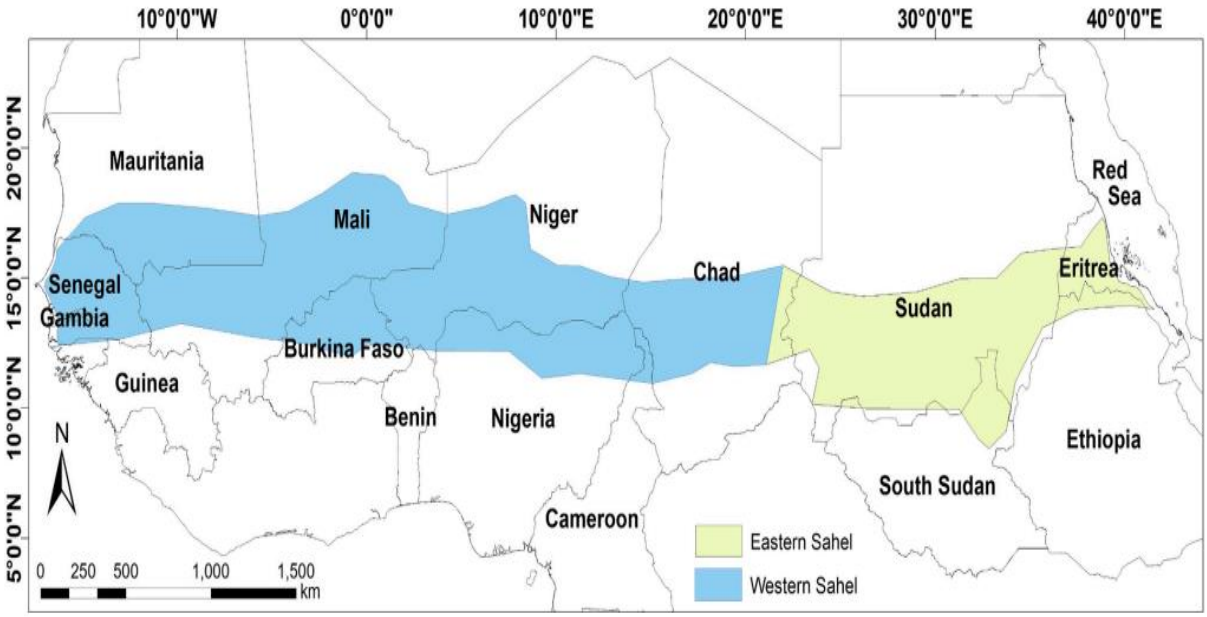

Fig.1. Map of the Countries Encompassing the Sahel Region
Source: Elagib, et al. (2021)

This project focuses on climate change issues and vulnerabilities in the Sahel, with particular emphasis on Niger. Niger, as one of the nine countries in the Permanent Inter-State Committee for Drought Control in the Sahel (CILSS), serves as a case study. Around 84% of Niger's population resides in rural areas, heavily dependent on rain-fed agriculture, which exposes them to climate-related risks. Furthermore, 89% of Niger's population experiences multidimensional poverty, including challenges related to health, education, and living standards, as indicated by the UNDP's Multidimensional Poverty Index (Bacci et al., 2020). The interplay of irregular rainfall and pervasive poverty worsens food insecurity within rural communities. According to Bacci et al. (2020), unpredictable rainfall patterns, exacerbated by climate change, significantly amplify this challenge. The Sahel region is susceptible to natural disasters such as droughts, floods, and extreme weather events, resulting in substantial economic losses and impacting vulnerable populations. During the latter half of the 20th century, human actions—such as deforestation and overgrazing—played a role in soil erosion and desertification (Coly et al., 2023; NourEldeen et al., 2020; Encyclopedia Britannica Inc., 2024). The unique geography of the

Sahel makes it especially vulnerable to recurring droughts, which pose significant challenges to the region.

1.3. Recurring Droughts Present Significant Challenges

In the last century, the Sahel experienced significant drought episodes causing devastating effects across the region from Senegal to Chad. By 1973, parts of the Sahara encroached southward by about 100 km (60 miles), resulting in an estimated 100,000 deaths from starvation and disease. Severe drought and famine struck the Sahel again from 1983 to 1985, with desertification continuing despite governments' reforestation efforts (CILSS, 2023). In 1984, an extreme drought had catastrophic consequences, leading to a rainfall decline of over 70%. Consequently, in 1985, West Africa's largest river, the Niger River, ceased flowing, reaching critically low levels. Certain sections, including Kennedy Point, became so shallow that they could be crossed on foot—an unprecedented occurrence (CILSS, 2023). Additionally, between 2016 and 2020, over 20 million people faced food insecurity and economic challenges due to droughts, leading to rural migration as urban areas struggled to provide sufficient economic opportunities (World Bank, 2022).

Figure 2 illustrates the annual precipitation in Niger from 1901 to 2022, highlighting significant fluctuations and trends over this period. The data reveal considerable variability in annual precipitation, with some years experiencing significantly higher rainfall than others do. For instance, 1922 marked a peak year for precipitation, while 1984 witnessed one of the lowest rainfall levels, emphasizing the Sahel region's vulnerability to climatic changes and extreme weather events (World Bank, 2024). The annual precipitation in Niger ranges between 100 mm and 350, which is relatively low compared to other tropical countries, even within the Sahel region.

For instance, Mali and Chad both receive between 200 and 700mm of rainfall, while Burkina Faso's average annual precipitation ranges from 700 to 900mm (World Bank, 2023).

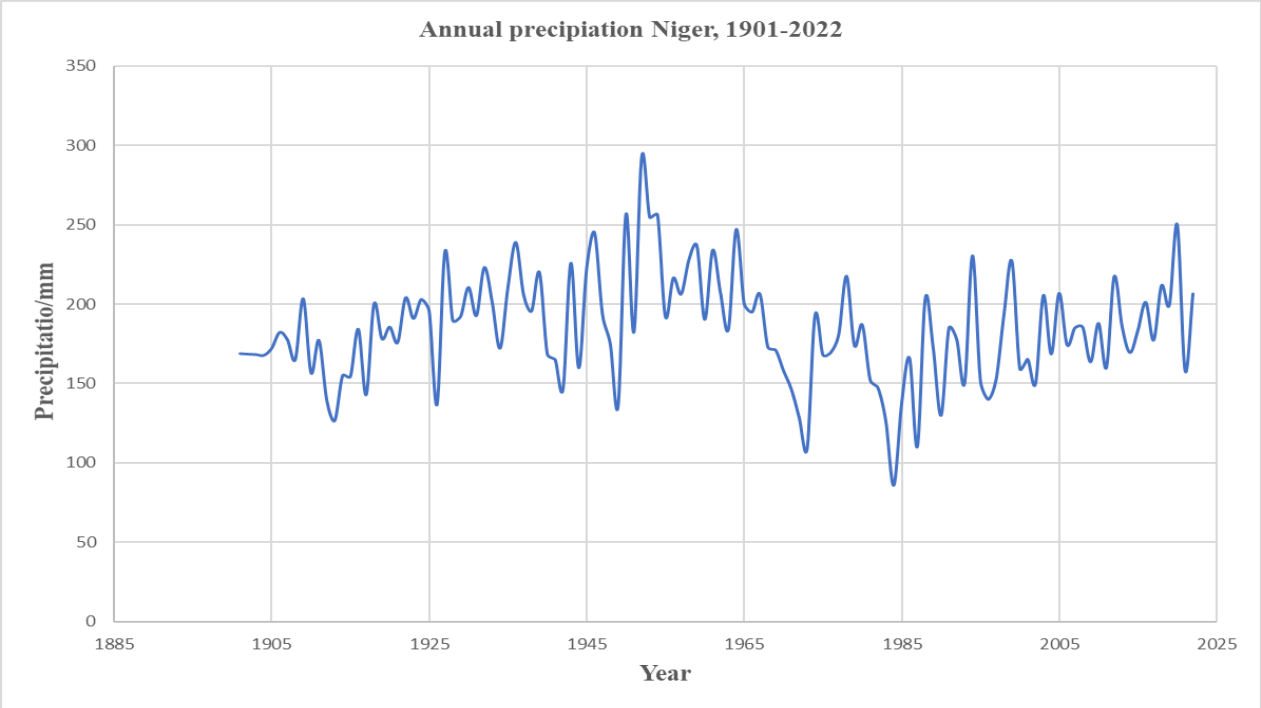

Fig.2. Annual Precipitation Observed in Niger from 1901-2022
Source: https://climateknowledgeportal.worldbank.org/country/niger

1.4. Flooding in the Sahel: Increasing Challenges and Impacts

Over the past few decades, the Sahel region has experienced an increase in flood occurrences, averaging approximately 10 incidents per year since the late 1990s. During the 2000s, a significant rise in natural disasters affected over 100,000 people in various areas due to climate change and population growth (Africa Renewal, 2013). In 2019, floods in Sudan affected 426,300 individuals, resulting in 78 deaths and extensive damage to residential properties. In Niger, during the same year, intense rainfall and subsequent flooding affected over 200,000 people. The Sahel region faced massive flooding in 2020, leading to significant losses and property damage. Chad was particularly affected, with hundreds of thousands of displaced individuals and damage to

cropland (Elagib et al., 2021). Figure 3 illustrates the varying impacts of floods across Sahel countries. Sudan was the most severely affected, with approximately 870,000 people impacted, 82,000 houses destroyed, and 160 flood-related deaths. Niger and Nigeria also faced significant effects. Although Chad had a high number of affected people, it experienced lower infrastructure damage and casualties, indicating different flood characteristics or response capacities across countries. Meanwhile, Burkina Faso, Mali, Mauritania, and Senegal showed notably lower impacts overall. These disparities underscore the need for tailored flood management strategies and further research into the factors contributing to these varied impacts.

