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Dedication

This Thesis is dedicated to my Late Supervisor, Professeur Fatou Gueye Lefebvre.

May God grant her Aldiana Firdaws.

To my daughter Fatoumata Zahra TALL, who was born in Cape Coast/Ghana during our English Proficiency Courses.

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Acronyms

ARM: Agency for Market Regulation

AU: African Union

CC: Climate Change

CEC: Equal Opportunities Map

CLM: Cell for the Fight against Malnutrition

CMU: Universal Health Coverage Program

CSI: Consumption Score Index

DPDAA: Detailed Program for Development of Agriculture in Africa

FAO: Food and Agriculture Organisation

FCS: Food Consumption Score

FSSP: Food Security Support Program

GAFSP: Global Agriculture and Food Security Program

GOANA: Great Agricultural Offensive for Food and Abundance

HFIAS: Household Food Insecurity and Acess Scale

HHDDS: Household Dietary Diversity Score

HHS: Household Hunger Scale

HIPC: Highly Indedted Poor Countries

HSRC: Human Science Reasearch Council

IPCC: Intergouvernmental Panel on Climate Change

LPDA: Letter of Agricultural Development Policy

LPDE: Letter of Policy of Development of Livestock

MCA: Multiple Correspondence Analysis

MDGs: Millenieum Development Goals

NCCRC: National Council for Consultante and Rural Coorporation

NEPAD: New Partnership for Development

NPA: New Agricultural Policy

NPDAA: New Partnership for the Development of African Agriculture

PAEP: Drinking Water Supply Program

PAPEL: Livestock Support Program

PSE: Emerging Senegal Plan

PNBSF: National Family Security Bursary Program

PNDN: National Nutrition Development Policy

PUDC: Community Development Emergency Program

SDGs: Sustainable Development Goal

SECNSA: Excecutive Secretariat of the National Food Security Council

SNSAR: National Strategy for Food Security and Resilience

UNFCCC: United Nations Framework Convention on Climate Change

WFP: World Food Program

WFS: World Food Security

Abstract

Countries, especially developing ones, have implemented several projects and programmes to address and prevent food insecurity in a context of climate change. The relationship between food insecurity and climate change deserves reflection. Therefore, it is important to examine the resilience of Senegalese households to climate change variations facing food insecurity. As part of this study, a survey was carried out among 2517 households throughout the country. The data obtained, combined with information on minimum and maximum temperatures and 20-year rainfall (2000-2020) enabled the study to be carried out. After a description of the data showing household characteristics, a Multiple Correspondence Analysis (MCA) was conducted to summarize information on household characteristics. The MCA results have been attached to the hierarchical classification to form a household typology. In addition, indicators for measuring food insecurity have been calculated and modelled, following a multiple regression at two levels (the commune at the first level and the households in the communes at the second level) to illustrate the determinants. In each model, the effects of climate change were simulated on the basis of an increase in minimum temperature, maximum temperature and rainfall. Measures to prevent these effects of climate change have been simulated through an increase in agricultural income, transfers, wages and social assistance or donations.In summury, the results distinguished between three groups of households: rich, middle income and poor. In addition, the synthetic index of food insecurity formed from the five indicators used here, shows that migrant transfer and trade are more consistent in significantly reducing the level of household insecurity while the minimum temperature significantly increases food insecurity. Food insecurity is higher in rural areas than in urban areas. The results of the simulation of the effects of climate change have disproportionate consequences depending on the index studied

Keywords: **climate change, food insecurity, multilevel model, simulation, index**

Résumé

Les pays, notamment ceux en développement, ont mis en place plusieurs projets et programmes pour faire face et prévenir l'insécurité alimentaire dans un contexte de changement climatique.La relation entre l'insecurite alimentaire et le changement climatique mérite réflexion. En effet, il est important d'examiner la resilience des ménages Sénégalais face à l'insécurité alimentaire dans ce contexte de changement climatique.Dans le cadre de cette étude, une enquête a été réalisée auprès de 2517 ménages répartis sur tout le territoire national. Ces données combinées aux informations sur les températures minimale et maximale et sur la pluviométrie sur vingt ans (2000-2020) ont permis de réaliser l'étude. Après une description des données ayant permis de montrer les caractéristiques des ménages, une analyse des correspondances multiples (ACM) a été faite afin de résumer les informations sur les caractéristiques des ménages. Les résultats de l'ACM ont été joins à la classification hiérarchique pour former une typologie des ménages. Par ailleurs, des indicateurs de mesure de l'insécurité alimentaires ont été calculés et modélisés suivant une régression multiple à deux niveaux (la commune au premier niveau et les ménages dans les communes au deuxième niveau) afin d'en illustrer les déterminants. Dans chaque modèle, les effets des changements climatiques ont été simulés sur la base d'une hausse de la température minimale, de la température maximale et de la pluviométrie. Les mesures de prévention face à ces effets des changements climatiques ont été simulées à travers une hausse du revenu agricole, des transferts, des salaires et des aides sociales ou dons.En résumé,les résultats ont permis de distinguer trois groupes de ménages: riches, moyens et pauvres. De plus, l'indice synthétique d'insécurité alimentaire formé à partir des cinq indicateurs utilisés ici, montre que le transfert des migrants et le commerce sont plus constants à réduire significativement le niveau de l'insécurité des ménages alors que la température minimale augmente significativement l'insécurité alimentaire. L'insécurité alimentaire est plus marquée en milieu rural qu'en zone urbaine.Les résultats de la simulation des effets des changements climatiques ont des conséquences disproportionnées suivant l'indice étudié.

Mots-clés : **Changement climatique, insécurité alimentaire, modèle multiniveaux, simulation, indicateur**

General introduction

The issue of food insecurity was at an early stage, a priority in international meetings. At the end of the Second World War, several heads of state met in Hot Spring, Virginia, in the United States of America to set up international institutions within the framework of the United Nations system. The Food and Agriculture Organization (FAO) was created in 1945 with the main mission of feeding the planet(Racine, 2016). It is about helping countries increase their food production to prevent food insecurity. Vulnerability to food insecurity is a cross-cutting issue that depends on the social, political and environmental (Bohle, 1994). The effects on the environment are often the combination of meteorological and climatic conditions that fall out of the range of values usually observed and thus constitute extreme values of climate (Seneviratne, *et al.*, 2012). This is how the issue of food insecurity was introduced in the Millennium Development Goals (MDGs), with the target of "eliminating extreme poverty and hunger" before 2015. As a result, several programmes of development were initiated and progress has been made since, reducing the global poverty rate by 20 percentage points (Webb, *et al.*, 2014).

However, food insecurity remains a persistent challenge. For example, several countries in Southern, Eastern, Central and Western Africa held the second highest hunger index in the world with alarming levels of hunger (PNUD, 2017). These under-performances appear in a context of extreme climate observed in several regions of the continent. Indeed, over a 100-year period, the temperature level has increased significantly on the African continent. With the increasing temperature at the earth's surface by 0.5°C over a 100-year period in several regions of the continent with a faster increase in minimum temperatures (Adelekan, Abdrabo, Ama, & Chris , 2014). In addition to these temperature disruptions, coastal erosion reduces the coastline of the oceanic facade by 1 to 2 m, also destroying the mangroves (Kane, 2019). The concept of sustainable production becomes an additional aspect in taking into account the issue of food insecurity.Thus, the Sustainable Development Goals, in its Goal 2, aims to "eliminate hunger, ensure food security, improve nutrition and promote sustainable agriculture."

The scarcity of food resources has been a concern in previous decades in Africa. Also, the appearance of unusual climatic phenomena has been felt in several parts of the continent. The most obvious are floods, droughts, temperature increases, disturbance of rainy seasons and heat waves directly affecting populations. More than 60% of the West African population depend on agriculture in the broad sense (GEMENNE, *et al.*, 2017).

In Senegal, agricultural activities affect 46.7% of households, 73.8% of which are located in rural areas (ANSD, 2014). Also, it is observed a transhumance of Senegalese breeders in search of pasture and water points in the interior of the country. To this end, the lack of water points observed in recent years has caused the loss of several heads of cattle. Moreover, the fishing sector has also been marked by the scarcity of fish resources. This has led some fishermen to venture beyond national boundaries at the cost of their lives sometimes. There is thus a risk of a shortage of the most consumed food products.But, according to (Wiel et al., 2020) that extreme weather conditions which is an effect of climate change do not usually conduct to extreme impacts in contrast extreme impacts may result from reasonable weather conditions.The challenge is both economic and social in that, according to the FAO, agriculture alone employs more than 60% of the labour force and contributes nearly 35% to GDP and is a food source for more than 77% of the West African population (Ayodotun, Sylla, & Aderonke, 2019). In addition, population growth increased from 13.5 million in 2013 to 16.7 million in 2020, an increase of 23.67% over seven years[1.] Also, in 2015, Senegal had a Human Development Index of 0.466, an unemployment rate of 15.7% among those over the age of 15, as well as interregional disparities that proves the degree of the vulnerability of populations to food insecurity[2.]

Climate change is a spatio-temporal concept defined as variations in climate under the effects of human action (Muhammad,2012). Furthermore, the Intergovernmental Panel on Climate Change defines climate change as the perceptible variation in the state of the climate through changes in the mean and/or variability of its properties that persist for a long time period, generally for decades or more (Faye,2018).The vulnerability of West African populations in general and Senegalese in particular is a major concern. The converging elements towards this risk of food shortage are the scarcity of fish resources, the loss of livestock, low agricultural yields as well as population growth, poverty and unemployment. It is therefore, important to consider the effect of climate change on the evolution of fish products, the quantities of crops cultivated and the number of livestock in Senegal leading to food insecurity.

1http://www.ansd.sn/ressources/publications/Projection-Population%20de%202013_age-sexe_par%20regions%20-2013-2025.xls

2 Rapport finale du Projet nationale d'Investissement Agricole pour la Sécurité alimentaire et la Nutrition 2018-2022, p

Indeed, it is becoming more and more common to observe phenomena related to extreme climates. The latter is defined as the occurrence of an environmental action at an intensity other than those usually observed (Seneviratne, *et al.*, 2012). Also, the Intergovernmental Panel on Climate Change defines climate change as "a rare event in a particular place and time of the year. […] an extreme weather event should normally be as rare, if not more so, than the tenth or nineth percentiles of the observed probability density function." (Cubasch, *et al*., 2013). Faye (2018) showed that during the 20th century, three main phases marked rainfall in Senegal: a first phase marked by a succession of dry, normal and humid periods (1896-1949), a second period of humidity (1950-1969) and a third phase of drought (1970-2000). The author also shows that the frequency of droughts is negatively correlated with agricultural yield and that the increase in temperature increases the water requirement of plants with an immediate impact on agricultural yields and biomass production. It becomes necessary to measure the level of food insecurity, which reflects any risk associated with the «physical and economic access to sufficient, healthy and nutritious food to meet energy needs and food preferences for healthy and active living" (FAO, 2011). Extreme events negatively affect agricultural production due to flooding that degrades crops and blocks market access (Faye, 2018).

Vulnerability refers to the level of resilience of an individual or system that is, its ability to reduce to or from its optimal level following a disruptive event (PROAG, 2014). The vulnerability of Senegalese populations, like that of the coastal countries of West Africa, there is a major concern because of the violent storms threatening the coasts. Added to this is the decrease in artisanal catches, which were reduced by an average of 5 kg per day per canoe around the 1950s to just under 1, 5 kg per day per canoe in the 2000s, thus increasing the risk of change in the activity of artisanal fishermen, 11 times less than industrial fishing per unit of effort (Barange, and al., 2018).

Food insecurity is a major concern in developing countries. Indeed, a study done by the National Food Security Council in Senegal in 2016 to show that households derive their sources of income from agricultural products (25%), trade (18%), handicrafts (11%), private wages (10%), public wages (7%) and transfers of remittances from migrants (7%). Agriculture also occupies nearly 40% of households, 80% of which are in rural areas. Livestock also occupies nearly 60% of agricultural households, the bulk of which (72%) are in rural areas.Moreover, this study also showed that nearly 60% of annual household spending was devoted to food. Rural households give more weight to consumption in spending (68%).

However, forecasts of extreme climate in the Sahel show a decrease in precipitation and the number of rainy days and an increase in the maximum duration of dry sequences (Sarr, and al., 2017). This makes the country vulnerable due to its population's dependence on agriculture in general (Sagna, *et al.*, 2015).

The issue of preventing household food insecurity in the face of climate change is poorly addressed in the literature, including the measurement of the efficiency of prevention strategies. This study will contribute to advancing research on strategies to prevent household food insecurity in the context of climate change.

Two types of analysis were applied to better conduct this study.A first step was to conduct an exploratory data analysis, specifically a multiple correspondence analysis (MCA) in order to summarize the information by group of variables and thus to overcome any difficulties of multicollinearity in the models to be considered.Also, the primary data were used to apply a Hierarchical Ascending Classification (HAC) in order to classify the household by adding the contribution of two axis which result of the Multiple Correspondence Analysis (MCA).The second step was about the specification of a multi-level model applied to the collected data to which the climatic information on the departments was attached.

These two models were implemented in full coherence with the set objectives.

0.1. Research Questions

The main research question of this study is: what are the impacts of climate change on food insecurity among Senegalese households?

The sub-questions are :

1. What is the level of food insecurity in the rural areas compared to the urban areas?
2. Who are the the most vulnerable populations to food insecurity?
3. How efficient are households' preventive strategies against food insecurity under changing climate?

0.2. Objectives

The main objective of this study is to examine the resilience of households to climate change variations facing food insecurity.

Specifically, the study aims to:

1. Analyze the current level of food insecurity;
2. Measure the impact of climate change on food insecurity indexes;
3. Make climate change effects simulation and evaluate some adaptation strategies such as transfert amunt increasing, agricultural income increasing, salary increasing and social aid increasing.

0.3. Hypotheses

The following null hypotheses were tested:

- ✓ There is no difference between the level of food insecurity in the rural areas and those in the urban areas.
- ✓ All agricultural sub-sectors have the same vulnerable level to food insecurity in the study areas.
- ✓ Household preventives strategies against food insecurity are efficient under changing climate.

The present thesis will be organized as follows:

Following the Gneneral Introduction, the chapter one will focus on the stylize facts of food insecurity and climate change in Senegal.The second chapter is dedicated of review of existing literature.literature. The thirt chapter is about the methodology use to assess this study.The last chapter is about results and discussions followed by the conclusion and recommendations.

Chapter 1: Stylized facts

1.1. Introduction

Policies to combat food insecurity in West Africa, particularly in Senegal, are mostly correlated with agricultural policies. In this chapter we highlight, the Senegalese government's programmes to combat food insecurity (or food security) from independence to the present day. Also, we analyze the current situation of insecurity. To this end, it will be a question of highlighting all the policies implemented by the Government of Senegal to ensure an acceptable level of food security. But also make an update on the current food profile in Senegal with food trends for both rural and urban settings. Finally, we describe the climate change situation in Senegal according to the localities

1.2. Programmes against food insecurity

Since independence, the Government of Senegal has implemented several programmes to fight food insecurity. In 1977, the government set up an agricultural programme with the adoption of a food investment strategy to increase the production of millet and rice but also to encourage the diversification of agricultural production with the introduction of products horticultural crops such as sugar cane, cotton, industrial tomatoes, melon, green beans, peppers, bananas, avocado, pineapple etc(A. S. FALL et al., 2020).

From 1984, the government adopted the "New Agricultural Policy (NPA)" with the aim of achieving 80% self-sufficiency in food. The NPA was developed as part of structural adjustment programme based on liberal policies. During its application, the NPA allowed an increase in cereal production from 607,284 tons in 1984/85 to 840,052 tons in 1992/93, an average growth rate of 3.1%.

The new agricultural policy followed up on several targeted agricultural policy letters, following the 1994 monetary devaluation. These are mainly:

The Letter of Agricultural Development Policy (LPDA): characterized by a specific price policy and institutional reforms on the rice, cotton, peanut and livestock sectors, taxation on agricultural inputs and equipment revised downwards and even totally exempted in the 97/98 agricultural programme and finally a reduced interest rate from 14% to 7.5%. A number of objectives were targeted for the good conduct of this programme:

Food security through good management of natural resources and land security:

- ✓ Sustained agricultural growth;
- ✓ The improvement of revenues;
- ✓ Promotion of private investment.

The Letter of Policy of Development of Livestock (LPDE) is more oriented towards the elevation with as target objectives:

- ✓ Sustained increase in animal production;
- ✓ Improving incomes and combating poverty;
- ✓ The preservation of natural resources.

However, despite the results obtained from the evaluation of the various programmes implemented since 1977, the situation of vulnerable groups persists despite a good return to economic growth. Indeed, it has emerged that food insecurity and poverty, which are two interdependent phenomena, continue to prevail in most Senegalese households.

In 1994, the Food Security Support Programme (FSSP) was set up with the aim of focusing on:

- ✓ A price policy and institutional reforms, especially for rice, cotton, peanut and livestock;
- ✓ A reduction in input taxes that will be eliminated later with the reinstatement of the agricultural programme in 1997-1998;
- ✓ A reduction in the interest rate for agricultural credit from 14% to 7.5%, following pressure from the peasant movement; structured around the National Council for Consultation and Rural Cooperation (NCCRC); created in 1993 during the food security support programme negotiation process.

The beginning of the year 2000 marked the end of the structural adjustment programme which has been determining policies since 1984. Senegal is one of the Highly Indebted Poor Countries (HIPC): With this funding, several programmes such as the Great Agricultural Offensive for Food and Abundance (GOANA) are implemented; an initiative aimed at ending Senegal's food dependence.

In 2006 another programme was set up; the REVA Plan which was a programme of Return to Agriculture. The REVA Plan was intended to fix young people and women in their localities to reduce the phenomenon of clandestine emigration; to increase significantly agricultural production with a penchant for horticulture and meeting the strategy objectives of accelerated growth and the fight against poverty and food insecurity.

In 2010 Senegal benefited from the Global Agriculture and Food Security Programme (GAFSP) initiated by the G20 initiative. In 2012, thanks to this aid, Senegal initiated livestock and agricultural development programme in the regions most exposed to drought (Matam; Kaffrine and Louga). In the same launch; the development of agricultural and pastoral hydro-infrastructure, the construction of rural roads and the financing of model ruminant and poultry breeding facilities were implemented. Also in 2012, the Government of Senegal launched an emergency programme to help the rural world with food, feed and malnutrition.

The objective of this programme was to distribute 39,980 tons of weld food; to support 120.000 children affected by malnutrition; and to meet feed requirements for 58,115 tons: To these projects to fight against food insecurity and the challenges of climate change in Senegal is added the Livestock Support Project (PAPEL), Community Tracks Project in Support of the National Local Development Programme (PPC PNDL), Rural Development Support Project in the Animated Basin; Rural Development Support Project in Casamance and Small Local Irrigation Support Project.

However, with the food crisis of 2007-2008, we witnessed a reorientation of the GOANA programme towards achieving self-sufficiency in rice by 2015(OYA & BA, 2013). At the same period; the government set up the Agency for Market Regulation (ARM) to cushion the volatility of food prices, a potential source of threat of food insecurity.

In 2013, a new programme was launched, the Senegal Emergent Plan, which has been translated into an orientation of agricultural and food policies, through new investments in infrastructure benefiting the agricultural sector as a whole and the rebalancing of support measures for consumers benefiting from social transfers (family grant).

With a view to combating food insecurity and malnutrition, the Government of Senegal adopted a National Strategy for Food Security and Resilience (SNSAR) with the objective of ensuring sustainable food and nutrition security for Senegalese populations and greater resilience to shocks by 2025.

In 2017, the National Food Security Support Programme was implemented under the coordination of the Executive Secretariat of the National Food Security Council (SECNSA). This programme was based on both food security and nutrition. Thus, the State, under the coordination of the Cell for the Fight Against Malnutrition (CLM); developed a multi-sector nutrition strategic plan covering the period 2018-2022 with the objective of operationalizing the National Nutrition Development Policy (PNDN); However, the overall objective of the

PNDN is to ensure a satisfactory nutritional status for all, particularly for children under five years of age, women of childbearing age, adolescent girls and adolescent boys.