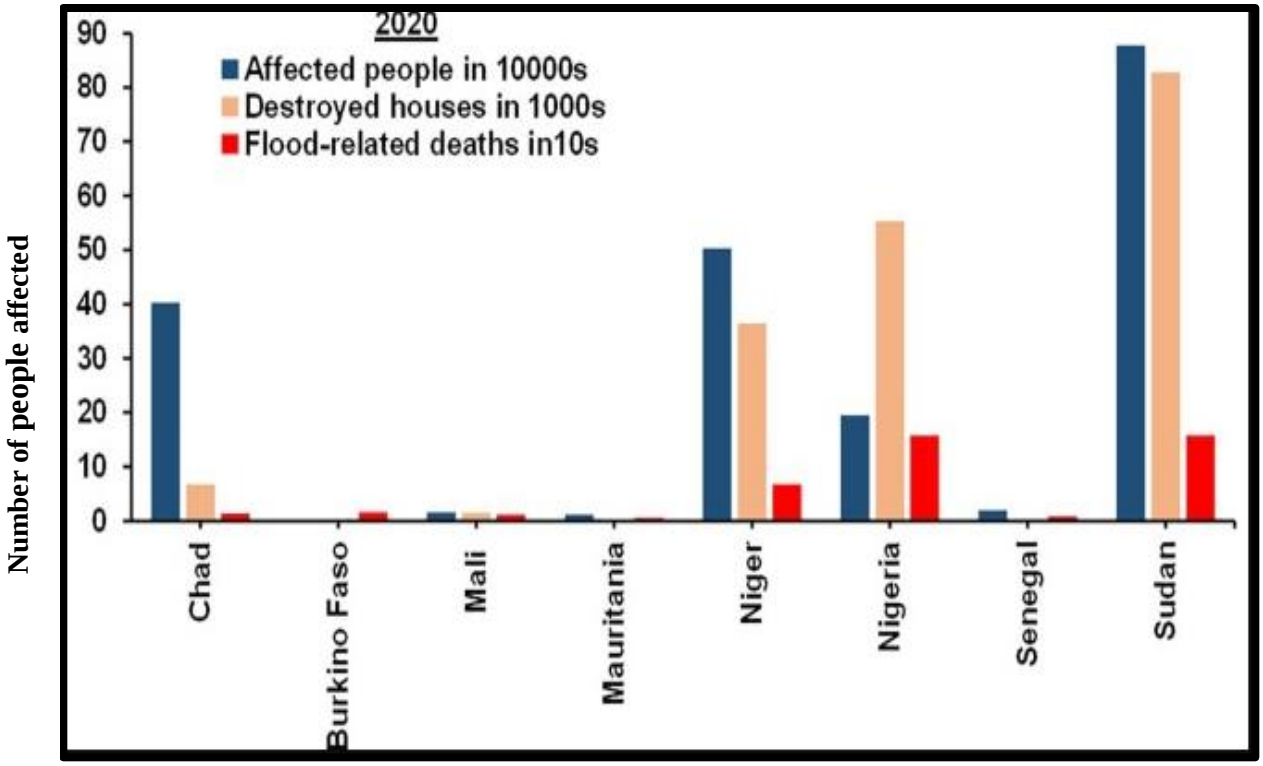

Fig.3. Flood Impacts on People and Houses
Source: Elagib et al. (2021)

On average, floods have affected approximately 248,000 people annually since 2000, damaging homes, infrastructure, and essential services (Elagib et al., 2021). The Sahel has also experienced severe multidecadal rainfall variations, with excessive rainfall in the 1950s-1960s followed by two decades of deficient rainfall, resulting in a significant negative trend until the mid-to-late 1980s. During this period, average annual rainfall decreased by 20-30% (Biasutti, 2019). Figure 4 illustrates a marked increase in the number of people affected by drought in Niger from 1900 to 2020, as evidenced by the growing height of the bars.

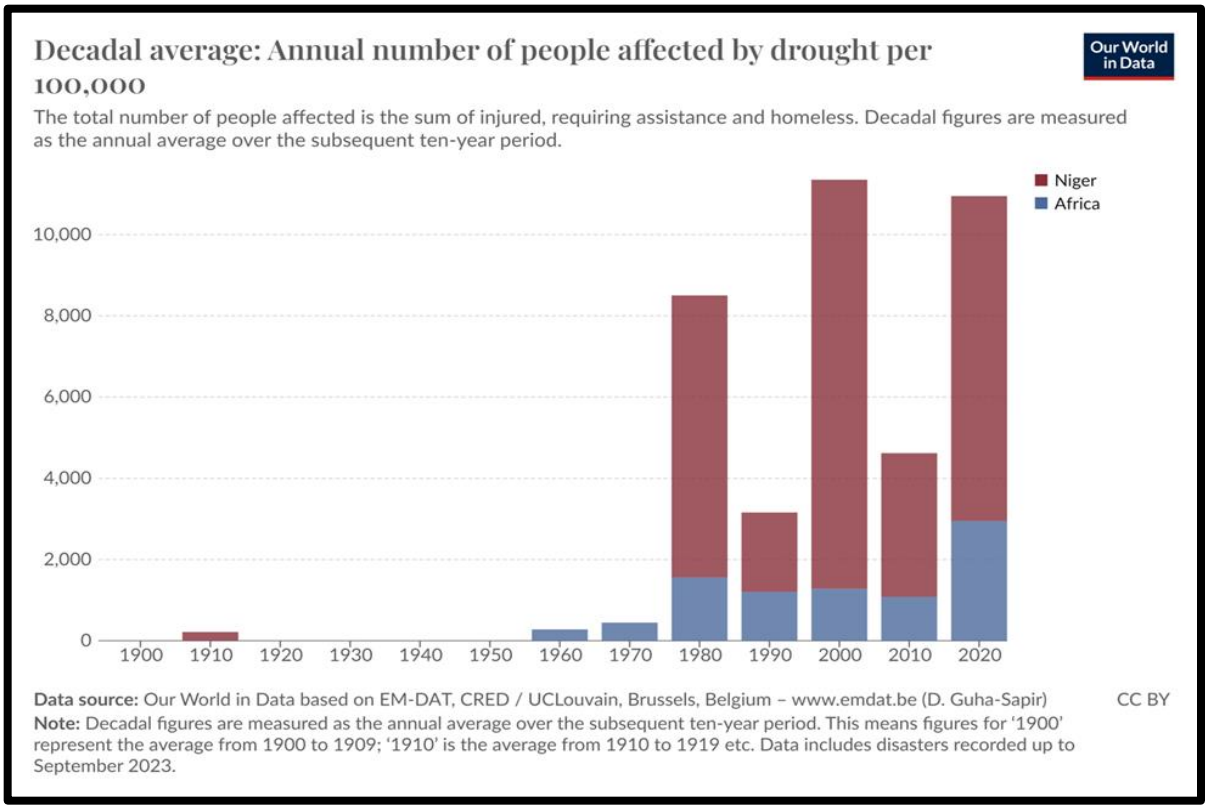

Fig.4. Niger's Increasing Drought-Related Challenges (1900 –2020)

1.5. Climate Change and Future Projections

Amidst the challenges posed by both droughts and flooding, the Sahel region faces an even more daunting and pervasive threat: climate change and its future implications. The G5 Sahel Region, an institutional framework established in 2014 to coordinate regional cooperation in

development and security matters across West Africa, includes countries like Burkina Faso, Chad, Mali, Niger, and Mauritania. This region is highly vulnerable to extreme climate events, as highlighted in the World Bank Country Climate and Development Report (2022). Among the top seven most vulnerable nations globally are Chad (score 0.632), Mali (score 0.596), and Niger (score 0.632). The other four countries highly vulnerable to climate change are Burundi (score 0.558), Central African Republic (score 0.584), Somalia (score 0.678), and Sudan (score 0.601) (Notre Dame Global Adaptation, 2023). These vulnerability scores indicate the significant challenges these countries face in terms of climate resilience, with higher scores reflecting greater vulnerability. The Intergovernmental Panel on Climate Change (IPCC) projects a temperature increase of at least 2°C (3.6°F) by 2040 in the Sahel region, which will exacerbate the ongoing threats from droughts and floods.

Although some rainfall recovery has been observed in recent decades, the characteristics of the rainy season have undergone significant changes, indicating ongoing shifts in the Sahel's climate patterns. The region has experienced a partial recovery of annual rainfall amounts, but new rainfall features have emerged, such as false starts, early cessation of rainy seasons, and more frequent and prolonged dry spells. These changes suggest a complex and evolving climate scenario (IPCC, 2022). Regional climatic trends in the Sahel show a general rise in temperature, coupled with erratic rainfall patterns. This combination of factors leads to many challenges, including desertification, droughts, floods, and environmental degradation, all of which worsen the livelihood challenges in the region and contribute to heightened vulnerability. The frequency and intensity of natural disasters are expected to continue increasing, posing significant threats to the Sahel's environmental stability and the well-being of its inhabitants (Mbaye, 2022).

Warming in the Sahel has led to more extreme heat and rainfall, resulting in reduced yields of 10-20% for millet and 5-15% for sorghum, two major crops in the region (FAO, 2022). These

negative effects on crop yields highlight the significant challenges faced by agricultural systems in the Sahel due to climate change. Furthermore, climate change disproportionately affects vulnerable groups, including smallholder farmers, who are particularly susceptible due to poverty, limited policy support, weak infrastructure, limited credit access, low market opportunities, and limited political representation. These factors contribute to their heightened vulnerability to climate change.

1.6. Socioeconomic Indicators of Some Sahel Countries

Beyond the environmental challenges, the Sahel region also grapples with significant socio-economic disparities that further compound the vulnerabilities of its populations. The socio-economic indicators for Sahel countries are summarized in Table 1 and discussed below. **Population:** Nigeria has the largest population among the listed countries, with over 218 million people. Niger and Sudan also have sizable populations, with approximately 26 million and 47 million people, respectively. Mauritania has the smallest population, with just under 4.74 million people. **GDP per capita (current US$):** Mauritania has the highest GDP per capita at $2,065.20, showing a higher standard of living compared to the other countries. Nigeria and Senegal also show higher GDP per capita figures, at $2,162.6 and $1,598.70, respectively. Niger has the lowest GDP per capita at $585.4, suggesting a lower standard of living. **Poverty headcount ratio at $2.15 a day (2017 PPP) (% of the population):** Niger has the highest poverty rate, with 50.9% of its population living below the poverty line of $2.15 a day. Burkina Faso and Chad also have extreme poverty rates, with 31.2% and 30.9% of their populations living below the poverty line, respectively. Mauritania has the lowest poverty rate at 6.5%, indicating a lower percentage of its population living in extreme poverty. **Unemployment, total (% of total labor force):** Sudan has the highest unemployment rate at 17.6%, highlighting significant economic challenges and a lack of job opportunities. Mauritania follows with a 10.8% unemployment rate. Niger has the lowest

unemployment rate at 0.6%, which may reflect an important level of informal or subsistence employment. **Hunger/people with insufficient food consumption (million):** Nigeria has the highest number of people with insufficient food consumption, with 100.4 million people affected. Niger also has a considerable number of people facing hunger, with 21.4 million people affected. Mauritania has the lowest number of people with insufficient food consumption, at 1.5 million. These indicators reveal significant disparities among the Sahel countries in terms of economic development, poverty levels, and food security. While countries like Mauritania, Senegal, and Nigeria show better economic indicators, they still face challenges such as unemployment and food insecurity. On the other hand, Niger, Burkina Faso, and Chad face more severe issues with extreme poverty, low GDP per capita, and large populations affected by hunger, underscoring the complex socio-economic landscape of the region.

Table 1. Socioeconomic Indicators of some Sahel Countries

Country	Population	GDP per capita (current US$)	Poverty headcount ratio at $2.15 a day (2017 PPP) (% of population)	Unemployment, total (% of total labor force)	Hunger\people with insufficient food consumption (million)
Burkina Faso	22,673,762	830	31.2	5.1%	11.2M
Chad	17,723,315	716.8	30.9	1.1	9.3M
Mali	22,593,590	833.3	15.2	3.1	13.2M
Mauritania	4,736,139	2,065.20	6.5	10.8	1.5M
Niger	26,207,977	585.4	50.9	0.6	21.4M
Nigeria	218,541,212	2,162.6	30.9	3.8	100.4M
Senegal	17,316,449	1,598.70	9.2	3	4.8M
Sudan	46,874,204	1,102.10	15.3	17.6	8.4 M
Average	47,083,331	$1,224.01	23.65%	5.26%	21.275 million

Source: https://data.worldbank.org/ https://hungermap.wfp.org/

Climate change significantly contributes to the food crisis in Niger. For decades, persistent droughts and flooding have accelerated desertification, now affecting between 66% and 77% of Niger's territory. From 2000 to 2012, Niger experienced several years of major agricultural production shortfalls due to these climatic hazards, notably in 2000/2001, 2004/2005, 2009/2010, and 2011/2012. These recurrent shocks have had a long-term impact on the resilience of vulnerable households, weakening their ability to cope with future crises (FAO, 2023). As one of the Low-Income Food Deficit Countries, Niger is experiencing alarmingly high levels of severe food insecurity, with 30.5% of its population facing severe food insecurity in 2021. This dire situation underscores the urgent need for initiatives to address the problem and ensure that everyone has access to a sufficient and nutritious food supply (FAO, 2021).

Chapter II: Climate Risks on Agriculture in Niger

2.0. Introduction

This chapter examines the complex relationship between climate change and agriculture in Niger, a country where agriculture is vital for both the economy and food security. As one of the world's most climate-vulnerable countries (World Bank, 2023), Niger faces significant challenges, including droughts, floods, and desertification. These climate threats undermine the country's efforts to maintain and improve agricultural productivity amid increasing climate variability and extreme weather events. The chapter begins with an overview of Niger's agricultural and livestock sectors, emphasizing their economic significance and the current challenges they face. It then delves into the issue of food security, investigating how climate risks exacerbate existing vulnerabilities. The primary focus is on analyzing the impacts of two major climate threats—droughts and floods—on both crop production and livestock. By exploring these interconnected issues, the chapter underscores the urgent need for adaptive strategies and resilience building within Niger's agricultural sector.

2.1. Overview of Agriculture and Livestock in Niger

Agriculture and livestock are crucial to Niger's economy, contributing 37.36% of GDP in 2019 (CNEDD, 2022). This sector employs over 83% of the working population, approximately 16 million people, as reported by the Crop Forecasting and Estimation Survey (EPER 2020). Millet is the dominant crop, covering 65% of the cultivated area and accounting for 75% of cereal production (SPN2A, 2020–2035). Other key crops include sorghum, rice, and maize, produced primarily for domestic consumption. Figure 5 illustrates the production of millet and sorghum, two

essential staples for Niger's food security, showing their resilience despite challenging climatic conditions.

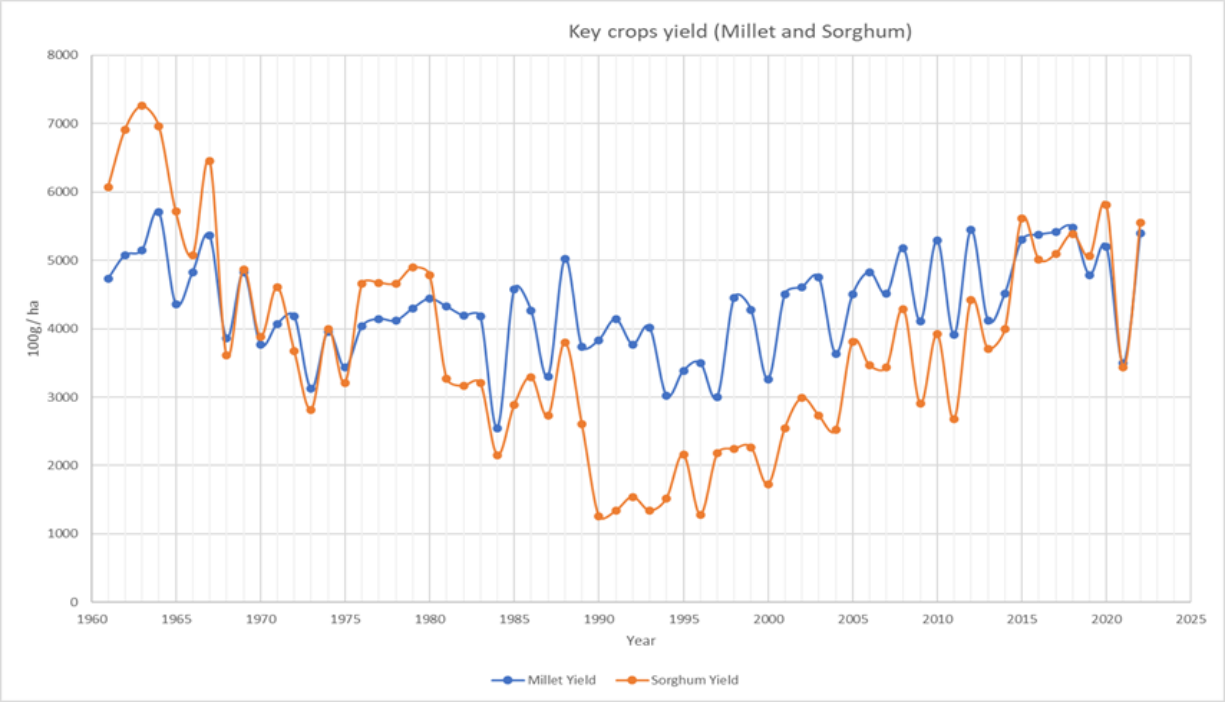

Fig.5. Millet and Sorghum Yields in Niger (1960-2023)
Source: faostat

Cash crops such as groundnuts, sesame, onions, and peppers are primarily destined for export. The cultivable area is estimated at 15 million hectares, which represents less than 12% of Niger's national territory (CNEDD, 2022). Between 2017 and 2020, total agricultural production averaged 6.26 million tons per year, with irrigated production increasing to 15.7% in 2020, thanks to the 3N Initiative (Nigeriens Nourish Nigeriens), a political program established in 2012, which aims to strengthen national capacities for food production, supply, and resilience in the face of food crises and disasters (High Commission for the 3N Initiative, 2021). The low productivity is in part due to the low use of purchased inputs, with only 6% of farmers using improved seeds, 11% applying synthetic fertilizers, and less than 3% utilizing modern soil preparation techniques (CNEDD, 2022). Unpredictable and variable weather conditions present significant challenges for smallholder farmers, raising concerns that rain-fed agriculture in Niger

might vanish by 2100 (World Bank, 2023). From a macroeconomic perspective, agriculture accounts for 27% of GDP in the strict sense and 38% in the broad sense over the 2018–2022 period, according to the National Institute of Statistics (INS, 2023). With 40% of its GDP derived from agriculture, Niger's economy is not well diversified (World Bank, 2024). In 2022, economic growth of 11.9% was fueled by a 25.5% increase in the primary sector, driven by a 35.2% rise in agricultural production following a decline in 2021. Food crops such as millet, sorghum, and rice made up about 60.4% of agricultural production in 2022. However, the yields of these crops remain extremely low and fluctuate due to their dependence on rainfall, as highlighted by the INS. Figure 6 illustrates the production levels of maize and rice, highlighting significant variations. The graph shows a marked improvement in rice production compared to maize, which exhibits more inconsistent outcomes.