Despite all of these food security programmes, in 2020 with the COVID 19 pandemic, the government of Senegal initiated an emergency programme of food aid to help households that were affected by the consequences of the pandemic to have enough food. This programme aims to distribute 1000000 of food package to 8 to 10 million of Senegalese households. Each beneficiary received 100 kg of rice, 10kg of sugar, 19 liter of oil and 18 pieces of soap.

Summury of programmes against food insecurity

Project	**Years Started**	**Objectives**
Agricultural Program**(PA)**	1960-1980	Food investment strategies to increase the production of millet and rice
New Agricultural Policies**(NPA)**	1984	Achieving 80% self-sufficiency in food
• Letter of Agricultural Development Policy **(LPDA)**		✓ Sustained agricultural growth; ✓ The improvement of revenues; ✓ Promotion of private investment.
• Letter of Policy of Development of Livestock **(LPDE)**		✓ Sustained increase in animal production; ✓ Improving incomes and combating poverty; ✓ The preservation of natural resources.
Food Security Support Program**(FSSP)**	1994	Price policies and institutional reforme,reduction of input taxes, reduction of interest rate for agriculture credit
REVA	2006	To reduce the rate of clandestine migration by fixing young and women

		in their localities by doing agricultural activities.
GOANA	2008	Cultivate 500000 tons of rice at the national level and 360000 tons of rice at St Louis areas
Global Agriculture and Food Security Program(supported by G20)	2010	Livestock and agricultural development program in the regions most exposed by drought (Matam, Kaffrine and Louga)
Emergency program to help rural areas	2012	Distribution of 39980 tons of weld food to support 12000 children affected by malnutrion. Feed requirements for 58115 tons
Plan Senegal Emergent	2013	Orientation of agricultural and food policies through investment in infrastructure benefiting the agricultural sector
National Strategy for Food Security and Resilience(SNSAR)	2013	Ensuring sustainable food and nutrition security for Senegalese population and greater resilience to shocks b 2025
National Food Security Support Program	2017	Operationalizing the national nutrition development policy by a satisfactory nutritional status for children under five years, women of childbearing age, adolescent girls and adolescent boys
Emergency aid program(due to Covid 19)	2020	To distribute 1000000 of food package to 8 to 10 million of Senegalese household. Each beneficiary received 100 kg of rice, 10kg of sugar, 19 liter of oil and 18 pieces of soap.

Source: **(SNSAR, 2015),Summurize by Author**

Beyond the policies and programmes implemented by the Government of Senegal for the fight against food insecurity since the advent of independence, there are other more recent social protection mechanisms.

These mechanisms contribute to the fight against food insecurity in Senegal:

- The National Family Security Grant Scheme: is implemented by setting up a cash benefit scheme for poor families. For an amount of 25000CFA per quarter for each household. The objective of the grant is to help these households to combat vulnerability and social exclusion.
- The school canteen programme: aims to contribute to the improvement of the rate of attendance as well as to the development of cognitive capacities and also to promote positive results of students.
- The project 'Purshase from Africans for Africa': implemented in the Kedougou region by the Government of Senegal with the support of WFP and FAO, aims to increase the production of small rice farmers and to improve household consumption.
- The emergency relief programme: intervenes in the distribution of food or food vouchers, with priority given to households most vulnerable to food insecurity.

1.3. Senegal's food security policies: international agreements

Discussing about the programmes and policies conducted by Senegalese Government against food insecurity cannot be possible without discussing about the international agreement on this issue. Senegal has signed a lot of international agreements that go in the direction of establishing partnerships with certain organizations to achieve the goals against food insecurity(SNSAR, 2015).

- World Food Summit

The World Food Summit took place from 13 to 17 November 1996 in Rome, Italy. This summit took place to provide a solution to the persistence of undernourishment that was hitting the world. At the end of this summit, the Rome Declaration on World Food Security was published. The Declaration adopted by the WFS reaffirmed 'the right of everyone to have access to safe and nutritious food, consistent with the right to adequate food and the fundamental right of everyone to be free from hunger'. It was considered both 'intolerable' and 'unacceptable' that 'more than 800 million people throughout the world, and particularly in developing countries, did not have enough food to meet their basic nutritional needs'. A target was set to 'reduce the number of undernourished people to half their present level no later than 2015'.

- New Alliance for Food Security and Nutrition:

The NAFSN is a partnership between the G8, the African Union (AU), the New Partnership for the Development of African Agriculture (NPDAA), African governments and several national and international companies. With the creation of NASAN in June, 2012, the G8 objective was to focus on food security in Africa through increased investment by multinationals in six countries in Sub-Saharan Africa, including Senegal.

- Detailed Programme for the Development of Agriculture in Africa (DPDAA):

Following the XXII Regional Conference for Africa, the African Ministers of Agriculture adopted on 08 February 2002 in Cairo, a resolution on key steps to be taken in the agricultural sector in the framework of the New Partnership for Africa's Development (NEPAD). To implement this resolution, they set up the African Agricultural Development Programme (DPDAA) in June 2002. The DPDAA aims to accelerate economic growth, eliminate poverty and hunger in African countries and promote agricultural development to improve food security and increase exports. In West African countries, including Senegal, the DPDAA focuses on specific areas for achieving its objectives:

- Land and water management,
- Rural infrastructure and trade-related capacity for better market access,
- Increase food supply and reduce hunger,
- Agricultural research, technology extension and adoption.

- The African Regional Nutrition Strategy (SRAN):

This strategy highlights the fact that nutrition, health and care, which constitute the conditions for nutrition, are necessary in each of them, but none is sufficient in itself to ensure optimal nutrition. It calls for a need to use multi-sectoral approaches, better coordination and better improvement of redevelopment and governance.

- The Sustainable Development Goals (SDGs):

The SDG1 and SDG2 focus on the elimination of poverty in all its forms, including extreme poverty, over the next fifteen years from 2015, and the elimination of hunger, ensure food security, improve nutrition and promote sustainable agriculture. This objective is in line with the Plan Senegal Emergent which gives an important place to the fight against poverty and inegalites.The achievement of these goals aim to eradicate poverty in all its forms and dimensions, including extreme poverty.

In the framework of the PSE, the Government of Senegal has initiated programmes to respond to goals.

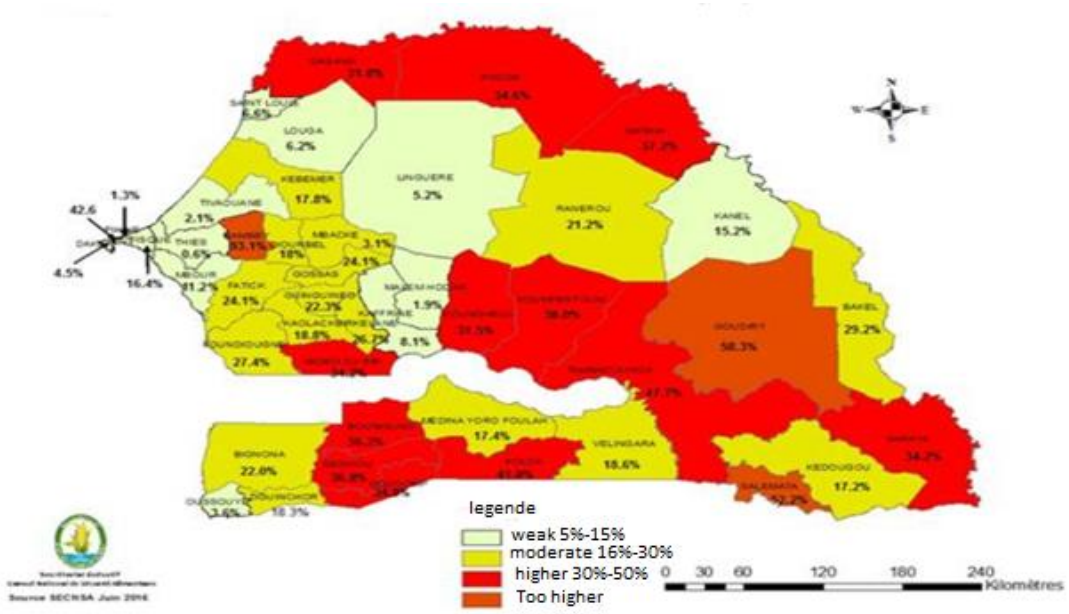
Among these programmes we have: the National Family Security Bursary Programme (PNBSF), the Universal Health Coverage Programme (CMU), the Equal Opportunities Map (CEC), the Drinking Water Supply Programme (PAEP) and the Community Development Emergency Programme (PUDC). However, the achievement of SDG2 is confronted by obstacles at several levels including climate shocks, the fragility of food systems, the lack of access to markets and the terms of trade that are often unfavourable for vulnerable small-scale farmers in rural areas.

1.4. Level of Food insecurity in Rural and Urban Areas in Senegal

The situation of food insecurity in Senegal is constantly monitored by the Senegal government through the Executive Secretariat of the National Council on Food Security (SECNSA).

To this end, SECNSA conducted a study in 2016 on food security. The results are illustrated in the following figure. It turned out that in 2016, the level of food insecurity was low for many households in the departments of Dakar, Pikine, Thiès, Tivaouane, Mbacké, Linguère, Louga, Saint-Louis, Kaffrine, Malem Hoddar and Oussouye. On the other hand, the number of households without adequate consumption was higher in departments such as Bambey, Goudiry and Matam. Also, the figure shows that the communities farthest from the capital are the ones with the most cases of food insecurity.

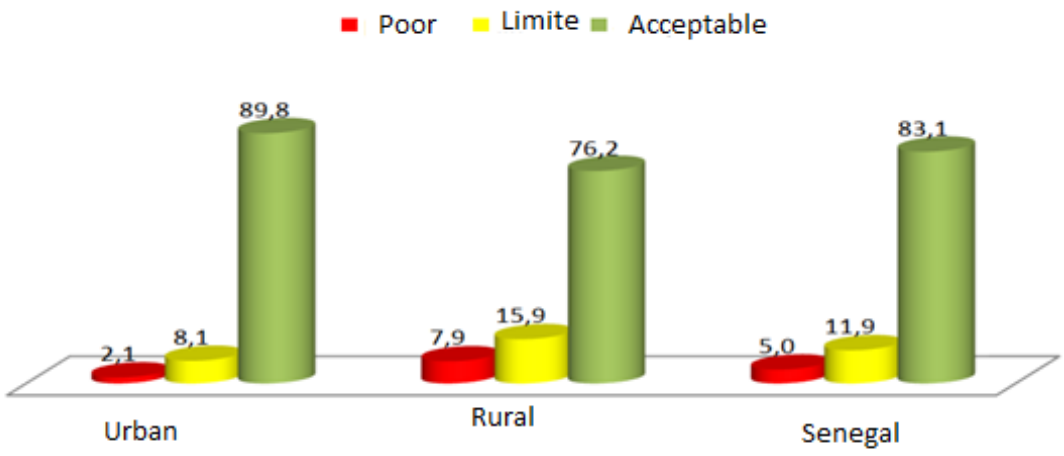
Figure 1: Prevalence of food insecurity in 2016



Source: **SECNSA, 2016**

The analysis by residential environment reveals disparities between rural and urban areas. By going over the food consumption score in three classes (poor, limited and acceptable), the results showed that the proportion of households with an acceptable food consumption is 76.2% in rural areas while it is 89.8% in urban areas. The percentage of households with poor food consumption is four times higher in rural areas compared to urban areas (7.9% versus 2.1%). Thus, already in 2016, food insecurity was more prevalent in the countryside than in cities.

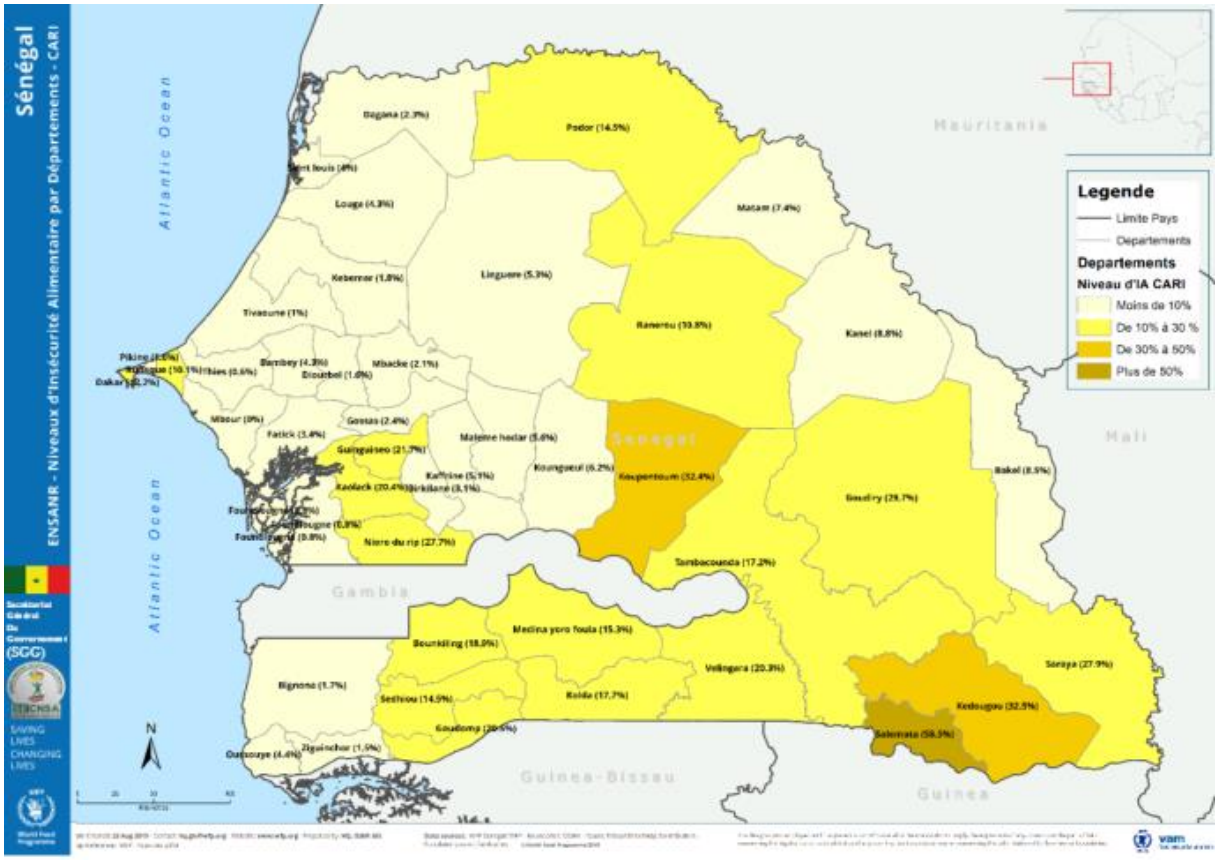
Figure 2: Distribution of households by food consumption score class



Source: **SECNSA, 2016**

Also, in 2019, the SECNSA carried out a diagnosis of the food situation of the country on the basis of a survey on the whole national territory. The prevalence of food insecurity was assessed with a synthetic indicator with the consolidated approach of food security indicators developed by the World Food Programme (WFP). The results showed that the prevalence of food insecurity is over 30% in the departments of Salémata, Koumpentoum and Kédougou. Also, the departments of the Kolda and Sédhiou region as well as the departments of Podor, Ranérou, Rufisque, Dakar and those of the Kaolack region have a prevalence of food insecurity between 10% and 30%.

Figure 3: Prevalence of food insecurity in 2019



Source: SECNSA, 2019

At home, the prevalence of food insecurity is twice as high among rural households (11.7%) as among urban households (4.8%). Food insecurity is more threatening in rural areas than in urban areas.

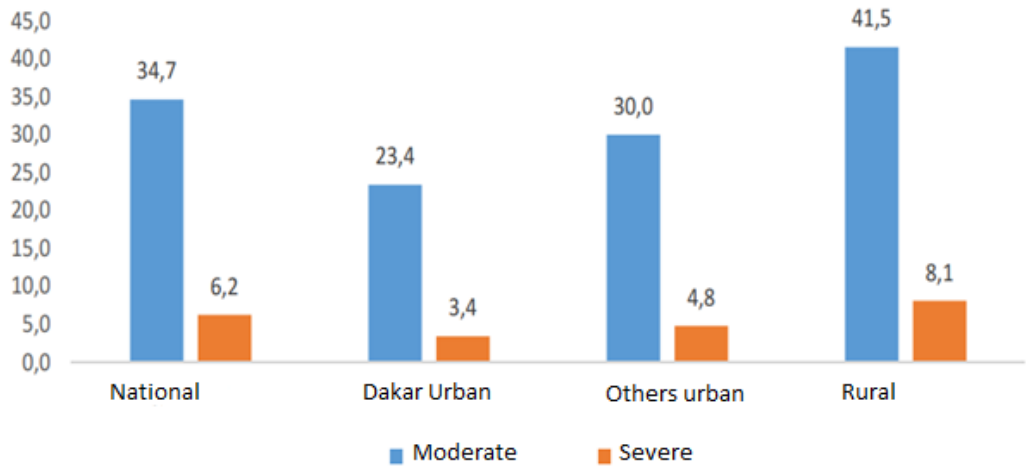
Figure 4: Distribution of food insecurity by place of residence

Source: SECNSA, 2019

In addition, the study on the living conditions of households carried out in 2019 by the National Agency for Statistics and Demography showed that the overall level of prevalence of food insecurity was 34.7% with an incidence of severe food insecurity of 6.2%.

In rural areas, the food situation was worse with a prevalence of 41.5% against 23.4% for those in urban Dakar and 30.0% for other urban areas. Serious food insecurity was estimated at 8.1% in rural areas. In urban Dakar and other urban centres, it affected 3.4% and 4.8% of people respectively.

Figure 5: Distribution of food status by place of residence



Source: SECNSA, 2019

1.5. The current situation of climate change in Senegal

The West African climate is subject to interannual variability that characterizes its climate. Then, the agricultural household used to sowing from the first rains is quick to face uncertainties that disturb their agricultural yields. The variability is also accompanied by a warming of the temperature, a multiplication of extreme phenomena, an increase of drylands, a decrease in agricultural yield and a migration of mosquitoes carrying dingues and malaria to unexposed areas(M. Braun, 2010).

In this climate context, people use adaptive means to mitigate the effects of climate. Indeed, the migration of populations to large cities (Dakar, Saint-Louis etc.) or outside the country, constitutes a strategy of survival and diversification of income for the local population through transfers(Sall et al., 2011).

Since 2014, the public policy framework, the Senegal Emergent plan, provides for a strangurie to mitigate the effects of climate change through the development of renewable energy, the protection of ecosystems, agricultural development and soil salinization control etc.