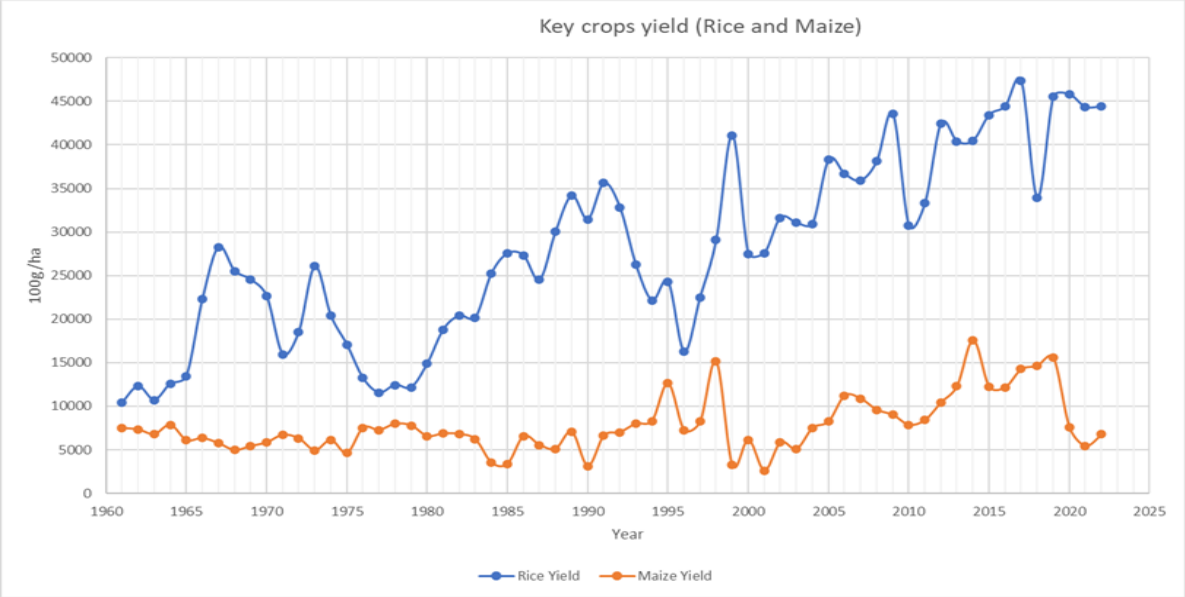

Fig.6. . Rice and Maize Yields in Niger (1960-2023)
Source: faostat

According to the National Strategy and Plan for Adaptation to Climate Change in the Agricultural Sector (SPN2A, 2020) and the National Plan of Adaptation (PNA, 2020), Niger is traditionally a livestock-breeding country, with over 87% of the population engaged in this activity.

In 2020, the national livestock population numbered 52.7 million animals across all species (CNEDD, 2022). Livestock production contributed 8.54% to GDP and 22.23% to the GDP of the primary sector in 2018 (SPN2A, 2020). Livestock products were the second-largest source of export revenue after mining resources, accounting for 21% of exports in 2013 (SPN2A, 2020).

However, local milk production meets only 50% of national demand, as noted in the First Biennial Report (CNEDD, 2022). Despite its economic significance, the agro-pastoral sector faces substantial challenges. It is highly vulnerable to recurrent climatic shocks and droughts (CNEDD, 2022). Pastoral lands, which cover approximately 62 million hectares (SPN2A, 2020), are increasingly threatened by the expansion of agricultural zones and land grabbing. Furthermore, climate change is projected to reduce yields for most rain-fed crops in Niger by 10–20% by 2050 compared to 2020 levels. Rising temperatures will decrease production potential, while erratic rainy seasons and more frequent and prolonged dry spells will disrupt the agricultural calendar (SPN2A, 2020). As illustrated in Figure 7, Niger's cereal sector is struggling to balance production, land use, and yield, affecting livelihoods, nutrition, and environmental sustainability. Against a rapidly growing population, much of the increase in food production has come from converting more wild land into agriculture, while yields have been stagnant. This indicates that more land has been converted into agriculture, but there has been no significant increase in yields.

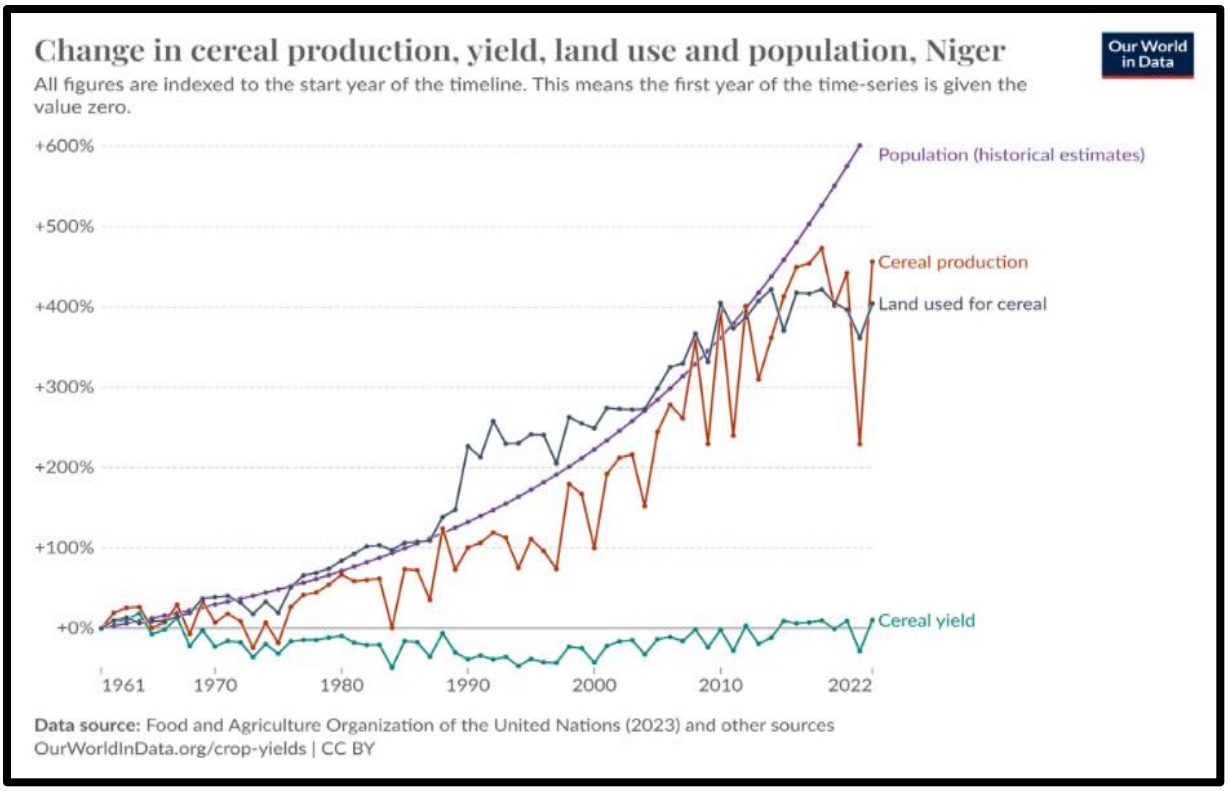

Fig.7. 1. Trends In Cereal Agriculture: Production vs. Land Use vs. Yield (1961-2022)

2.2. Overview of Food Security in Niger

Over Niger's 27.8 million estimated inhabitants, 3.2 million people (around 12%) are acutely food insecure (FAO, 2023). An additional 7.3 million people are at risk of falling into this category of severe food insecurity. Malnutrition significantly impacts Nigerien children under 5 years old, with 47% suffering from chronic malnutrition and over 12% from acute malnutrition in 2022 (WFP, 2022). According to the National Nutritional Security Policy (2017-2025), between 20% and 48% of the population—equivalent to 3 to 7 million Nigeriens—has experienced moderate to severe food insecurity over the past five years. This persistent issue is exacerbated by population growth, low agricultural productivity, soil degradation, and climate change, which result in significant cereal deficits every third year throughout the country in the different regions (National Nutritional Security Policy, 2017–2025). Figure 8 illustrates a detailed map of Niger, highlighting its different regions.

Fig.8. Map Of Niger with the Different Regions
Source: Wikipedia contributors (2024)

Crisis-level food insecurity (IPC Phase 3) persists in the regions of Tillabéri, Tahoua, Maradi, and Diffa due to ongoing security crises disrupting economic activities and trade flows. However, in Maradi and Diffa, food insecurity has been reduced to a stress level (Phase 2) thanks to food aid that covers at least 50% of energy needs for more than 20% of the population. This is not the case in Tillabéri and Tahoua (Fews Net, 2024). The Famine Early Warning Systems Network (FEWS NET) report highlights that security, and socio-political crises hinder local income opportunities and disrupt both domestic and cross-border food product flows. This disruption has led to reduced market supplies and a general rise in food prices: +42% for maize, +36% for imported rice, +34% for sorghum, and +29% for millet over the past five years (Fews Net, 2024). In the pastoral zone, the peak of the lean season has led to depleted pastures and drying

water holes, resulting in a decline in animal conditions. Livestock prices are lower compared to last year and the average of the past five years, with pastoral households' income from livestock sales falling by over 30%, reducing their economic access to food (FAO, 2023). Women and children aged 0-59 months are particularly vulnerable, being the first to suffer from food and nutritional insecurity (FAO, 2023). This situation is contributing to increased rural-to-urban migration, exacerbating the rural exodus.

2.3. Historical Climatic Impacts on Agriculture

Niger has faced droughts, floods, locust invasions, and other parasitic infestations over the past 30 years, which have negatively affected household incomes and the agricultural sector (Abdoul Habou et al., 2016). Previous studies have identified various climatic risks to Niger's agriculture, including heat waves, sand winds, bushfires, droughts, floods, and pests affecting crops (CNEDD, 2011). Climate change and its associated risks—droughts, floods, and rising temperatures—pose significant threats to agriculture in Niger. The agricultural sector is highly vulnerable to these climate-related hazards, which directly affect the country's food and nutritional security. Drought represents a major risk due to its high likelihood of occurrence and severe impact on both crop and livestock production systems. Even a brief 10-day period of inadequate soil moisture can result in substantial yield reductions, highlighting the sector's vulnerability to water scarcity (LeMarois et al., 2021). The impacts of climate change include decreased and irregular rainfall, leading to delayed and prematurely ending rainy seasons, and increased occurrences of drought "pockets" associated with rising temperatures (Bouba et al., 2023).

2.4. Impact of Drought on Livestock and Crop Production in Niger

Drought significantly affects livestock and crop production, leading to reduced yields and substantial economic damage (Bouda et al., 2022). The frequency of dry years has increased since 1968, causing recurring food shortages and heightened dependence on imports and international aid. Drought has thus become a persistent issue. Agricultural and agro-pastoral zones are particularly vulnerable, experiencing chronic cereal deficits annually, which exacerbates food insecurity (Figure 9 shows Niger's livelihood zones). The consequences of droughts—including decreased agricultural production, market disruptions, and the loss of both human and animal lives—have significant implications for food and nutrition security, poverty, and the overall economy of Niger. Historical data shows a strong correlation between drought years and food crises, with notable instances in 1972, 1973, 1974, 1982, 1983, 1984, 2004, 2009, and 2013, where droughts coincided with severe food and nutrition crises (Bouda et al., 2022).

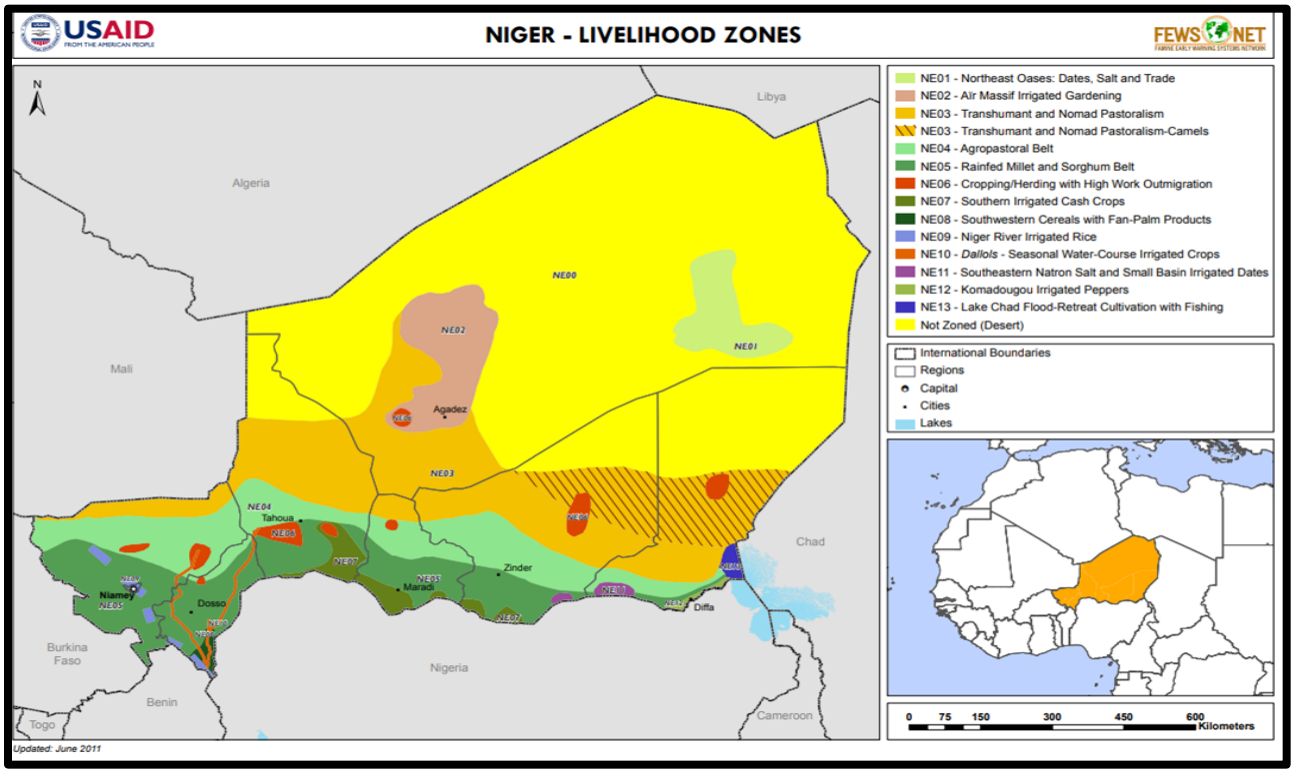

Fig.9. Niger's Livelihood-Zone-Map
Source: FEWS NET

Drought leads to a decline in water levels, leaving crops and livestock without sufficient water and reducing the production of cereals and pastures. It often coincides with heat stress, which further exacerbates the challenges for livestock. Consequently, drought has the potential to cause significant food insecurity (LeMarois et al., 2021). Additionally, drought intensifies sand and dust storms, worsening land degradation. This degradation, in turn, exacerbates water scarcity and increases vulnerability to future droughts (Reichhuber et al., 2019). Land degradation is particularly detrimental in areas such as Agadez, Diffa, Tahoua, and Tillabéri, where a large portion of the country's food-insecure population resides. Malnutrition is most prevalent in regions heavily reliant on subsistence farming, such as Maradi, Tahoua, and Zinder, as food insecurity directly contributes to malnutrition (World Bank, 2023). In the Tillabéri region, drought and severe winds pose major challenges to the millet value chain, reducing millet germination and production. Furthermore, drought adversely affects the rice supply chain in Tillabéri, which produces 75% of the country's rice. The reduced quality and quantity of seeds due to drought will impact rice availability and quality during the post-harvest phase (Bouba et al., 2023)

Climate change significantly impacts livestock farming, affecting forage yield, water availability, water usage, plant material quality, and the severity and extent of livestock diseases (Abdoul Habou et al., 2016). To analyze these impacts, we drew on the framework document for improving livestock resilience to climate variability and change in Niger (2016). Livestock accounts for 25% of the required food and 15% of household income. After mining resources, it contributes 22% of total export value and generates the second-highest export earnings for Niger (CILSS/MAGEL, 2016). As a source of essential nutrients, including proteins, fats, carbohydrates, minerals, and amino acids, livestock farming is crucial for the population's balanced diet. However, various hazards, particularly those related to climate change, pose significant threats to pastoral production systems. Drought is the primary climatic constraint affecting livestock production in

Niger, leading to reduced fodder availability and increased water scarcity. For instance, years with low fodder production, such as 2000, 2002, 2004, 2009, and 2011, align with periods of pastoral crisis. From 1973 to 2015, Niger experienced major livestock losses due to droughts and floods, with fodder shortages resulting in the loss of 2,725,427 head of livestock, representing 13.51% of total livestock numbers in affected areas (CILSS/MAGEL, 2016). During the 2009–2010 period, drought followed by heavy rains and flooding led to an estimated loss of 26% of cattle, 39% of sheep, 31% of goats, and 3% of camels in agropastoral and pastoral zones (USAID, 2017). Extreme weather events, including floods and heatwaves, are expected to become more frequent and intense due to climate change, further impacting fodder resources, water access, and herd mobility. Additionally, droughts exacerbate mortality and morbidity by altering disease dynamics, causing food price spikes, and escalating conflicts over rangeland and water resources. Variable rainfall and severe dry seasons may lead to rangeland degradation and reduced grazing capacity (USAID, 2017).

2.5. Crop production and Vulnerabilities in Niger: Impact of Climate Variability

Niger's Sahelian climate is characterized by significant annual variations in rainfall, leading to an increasing frequency of dry years. The negative impacts of climate change, which hinder the country's development, are intricately linked to this variability. Since the severe droughts of the 1970s and 1980s, Niger has experienced rapid environmental degradation (CNEDD, 2011). Crop yields in Niger, which are heavily dependent on precipitation, are significantly affected by drought, as most crops are rain-fed (World Bank, 2023).

By 2050, yields of Niger's rain-fed crops are projected to decrease by 10–20% compared to 2020 levels due to rising temperatures and shifting rainfall patterns. The agricultural calendar is expected to be disrupted by increasingly unpredictable rainy seasons and more frequent and prolonged dry spells (CNEDD-SPN2A, 2020). For instance, elevated temperatures could render

sorghum nonviable by 2030 and finger millet nonviable by 2050. An increase of more than 2°C by late this century could lead to a 15–25% reduction in yields for millet and sorghum in southern Niger. Extreme temperatures in Niger have already reached 48°C, surpassing the tolerance thresholds for sorghum (44°C) and millet (46°C, at which development ceases for millet and 42°C during flowering) (USAID, 2017). Figure 10 provides a comprehensive overview of Niger's climate patterns from 1991 to 2020. The graph combines monthly average minimum, mean, and maximum surface air temperatures with precipitation data, offering insights into the country's distinct seasonal variations. It clearly depicts Niger's hot, arid climate, characterized by a brief but intense rainy season and significant temperature fluctuations throughout the year. This climatic profile is essential for understanding the agricultural challenges and opportunities in the region, as well as the broader environmental and socioeconomic implications for Niger.