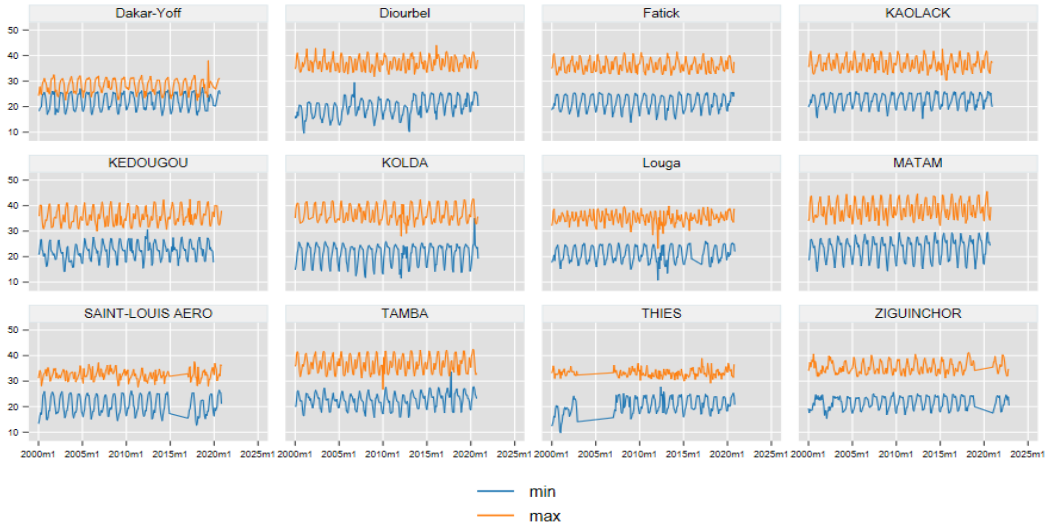
The potential climate risks in Senegal can be summarized as follows: a greater inter-annual irregularity in rainfall, a decrease in surface water resources and the reduction of alluvial layers, the decline of wetlands with declining biodiversity. In addition, climate change could lead to a

rainfall deficit of 20 to 30% despite the country's hydropower potential of 35 billion m^3 per year(Ndiaye et al., 2015). Declining precipitation has led to a shift in isohyaetes from the north to the south of the country since 1940[3].

These effects make it difficult to cultivate certain types of speculation, particularly in certain areas such as the southern, eastern and south-eastern regions which are most vulnerable, in particular the regions of Tambacounda, Kaffrine, Sédhiou, Kolda and Kédougou(Pathways & Rcp, 2022).

Temperature observation between 2010 and 2020 shows an increase in the minimum temperature in several departments across the country (Figure 6). Moreover, the Dakar region is the only one where the differences between the minimum and maximum temperatures have remained stable. It should also be noted that high values of minimum temperature have appeared in recent years, such as in Dakar in 2018 (27.5°C), Kolda in 2020 (30°C) and Tamba in 2017 (33.6°C).

Figure 6 Evolution of minimum and maximum temperatures in twelve departments.



Source:

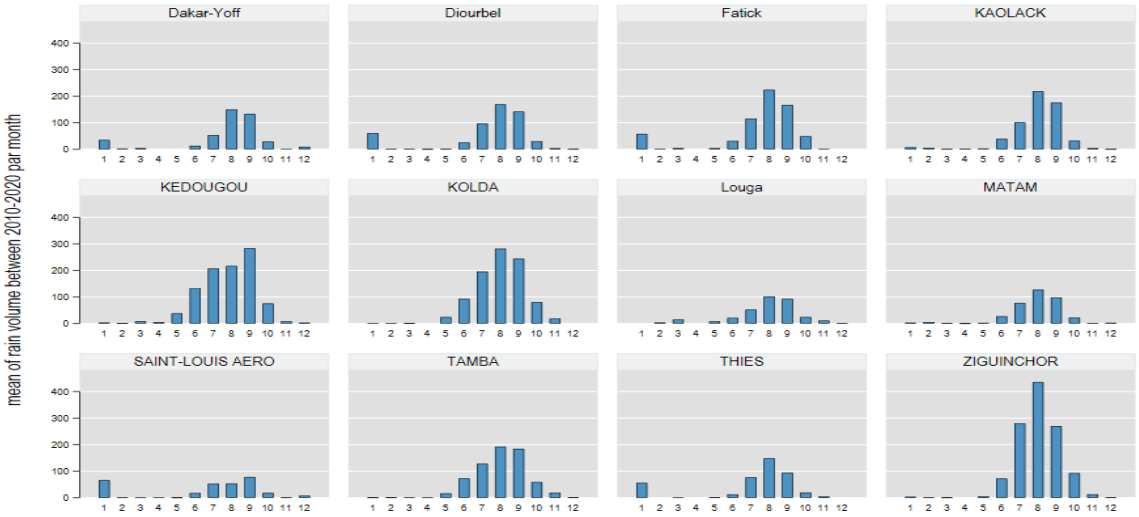
Author, Anacim 2020

Also, the average monthly rainfall between 2010 and 2020 shows a significant spatial disparity. In fact, the northern regions recorded less than 150 mm on average per rainy month (example of Matam), those in the centre a little more than 200 mm (Fatick) and those from the south up

[3] CONTRIBUTION DÉTERMINÉE AU NIVEAU NATIONAL DU SENEGAL, 2020

to more than 400 mm. This is in phase with drift of the isohytes from the north to the south stated above.

Figure 7 Ten-year Average Monthly Rainfall (2010-2020)



Source: **Author, Anacim 2020**

1.6. Partial conclusion

Food security and resilience in the context of Climate change is still a priority for Senegal and at the same time presents multiple type of challenges.

Sengalese government has given a great place to the fight against food insecurity in all the social policies. Despite all the programmes, policies and international agreements, acheiving food security for all Senegalese households is still a challenge.

Food insecurity remained prevalent both in 2016 and in 2019 a little in the North (Podor and Ranérou), in the Centre (Koumpentoum) in the South (Sédhiou and Kolda) and in the East (especially the departments of Salémata and Kédougou).

Chapter 2: Literature review

The concepts of climate change and food insecurity have always held a prominent place in the economic literature, ranging from theory to the search for an empirical relationship between these two factors. Despite the many studies that have been done to help policies, food insecurity remains a problem for the world, but more particularly for developing countries such as those in West Africa. As the problem persists, it is important to make an assessment of food insecurity in a context of climate change without ignoring the question on the vulnerability of households to this phenomenon.

In this chapter, we present a literature review of climate change and food insecurity. The first section deals with theoretical review, the second one with empirical review and a third section which synthetize these two first sections.

2.1 Theoretical review

Climate change and the risks of food insecurities are phenomena that are widely discussed in the literature.

In this section, we will discuss existing definitions in order to shed light on the concepts of climate change and food insecurity.

Also, sources of household vulnerabilities will be addressed as well as the different economic thoughts related to food insecurity that constitute a solid and diversified knowledge support.

In addition, the causal relationships discussed in the literature will be presented to show how climate change is affecting household food insecurity.

2.1.1. Concepts of climat change and food insecurity

In this part, it will first present the concepts related to climate change before addressing those related to food insecurity in a second time.

a) Climate change

Climate change (CC) remains a global concern, due to its disastrous consequences on nature. In fact, it is generally felt in different ways, a delay in the arrival of rains, a variation in the height of rainwater, an increase in the frequency and violence of extreme weather events such as cyclones and frosts (Dugué, 2012).The concept of climate change can be defining in the

different way. According to NASA's scientist [4]climate change can be define as "a broad range of global phenomena created predominantly by burning fossil fuels, which add heat-trapping gases to Earth's atmosphere. These phenomena comprise the rising temperature trends described by global warming, but also cover changes such as sea-level rise; ice mass loss in Greenland, Antarctica, the Arctic and mountain glaciers worldwide and extreme weather events". Furthermore, Climate change words is not simply the changes in weather. Climate change is defined by the Intergovernmental Panel on Climate Change (IPCC) cited by(Oakes, 2009) as "any change in climate over time, whether due to natural variability or as a result of human activity" This definition of climate change is different from the one of the United Nations Framework Convention on Climate Change (UNFCCC,1992), where climate change refers "to a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods"(IPCC, 2007.). Changes in climate refer to changes in means and variability of, for instance, temperature, precipitation, and wind over the course of months to millions of years. Climate in a narrow sense is usually defined as the average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years (Dellasala & Goldstein, 2017).Also, climate change is define as the average weather over a long period, specifically 30 years or more(Chadwick, 2019).

b) Food insecurity

The definition of the concepts of food insecurity is broad and include many different understanding and its meaning has changed over the time (FAO, 2003).Some definitions are directly related to the definition of the concepts of food security. The FAO's own definition of food insecurity is a "(. . .) situation that exists when people lack secure access to sufficient amounts of safe and nutritious food for normal growth and development and an active, healthy life". Food insecurity is a major issue in some countries during the past many years, while others

[4] https://www.photoop.it/en/events/everydayclimatechange-fotografare-il-cambiamento-climatico/#:~:text=Climate%20change%20refers%20to%20a%20broad%20range%20of,with%20severe%20dramatic%20effect%20on%20our%20daily%20life.

have experienced relatively rapid economic growth, but still be under food insecurity according to their rates of food insecurity (ex: India and some African countries).

The food insecurity in many countries in particular in Africa is directly correlated with poverty. Therefore, it is important to highlight that the concepts of food security, hunger and famine are different, although they are related with the same, most basic, need of life which is food. Food security is related to the availability of food, while hunger and famine refer to the effect of non-availability of food(Milà-Villarroel et al., 2015).

According to World Bank (1986), food security is defined as "access to food at all times to enough food for an active and healthy life». This definition implies that indicators of warning systems for food insecurity are related to food production, distribution and consumption. The UNDP definition considers food security to be the possibility of access to food both physically and financially (UNDP, 1994).

Cited by (Burgess & Shier, 2016),the United Nations World Food Program (2016) defines food security as built on three pillars: (1) food availability, that is, sufficient quantities of food available on a consistent basis; (2) food access, or sufficient resources to obtain appropriate foods for a nutritious diet; and (3) food use, or the appropriate use based on knowledge of basic nutrition and care, as well as adequate water and sanitation. These dimensions of the food security concept, however, need to be viewed in a dynamic context, where food and nutrition insecurity compromises the resilience of poor people and developing countries with low income and thus worse economic insecurity, often eroding societal cohesion(J. von Braun, 2014). Therefore, these dimensions are linked in the way that: availability, access, and utilization are hierarchical in nature. The dimension of food availability is necessary but not sufficient for access, and access is necessary but not sufficient for utilization(Webb et al., 2006).

Food insecurity occurs when food systems are disturbed at the situation where food is not available(production, distribution and exchange),accessible(affordability, allocation and preference), or utilization(nutritional value, societal value and safety) is constrained(Thompson et al., 2010). In developing countries, food insecurity shows a issues related to the availability of food at national level affecting household inadequate and inequitable food household(Abdu-Raheem & Worth, 2011)

A successful design of food policy addresses all these three dimensions including the stability. When there are gaps in any of these dimensions at the national level, policy makers should pay

attention to the dimension as a high priority. For example, there is plenty of food available in a certain country but the consumers face challenges to access the food commodities and/or the food stability or utilization in the country is lacking, then such a case represents a threat and requires the policy design to address such lacking(Fathelrahman & Muhammad, 2016).

According to the Human Science Research Council (HSRC) cited by (Masipa, 2017),a country must have enough quantities of food available on consistent basis at all level (national and household).

- **Food availability**

Availability of food depends in many factors such as household production, commodities prices and stock levels and net trade. Food availability translates on the availability of enough quantities of food of appropriate quality, supplied through domestic imports or production(Mockshell & Villarino, 2018)

The availability of food can be disturbed by several factors such unstable social and political environment that prevent sustainable economic growth.Also,war and civil strife, macroeconomic imbalances in trade, natural resource ,gender inequality, inadequate education ,poor health, natural disasters and bad governance, all of these factors can be the causes to insufficient national food availability to food by households and individuals(Ilaboya et al., 2012).

The situation of food insecurity in developing countries shows limited food availability at national stage affecting households, inadequate and inequitable access to food(Abdu-Raheem & Worth, 2011).

At the household level, availability is the capacity to acquire the food it needs which primarily could be satisfied by producing it. Any activity of a household that contributes to improve agricultural production or food supply would be considered as part of food availability strategy.

However, food availability comprises many constrains such as inappropriate agricultural knowledge, technologies, and practices; inappropriate economic policies, including pricing, marketing, tax and tariff policies; lack of foreign exchange; inadequate agricultural inputs; non-existent or ineffective private sector; population growth rates that offset increased production or imports; marketing and transportation systems which inhibit the cost-effective movement of food from source to need; inability to predict, assess and cope with emergency situations which

interrupt food supplies; natural resource, climatic. In the case of African countries, disease constraints; lead to makes donor disinterested or fatigued; and political choice on the part of the host government at any level.

Food availability is assessed through indicators of static and dynamic, that are:

- The adequacy of average energy supply,
- the average value of food production,
- The share of food energy intake from cereals, roots and tubers,
- The average protein diet, -
- The average diet of proteins of animal origin.

Food Access:

Defined by entitlement to produce, purchase or exchange food or receive it as a donation .Also, food access can be defined as the strategy that households apply to get the food. Households and individuals may acquire food through own production, purchase or national safety net mechanisms. Access is also the ability of a household to purchase food i.e., the physical availability of food commodities on the local market and ability of the household to purchase food. The concept of vulnerability is highly related with the idea of access.

According to (Faizah, 1992) food access is the situation when individuals have favorable incomes or others resources to purchase to obtain levels of appropriate foods needed to maintain consumption of an adequate diet/nutrition level. This means that people have sufficient economic, social and physical resources to acquire nutritious foods in a good way .Policies and programs to achieve food access include i) public works programs (PWPs)[5], ii) food subsidies[6], and iii) credit and insurance institutions[7].(Caiafa & Wrabel, 2018).

The individual's food access face in several constraints such as economic growth that is inadequate in the aggregate, or insufficiently broad-based, in general, leading to a lack of job

[5] In public works programs (PWPs) governments provide labor opportunities for unemployed or underemployed people that provide temporary employment in exchange for food or income.

[6] With food subsidies, the government pays a portion of the market price of a crop or food to either the producing farmer or consuming household.

[7] Agriculture-dependent households without access to credit survive in a continuous cycle of poverty.

opportunities or lack of incentives to become a productive participant in the economy; negative impacts of national economic policies; inadequate training and/or job skills; lack of credit or other means to exchange assets or income streams; and food losses associated with ineffective and inefficient harvesting, storage, processing and handling; political decisions favoring one group over another.

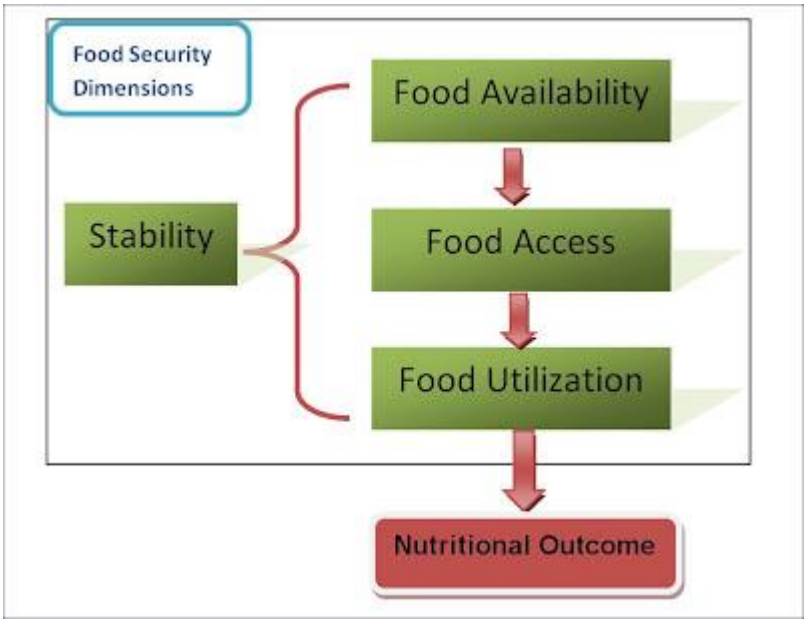
- **Food Utilization:**

Is the proper biological use of food, requiring a diet providing sufficient energy and essential nutrients, potable water, and adequate sanitation(Oluseyi & Oluseun, 2011). Effective food utilization depends in large measure on knowledge within the household of food storage and processing techniques, basic principles of nutrition and proper childcare(Fanzo, 2014). Food insecure households tend to have larger and high number of dependents. Appropriate food use includes that household meets food needed.

Utilization is often used interchangeably with nutrition, yet while utilization focuses on nutrition; it also includes food storage, processing, health and sanitation as they relate to nutrition.

According to (Faizah, 1992) food utilizations sometimes limited by many elements such as: nutrient losses associated with food preparation; inadequate knowledge and practice of health techniques, including those related to nutrition, child care, and sanitation; and cultural practices that limit consumption of a nutritionally adequate diet by certain groups or family members.

Figure 8 : The main component of food systems



Source: https://www.foodandenvironment.com/

Nowaday, two additional dimensions has been developed to better ensure that the whole people in the planet is secure, instead of to day, but into the distant future.These two dimensions are agency and sustainability, each have been widely recognized in the scholarly literature as being relevant to food security for several decades(Clapp et al., 2022) .The agency is define as the capacity of individuals or groups to build their own decisions about their engagement with food systems and their ability to participate in processes that shape food system policies and gouvernance.While, sustainability refers to the long term ability of food systems to provide food security and nutrition in such a way that does not compromise the economic,social and environmental bases that generate food security and nutrition for future generations ((HLPE, 2021).

Food insecurity emerges from these definitions as a corollary and can be defined as any risk that could compromise food security. These risks relate to events that may affect food production, market access or food prices. Climate change or extreme climate (floods, droughts, and heat waves) is certainly not without effects on food security. Another definition from the US department of agriculture is that, food insecurity can be define as “a household-level economic and social condition of limited access to food”(Gundersen & Ziliak, 2016).

Famine and hunger are both related to food insecurity. According to the food security's analysts it has two general types of food insecurity. Food insecurity can be categorized as either chronic or transitory. Chronic food insecurity corresponds to a high degree of vulnerability to famine. Thus, in conditions of chronic food insecurity there is always an impending famine(Hart, 2009). Transitory food insecurity translates into a temporary or seasonal shortage of food because for unexpected factors for only a limited period. In addition, chronic food insecurity implies a continuing inability of unable of a household to access adequate food and generally occurs due to inadequate access to resources(Barrett & Sahn, 2001). On the other hand, transitory food insecurity is temporal and as a result of shocks, economic failures and human induced or natural disasters. This means that climate change may cause transitory food insecurity and if unchecked, would lead to chronic food insecurity.

2.1.2. Vulnerability of household to food insecurity

Vulnerability is an important aspect of food insecurity that remains difficult to measure. To understand the household vulnerability to food insecurity by measuring the level of vulnerability is critically important to the formulation of policies and strategies to achieve food security and reduce vulnerability to food insecurity at all levels. There is no consensus in the literature concerning the most appropriate approach to analyze the vulnerability to food insecurity.

Vulnerability to food insecurity is a common issue for all countries which are facing to food insecurity**.** In the case to assist those who are exposed to food insecurity ,it is great to examine which households are currently food insecure and which are vulnerable on it(Hart, 2009).

The concept of vulnerability is used under different understanding. A main difference between vulnerability as the way to defense face of natural event like drought and vulnerability to a specific negative outcome like food insecurity. Vulnerability is the ability of exposure to shocks and the resilience to the risk(Babatunde et al., 2008).

Many definitions of vulnerability have emerged in the literature but the most considered is the one from(Chambers, 1989) "Vulnerability refers to exposure to contingencies and stress and difficulty in coping with them. Vulnerability thus has two sides: an external side of risks, shocks and stress to which an individual or household is subject and an internal side which is defenselessness, meaning a lack of means to cope without damaging loss". From this definition, it has two mains components of vulnerability: the external side and the internal side. The

external side referring to the structural elements that determine sensitivity and risk to exposure while the internal side is the ability of households to respond and cope with stressors and the actions makes to overcome them

Over the past 25 years ,the main objective in thinking about food insecurity has been the linkage between poverty that couldn't be dissociate to food insecurity and vulnerability, to emphasize consumption rather than production(Lang, 2008).

Vulnerability is a forward-looking concept examining how community and household respond to future shocks. Ultimately, to estimate the vulnerability of a household or community is like to determined their ability to cope with their exposure to the risk posed by shocks such as droughts, floods, crop blight or infestation, economic fluctuations, and conflict. This ability is determined largely by household and community characteristics, most notably a household's or community's asset base and the livelihood and food security strategies it pursues(FAO, 2009).