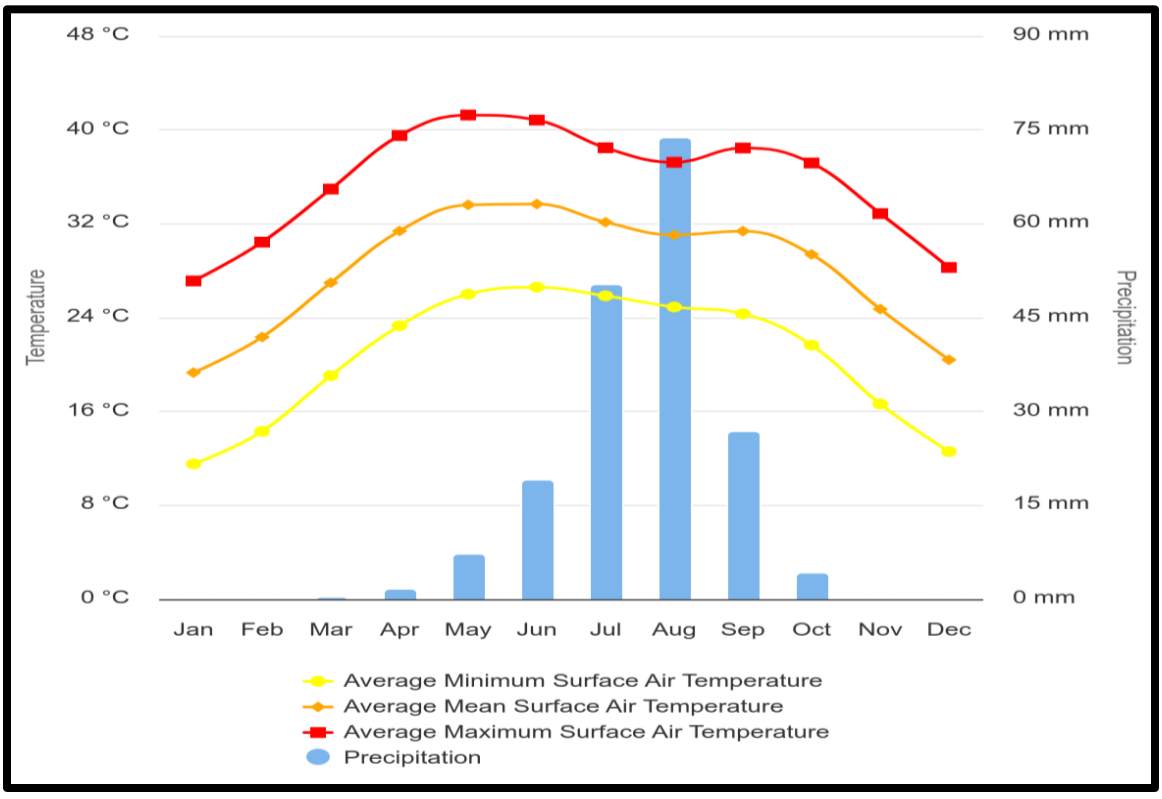

Fig.10. Monthly Temperature and Precipitation Patterns in Niger (1991-2020)
Source: World Bank (2024)

Based on rainfall, four agro-climatic zones can be distinguished (Figure 11):

1. Sahelo-Sudanian Zone: Covering around 1% of the country's total surface area, this zone receives 600 to 800 mm of rain per year in normal years.
2. Sahelian Zone: This zone covers 10% of the country and receives 500 to 600 mm of rain annually.
3. Sahelo-Saharan Zone: Accounting for 12% of the country's surface area, this zone receives 150 to 350 mm of rain per year.
4. Saharan Desert Zone: Covering 77% of the country, this zone receives less than 150 mm (CNEDD, 2011).

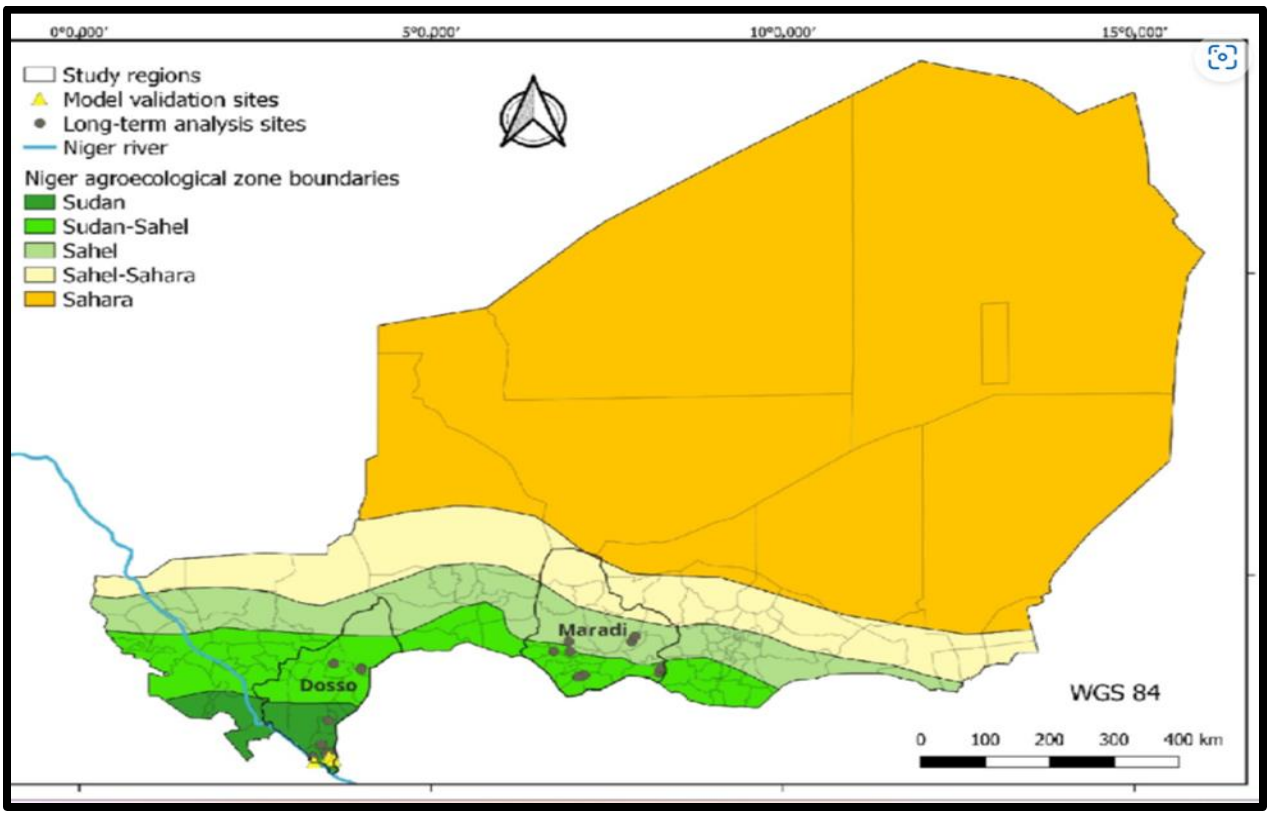

Fig.11. Niger Agro-Climatic Zones
Source : Kamara et al. (2023)

2.6. Impacts of Flooding on Agriculture and Livelihoods in Niger

Flooding also poses significant threats to agriculture in Niger. For instance, in 1998, floods damaged 588 hectares of rice fields, 8,608 hectares of millet farms, and 203 orchards (CNEDD, 2011). Plants and animals adapted to the Sahel's dry conditions may struggle with increased humidity and flooding (CNEDD, 2020). Data from the Niger Flood Database ANADIA (BDINA, 2021) reveal that between 1998 and 2020, floods affected 3,115,290 people across over 7,100 locations. Approximately 205,000 hectares of crops and 46,540 tropical livestock units (UBT) were lost, and more than 225,000 houses were destroyed. The number of affected localities and people have significantly increased over this period. Figure 12 illustrates the spatial distribution of flood events across different localities in Niger from 1998 to 2020, providing valuable insights into flood frequency and highlighting areas prone to inundation.

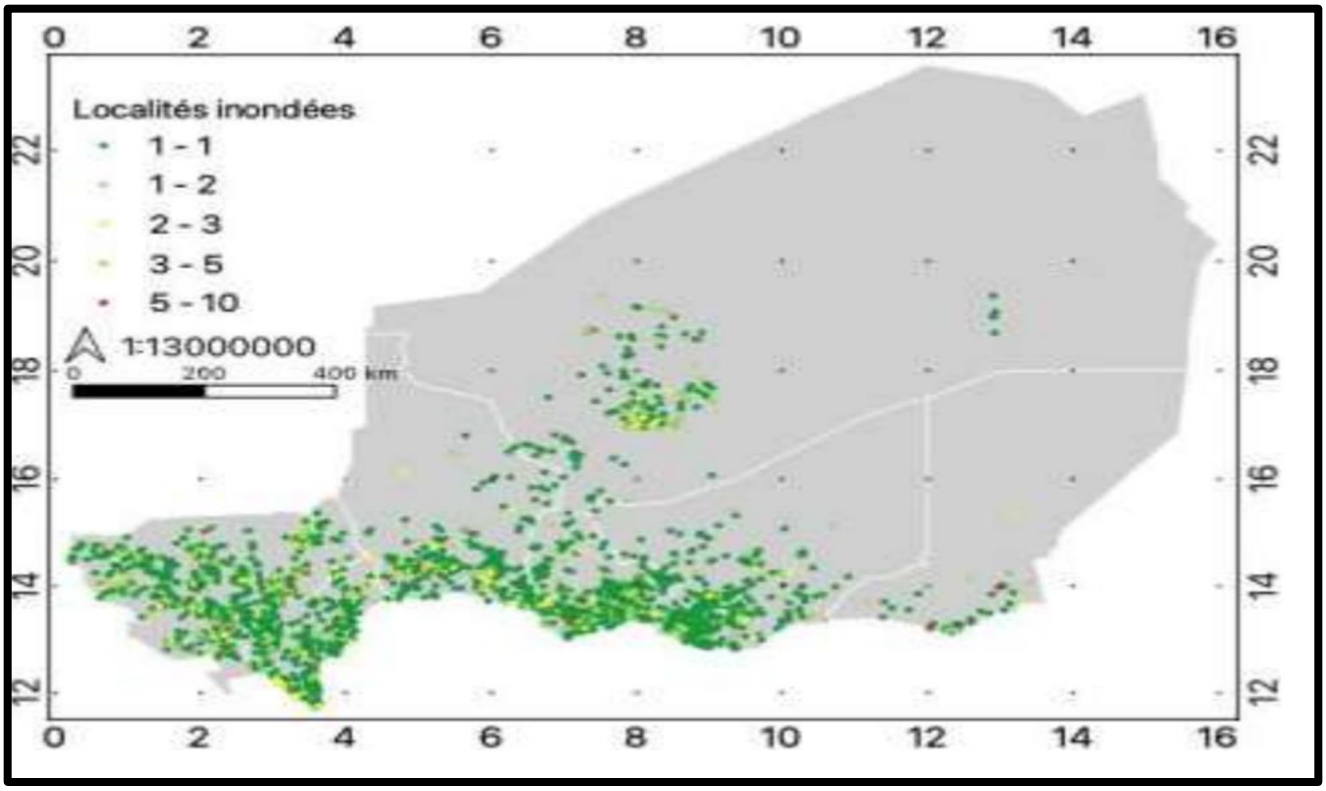

Fig.12. Spatial Distribution of Flooded Localities in Niger (1998-2020)
Source: Niger Flood Database (July,2021)

The geographical distribution of flooded areas indicates that no part of Niger remains unaffected by flooding, though there is a greater concentration in the southern region and along the Niger River, particularly in areas such as Dallols, Goulbi, Korama, Koumadougou, and around the Massif of Air. On the map, green areas have experienced flooding only once within the past 24 years, while red areas have been inundated more than five times, indicating flooding occurs every five years or more frequently. Between 1998 and 2020, thousands of hectares of crops from Agadez to Zinder were destroyed by floodwaters. Tillabéri and Dosso are the most severely impacted areas. In Tillabéri, 23% of the population has been affected, 24% of the localities have experienced damage, 16% of the houses have been destroyed, and 57% of the crops have been impacted. In Dosso, 18% of the population has been affected, 22% of the localities have been impacted, 20% of the houses have been destroyed, and 18% of the crops have been affected. A

study by Bouba et al. (2023) highlights that flooding disrupts transportation and the availability of input suppliers for the rice value chain. It also leads to a reduction in the area used for rice cultivation (48% of underdeveloped areas in 2020), an increase in saline levels, and an invasion of weeds. Flooding further complicates the post-harvest stage of rice cultivation, reducing both availability and quality, while increasing transportation costs. Additionally, Zinder saw the destruction of 561.03 hectares of crops in 2022, and Maradi experienced the loss of 12.5 hectares (OCHA, 2022). The impacts of climate risks are summarized in the following table (2).

Table 2 Climate Risks and Agricultural Impacts

climate risks	**Generic impacts related to the degree of adverse effects**
Drought conditions	• Reduced water resources; • Unsatisfied crop water needs during certain critical development phases; • Increasing numbers of crop pests such as locusts, grasshoppers • pests such as locusts, grasshoppers, earworms, etc.; • Reduction/loss of crop yield and production; • Increased food insecurity and malnutrition; • Increased need for imports and food aid.
Flooding	• Water erosion of productive land and silting of watercourses • Local flooding of areas bordering water points • loss of young plantations; • Loss of agricultural production and stocks; • Damage to agricultural infrastructure.
Extreme weather	• Plant burns; • Increased potential evapotranspiration

Source: (CNEDD, 2020)

These climatic risk factors exacerbate the vulnerability of agricultural and food systems in Niger, underscoring the need for adaptation measures to enhance community resilience against climate change.

Chapter III: Adaptation Strategies for Smallholder Farmers in Niger

3.0 Introduction

This chapter presents a comprehensive analysis of the adaptation strategies employed by smallholder farmers in Niger to address the impacts of climate change. It delves into the current practices and explores potential improvements, focusing on the unique environmental and socioeconomic challenges faced by the region. The discussion covers a range of strategies, including cropping systems, water management, conservation agriculture, agroecological approaches, and livestock improvement. The goal is to provide a detailed overview of how these practices are currently implemented, identify gaps in the existing strategies, and suggest sustainable approaches tailored specifically to the needs of Niger's agricultural landscape.

Given Niger's vulnerability to climate variability and its predominantly agricultural economy, it is crucial to enhance the resilience of its farming systems. This chapter will evaluate both traditional practices and innovative methods being developed to cope with environmental stresses, such as erratic rainfall patterns, soil degradation, and extreme temperatures. By integrating scientific research with local knowledge, the chapter aims to propose actionable solutions that can sustainably improve agricultural productivity and ensure food security in the face of climate change. Furthermore, the chapter will highlight the role of governmental and non-governmental initiatives in supporting farmers through the provision of resources, training, and access to technology. The effectiveness of these interventions, as well as their scalability and sustainability, will be critically assessed to recommend ways to optimize support for Niger's smallholder farmers.

3.1. Current Adaptation Strategies

Farmers in Niger have developed various adaptation strategies to mitigate the negative effects of climate change on agriculture. . They are divided into six main strategy groups: climate-resilient crop varieties, improved agronomic methods, irrigation and water conservation, crop diversification, income diversification, and agroforestry (Zakari et al., 2022) . These strategies include land restoration techniques such as zaï pits, stone bunds, half-moons, and farmer-managed natural regeneration. Zaï Pits are small pits created during the dry season by perforating crusted soil. Farmers place compost, sorghum grains, and light soil in these pits. When the rains arrive, they catch and retain water, allowing seeds to sprout and thrive. Stone Bunds are semi-circular basins concentrate run-off water and organic matter. They prevent soil erosion and enhance soil fertility. Half-Moons are similar to stone bunds, they capture rainwater and organic material, improving soil moisture and fertility (Zougmoré, 2018; Sawadogo et al., 2017). Additionally, farmers employ cropping systems and crop diversification to reduce climate-driven crop failure and enhance resilience (Ado et al., 2019; Wildemeersch et al., 2015). The government of Niger supports farmers through initiatives, including the distribution of agricultural inputs and the implementation of national planting programs. Overall, these adaptation strategies and government support aim to enhance the resilience of agricultural communities in the face of climate change (Moussa & Tougiani, 2020). Zakari et al. (2022) identified that crop diversification (72.74%) and changing planting times (55%) are the most common adaptation techniques used by households in Niger's four major agricultural regions, namely Tillaberi, Dosso, Maradi, and Zinder.

In addition, Ado et al. (2019) describe agronomic adaptation strategies to enhance agricultural resilience, implemented either individually or collectively. Individual strategies include crop and livestock management, soil fertility management, and income diversification. Specific practices include crop combinations (mainly pearl millet, sorghum and cowpea), the use of organic manure, and farmer-managed natural regeneration (FMNR). Farmers also adjust planting dates (early or late season), use improved seed varieties, plant preferred trees (leguminous and indigenous fruit trees like Faidherbia albida and Adansonia digitata), apply insecticides and mineral fertilizers, and adopt soil conservation measures (such as covering soil with crop residues). Many of these practices, such as FMNR, tree planting, improved seeds, mineral fertilizers, and soil conservation, were introduced by extension services to improve productivity and sustainability. However, current responses are insufficient, lacking long-term sustainability and capacity building for local stakeholders. There is a need for research to generate contextual knowledge to guide adaptation policies and provide support for adaptation (Moussa et al., 2022). Hence, through this project, the following strategies should be improved to adapt agriculture to climate change to increase productivity and revenue, ensuring food security in Niger.

3.2 Strategies for Cropping System Improvement

3.2.1 Crop Diversification and Improved Varieties

Crop diversification and the adoption of improved crop varieties are critical strategies for enhancing climate resilience among farmers in Niger. A study by Zakari et al. (2023) demonstrates that using improved varieties significantly increases household income and access to resources, especially in the Sahel region. These varieties, which are better suited to harsh climatic conditions, enable farmers to maintain stable yields despite climatic challenges. Additionally, adopting these varieties substantially reduces the risks of poverty and hunger by enhancing food security and

generating commercial surpluses. This underscores the importance of promoting these practices on a larger scale to improve the resilience of agricultural systems in Niger.

In addition, Issoufou's (2021) study reveals that Nigerien farmers who adopt practices such as crop association, adjusting planting dates, and using drought-resistant or early-maturing varieties not only improve crop productivity but also enhance soil fertility and mitigate losses due to droughts and floods. If these practices were widely adopted across the country, they could transform Nigerien agriculture into a more resilient and productive sector. Integrating these strategies at the national level would be a powerful lever to enhance agricultural production, stabilize household incomes, and reduce food insecurity, thereby contributing to sustainable development and a better quality of life for rural populations (Issoufou, 2021).

3.2.2 Rainwater Harvesting and Small-Scale Irrigation

Water scarcity in the Sahel region significantly impacts agricultural productivity. Therefore, improving the irrigation system will be a significant adaptation technique for increasing yields (Zakari et al., 2022). Rainwater harvesting (RWH) could potentially make significant contributions as a coping mechanism for climate change and variability (Lee & Kim, 2012). Water harvesting during the rainy season and irrigation throughout the dry season can increase production and productivity while also addressing climate variability. The purpose of a rainwater harvesting system to mitigate climate change unpredictability is twofold: first, to provide an alternate source of clean water during a drought, and second, to provide adaptive measures to reduce flooding. RWH may increase agricultural production by providing water during dry periods (Tolossa et al., 2020). Umukiza et al. (2023) demonstrated that RWH may reduce soil erosion, improve soil water retention, and alleviate moisture stress on crops and vegetation by reducing runoff rates. Given the scarcity of water resources in Niger, improved techniques for RWH systems can present significant potential for rainwater use efficiency.

In Niger, “small-scale irrigation” refers to any autonomous hydro-agricultural activity of regulated scale, whether individual or collective, economically successful and environmentally sustainable, created with methods tailored to local expertise. It enables farmers to efficiently deliver water to their crops to increase yields and guarantee food security (SPIN, 2015). Research conducted in Ethiopia by Jambo et al. (2021) demonstrates various ways in which small-scale irrigation might support food security. There are two primary ways in which it can increase the quantity of food available to the household. Access to irrigation water can enhance the quantity and variety of food produced domestically, and households may be able to buy more food due to increased revenue from the sale of irrigated goods. It also allows for the cultivation of a range of crops for personal use, sale, and purchase of other foods, all of which impact food security.

Following the 1983 droughts, small-scale irrigation started to take off thanks to political support. It was known as counter-season farming at the time, as opposed to winter agriculture. According to the Small-scale Irrigation Strategy in Niger (Spin, 2015), the country has several agricultural research and training institutions (INRAN, the Agronomy Faculties of Abdou Moumouni University and University of Maradi, IPDR of Kollo, and ICRISAT), which, despite limited resources, are achieving good results in applied research. However, research interventions should become more involved in the irrigation sub-sector based on demand while complying with market requirements. Public services for rural development are currently in a state of lethargy. Apart from the Hydro-agricultural Amenagement Scheme, there are hardly any specialized support services or consultancy services for irrigated crops.