According to(Krishnamurthy et al., 2014),vulnerability related from the link between socio economic, institutional and environmental system which makes difficult any assessment or quantification. He adds in his study that, to succinctly examine the impact of climate on food (in) security it is important to integrate the aspect of relevant factors that contribute to vulnerability including exposure, sensitivity and adaptative capacity. Therefore, to quantify vulnerability is important to help decisions making by prioritization and planning of activities including to changing climate. From this definition, vulnerability is function of:

- ✓ Exposure to risks: the magnitude and frequency of stress experienced by the entity;
- ✓ Sensitivity: the impacts of stress that may result in reduced well-being owing to the crossing of level;
- ✓ Adaptive Capacity: the extent to which an entity can modify the impact of a stress, to reduce its vulnerability.

Therefore, these three functions are linkage, the greater exposure or sensitivity, the greater is the vulnerability, and the greater the adaptive capacity, the lesser the vulnerability. Thus, adaptive capacity is inversely related to vulnerability. To reduce vulnerability, it is necessary to reduce exposure or rise adaptive capacity

2.1.3. Theories related to Food insecurity

The points discussed in this section deal with the theory of hunger and the need for food in relation to economic theory.

a) Theory of hunger

Hunger can be basically defined as the failure to get quality and quantity of food to satisfy our need or in socially acceptable ways, or the uncertainty that one will be able to do so (Radimer et al., 1990). Hunger is not a recent phenomenon; it has always existed in the history has involving many regions in the world during a long or short period. It is derived by various factors such as: wars, poor harvest, natural disease or economic crises. Therefore, it is important to study the theoretical frameworks that have been developed to explain this phenomenon.

Maltus & Amatya Sen are the two major researchers to analyze the causes of the hunger in the world. Each of them had used his own analysis to explain these phenomena.

i. Classic Analyze: Malthusian and Neo Malthusian theories of hunger

Robert Thomas Malthus (1766-1834) is the pioneer of the analysis of the causes of hunger in the word. According to him, in his essay the principle of the population (1798), since the number of people grows geometrically, whereas the amount of available food grows arithmetically. This situation has the consequence of expanding the gap between food needs and availability. Malthus affirms that in order to avoid the catastrophic situations, a decrease in the growth rates of the population was essential so as to increase food availability.

Malthus advocates preventive brakes on population growth. He argued that two types of check hold population within resources: either preventive check to lower birth rates or positive check to permit higher mortality. In the same way, he also advocates that we should be actively restraining the growth of the population that is, wars, famines, diseases which permanently reduce the number of men to a level compatible with that of food. Through these theories, Malthus consider that rapid growth of the population is the main cause of hunger in the world that make people under food insecurity situation.

The Malthus's theories instilled many analyses but also have many critics[8]. In several famous reports such as the Report on the Limits of Growth, Club of Rome (1972), the state of the planet

a) [8] Malthus wrote thinking of the English agricultural situation in the eighteenth century when it was based on subsistence agriculture.

annual report of the World Watch Institute, these pessimistic analyses of Malthus have been taken up to assert that population growth combined with the growth of human activities (agriculture industry) are likely to deplete natural resources and threaten the future of future generations.

Nowadays, Malthusian theories have evolved with some new arguments that is different from the first theory. These two proposals are different because it shows that the constraint on population growth is represented not only by arable land and food scarcity but also by some others factors like water availability, raw materials, and energy supply and air pollution. From this observation, the neo-Malthusian approach point out the strongly supported by increasing the awareness of the need to protect environment and its resources to permit future generation to enjoy these resources.

Despite these critiques, these theories are quite current as they take into account the availability and safety of natural resources and non-pollution air and water, thus highlight the social and environmental of our living planet (Milà-Villarroel and al., 2015).

ii. Amartya Sen's theory of hunger (1981)

Before Sen, the debate on food insecurity was oriented on food supply, with an analysis focused on the role of natural disasters trends in domestic supplies, price effects of economic policies, and global food balance sheets(Webb et al., 2006).

Amartya Sen is the second analyst after Malthus, who analyses the causes of hunger in the world. His analyses started from the critiques of Malthusian theories by showing, the ratio of food supply/population as noted by Malthus is not enough to explain hunger in the world. Sen illustrate his point of view, by showing that in several major famines as Bengal in 1943 and Bangladesh in 1974, the food supply per person is not decreasing and sometimes even more important than in periods without famines. Amartya Sen proposed a new approach to analyses the causes of hunger known as food entitlement. He focuses on the entitlements of individuals and households. Sen define entitlement as "the set of alternative commodity bundles that a

b) Malthus failed to foresee the agricultural, transport, industrial revolution and demographic transition
c) Geographically marginal land is not necessarily less fertile, even if it is the furthest
d) Famine did not act as a "Malthusian leveler"

person can command in a society using the totality of rights and opportunities that he or she faces». According to Sen by demonstrated in many studies that famine was not usually due to a lack of supplies, but rather to a sudden loss of entitlement in families that are most affected by famine, until reaching a point that food needs could not be meet. He also considers that one cannot talk about famines without constantly consider aggregate food supply(Bowbrick, 1986). As he critiques Malthusians theories, Sen theory was also critiqued by some authors. Pursottan Nayak criticize Sen to do not take in account the background causes or dynamics once the process is initiated. Sen explain only the immediate cause of famine such as the loss of entitlements.

Another critical analyze(Devereux, 2001) argued that Sen's theory focuses on the excessively economic vision of the famine problem and omits other essential factors of famines like the impact of epidemics on increased wars, violence, mortality and population movements or social destruction.

Beyond all these critiques, the fundamental criticism of Sen's theory is that it considers famine as a sudden collapse in food consumption that causes a specific virulent form of starvation and involves widespread death.

In his book of famine and poverty(Sen, 1982), Amartya Sen highlight the limitatiins of entitlements approches. First, it exist an ambiguities in the determination of entitlements. Second, whereas the given legal structure in that society, some transfers imply violation of these rights, such as looting or brigandage.Third, the actual level of people food consumption may decrease below their entitlements for a variety of other reasons, such as ignorance, fixed food habits or apathy.Finally, the entitlement approach focuses on starvation, which has to be distinguished from famine mortality.

b) Meeting food needs according to economic theory

Food is an important input into performance well-being. Also, food is a source of pleasure except its physiological need.

Food security can't be achieved if the people are not able to satisfy their food needs. According to the Mercantilists, the main objective for each society is to guarantee enough and regular food

for its population. Adam Smith analyzes the fact that no society can be flourishing and happy if the majority of these members are poor[9].

Many researches have been done about food needs but there is no consensus on the modalities of such satisfaction on food.

i. Mercantilist's Analyze

According to the Mercantilist (Jean Baptiste Say, 1814), in the context of lack of true theoretical market thinking, Government must ensure that supply of food to populations and at low market prices. To guarantee a price within reach of all, the Government through its administration must constantly monitor and mentor markets and intervene at any time if necessary. A strong politic of public stock which help to stabilize the prices is necessary for the Government to achieve this mission. He concludes by saying that ``Perhaps a government is still doing well to some incentives to a production, which, although giving loss in the beginnings, must however of course give profits after a few years"

Also, the mercantilists argued that alongside this government intervention, a reduction in the movement of grain outside the nation and thus prevent any exit from the territory of agricultural products. For example, «France was never hungry, that is to say that it has richly what to feed his people whatever bad year comes, provided the stranger does not empty our barns". So foreign trade is only allowed if the country is good supplied.

Such policies are not simply developed by the Mercantilists because they are particularly well defended, to varying degrees, by many authors more or less sensitive to the role of the government: Boisguilbert, Galiani, Linguet, Mably, Steuart, Bentham and Malthus. This concept of the nurturing government is, however, restored the liberal ideas which began to develop in Europe at the end of the 17th century.

ii. Liberal's Analyze

Unlike the mercantilists, the liberals argued that the best way to ensure a good food supply of populations is to let the market make with a harmonization of the latter through adjustments through prices and wages. This includes total free movement of agricultural products both

[9] Adam Smith Quotes. (n.d.). BrainyQuote.com. Retrieved February 23, 2021, from BrainyQuote.com Web site: https://www.brainyquote.com/quotes/adam_smith_389733

inside and outside the country without the government regulating the market as required by centuries-old tradition. To allay the fears of in the face of this liberalization of agricultural trade, the liberals are specificities of food goods.

In the context where agricultural products are the most food consume to against food insecurity, Pierre Samuel Dupont de Nemours speaks of "reborn wealth». The agricultural products are analyzed as a generation and not a simple addition of wealth that the nourishing land multiplies and that is assimilated to a true free donation of the nature (physiocratic analysis). In addition, the voluminous and perishable character of the goods makes them difficult to transport compared to other goods. Thus, foreign trade is a small part of domestic production. The people's concerns about the dangers of foreign trade in food products have no reason to exist.

2.1.4. How climate change affect food insecurity?

Food insecurity is a complex phenomenon resulting from multiple causes such as climate change, food prices, depletion of natural resources, shifting diets and population growth. Achieving food security become a big challenge for all countries but climate change makes difficult to reach this goal due to the negative impact of climate change to agriculture. People depend directly to agriculture for their food or livelihood.

Nowadays climate change is becoming a big issue that face all the countries in the world. Climate change has finished to affect people around the world ,their livehoods and ecosystems and become a big challenge for the poor people specifically those in developing countries(Khanal, 2009).

The relation between climate change and food security or insecurity is reflected in relation to impact on crop productivity and hence, food production(Gregory et al., 2005). Climate change is expected to manifest with warmers temperatures, changes to rainfall patterns and increased frequency and sometimes severity of extremes weather(Wheeler & Von Braun, 2013)

The negative effect of climate change is more view in the context where many developing countries are facing to the higher prevalence food insecurity. The importance of climatic and ecological food production processes for African countries, makes climate change effect a serious challenges for achievement food security(Thompson et al., 2010).

According to World Population Project (2015), the population of Africa is expected to double to 2.48 billion of people by 2050.This evolution of the number of population has a serious

challenge of increasing the food supply to meet the need for food for the future(Onyutha, 2019).The variability in weather patterns has a negative effect in the sustainability of agriculture more specifically in crop production. The poor countries like Sub Saharan African countries are vulnerable to the impact of global climate change such as increase in the number of duration and severity of tropical storms and longer periods of drought. The frequency of poverty in many countries in the world is the main challenge in mitigating the negative effect of global climate change(Urama & Ozor, 2011).

Therefore, climate change can be considered as the most serious environmental threat to the challenge against hunger, malnutrition, disease and poverty in the world particularly in Africa, through its impact on agricultural productivity. It is expected that crop yield in Africa may decrease by 10-20% by 2050 or even up to 50% due to the effects climate change such as warming and drying(Jones & Thornton, 2009).This may happens because African agriculture is more dependent on rain fed.Also, climate change impact on crop yield will vary broadly with others factors such as use of different crop varieties, soil texture, nutrient and organic matter levels etc. (Fyles & Madramootoo, 2016).According to (Enete & Amusa, 2010) climate change is predicted to present a serious risk and consequences in Africa. However climate change has not only negative impact on agriculture, temperature increasing for example helps to crops development in high altitude areas towards the poles(Enete & Amusa, 2010). The ground of the negatives consequences of climate change are dependent on many factors such as latitude,altitude,livestock reared and type of crop grown(Khanal, 2009).

In the literature some authors like(Gregory et al., 2005; Gross, 2013; Kiprutto et al., 2015) argued that climate change impact on food security or insecurity is expected to impact all the three main components of food security: availability, access and utilization. Climate change may affect food system in different ways through direct effect on crop production to changes in markets, food prices and supply chain infrastructure(Gregory et al., 2005).

a) Impact on food availability

According to (Thompson et al., 2010),availability is the most factors who respond to the impact of climate change due to the changes in crop production. Climate change impact on food availability of sub-Saharan African countries projected to be serious due to their vulnerability of subsistence farmers who have low coping capacity with environmental constraint (Gregory et al., 2005).Crop yield is expected to decrease because of the climatic effect on soil and water.

As water insecurity is closely linked to food insecurity, climate change effects on water resources will have significant impact on crop productivity (Wheeler & Von Braun, 2013).This will affect the food production (availability) especially to vulnerable subsistence farmers in Sub Saharan African countries where there are no well-established adaptation strategies. Although, moderate increase in temperature (1°C- 3°C) can have a benefit to food production in temperate regions, it has a negative impact in tropical and seasonally dry regions. When the temperature is more than 3°C, it has a negative effect on food production (availability) in all regions. At the household level, shocks may have a negative impact on food availability and eventually conduct to food insecurity(Gershon & Ansah, 2019).

b) Impact on food access

Effect of climate change on food accessibility dimension is not well investigated due to its factor's complex interaction. Food access is linked to climate change through indirect pathways. In developing countries access to food has been improved over last 30 years based on the falling real prices for food and rising real incomes. However, this trend may be reversed due to a possible increase in food price and a decline in the rate of income growth resulting from climate change (Ludi, 2009)

Access depends on the ability to produce food, thus, it may be affected on both sides of the consumption process in the presence of high food prices or lack of financial capital to acquire goods. Therefore; due to climate change, drought and low crop productivity are expected to increase. In addition, consumption of purchased foods which is expected to increase based on the frequency of drought will also increase. In addition, the ability of people to access food may be exacerbated due to rising food prices and unemployment (Gregory et al., 2005).Climate change has a potential to affect food price, access to markets, the level of poverty, employment condition and educational status and these can affect people food accessing capacity and will lead to food insecurity and malnutrition.

The increase of food prices in West Africa will have a negative impact on both urban population and farmers, the majority of whom are not grain purchasers(Brown & Higgins, 2009).Higher food prices and unemployment may impact the possibility of people to access them. In addition, financial means issues and high food prices will severely affect accessibility and serve as future food insecurity in the face of climate change (Thompson et al., 2010).When

food prices increases, the poor household, which spend most of their income on food are obliged to reduce both quality and quantity food consume (Fyles & Madramootoo, 2016).

c) Impact on food utilization

This dimension appreciates whether a person will be able to derive sufficient daily nutrition from the daily nutrition from the available and accessible food .This necessitates the proper biological use of food, requiring a diet providing sufficient energy and essential nutrients, potable water; and adequate sanitation: It also depends to a good extent on knowledge within the household of food storage and processing techniques, basic principles of nutrition and proper child care and illness management(Hyacinth & Kwabena, 2015)

Utilization is an important component of food security in a climate change context. It has limited research related to the impact of climate change on food utilization. The direct effect is through decreasing productivity of plants that are rich in micronutrients or it alters the micronutrient contents of specific crops trough flooding of the cropland. Others effects of climate change are its influence decisions of farmers on whether to cultivate or not crops with high nutritious value. And also, its effect on food prices and in addition to its effect on food access, high food price can also influence people to consume less preferred quality of food items and allocate food only to certain household members. Food utilization, to achieve nutritional well-being is related upon water and sanitation and will be impacted by any effect of climate change on the health environment(Wheeler & Von Braun, 2013).

In general, climate change expected to affect agriculture through four major ways increased carbon concentration, changes in climate averages, altered weather and weather events and induced secondary effects on social and economic systems. In African countries more specially in Sahelian countries, for instance, the overall Impacts of climate change on agriculture are projected to be negative hence threatening regional food security (Jalloh et al., 2013). These impacts are:

- Direct on crops and livestock productivity,
- Indirect on the availability or prices of food domestically produced and in international markets
- Indirect on income from agricultural production at both farm and country levels

Definitely climate change will negatively affect development and living standards in West Africa due to some exogenous factors such as (Adiku et al., 2015)

- High resilience of people and their loverhoods on natural resources, livestock and cropping agriculture
- Increasing rate of degradation of these natural resources, which make them less resilient
- Extreme poverty with low per capita

Lack off social intervention schemes such as insurance, which makes it difficult to respond to the adverse effects of climate extremes.Also, the changing of dietery change and their relation to climate and health need to be highlited (C.Rosenzweig et al, 2020).

2.2 Empirical review

The case studies that will be presented in this section cover techniques for measuring food insecurity in a context of climate change, measuring vulnerability, the importance of measuring household food insecurity, the relationship between climate change and food insecurity and the effects of climate change on crops, livestock and fisheries.

2.2.1. Measurement of food insecurity in the context of climate change

Food insecurity is a multidimensional problem, there is need to consider how to measure it in its all dimensions to ensure that its critical components are not overlooked. According to the engineer Lord Kelvin “When you cannot measure [something] your knowledge is of a meager and unsatisfactory kind. It may be the beginning of knowledge, but you have scarcely, in your thoughts, advanced to the stage of science, whatever the matter may be’’.

Food insecurity is difficult to quantify because of its concepts and measurement issues. In the case of food insecure issue, to better use resources to where they can do the greatest good, information to better guided it must be taken to answer to the questions like who is food insecure, where, when and why .This requires improved measurement of food insecurity and its relatives and greater attention to key institutional and policies(Barrett, 2010).

In economic theory, food insecurity is measured by several indicators. The two most common are the energy balance per person and poverty rate. The energy balance measures the energy inputs of food and poverty rate reflects the ability to obtain food on the market. Energy requirement is related on age, sex, body weight, activity and lots of other factors.

The Food and Agricultural organization measures food insecurity or security by focuses on calorie and energy absorption. This measurement requires information on the number of calories people consumed in a period of specific time. Also, it need "the coefficient of variation of caloric intake to generate the energy distribution curve, cut-off point to estimate the range of people under the minimum caloric requirement"(Pérez-Escamilla & Segall-Corrêa, 2008).

Practically,(WHO, 1986) recommendation is focused which is based on normatively specified the minimum level of energy consumption given a minimum acceptable body weight for healthy people at each age and sex group. When the percentage of people, as opposed to households, is measured, each person is assigned the energy deficiency status of her or his household.These two indicators cannot measure insecurity as some households produce part of their own food (Badolo, 2015).

Other indicators are also used to measure food insecurity. The most common in economic theory are the under-five mortality rate, child malnutrition and the proportion of undernourished people. More authors have criticized these indicators in particular Wiesmann (2004) for whom under-five mortality and child malnutrition may be due to different reasons name health. Another major limitation is that under-five mortality and child malnutrition cover only one age group of the population (less than five years) as well as the proportion of undernourished people who do not include children under five.

The recent theory recommends measuring food insecurity using the Global Hunger Index (GHI). The GHI measures the level of food insecurity taking into account insufficient food availability, deficits in the nutritional status of children and premature mortality caused directly or indirectly by undernutrition (Badolo, 2015). This index is a score whose values vary between 0 and 1, 0 corresponding to the state of total food security and 1 to that of total insecurity.

Also, others indicator was developed to measure the level of food insecurity for a specific country and for the developing counties. The US Department of Agriculture developed the Household Food Security Survey Model to estimate the prevalence of food insecurity and monitor over time among groups of households in the United States. This indicator aims to measure whether households had sufficient food or money to meet basic food needs and what their behavioral and subjective responses to that condition were. In view of the good success of US HFSSM, US Agency for International Development (USAID) funded Food and Nutrition Technical Assistance Project (FANTA) ordered work to develop another indicator which called

Household Food Insecurity Access Scale (HFIAS) to help development organizations in evaluating their food security programs in developing countries(Leroy and al., 2015).

According to the report from the National Research Council (2005), to monitor the well-being of a population of interest it is better to estimates of the prevalence of food insecurity level . These estimates can help to know how a population is faring over time, whether its food insecurity situation is improving, deteriorating, or still be at same level. Also, these estimates can serve as an important surveillance tool for identifying whether specific subgroups are doing poorly for example rural and urban groups, regions and states, family and household structures.

Another tool which mane is the Coping Strategies Index (CSI) was developed in some African countries such as Ugandan and Ghana but has early warning and food insecurity assessment in others African countries like Kenya, Ethiopia, Zimbabwe, Malawi and Burundi(Daniel Maxwell & Richhard, 2008). This Index is an indicator of household level of food security that is relatively simple and quick to use, straightforward to understand and correlates well with others complex measure of food (in)security.The CSI can be used to measure the impact of food aid programs, as an early warning indicator of future food crisis, and as a tool for assessing both food aid needs and whether food aid has been targeted to the most food insecure households in the country(Dan Maxwell et al., 2003)

Some study use also anthropometry which refers to measure how the lack of food and healthy diet influence individuals. It is experimented in national survey using height and weight of the child, infants, young children, youth and adults.

According to(Daniel Maxwell et al., 2014a) food security indicators can be classifying as follow

a) Dietary diversity and food frequency

This kind of measurement captures the number of different kinds of food or food groups that people eat and the frequency of which they eat them and sometimes involves weighting these groups. The metrics which are the component of dietary diversity and food frequency are, the Food Consumption Score (FCS) developed by the World Food Program (WFP) and the Household Dietary Diversity Score (HHDDS) promoted by the United Nation Food and Agriculture organization (FAO) and USAID.

Food Consumption Score (FCS): represent the score calculated using the frequency of consumption of different food groups consumed by a household during the 7 days before the

survey. This proxy indicator of food security measures caloric intake and diet quality at the household level. When combined with other household access indicators, it gives an indication of the food security status of the household.

Household Dietary Diversity Scale (HHDS): This indicator represents the number of different foods or food groups consumed over a given reference period and is approximatively similar to the FCS, but usually with a 24-hour recall period without frequency information or weighted categorical cut offs. This proxy measures off household food access widely promoted by UN Food and Agriculture Organization and USAID targets individuals' household level or focus on women.

b) Consumption behaviours

From measuring behaviors related to food consumption, these indicators capture food security indirectly. As mentioned by (Maxwell & Caldwell, 2008) the coping Strategy Index(CSI) which counts the frequency and severity of behaviors in which people engage when for example they do not have enough food or enough money to buy food. Reduce Coping Strategy Index (rCSI) which tends to measure only the less severe coping behaviors has developed and is probably now more used than the original one. It considers the five most common strategies with standardized weights.

Coping Strategy Index: Measure the behavior of people when they cannot access enough food, thus measures the adjustments households make in consumption and livehoods. The coping can be consumption changes, expenditure reduction, and income expansion. This index has been widely used by WFP/VA (World Food Program/Vulnerability Analysis mapping unit), FAO/FSNAU (UN Food and Organization/Food Security and Nutrition Analysis Unit for Somalia), and the global IPC (Integrated Phase Classification) team, among others.

Household Food Insecurity and Access Scale (HFIAS): It is designed to capture household behaviors signifying insufficient quality and quantity, as well as anxiety and uncertainty over household insecure access or food supply.

The household Hunger Scale (HHS): This is essential a behavioral measure which tends to capture more severe behaviors. Such questions are asked for its construction: Was there ever no food to eat any kind in your house because of lack of resources to eat food? Did you or any

household member go to sleep at night hungry because there not enough food? Did you or any member of a whole day and night without eating anything because there was not enough food?

c) Experiential measure

These are indicators combining behavioral and psychological measures. This widely used in international context are the Latin American and Caribbean Food Security Scale(ELCSA) and the household Food Insecurity Access Scale (Daniel Maxwell et al., 2014b)

d) Self-assessment measures

They have been introduced recently and are highly subjective in nature and likely too easy to manipulate in programmatic recall period and the change in livehood status over a longer period of time.

e) Global Hunger Index

This metric uses undernourishment, child underweight and Child mortality to calculate hunger.

2.2.2. Vulnerability to food insecurity and its measurements

A method to assess vulnerability, an index has been developed jointly by the United Nations World Food Program and the UK Met Office Hadley Center in 2004. This Experimental Hunger and Climate Change vulnerability index may help to find the most vulnerable to climate change and provide inputs to identify the countries that are most vulnerable to climate change in the context of food (in) security. By doing that, the index assesses a country-level of vulnerability to food insecurity as a result from the climate events by combining information about exposure to present-day climate hazards (such as floods, droughts and storms) and food security relevant measures of sensitivity and adaptive capacity(Richardson et al., 2018). (Mirzabaev et al., 2023),consider that the vulnerability to food insecurity of the population in the context of climate change is due to the lower access to income,lower access to nutritious food and social discrimination. However, on the study of poverty in the economic context, three important methods of measuring vulnerability was developed to see the vulnerability of poverty: (1) uninsured exposure to risk, (2) expected poverty, or (3) low expected utility(Günther & Harttgen, 2006).

In the literature, measurement of vulnerability should be done by an understanding of the concept of vulnerability. Fisrt,according to (Cannon et al., 2003) any measure of vulnerability

should have a “predictive quality”. This is to try to know what will happen to the population who are facing to a particular risk and hazard.Second,define vulnerability in relation to a socially acceptable level of outcome is important for the measurement of vulnerability (Siegel & Alwang, 2001). Third, the indicators of vulnerability should help to identify the causes of vulnerability and importance of idiosyncratic and covariate risk.Fourth,a good measure of vulnerability should point out the particular cause of vulnerability to better help for the solving of the problem(Günther & Harttgen, 2006).Fifth, to measure vulnerability goodly ,consider the dynamics of vulnerability in all period(before, during and after hazard occurs) is important(Birkmann, 2008).Finally, assessing vulnerability cannot be done without assessing a system’s way and coping with risk.

The issue of food insecurity and climate change has inspired several authors .Webb P. et Roggers B. (2014) define food insecurity based on four major concepts: availability, access, use and risk associated with disrupting any of these three factors. To this end, the main major risk to food availability is climate change due to dependence on rainfall, inter-climatic variability seasonal, recurrent extreme events affecting both crops and livestock, and poverty that limits the capacity of adaptation (Adelekan, and al., 2014). The question of vulnerability arises because of inadequate means of adaptation, the risk of serious consequences and the slowness of recovery after an extreme event shock (Bohle, 1994). According to FAO, demand of cereals in developing countries will grow by more than 75% by 2050 (Vermeulen, and al., 2011).

Badolo (2015) studies price shocks, vulnerability and food security in developing countries by adopting a data analysis of panels in which they have climate data on localities and economic, socio-demographic data on households. It shows that developing countries, particularly African countries, are highly vulnerable to food price shocks and climate change. Also, the vulnerability of Malagasy households to climate change was studied using survey data with which a classification was used, in particular a factor analysis of correspondences (AFC) and a hierarchical ascending classification (CAH). Results showed that households have low resilience due to lack of financial and material resources (Rajaoberison, 2015). Similarly, Ballet and al. (2014) showed through panel data that households have resilience factors in the face of food insecurity, the most obvious of which are the savings and the amount of farmland available to the household.

N'da (2014) studied the resilience of Ivorian households using survey data. It adopts an analysis as a main component to consider household adaptation strategies and their characteristics. Also, it uses a logit model to determine the explanatory factors for the decision of a choice of adaptation methods. In the same way, by analyzing Factors Affecting Farmers' Resilience to Food Insecurity in the Peanut Belt of Senegal,(M. T. FALL, 2018) found that households that strongly depend on agricultural production for their food face severe risks of food insecurity.

Yabile (2011) analyzed the vulnerability of populations to food insecurity in Côte d'Ivoire using survey data. It adopts a logit regression and has shown that demographic, societal and geographical characteristics are the main factors that influence the food situation of households.

Djibo (2018) studies the choice of peasant alternatives in the face of food insecurity through a socio-economic analysis of the cluster of Tolkoneye villages. It uses cross-sectional data to perform a linear regression model and shows that 80% of households had a lack of means of survival.

Ly (2014) uses time-series data on Senegalese households in several municipalities as well as climate data on the localities of these households. It uses an analysis based on a Ricardian model. Its results have shown that climate change will have sudden effects that will increase household vulnerability.

By analyzing the household 's vulnerability to food insecurity and its influencing factors in East Hararghe in Ethiopia using the vulnerability as expected poverty(VEP) approach,(Sileshi et al., 2019) found that using improved seeds and soil and water conservation would in turn reduce the household vulnerability to food insecurity.

Babatunde et al.(2008),in their study of gender-based analysis using primary data collected through a cross section survey of representative farm households in Kwara state in the north-central region of Nigeria. They found that female headed households were more vulnerable to food insecurity than male headed households.(M. T. FALL, 2018) report a similar relationship: he found that homes with aged household head face with food insecurity. The same finding was also point out by (Zakari et al., 2014) in their study that investigate the factors affecting household food security in Niger. Based on survey data covering 500 households, the main finding was that female headed households are more vulnerable to food insecurity compared to male headed household.This result is contradicted by (Delisle, 2014) who find that Women play an importante role in providing and benefiting from the qualitative aspect of food security.

The study of examining household food insecurity vulnerability in the face of climate change in Paraguay show that climate change is expected to increase household vulnerability to food insecurity at the national level by 8% points by 2050 and by 28% points by 2100.Another finding is that climate change is proved to have a negative effect on household agriculture and food security in this country (Ervin & Gayoso de Ervin, 2019).

2.2.3. The important of measurement household food insecurity

Many and different elements contribute to food (in)security, such as, the continued access to food, the availability and consumption of nutritive food, and the importance of social values. The summary on each of these elements leads to the measurement of the extent and prevalence food (in)security in alternative ways(Von & Zeller, 2007).

Food insecurity is an issue which touch every part of the world but more sensitive are the developing countries. At this time, it is important to know who the food insecure are. Where are they located? And why are they food insecure? Design the measurement of food insecurity to best estimate prevalence and accurately identify household characteristics to manage food insecurity, because food insecurity negatively impacts quality of life(Jensen, 2010).In addition, food insecurity may be caused by lack of available and safe food, inappropriate or inadequate use of food at the household level(Milà-Villarroel et al., 2015).

In the fact that many regions around the world face the problem of food insecurity and since its implication are so severe it is a necessity to identify the currents status, to have information about the factors which contribute to food insecurity and moreover to have deeper knowledge of those who are sensible of future deprivation in order to help policies makers and organizations to devise appropriate context specific solutions on this issue.

2.2.4.

2.2.5. Empirical review on the relationship between climate change and food insecurity

The links between climate change and food (in)security is reflected in relation to impact on crop productivity and hence food production(Gregory et al., 2005). Food insecurity is the result of food system process all along the food chain. Climate change will affect food security through its impacts on all stages of global, national and local food systems. It will first affect the people and food systems that are already vulnerable and highly sensitive to rainfall

variability. The IPCC report (2013) argued that climate change has negative effect on people's livehood, agriculture, freshwater supply and their natural resources that are important for human live.However,food insecurity is showed to be persistent in the parts of the world where industrial agriculture, long distance marketing chains and diversified agricultural livelihood opportunities are not significant in the view of economic(FAO, 2008).

To highlight the impact of climate change on food (in)security, its need to see the impact of climate change on agriculture in the boarder sense due to the fact that most of the population in the world particularly in African depend on agricultural production for their living subsistence. Many studies have shown that there is a connection between climate change and these four dimensions of food security. Among these dimensions, only food availability and climate change were well studied, with little emphasis placed on other components that guarantee adequate consumption(Zewdie, 2014).

The study from historical data over the last 30 years in West Africa shows that some areas experienced increased rainfall by as well as 20% to 40%,others locations experiences a decreased in annual rainfall by about 15%(Adiku et al., 2015).Therefore,the increased warming and shifts in rainfall patterns associated with climate change would adversely affect West Africa agriculture, which contributes between 40% and 60% of gross domestic product (GDP).Another author,(Haile et al., 2017) climate change is expected to reduce crop production by 9% in 2030 and as high as 23% in the 2050s.Previously,studies such as (Parry et al., 2005) also observed that food security risk in Africa are deteriorating under climate change and natural variability induced changes in global food production could be beyond 50% in 2080s.

Zakari et al.(2014) examined the factors affecting household food security in Niger with a survey data covering 500 households. Using logistic regression revealed that the gender of the head of household, diseases and pests, labor supply flooding, poverty, access to market, the distance away from the main road and food aid are significant factors influencing the odds ratio of a household having enough daily ratios. The result show that Nigerien population continuous to be under food insecurity because of many effects of climate change such as drought, flooding, soil infertility.

Thompson et al.(2010) investigate the link between climate change and food insecurity, a systematic review was done of the per reviewed literature. Analysis of the literature found consistent prediction of decreased crop productivity, land degradation, high market prices, and

negative impact on livehood and increased malnutrition. In the same way (Mosha, 2012) review through literature search, the impact of climate change on food security in Nigeria with a view to making suggestions on strategies to mitigate the impact of climate change on the environment generally and food security in particular. The author conclude that the menace of environmental degradation occasioned by climate change has affected agricultural production in sub-Saharan Africa in general and Nigeria in particular.

Lemma et al., (2013) study the implications for household food security in agropastoral areas of Jigjira district, Eastern Ethiopia by using rainfall and temperature data from the period 1952 to 2010 and primary data gathered from 140 sample households and focus group discussions The Rash model estimation result based on the Food Security Core Module showed high prevalence of food insecurity in the district with 81 per cent of food insecure households consisting of 27 per cent food insecure without hunger, 29 per cent food insecure with moderate hunger, and 25 per cent food insecure with severe hunger. The main finding of this study is that climates factors (drought, invasion of unwanted plant species, low annual rainfall, high temperature, and water shortage) are the most causes of food insecurity in this areas. In this fact, the food insecure households comprised of; 35 (25 percent) food insecure without hunger, 41 (29 percent) food insecure with moderate hunger, and 37 (27 percent) food insecure with severe hunger.

Mamadou Abdoulaye et al., (2019) used the Factor Augmented Vector Auto Regression (FAVAR) approach and the principal components analysis to examine the impact of climate change on food yield in Senegal. The authors identified two major shocks representative of climate change. The finding of this study shows a positive impact of the thermal shock on the yields of rice, maize, millet the results from two stages, with a much greater impact on rice and maize yield. Rising temperatures are, however detrimental to sorghum. A decline in rainfall has a negative impact on the yields of all cereals.

Mariyani et al., (2019) analyze the resilience of rain fed farming communities against the threat of food insecurity. This study focuses in the Marga Kayta Village, Lamoung province and use data collected by survey method taking 100 respondents with simple random sampling. The results showed that the rain-fed farming community has been resilient to face the threat of food insecurity due to climate change. Rain-fed farming community through a network of adaptive capacity, especially social capital and manage available resources can maintain the existence of institutional barns to face the threat of food insecurity.

Olofin, (2016) examines empirically the interaction among per capica income growth, climate change and food security in fifteen West African Countries. The used Panel Var (PVAR) techniques on annual secondary data obtained World Development Indicator (WDI) between 1990 and 2013.The results show that evidence of income growth spurring food security in the short run and reducing it in the long run, while climate change increased food insecurity throughout in West Africa. The author suggest that climate change variables is need to be controlled if African Countries want to achieve food security goal.

Boukary et al (2016) study focus on identify factors affecting rural households' resilience to food insecurity in Niger (Diffa, Dosso, Maradi, Tahoua, Tillabery, Zinder and Niamey). They create a resilience index by using principal component analysis and later apply structural equation modeling to identify its determinants. Data from the 2010 National Survey on Households' Vulnerability to Food Insecurity done by the National Institute of Statistics was used. The result of the study show that asset and social safety net indicators are significant and have a positive impact on households' resilience. Climate change approximated by long-term mean rainfall has a negative and significant effect on households' resilience. Therefore, to strengthen households' resilience to food insecurity, there is a need to increase assistance to households through social safety nets and to help them gather more resources in order to acquire more assets.

Adjin et al.,(2019) studies the Farmers organizations and food availability in Senegal: An impact analysis using a spatial econometrics approach and applying various econometrics estimations techniques that control for selection biases and spatial heterogeneity. The result show that being a member of farmer organization have a positive impact of productivity by increasing of 19% cereals production. This includes that organize the famers as an organization will help to against food insecurity in the study areas.

Jane Kabubo-Mari ara & Kabara, (2015) investigates the effects of climate change on food security in Kenya. They estimated Fixed and random effects regressions for food crop security. Using the Special Report on Emissions Scenarios and Atmospheric Oceanic Global Circulation Models to simulate the expected impact of future climate change on food insecurity. The study is based on county-level panel data for yields of four major crops and daily climate variables data spanning over three decades.The findings show that climate variability and change will increase food insecurity. Food security responds positively to favorable agro-ecological zones, soil drainage and depth, and high population density.

Cited by (Wheeler & Von Braun, 2013), a recent systematic review of changes in the yields of the major crops grown across Africa and South Asia under climate change found that average crop yields may decline across both regions by 8% by the 2050s (28). Across Africa, yields are predicted to change by –17% (wheat), –5% (maize), –15% (sorghum), and –10% (millet) and, across South Asia, by –16% (maize) and –11% (sorghum) under climate change.

Lobell,(2008) use crop models to calculate changes in agricultural production projected in 2030.The findings are that climate change is likely to reduce agricultural production, thus reducing food availability that lead to food insecurity.He gives a suggestion that communities can cope with climate change by having an alternative crop like producing corn to producing sorghum,whose need of water is lower (Jemal & Kim, 2014) and higher temperature tolerances are better suited to a warmer and drier climate.

Jemal & Kim, (2014) evaliuated the determinants of food security amonng rural household in Ethiopia using data from the latest around of Ethiopia rural household survey. OLS regression were first run to identify important determinant based on the two measures.The findings show that many factors such as age and education of household head,adequacy of rainfall,livestock possession,participation in of farm activities,soil conservation expenditure were significantly and positively related to household food security while access to credit and remittance had negative influence.

Wheeler & Von Braun,(2013) established from broard the mains priorities for future researches on climate change and food security:

- Gathering evidence on the effects of climate change impact on the food access,utilisation,stability dimensions in order to understanding of food security;
- Understanding the indirect impacts of climate change on food security requires more comprehensive analitical approches and sophisticated models,including links to political economy;
- Improving projections of regional climate change effects on food security at country level and on smaller scales that are crucial for decision making for adptation food system;
- Better integrating of human dimensions of climate change impacts into food security planning because food systems are ultimately driven by perceived changes in their local climate that will be central to the adaptation to climate change and actions to address.

Futhermore,the same authors Wheeler and Von propose from existing evidence six percepts for impact of climate change on food security:

- Climate change impact on food security will be worst in countries already suffering high levels of hunger and will worsen over time;
- The consequences for global undernutrition and malnutrition of doing nothing in response to climate change arepotentially large and will increase over time;
- Food inequalities will increase,from local to global levels ,because the degree of climate change and the extent of its effects on people will differ from one part of the world to another,from one community to the next and between rural and urban areas;
- People and community who are vulnerable to the effects of extreme weather now will become more vulnerable in the future and less resilient to climate shocks;
- There is a commitment to climate change of 20 to 30 years into the future past emissions of greenhouse gases that necessitates immediate adaptation actions to adress global food insecurity over the next two to three decades;
- Extreme weather events are likely to become more frequent in the future and will increaserisks and uncertainties within the global food system.

2.2.6. Climate change and livestock

Livestock production is the one of the dominant land use in the world wich cover around 45% of the Earths land surface(Baumgard et al., 2012).Also,livestock remains a non negligeable contributor to microeconomic and macroeconomic level of many West African countries(Zougmoré et al., 2016).Livestock plays an important role in the West African Economies by occupied 44% of agricultural GDP.In addition to this ,60 millions heads of cattle and 160 small uminants ,400 million poultry,make West Africa more specifically Shelian countries an exceptional region of livestock.The statistics show the Sahel and West Africa contain 25% of the cattle, 33% of the sheep, and 40% of the goats(Mulumba et al., 2015.). Therefore the importance of livestock in the food subsistance for people live is the fact that we need to be informed how climate change can affect livsestock. Drought is consider as the of major constraint to livestock production in West Africa countries but more specifically Sahelian countries(Hiernaux et al., 2009).Drought may affect livestock production through decreasing herbage production and water scarcity which usually leads to herb mortality. Climate change is also projected to affect livestock at both the species and breed levels,although this is a major research gap (Zougmoré et al., 2016). A particular impact of climate on livestock may include

changes in availability and quality of forage resources,access to water,species and breeds of livestock that can be kept livestock mobility and animals diseases(Thornton et al., 2014).