3.2.3. Conservation Agriculture Techniques

In Niger, land degradation is a major factor contributing to low agricultural productivity, food insecurity, and poverty. Over 200,000 ha of arable land is degraded every year as a result of climatic variability or human intervention (Forum, 2015). Thus, (CA) conservation agriculture techniques aim to address the challenges of soil degradation, nutrient deficiency, and water stress in semi-arid regions by promoting minimum or zero tillage, maintaining a permanent soil cover, and implementing a diversified and profitable crop rotation (Lahmar et al., 2012). These practices help reduce soil degradation, mitigate the effects of drought, and increase crop productivity while reducing production costs. However, Lahmar et al. (2012) explained that the limitations of organic resources in Sahelian agroecosystems due to low biomass productivity and multiple uses of crop residues hinder the success of conservation agriculture. Therefore, it is essential to identify alternative sources of biomass to support CA practices effectively.

An important feature of CA in degraded lands in the semi-arid tropics, such as in Niger, is the presence of an organic soil cover. This cover has significant effects on the balance of soil water, biological activity, the accumulation of soil organic matter, and the regeneration of soil fertility (Lahmar et al., 2012). As positive impacts, in Kenya, the mean yield for maize using ripping in combination with fertilizer was 6845 kg/ha, and for basin + fertilizer (a method where small pits collect rainwater, and fertilizer is added to boost plant growth in dry areas) was 6660 kg/ha, both significantly higher compared to conventional tillage with a mean yield of 3153 kg/ha. In Ethiopia, the mean yield for maize using ripping and ridging was 1775 kg/ha, which was significantly higher compared to conventional tillage with a mean yield of 1458 kg/ha (Rockström et al., 2009). These findings show significant yield improvements with conservation farming practices compared to conventional tillage methods. Thus, with the use of these methods, Niger's smallholder farmers could improve their agricultural systems' vulnerability to the negative effects of climate change.

3.2.4. Enhancing Resilience through Agroecological Approaches

Agroecology is an integrated strategy that uses ecological and social concepts and principles to develop and manage food and agricultural systems. It aims to optimize interactions between plants, animals, people, and the environment while also considering the social issues that must be addressed for a fair and environmentally friendly food system (FAO, 2018). Agroecological techniques that reproduce and utilize natural processes offer a possible path for increasing the resilience of Niger's agricultural systems to climatic variability and change. These approaches highlight ecological services and biodiversity at many scales (field, farm, and landscape) to promote profitable farming while reducing dependency on external inputs (Altieri et al., 2015). Many of these agroecological techniques that reduce vulnerability to climate variability include crop variety, preserving genetic diversity locally, integrating animals, managing soil organic matter, conserving water, and harvesting, according to Altieri et al. (2015).

To transform food and agricultural systems in Niger, successful agroecological practices should be grounded in the 10 FAO Elements: Diversity, Synergies, Efficiency, Resilience, and Recycling (System Characteristics). Co-creation, Knowledge Sharing, Innovation (Knowledge and Innovation Approaches) Human Values, Social Values, Culture, Food Traditions (Context Features) Responsible Governance, Circular Economy, and Solidarity Economy (Enabling Environment). These 10 Elements are interconnected and interdependent (Figure 14).

3.3. Strategies to Improve Livestock Systems

Adaptation strategies for livestock systems in Niger, aimed at addressing climate variability, include diversifying livestock types, improving management practices, enhancing breeding programs, implementing water management strategies, and improving healthcare and disease management. These approaches are designed to boost the resilience and sustainability of livestock production amid changing environmental conditions (Amadou & Yacob, 2023). Additionally, Amadou and Yacob

(2023) highlight that diversifying crop-livestock value chains can enhance resilience to climate change, improve welfare, combat malnutrition, promote sustainable agriculture, target specific interventions, and strengthen urban-rural linkages. Collectively, these strategies can lead to greater resilience, better livelihoods, and more sustainability in agricultural systems.

3.3.1. Diversification, Breed selection and Improvement

In Niger's arid landscape, diversifying livestock and enhancing animal breeds are essential for survival and economic resilience. These measures are pivotal in adapting to the volatile climate and environmental pressures of the Sahel. Transitioning to a diverse animal husbandry model, which includes species like camels and local sheep breeds, offers a more dependable source of livelihood and nutrition. Ngigi et al. (2020) highlights the significance of a varied livestock portfolio for its collective resilience to shocks and climate hazards, which leads to better welfare. A wider array of species allows farmers to cope with environmental stressors more effectively, as each species has unique adaptability traits. Descheemaeker et al. (2016) note the importance of selecting and improving breeds that thrive in arid conditions. For example, the Sahelian goat is favored for its resistance to heat and water scarcity, bolstering sustainability and economic fortitude. Bouba et al. (2023) advocate for techniques like artificial insemination to improve local breeds' productivity while preserving their hardiness. Innovative practices such as mixed farming systems, which pair livestock rearing with drought-resistant crops, optimize resource use and provide security against the failure of any single component. Megersa et al. (2014) view diversification as a defense against climate and disease risks, helping farmers achieve a range of livelihood goals. This strategy supports Niger's National Adaptation Program of Action (NAPA), underscoring agricultural diversification to counter climate variability. By fusing diversification with strategic breed selection, Nigerien farmers can forge agricultural systems that are both resilient and productive. This comprehensive approach not only tackles the immediate challenges

of Niger's climate but also lays the groundwork for enduring agricultural viability and regional economic growth.

3.3.2. Transhumance as an Adaptation Strategy

Transhumance is a livestock management system characterized by the seasonal and cyclical migration between ecologically diverse areas (Ayantunde et al., 2010). This adaptive strategy is primarily motivated by the quest for sufficient water and forage, particularly in response to their limited availability in arid regions such as the Sahel. As a result, livestock are periodically moved to milder sub-humid zones where these essential resources are more abundant. This method is a deliberate adaptation to not only the seasonal fluctuations but also a tactical means of utilizing varied environmental resources to support the well-being of the livestock. (Ayantunde et al., 2010). Transhumance is a fundamental adaptation strategy for managing the uneven spatial and temporal distribution of pastoral and water resources. It helps mitigate the limited renewal rate of these resources and can also protect livestock from certain epizootics (Abdou et al., 2020). Research by Anderson and Monimart (2009) and Hiya et al. (2015), as cited by Abdou et al. (2020), shows that transhumance is highly effective for managing natural resources and adapting to the major challenges posed by climate change, thereby securing livestock production in the Sahel region of Niger.

3.3.3. Insurance Programs for Climate Risks

Index-based insurance programs, such as the Kenya Index-based Livestock Insurance (IBLI, 2017), are designed to mitigate the financial impact of climate variability, particularly for those in the agricultural sector. The IBLI, initiated by the International Livestock Research Institute (ILRI) in 2017, is a prime example of such a program tailored to address the challenges faced by pastoralists in drought-prone areas. The core principle of the IBLI program lies in its use

of indices—such as satellite data on vegetation cover or regional rainfall measurements—to determine insurance payouts. This method contrasts with traditional insurance, which typically requires verification of individual losses. By utilizing indices that correlate strongly with livestock mortality, the program ensures a more efficient and objective claims process.In countries like Niger, where pastoralism is a way of life, the introduction of an index-based insurance program could be revolutionary. It promises enhanced climate resilience by providing pastoralists with a safety net against extreme weather events. The financial security offered by such programs encourages farmers to maintain and potentially expand their herds, knowing that they have a fallback in case of environmental shocks.The economic benefits extend beyond immediate compensation for losses. With the security of insurance, farmers are more likely to invest in quality feed, veterinary services, and better breeding practices, leading to healthier livestock and increased yields. This proactive investment contributes to a cycle of growth and sustainability, elevating the overall standard of living for the community. The effectiveness of livestock insurance as a tool for climate risk management is supported by empirical evidence. A study by Aina et al. (2024) on a pilot program in Nigeria demonstrated significant positive outcomes. Farmers with insurance coverage showed a greater propensity to invest in their livestock, which translated into improved resilience and recovery capacity in the face of climate adversities. The implementation of index-based insurance programs like IBLI in Niger could serve as a cornerstone for building a more resilient agricultural sector. By safeguarding against the financial risks of climate change, such programs empower farmers to thrive despite the uncertainties posed by their environment.

Conclusion

This project has highlighted the acute vulnerability of farmers in Niger to climate change, particularly the increasing frequency and severity of droughts and floods. These climatic risks pose significant threats to agricultural productivity, food security, and livelihoods in one of the world's most climate-vulnerable countries. Current adaptation strategies, while showing promise, are often insufficient to address the scale and complexity of the challenges faced. The project has identified promising adaptation strategies, including crop diversification, improved irrigation systems, conservation agriculture techniques, agroecological approaches, and livestock system improvements. To effectively implement these strategies, a multi-faceted approach is required. This involves increased investment in agricultural research and extension services to develop new technologies and practices that can improve crop yields and resilience to climate change (Ado et al., 2019). Extension services are essential for transferring these innovations to farmers, ensuring they have the knowledge and tools necessary to implement them effectively. Enhanced access to climate information is also crucial, as it allows farmers to make informed decisions about planting, harvesting, and managing resources (Zakari et al., 2022). Improved institutional support can provide consistent support to the agricultural sector, including policies that encourage sustainable agricultural practices, financial incentives or subsidies for farmers who adopt eco-friendly methods, and insurance schemes to protect against climate-related losses. Finally, strengthened partnerships between various stakeholders, including governments, NGOs, private sector, and farmers, are essential for a cohesive approach to agricultural challenges (Bouba et al., 2023). By addressing these areas with a comprehensive strategy, the agricultural sector can become more resilient and productive, ensuring food security in the face of changing climate conditions. The success of these strategies hinges on the commitment and cooperation of all parties involved, from policymakers to the farmers who are the backbone of the industry. Looking ahead, adapting to climate change in

Niger's agricultural sector is both an environmental necessity and a socio-economic imperative. By adopting a holistic, context-specific approach to adaptation, Niger can work towards a more sustainable and climate-resilient agricultural sector, ensuring food security and improved livelihoods for its rural population amidst ongoing climate challenges (Bacci, Idrissa, et al., 2023).

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