Mertz et al., (2010) study Climate Factors Play a Limited Role for Past Adaptation Strategies in West Africa.Using the perceptions of 1249 households in five countries across an annual rainfall gradient of 400-900 mm, authors provide an estimate of the relative weight of climate factors as drivers of changes in rural households during the past 20 years. The findings show that rainfed crop production is mainly constrained by climate factors, livestock and pasture are less climate sensitive in all rainfall zones.Another finding is that,the decrease of the number of cattle in all three rainfall zones with most significantly in the drier areas.Also,the decrease of cattle,sheep and goat numbers are not directly related to climatic factors and are highly dependent on the rainfall zone.

Samuel, (2014) examine the impacts of climate change on livestock husbandry and adaptation options in the Arid Sahel belt of West Africa. Author used data from where climate change baseline survey data collected from 421 households in Burkina Faso, Mali and Niger. He used probit model for the data analysis results from this study show that drought mostly affected sheep with 17.86% in Burkina Faso than Mali with 8.5%. Another finding is that 12.86% of farmers from Burkina Faso introduced new oxen on their farms as a way coping while 18.5% and 17.86% of the farmers from Niger stopped keeping dairy cow and goats respectively. Result from probit model show that access to media information getting assistance during flooding, access to non-farm credit, aged dependency and access to credit were found to influence adaptative capacities of livestock farms. The author conclude that drought is pressing economic challenge to livestock farmers and effort to reduce its impact should focus on more provision of assistance and media information.

Climate change impact on livestock can be materialize on its impact on feed crop system and grassland such as(Hopkins & Prado, 2007):

- A change in herbage growth brought about by changes in atmospheric CO_2 concentrations and temperature;
- A change in the composition of pastures, such as changes in the ratio of gasses to legumes;
- A change in herbage quality, with changing concentrations of water-soluble carbohydrates and N at given dry matter (DM) yields;

- A greater incidence of drought, which may offset any DM yield increases;
- A greater intensity of rainfall, which may increase N leaching in certain systems.

2.2.7. Climate change and fisheries

The impact of climate change on food insecurity in the world particularly in West Africa is visible in agricultural broader sense .Fisherie is an activity doing by many people for their food and income,so that it is important to find in the literarute how climate change can affect fisherie and its link to food insecurity. The impacts of climate change on the ocean environment particularly ocean warming acidification and level rise will have an effects on fish stocks and fishers in important ways.These impacts includes changes in fish stocks productivity and distribution, human migration to and away from coastal areas, stresses on coastal fisheries infrastructure, and challenges to prevailing maritime boundaries (Mendenhall et al., 2020).

Taylor et al., (2012) Study the potential impacts of climate change on fisheries and their effects on the economics, food and nutritional security in West Africa.They use a dynamic bioclimatic envelope model to project future distribution and maximum fisheries catch potential of fish and invertebrates in West African waters.The projections show that climate change may reduce in marine fish production and decline in fish protein supply in this region by the 2050s under the Special Report on Emission Scenarios (SRES) A1B. Associate with economic parameters, they project a 21% drop in annual landed value, 50% decline in fisheries-related jobs and a total annual loss of US$311 million in the whole economy of West Africa. All of these changes are expected to have an impact on food security by increasing the vulnerability of the region through economics and food security of West Africa to climate change.

Failler,(2014) analyze the changes in fishing practices in West Africa both by national and foreign vessels and in trade patterns, as well as on the way in which these affect the economic and nutritional patterns of the Western and Central African countries, especially when climate variability is taken into account.The author elabore many senarios to highlight the link between climate change ,fishing pratices and food insecurity.The projections show that when environmental conditions are unfavourable, the supply-demand gap could rise to 1.8 million tonnes. However, even the best environmental conditions will not be able to satisfy the demand if the fish consumption per capita increases and the gap will progressively grow with time reaching 2.9 million tonnes in 2025.However,the pessimistic scenario presents a worrying

picture of the future supply of West Africa where the gap between demand and supply may reach 3.3 million tonnes in 2025. In both scenarios, market mechanisms will adjust demand and supply by increasing the price of fish reducing therefore the accessibility for poor people and inhabitants of rural and areas far from the main fish markets.The author conclude that climate variability increases the food security risks both in terms of quantity and quality.

Lauria et al.,(2018) study the important of fisheries for food security acrss three climate change vulnerable Deltas areas.Autors done economic and integrated modelling using future scenarios,they suggest that changes in temperature and primary production could reduce fish productivity and fisheries income particularly in the Volta and Bangladesh deltas.Nevertheless,these losses could be mitigated by reducing management at regional level.

Allison et al., (2009) examine Vulnerability of national economies to the impacts of climate change on fisheries. Authors compare the vulnerability of 132 national economies to potential climate change impacts on their capture fisheries using an indicator-based approach. They identified countries like Countries in Central and Western Africa (e.g., Malawi, Guinea, Senegal, and Uganda), Peru and Colombia in north-western South America, and four tropical Asian countries (Bangladesh, Cambodia, Pakistan, and Yemen) as most vulnerable. The findings are, many vulnerable countries were among the world's least developed countries whose inhabitants are among the worlds poorest and twice as reliant on fish, which provides 27% of dietary protein compared to 13% in less vulnerable countries. These countries also produce 20% of the world's fish exports and are in greatest need of adaptation planning can make to poverty reduction.

2.3 Partial conclusion and potential literature gaps

Climate change and food insecurity are both a big concerns and challenges for world but particularly for less developing country such as West Africa. The link between these two factors are shown in the literature to be harmful for population and animals survive. Therefore, it become more and more important to deal with climate change and its impact on food (in)security .Many studies was done to understand the link between climate change and food insecurity by focusing in how climate change may contribute to make people in the food insecurity situation. However, despite all studies done in this context, most of the countries in the world still be under food insecurity.According to (FAO, 2020),in its report, recent estimates show that nearly 690 million people are hunger, or 8.9 percent of world population up by 10 million people in on year and by nearly 60 million in five years. In 2019 close to 750 million

or nearly one in ten people in the world were exposed to severe levels of food insecurity. The world is far from achieving Zero Hunger by 2030 because if the recent trends continue, it is projected that the number of people affected by hunger would surpass 840 million by this year.

To plan to evaluate the level of food insecurity in the context of climate change, linkage between food insecurity and vulnerability of household should be considered. Many indicators of measurement of household food insecurity level were developed but the most used to assess the level of food insecurity of West African Countries is the Household Food Insecurity Access Scale.

The literature argued that the effect of climate change on food security is negative. More generally this negative impact is through agriculture in board sense (crops, livestock and fisheries). Most of the study show that household with larger family size, non-educated head and household headed by old person are more exposed to food insecurity.

Therefore, issue of preventing household food insecurity in the face of climate change context is poorly addressed in the literature, including the measurement of the efficiency of prevention strategies This study, in evaluation food insecurity in face of climate change, will provide a more complete information to policy makers and improve literature on food insecurity assessment in the climate change context.

The next chapiter will talk about the methodology used to evaluate the level of food insecurity in the study areas.

Chapter 3: Methodological approach

The methodology adopted covers the data sources, the study areas, the sampling method and the analytical model. Data sources are of two types: primary data and secondary sources. These mainly cover climate data produced by the National Civil Aviation and Meteorology Agency (ANACIM). In addition to this information, a survey was conducted with a sample of households. The corresponding collection procedure is explained in the following subsection.

3.1 Study Areas

This research aims to assess the level of food insecurity and the prevention strategies of Senegalese households in the face of the effects of climate change. Thus, the geographical field covers the entire Senegalese territory. Below is presented the map of Senegal.

Figure 9 : Senegalese Map

Source: www.ohada.org

Senegal, West African country with an areas of 196,712 km² and the population of 17,738,795 inhabitants (projection of 2022, ANSD). Is bounded to the North by Mauritania; to the East by Mali; to the South by Guinea and Guinea Bissau; to the West by the Atlantic Ocean on a 500 km façade. It is bordered by the Atlantic Ocean to the west, Mauritania to the north-north-east, Mali to the east-south-east, Guinea to the south-east and Guinea-Bissau to the south-south-west.

The Gambia forms a quasi-enclave in Senegal, penetrating more than 302 km inland. The islands of Cape Verde are located 560 km from the Senegalese coast.

The country has two climate types: the desert climate in the north and the tropical climate in the south. The agriculture sector is defined as a driving sector of the economy in the Plan Senegal Emergent (PSE) which serves as a framework for public policies for the period 2014-2035. This sector represents 17% of GDP in 2018. Despite the decline recorded by some agricultural sub-sectors; millet, groundnuts and maize in connection with a lack of rainfall; the horticulture sub-sector is constantly evolving.

3.2 Data Source

The data used in this research are of two types: secondary data on public information on climate and temperature, and data from the household survey carried out in this thesis.

3.2.1. Secondary data

The climate data are taken from the National Agency of Civil Aviation and Meteorology (ANACIM). These are data on temperature and rainfall trends at 24 stations across the country.

The temperature data relate to two variables: one relating to the maximum monthly temperature and the other to the minimum monthly temperature.

The rainfall data relate to the volume of rain recorded during the month. Thus, information is available for the months of June, July and August and extends until the month of September in the southern part of the country.

However, for the purposes of this research, these data have been reorganized to include them with the collected data. Three variables have been calculated for this purpose.

The data is a monthly series from January 2000 to December 2019. The 24 survey points cover the localities of Bakel, Bambey, Dakar-Yoff, Diourbel, Fatick, Goudiry, Kaolack, Koungheul, Kedougou, Kolda, Velingara, Linguere, Louga, Matam, Mbour, Nioro, Podor, Ranérou, Saint-Louis, Simentithie, Tamba, Cap-Skirring and Ziguinchor. For each survey point, the following three variables are calculated:

- Average monthly maximum temperatures over the period 2000 to 2019;
- Average monthly minimum temperatures over the period 2000 to 2019;
- The average volumes on rainfall over the period from 2000 to 2019.

The data organisation aims to create variables covering the 45 departments. For this purpose, when the name of the survey point refers to a department, the associated data are then directly reported. For the 21 departments that do not have survey points, the data are estimated by means of the information on the two nearest survey points.

Thus, these climatic data on the departments will be attached to the information from the survey in order to show the effects due to the climatic realities in each department.

3.2.2. Survey data

The purpose of the data collection operation is to obtain information on the characteristics and living conditions of households with regional representativeness and according to the living place (urban or rural). The sampling frame to be used is the 2013 Census of Habitat, Agriculture and Livestock Population (RGPHAE) conducted by the National Agency for Statistics and Demography (ANSD).

This base was divided by region and environment to form a matrix of 28 elements that represent the strata. The structure of the strata in the population was repeated in the sample: it is therefore a proportional draw.

The overall sample size is determined using the following formula:

$$\boldsymbol{n = \frac{1}{1 - t_{NR}} \left[\frac{1}{PQ} \left(\frac{k}{z_{1-\alpha/2}} \right)^2 \right]^{-1}}$$

Where P = proportion of the population;

$Q = 1 - P$;

k = level of precision;

$z_{1-\alpha/2}$= the quantile of order α of the law $N(0.1)$;

t_{NR} = the rate of non-response.

With a 95% confidence interval, a 5% margin of error and an estimated 20% response rate, the sample size is 2517 households.

The data collected relate to information on demographic characteristics, food and non-food expenditure, income-generating activities, other sources of income (transfers, rents, renting, etc.), material goods, number of animals (poultry, cattle, sheep, goats, equines) and number of agricultural land available to the household. The questionnaire is structured into four sections :

- Section A: household identification (region, department, commune, residential adress, GPS coordinates, etc.);
- Section B: Characteristics of the head of household (number of persons, sex of head, marital status, level of education, socio-professional category, age);
- Section C: Household wealth, types of economic activity carried out by (at least) one member of the household, number of animals (excluding pets), number of agricultural parcels/areas of agricultural parcels, amount of rents received in the year, the amount of monthly rent received and the amount of transfers received by month);
- Section D: household expenditure and consumption.

In this last section, a module will be added on the number of climate change effects (floods or droughts) experienced by the household during the last ten years, the number of livestock or crop losses due to flooding or high heat over the past 10 years, as well as the number of times the household has experienced market difficulties due to climate change effects (high heat, flooding).

For a month data collection over the territory and a sample of 2517 households, the number of collection agents required was 20. Thus, the workload of an investigating officer was 10 copies of questionnaire per day.

A list of the bulk of the collection material is provided below.

- Tablets or smartphone;
- Pads for Controllers and Supervisors;
- Pens, pencil, eraser and pencil sharpener;
- Bags; and
- Paper clips, staplers, staples.

In addition to these materials, the teams had transport fee, manuals, census area maps with a location of the households drawn, and follow-up sheets for field work.

The questionnaire was implemented on tablets by the search wizard which was free to use one of the platforms by: ODK (or its variants), Survey solution, Cspro/CsEntry.

3.3 Model specification

Although various controls had been incorporated into the application, the clearance of the following data base focused on the processing of inconsistent and implausible data, total and partial non-responses.

The processing was done using the STATA software for all the data tabulation and modeling.

Two types of analysis were applied:

- A first step was to conduct an exploratory data analysis, specifically a multiple correspondence analysis (MCA) in order to summarize the information by group of variables and thus to overcome any difficulties of multicollinearity in the models to be considered. The MCA has specificities which makes it good to use. In the comparative study between using MCA and OLS,(Modèles et al., 2007) find that MCA have more advantages than the OLS .First, It provide typologiy of the individuals, that is to study the similarities between them from a multidimensional perspective .Second, the MCA assess the relationships between the variables and study the associations between the categories.Third, MCA help to link together the study of induviduals and that of variables then to characterize the individuals using the variables(Johs, 2018). Also, the primary data were used to apply a Hierarchical Ascending Classification (HAC) in order to classify the household by adding the contribution of two axis which result of the Multiple Correspondence Analysis (MCA).
- The second step was about the collected data to which the climatic information on the departments was attached. This model has higger power in finding effects and contrasts in the data and there is no need to disputable assumptions,notably those of homoschedasticity(Quené & Van Den Bergh, 2004).

These two models were implemented in full coherence with the previously set objectives.

- **Model 1: Classification and typology of households**

The cross-sectional data (primary data) thus collected were analyzed in order, on the one hand, to summarize certain information but also to carry out an exploratory analysis of the data on the other hand. The latter consists of applying a model of multiple correspondence analysis (MCA) in order to characterize Senegalese households.

In order to explore the theoretical framework of the MCA, we considered a set of variables q categorical of N observations:

$$\boldsymbol{x} = (\boldsymbol{x_1}, \dots, \boldsymbol{x_q})$$

For each $\boldsymbol{x_j}\ j = 1, \dots, q$ we suppose, without loss of generality, that $\boldsymbol{x_j}$ is coded with consecutive integers: $\boldsymbol{1}, \dots, \boldsymbol{n_j}$

We define an $\boldsymbol{N}$x $\boldsymbol{n_j}$ binary indicator matrix associated with $\boldsymbol{x_j}$: $\boldsymbol{Z_{ih}^{(j)} = 1}$ if only $\boldsymbol{x_{ij} = h}$ so then the $\boldsymbol{N}\mathbf{x}\boldsymbol{J}$ of set of variables is defined as follow:

$$\boldsymbol{Z} = (\boldsymbol{Z^{(1)}}, \dots, \boldsymbol{Z^{(q)}})$$

With $\boldsymbol{J} = \boldsymbol{n_1} + \cdots + \boldsymbol{n_q}$

We index $\boldsymbol{i}$ for observations, $\boldsymbol{j}$ for variables and $\boldsymbol{h}$ for categories. The $\boldsymbol{J} \times \boldsymbol{J}$ Burt matrix is defined as $\boldsymbol{B} = \boldsymbol{Z'Z}$. Here, the diagonal block of B associated with variable xj is a diagonal matrix with the frequencies of $\boldsymbol{x_j}$ on the diagonal. The off-diagonal block of B associated with variables $\boldsymbol{x_j}$ and $\boldsymbol{x_k}$ is the two-way cross-tabulation of $\boldsymbol{x_j}$ and $\boldsymbol{x_k}$. So, the MCA is simply the Correpondence Analysis of Burt matrix$\boldsymbol{B}$.

In addition, in this part of the modelling, several indicators of food insecurity were assessed.

Also, a model of hierarchical ascending classification were applied in order to make a typology of households. For this purpose, typologies were determined which charaterized the similarities of their characteristics (sex, income, level of education ect.).

Theorically, hierarchical clustering creates hierarchically related sets of clusters. Hierarchical clustering methods are generally of two types: agglomerative or divisive. Agglomerative hierarchical clustering methods begin with each observation being considered as a separate group ($\boldsymbol{N}$ groups each of size 1). The closest two groups are combined ($\boldsymbol{N - 1}$ groups, one of size 2 and the rest of size 1), and this process continues until all observations belong to the same group. This process creates a hierarchy of clusters. Unlike hierarchical agglomerative clustering, divisive hierarchical clustering begins with all observations belonging to one group. This group is then split in some fashion to create two groups. One of these two groups is then split to create three groups; one of these three is then split to create four groups, and so on, until all observations are in their own separate groups. The agglomeration or division is made by similarity or dissimilarity distance function. The value of observation $\boldsymbol{i}$ for variable $\boldsymbol{v}$ is denoted by $\boldsymbol{x_{iv}}$**.** The main similarity or dissimilarity distance functions are:

- L(p) distance:

$$d(\boldsymbol{u},\boldsymbol{v}) = \left(\sum_{i=1}^{N}(\boldsymbol{x_{iv}} - \boldsymbol{x_{iu}})^2\right)^{\frac{1}{p}}$$

- Minkowski distance metric with argument d :

$$d(\boldsymbol{u},\boldsymbol{v}) = \sum_{i=1}^{N} |\boldsymbol{x_{iv}} - \boldsymbol{x_{iu}}|^{\boldsymbol{d}}$$

- Maximum distance:

$$d(\boldsymbol{u},\boldsymbol{v}) = \boldsymbol{max_{i=1,\ldots,N}}|\boldsymbol{x_{iv}} - \boldsymbol{x_{iu}}|$$

- Caberra distance:

$$d(\boldsymbol{u},\boldsymbol{v}) = \sum_{i=1}^{N}\frac{|\boldsymbol{x_{iv}} - \boldsymbol{x_{iu}}|}{|\boldsymbol{x_{iv}}| + |\boldsymbol{x_{iu}}|}$$

- Correlation distance :

$$d(\boldsymbol{u},\boldsymbol{v}) = \frac{\sum_{i=1}^{N}(\boldsymbol{x_{iu}} - \overline{\boldsymbol{x}}_{.u})(\boldsymbol{x_{iv}} - \overline{\boldsymbol{x}}_{.v})}{(\sum_{i=1}^{N}(\boldsymbol{x_{iu}} - \overline{\boldsymbol{x}}_{.u})^2 \sum_{i=1}^{N}(\boldsymbol{x_{iv}} - \overline{\boldsymbol{x}}_{.v})^2)^{\frac{1}{2}}}$$

With $\overline{\boldsymbol{x}}_{.u}$ and $\overline{\boldsymbol{x}}_{.v}$ being the mean of the variables $\boldsymbol{u}$ and$\boldsymbol{v}$.

- Angular distance:

$$d(\boldsymbol{u},\boldsymbol{v}) = \frac{\sum_{i=1}^{N}\boldsymbol{x_{iu}}\boldsymbol{x_{iv}}}{(\sum_{i=1}^{N}(\boldsymbol{x_{iu}})^2 \sum_{i=1}^{N}(\boldsymbol{x_{iv}})^2)^{\frac{1}{2}}}$$

There are other similarity measures for binary data based on the values from the cross-tabulation.

- **Model 2: Analyzes the determinants of food insecurity indicators and the prevention of food insecurity.**

In this model, the food insecurity indicators considered cover the different dimensions of food insecurity. These are :

- The Food Consumption Score (FCS)
- The Consumer Score Index (CSI)
- The Reduced Consummer Score Index(rCSI)
- Household Food Diversity Score (HDDS)

- Household Food Access Score Index (HFIAS)
- The Household Hunger Scale (HHS)

The analysis consists in identifying the differences in the level of food insecurity attributable to the average of annual temperature (minimal and maximal) and precipitation over 20 years by department. For this purpose, the econometric model is defined by:

$$Y_{ij} = \alpha + \sum_{k=1}^{M} (X_{ijk} * \beta_{ijk}) + TMAX_j * \gamma_{1j} + TMIN_j * \gamma_{2j} + R_j * \gamma_{3j} + \delta_j + \epsilon_{ij}$$

With:

Y_{ij}: A food insecurity index for household i in department j

X_{ijk}: The value of the variable relating to the characteristic k (with k = 1, , M) of household i in department j

$TMAX_j$, $TMIN_j$ et R_j: 20-year average values of maximum and minimum temperature and 20-year average volume of rainfall in department j.

Each food insecurity index was considered as a dependent variable. In addition to this modelling, simulations were made to measure the marginal effects of a variation in income by source in a context of changing temperature and rainfall.

Therefore, the multilevel generalized linear model is used in all the following estimation.

This model fits multilevel mixed-effects generalized linear models of the form:

$$\boldsymbol{g}\{\boldsymbol{E}(\boldsymbol{y}|\boldsymbol{X},\boldsymbol{u})\} = \boldsymbol{X\beta} + \boldsymbol{Zu}, \quad \boldsymbol{y} \sim \boldsymbol{F}$$

Where $\boldsymbol{y}$ is the n×1 vector of responses from the distributional family $\boldsymbol{F}$, $\boldsymbol{X}$ is an n×p covariate matrix for the fixed effects β, and $\boldsymbol{Z}$ is the n × q covariate matrix for the random effects $\boldsymbol{u}$.

The **Xβ + Zu** part is called the linear predictor, and it is often denoted as $\boldsymbol{\eta}$.

The function $\boldsymbol{g}(\cdot)$ is called the link function and is assumed to be invertible such that:

$$\boldsymbol{E}(\boldsymbol{y}|\boldsymbol{X},\boldsymbol{u}) = \boldsymbol{g}^{-1}(\boldsymbol{X\beta} + \boldsymbol{Zu})$$

Without a loss of generality, consider a two-level generalized mixed-effects model:

$$\boldsymbol{E}(\boldsymbol{y_j}|\boldsymbol{X_j},\boldsymbol{u_j}) = \boldsymbol{g}^{-1}(\boldsymbol{X_j\beta} + \boldsymbol{Z_j u_j})$$

With $\boldsymbol{j}$ thorw **1** to **M** clusters, (here the number of departments) with the $\boldsymbol{j^{th}}$ cluster consisting of $\boldsymbol{n_j}$ observations (number of households).

For the $\boldsymbol{j^{th}}$ cluster, $\boldsymbol{y_j}$ is the $\boldsymbol{n_j \times 1}$ response vector, $\boldsymbol{X_j}$ is the $\boldsymbol{n_j \times p}$ matrix of fixed predictors, $\boldsymbol{Z_j}$ is the $\boldsymbol{n_j \times q}$ matrix of random predictors, $\boldsymbol{u_j}$ is the $\boldsymbol{q \times 1}$ vector of random effects, $\boldsymbol{\beta}$ is the $\boldsymbol{p \times 1}$ vector of regression coefficients on the fixed predictors.

For the following estimation purpose we used $\boldsymbol{\Sigma}$ to denote the unknown $\boldsymbol{q \times q}$ variance matrix of the random effects. For simplicity, we considered a model with no auxiliary parameters. Let $\boldsymbol{\eta_j}$ be the linear predictor:

$$\boldsymbol{\eta_j = X_j\beta + Z_j u_j}$$

We denoted by $\boldsymbol{y_{ji}}$ and $\boldsymbol{\eta_{ji}}$ be the ith individual elements of $\boldsymbol{y_j}$ and $\boldsymbol{\eta_j}$: $\boldsymbol{i = 1; \ldots .; \eta_j}$. We defined the conditional density function for the response at observation i by $f(\boldsymbol{y_{ji}|\eta_{ji}})$.

The conditional independent assumption of the observations helped us to overload the definition of function $\boldsymbol{f}(\cdot)$ with vector inputs to become as in the following formula:

$$\log\left(f\left(\boldsymbol{y_j}|\boldsymbol{\eta_j}\right)\right) = \sum_{i=1}^{\boldsymbol{\eta_j}} \log(f(\boldsymbol{y_{ji}}|\boldsymbol{\eta_{ji}}))$$

The random effects $\boldsymbol{u_j}$ are assumed to be multivariate normal with mean **0** and variance $\boldsymbol{\Sigma}$. The likelihood function for cluster $\boldsymbol{j}$ is given by:

$$\boldsymbol{\mathcal{L}_j(\beta, \Sigma) = \frac{1}{\sqrt{(2\pi)^q|\sum|}} \int_{\mathbb{R}^q} f\left(y_j|\eta_j\right) \exp(-\frac{1}{2} u_j' \sum^{-1} u_j) du_j}$$

The log likelihood for the entire dataset is simply the sum of the contributions of the M departments:

$$\boldsymbol{\mathcal{L}_j(\beta, \Sigma) = \frac{1}{\sqrt{(2\pi)^q|\sum|}} \sum_{j=1}^{M} \int_{\mathbb{R}^q} f\left(y_j|\eta_j\right) \exp(-\frac{1}{2} u_j' \sum^{-1} u_j) du_j}$$

To evaluate the multivariate integral above, a numerical method is adopted by using a change-of-variables technique to transform this multivariate integral into a set of nested univariate integrals that can be evaluated using one of the three form of Gauss–Hermite quadratures: Nonadaptive Gauss–Hermite quadrature (GHQ), Adaptive Gauss–Hermite quadrature (AGH) and the Laplacian-approximation method.

a) Noadaptive Gauss–Hermite quadrature (MVAGH)

This formula based on the Choleski decomposition of the variance matrix $\boldsymbol{\Sigma}$: $\boldsymbol{\Sigma} = \boldsymbol{LL'}$. Then we have the following results:

$$\boldsymbol{\eta_j} = \boldsymbol{X_j\beta} + \boldsymbol{Z_jLv_j}$$

Where $\boldsymbol{u_j} = \boldsymbol{Lv_j}$ whith $\boldsymbol{v_j}$ a $\boldsymbol{q} \times \mathbf{1}$ random vector whose elements are independently standard normal variables. So, the likelihood function becomes:

$$\begin{aligned}
\boldsymbol{\mathcal{L}_j(\beta,\Sigma)} &= \frac{\mathbf{1}}{\sqrt{(\mathbf{2\pi})^q}} \int_{\mathbb{R}^q} \boldsymbol{f(y_j|\eta_j)} \exp(-\frac{\mathbf{1}}{\mathbf{2}} \boldsymbol{v_j' v_j}) \boldsymbol{dv_j} \\
&= \frac{\mathbf{1}}{\sqrt{(\mathbf{2\pi})^q}} \int_{\mathbb{R}^q} \boldsymbol{exp\{logf(y_j|\eta_j) - \frac{1}{2} v_j' v_j\} dv_j} \\
&= \frac{\mathbf{1}}{\sqrt{(\mathbf{2\pi})^q}} \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} \dots \int_{-\infty}^{+\infty} \boldsymbol{exp\{logf(y_j|\eta_j) - \frac{1}{2} v_j' v_j\} dv_{j1} dv_{j2} \dots dv_{jq}}
\end{aligned}$$

Let's consider a q-dimensional quvvadrature grid containing $\boldsymbol{r}$ quadrature points in each dimension and a point on this grid being $\boldsymbol{a_k} = (\boldsymbol{a_{k1}}, \dots, \boldsymbol{a_{kq}})'$ and a vector of correspondaning weights defined by $\boldsymbol{w_k} = (\boldsymbol{w_{k1}}, \dots, \boldsymbol{w_{kq}})'$ then the nonadaptive Gauss–Hermite quadrature (GHQ) approximation to the likelihood is:

$$\begin{aligned}
\boldsymbol{\mathcal{L}_j(\beta,\Sigma)} &= \sum_{k1}^{r} \dots \sum_{kq}^{r} \left[\boldsymbol{exp\{logf(y_j|\eta_{jK})\}} \prod_{p=1}^{q} w_{k_p} \right] \\
&= \sum_{k1}^{r} \dots \sum_{kq}^{r} \left[\boldsymbol{exp} \left\{ \sum_{\boldsymbol{i=1}}^{\boldsymbol{n_j}} \boldsymbol{logf}\left(\boldsymbol{y_{ij}|\eta_{ijK}}\right) \right\} \prod_{p=1}^{q} w_{k_p} \right]
\end{aligned}$$

Where $\boldsymbol{\eta_{ijK}}$ is the i^{th} element of $\boldsymbol{\eta_{jK}} = \boldsymbol{X_j\beta} + \boldsymbol{Z_jLa_k}$

b) Adaptive Gauss–Hermite quadrature (AGH)

There are two versions of this aproach: mean–variance adaptive Gauss–Hermite quadrature (MVAGH), mode-curvature adaptive Gauss–Hermite quadrature (MCAGH).In what follow, we use $\emptyset(\boldsymbol{v_j})$ to denote a multivariate standard normal with mean $\mathbf{0}$ and variance $\boldsymbol{I_q}$ and we use $\emptyset(\boldsymbol{v_j}|\boldsymbol{\mu_j}, \boldsymbol{\Lambda_j})$ to denote a multivariate normal with mean $\boldsymbol{\mu_j}$ and variance $\boldsymbol{\Lambda_j}$. The posterior density for $\boldsymbol{y_j}$ for fixed model parameters, is proportional to the following term:

$$\emptyset(v_j)f(y_j|\eta_j)$$

With:

$$\eta_j = X_j\beta + Z_j v_j$$

Then the approximation for the posterior density is given by:

$$\mathcal{L}_j(\beta, \Sigma) = \int_{\mathbb{R}^q} \frac{f(y_j|\eta_j)\emptyset(v_j)}{\emptyset(v_j|\mu_j, \Lambda_j)} \emptyset(v_j|\mu_j, \Lambda_j)\, dv_j$$

We define by a_k^* and $w_{jk_p}^*$ the abscissas and weights after an orthogonalizing transformation of a_k and w_k. The adaptive Gauss–Hermite quadrature (AGH) is deducted from the equation above:

$$\mathcal{L}_j(\beta, \Sigma) = \sum_{k1}^{r} \dots \sum_{kq}^{r} \left[exp\{logf(y_j|\eta_{jK})\} \prod_{p=1}^{q} w_{jk_p}^* \right]$$

With $\eta_{jK} = X_j\beta + Z_j L a_k^*$

The adaptive Gauss–Hermite quadrature (AGH) use two methods to compute the mean μ_j and variance Λ_j. For the first method, the mean μ_j and variance Λ_j are computed iteratively by updating the posterior moments approximation, starting with a 0 mean vector and identity variance matrix. This approach is called the Mean-Variance Adaptive Gauss–Hermite quadrature (MVAGH).

For the second method, the mean μ_j and variance Λ_j are computed by optimizing the integrand with respect to, v_j where μ_j is the optimal value and Λ_j is the curvature at μ_j. This approach is called the Mode-Curvature Adaptive Gauss–Hermite quadrature (MCAGH).

c) Laplacian approximation

We considere the following likelihood:

$$\mathcal{L}_j(\beta, \Sigma) = \frac{1}{\sqrt{(2\pi)^q|\sum|}} \int_{\mathbb{R}^q} f(y_j|\eta_j) \exp(-\frac{1}{2} u_j' \sum^{-1} u_j) du_j$$

$$\mathcal{L}_j(\beta, \Sigma) = \frac{1}{\sqrt{(2\pi)^q|\sum|}} \int_{\mathbb{R}^q} exp\left[logf(y_j|\eta_j) - \frac{1}{2} u_j' \sum^{-1} u_j\right] du_j$$

$$\boldsymbol{h(\beta, \Sigma, u_j) = \ logf(y_j|\eta_j) - \frac{1}{2} u_j' \Sigma^{-1} u_j}$$

$$\boldsymbol{h(\beta, \Sigma, u_j) = \ logf(y_j|X_j\beta \ + \ Z_j u_j) - \frac{1}{2} u_j' \Sigma^{-1} u_j}$$

We use the second-order Taylor expansion of $\boldsymbol{h(\beta, \Sigma, u_j)}$ about the value of $\boldsymbol{u_j}$ that maximizes it. The first and second partial derivatives with respect to $\boldsymbol{u_j}$ are:

$$\boldsymbol{h'(\beta, \Sigma, u_j) = \frac{\partial h(\beta, \Sigma, u_j)}{\partial u_j} = Z_j' \frac{\partial log f(y_j|\eta_j)}{\partial \eta_j} - \Sigma^{-1} u_j}$$

$$\boldsymbol{h''(\beta, \Sigma, u_j) = \frac{\partial^2 h(\beta, \Sigma, u_j)}{\partial u_j \partial u_j'} = Z_j' \frac{\partial^2 log f(y_j|\eta_j)}{\partial \eta_j \partial \eta_j'} Z_j - \Sigma^{-1}}$$

If there is a maximizer $\boldsymbol{\hat{u}_j}$ for the function $\boldsymbol{u_j : \longrightarrow h(\beta, \Sigma, u_j)}$ then:

$$\boldsymbol{h'(\beta, \Sigma, \hat{u}_j) = 0}$$

and the tyolor first approximation is given by:

$$\boldsymbol{h(\beta, \Sigma, u_j) \ \approx \ h(\beta, \Sigma, \hat{u}_j) + \frac{1}{2}(u_j - \hat{u}_j)' h''(\beta, \Sigma, \hat{u}_j)(u_j - \hat{u}_j)}$$

The integral is approximated by:

$$\boldsymbol{\mathcal{L}_j(\beta, \Sigma) = \int_{\mathbb{R}^q} \exp\left(h(\beta, \Sigma, u_j)\right) du_j}$$

$$\boldsymbol{\approx \ (2\pi)^{-\frac{q}{2}} |-h''(\beta, \Sigma, \hat{u}_j)|^{-\frac{1}{2}} \exp(h(\beta, \Sigma, \hat{u}_j))}$$

Partial Conclusion:

The climatic data and those resulting from the survey offer a structure of the generalized linear model at two levels. The exploratory analysis provides a first insight into household food insecurity by grouping them into different homogeneous groups. This step illustrates household profiles through food insecurity indicators. In addition, this typology is useful for the formulation of different scenarios for preventing the effects of climate change in accordance with household situations.

The two-level generalized linear model applied to each indicator makes it possible to measure the effects of temperature and rainfall and to apply prevention scenarios specifically to each indicator. In addition, the taking into account of the random component in the model will be studied by means of the Hausman test. When the significance is not proven, the mixed model will be applied. In the model specification, likelihood estimation uses several numerical approaches as discussed above. Among these methods, the adaptive Gauss–Hermite quadrature is the one that will be applied in particular with the iterative calculation of the mean and the variance. This approach gives faster convergence.

Chapter 4: Data analysis and impact measurement

In this chapter data are used to show preliminary results before econometric modelling.

4.1 Preliminary results

The first results concern the description of the characteristics of households and their typology through an exploratory analysis. Also, the various indices of food insecurities discussed above are evaluated. Similarly, data on temperature (maximum and minimum) and rainfall are used.

4.1.1. Descriptive analysis

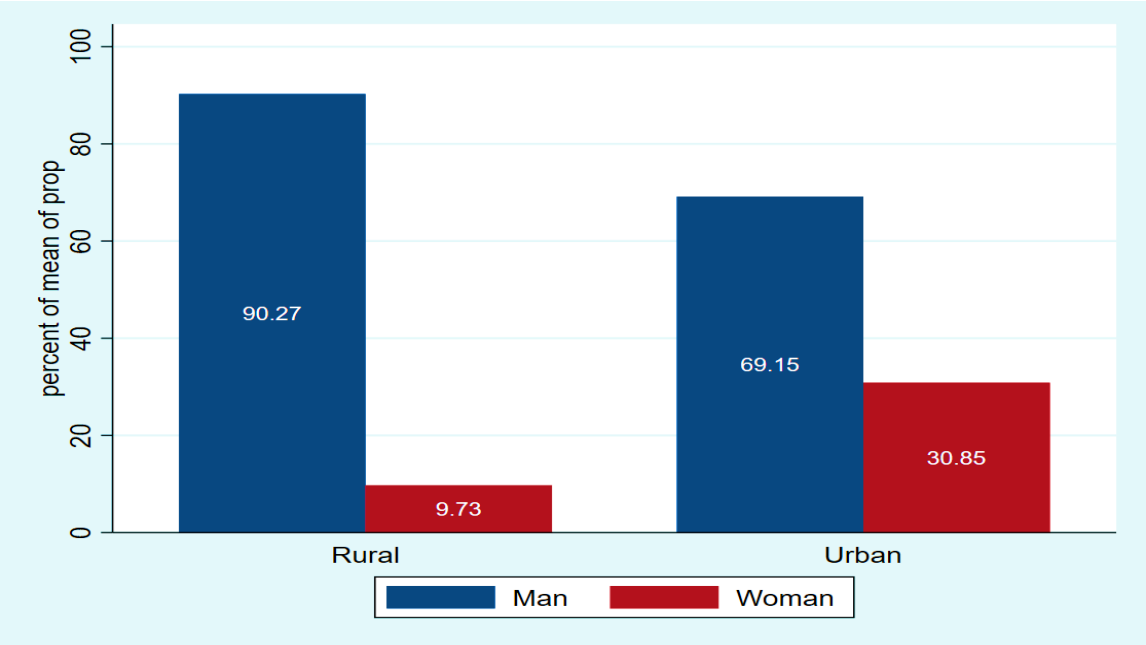
In this section, the analysis focuses on the description of the household head profile and the characteristics of the households.

a) Household head profile

The characteristics of the head of household presented below relate to sex, level of education, marital status, socio-professional category, chronic diseases and age.

The following figure shows the structure of the population by sex of the head of household and by place of residence. The results show that most of households are headed by men, both in urban areas (69.15%) and in rural areas (90.27%).

Figure 10: Household head gender by areas

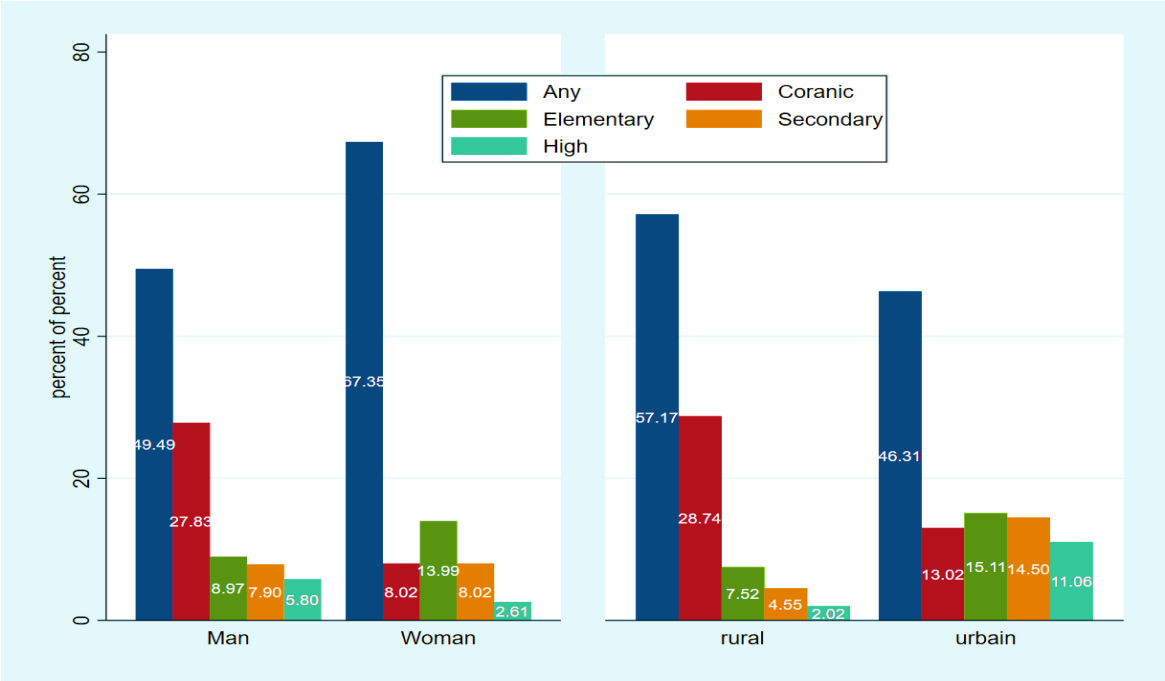


Source: Author, 2022

The characteristics analysed below are separated on the one hand by the sex of the head of household and on the other by the place of residence.

The following graph shows the structure of the population according to the level of education of the head of household. The results show high percentage of non-instructed women (67.35%) while non-instructed men represent 49.49%. In addition, uneducated heads of households are more concentrated in rural areas (57.17%) and a large proportion of them have only a Koranic level (28.74%).

Figure 11: Distribution of the population according to the level of education of the head of household



Source: Author, 2022

The marital situation of heads of households is also analysed. The results in the figure below show that most heads of household are monogamous. However, among women in households, it is the divorced or widowed who dominate (41.23%).

Polygamy is more common in rural areas than in urban areas, at 56.35% versus 54.18%. In addition, divorcees and widowers are more common in urban areas with 19.78% compared to 6.32% in rural areas.

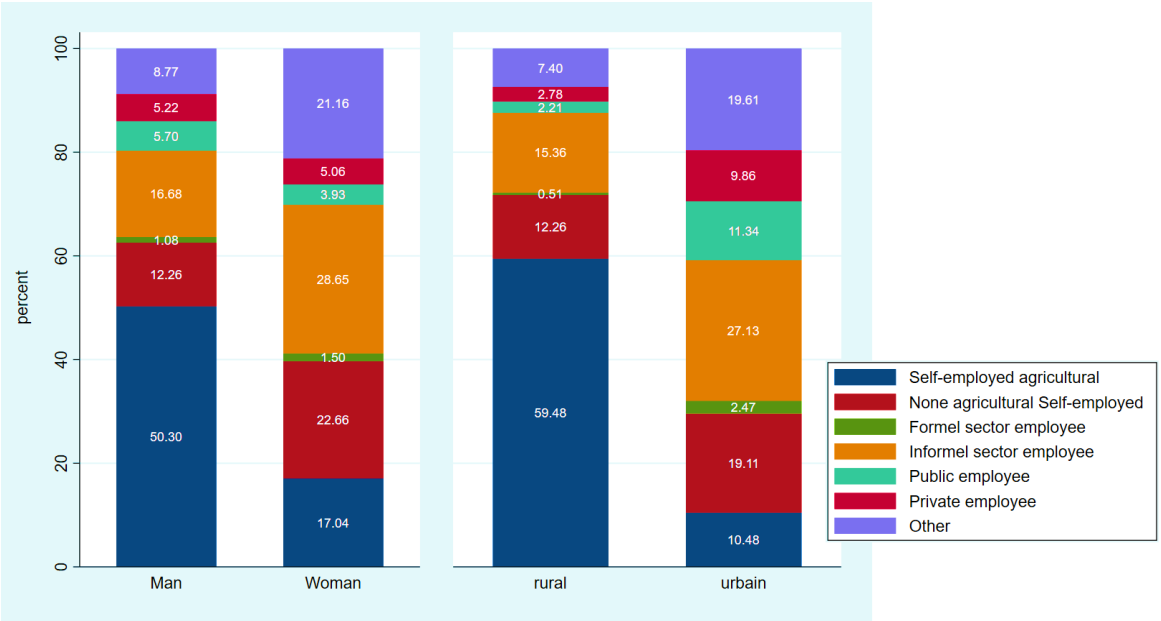
Households headed by singles are less important both in terms of sex and the place of residence with less than 2%.

Figure 12: Population structure according to marital status

Source: Author, 2022

The structure of the population according to the activity of the head of household is illustrated in the figure below. The results show that male heads of household are mainly self-employed in agriculture (50.3%) while women are more frequent in the informal sector (28.65%). Also, with regard to the place of residence, self-employed farmers are more common in rural areas (59.48%) while in urban areas, heads of households are much more active in the informal sector (27.13%).

Figure 13: Employment of heads of households



Source: Author, 2022

The health of heads of household is also observed. The following table shows the population structure according to the health status of heads of households. The results show that 18.89% (100%-81.19%) of male heads of household have a chronic disease of which the most common is cardiac: hypertension or hypotension (8.17%). Among women heads of household, the proportion of chronic disease is higher, at 33.96%. They also mostly have heart problems (17.91%). In terms of the residential place, the urban areas have more chronic disease (26.54% versus 19.96% in rural areas).

Table 1: Chronic heads of household disease

	Man	**Woman**	**Rural**	**Urbain**	**Total**
Any	81,19	66,04	80.04	73,46	77,81
Diabetes	2,20	3,92	1,39	4,91	2,59
Hyper/hypotension	8,17	17,91	9,10	12,78	10.35
Drepanocytosis	0.16	0.56	0.13	0.49	0.25
Tuberculosis	0.11	0.00	0.13	0.00	0.08
Renal failure	0.05	0.19	0.06	0.12	0.08
Anemia	0.21	0.75	0.25	0.49	0.33
Respiratory infection	1,88	1,12	2,08	0.98	1,71
Don't know	1,13	1,31	1,33	0.86	1,17
Other	4,89	8,21	5,50	5,90	5,63
	100.00	100.00	100.00	100.00	100.00

Source : **Author's calculation ,2022**

The age structure of the heads of households is illustrated in the figure below. Heads of households are mainly between 45 and 54 years old. Indeed, the results show that in terms of sex, 27.4% of male heads of households are between 45 and 54 years of age, for women this percentage is 31.72%.

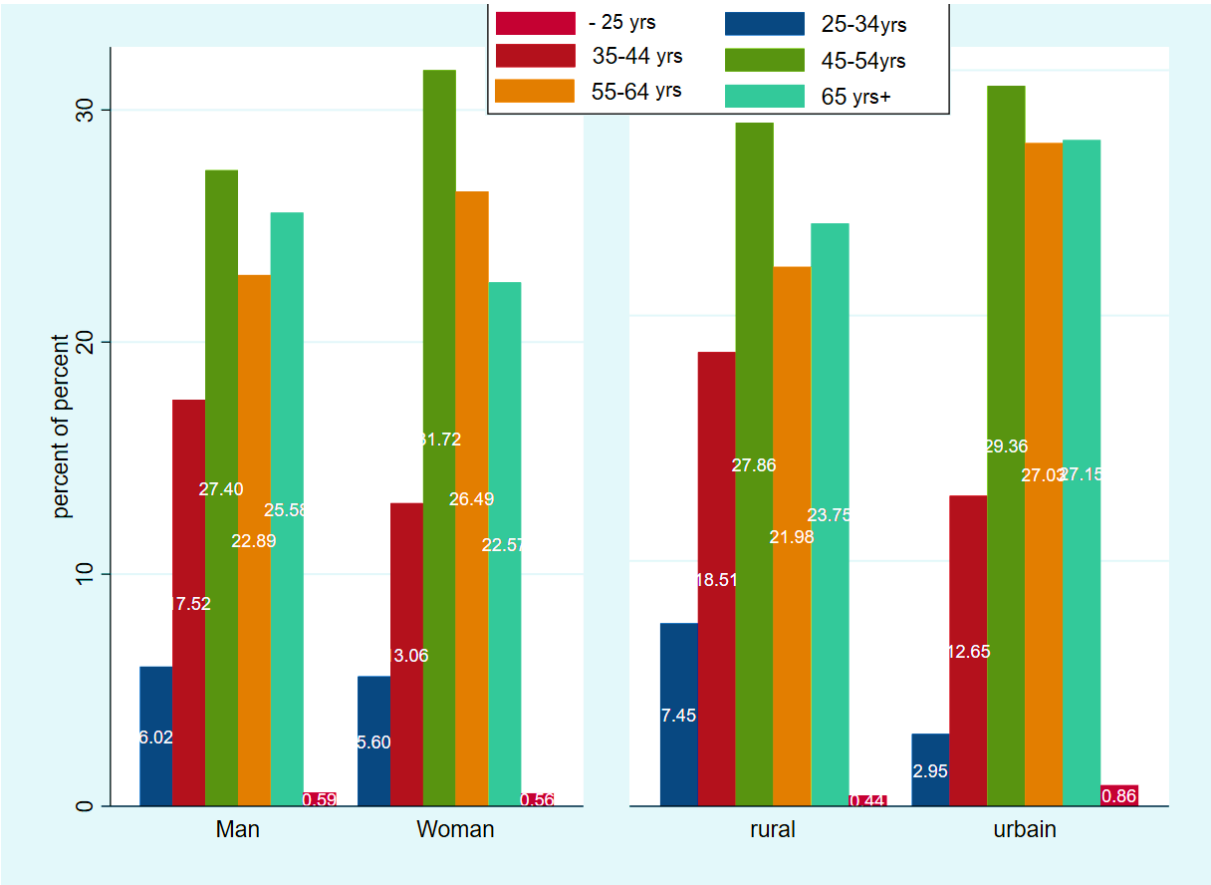
At the same time, 27.86% of heads of households in rural areas are aged between 45 and 54 and this age group represents 29.36% in urban areas.

Among male heads of household, the second largest age group is those aged 60 and over, at 25.58%. For women heads of household, the 55-64 age group ranks second with 29.36%.

The most unpopular age groups are those under the age of 25, who represent less than 1% both by sex and by place of residence. The same applies to the 25-34 age group, which account for 5.60% of women, 6.02% of men, 2.95% in urban areas and 7.45% in rural areas.

In addition, the class of heads of households aged 35 to 44 is also important. Indeed, it represents 13.6% among women and 17.52% among men. In terms of the residential environment, this proportion is 12.65% in urban areas and 18.51% in rural areas.

Figure 14: Age group of heads of household



Source: Author, 2022

b) Household characteristics

For the description of the households, the characteristics presented are those relating to the main source of income, total income, total expenditure and the mode of occupation of the habitat.

The following graph shows the structure of the main source of income according to the sex of the head of household. The different types of income sources considered in this section are agriculture, trade, livestock, fishing, rent, wages, transfers, transport, manufacturing and other

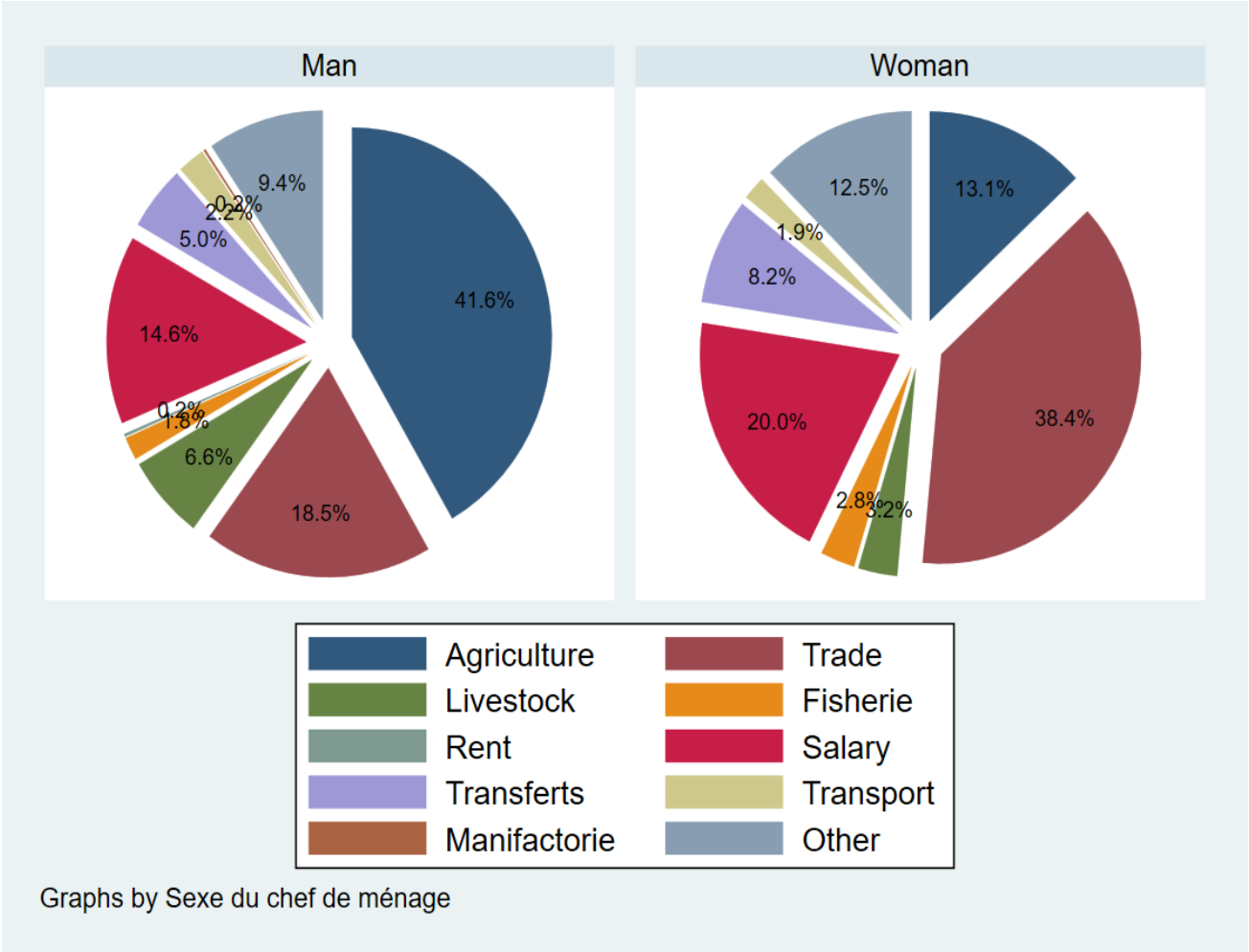
sources of income (such as retirement pension, donations, social assistance, assistance from a parent, etc.).

The results show that in male-headed households, the most common sources of income are agriculture (41.6%), trade (18.5%) and wages (14.6%). In these types of households, renters are rarely present (0.2%) and there is little processing activity (0.2%).

As for households headed by women, the main sources of income are mainly trade (38.4%), wages (20.0%) and agriculture (13.1%). These households have no income (0.0%).

On the other hand, households headed by women are relatively more important in counting transfers as the main source of household income, at 8.2% compared to 5.0% for households headed by men.

Figure 15: Main source of income by sex of head of household



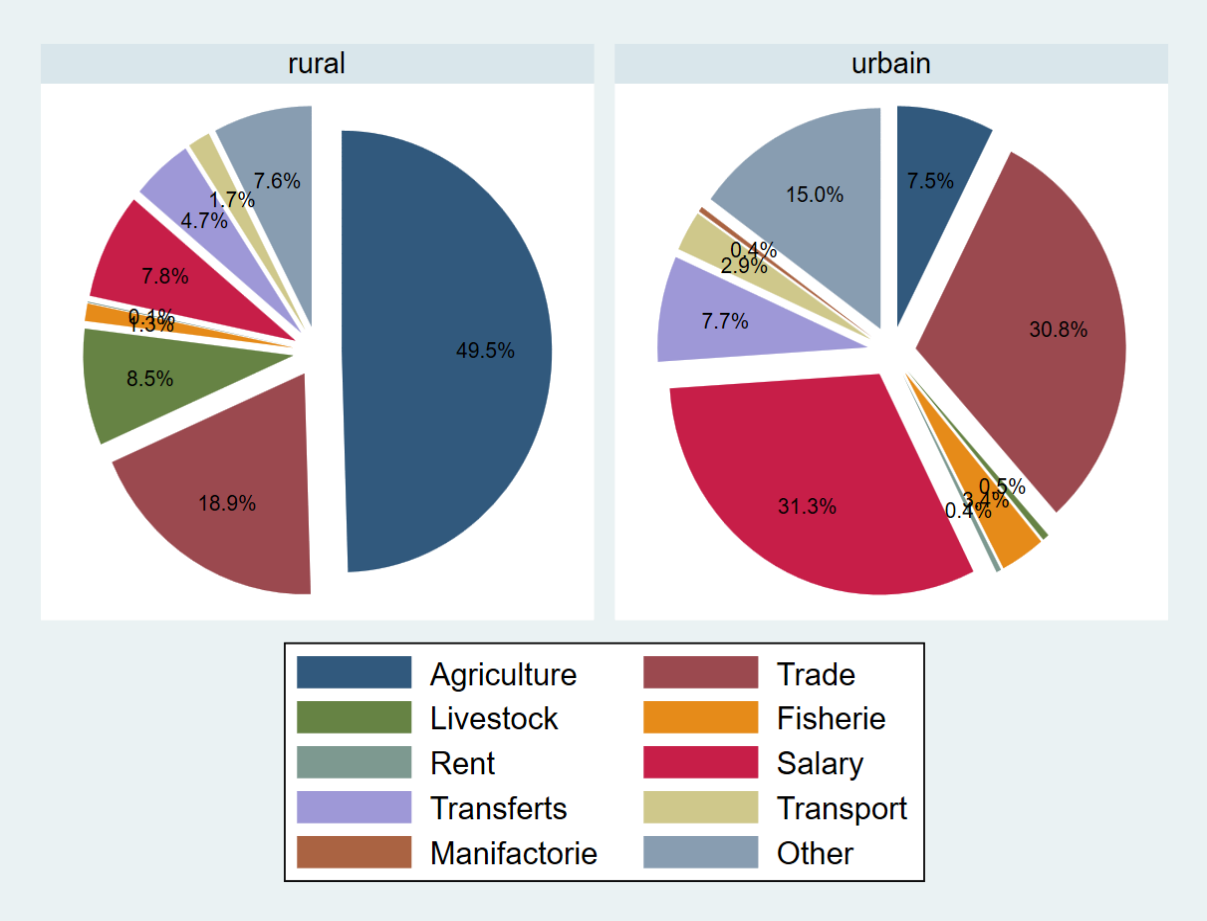
Source: Author, 2022

The structure of the main sources of household income is also analysed according to the place of residence. The figure below illustrates the differences between the main sources of income with respect to the place of residence.

The results show that in rural areas, agriculture is the main source of income for one in two households. Also, trade is also representative, providing the main source of income for 18.9% of households. Similarly, livestock and wages represent the main source of income for 8.5% and 7.8% of households respectively.

In urban areas, households live mainly on wages (31.3%) and trade (30.8%). Agriculture and transfers are also significant, providing the main source of income for 7.5% and 7.7% of households respectively.

Figure 16: Main source of household income



Source: Author, 2022

The following table shows the structure of household income and expenditure according to the sex of the head of household and the place of residence.

The table below shows the structure of total income, food expenditure and total household expenditure on average per month. The results show that in male-headed households, total income is lower, at 178077 FCFA compared to 184263 FCFA. Also, total household expenditures led by women are higher. In fact, in these households, the average monthly food expenditure is 105180 FCFA for a total monthly average expenditure of 159286 FCFA. For male-headed households, monthly food expenditure averages 105840 FCFA for a total monthly expenditure of 149860 FCFA on average. The structure of income and food and total expenditure according to the place of residence also shows differencies in rural and urbain areas. Firtly, the income and expenditures are higher in urbain. Secondly, there is only in rural areas where women headed households have a higher total expenditure (137910 FCFA vs 134667 FCFA for men headed household).

Table 2: Monthly household income and expenses

	Rural	**Urbain**	**Total**
	Food Expenditure		
Man	100677	120168	105840
Woman	94779	112146	105180
Total	***99876***	***117004***	***105692***
	Total Expenditure		
Man	134667	192021	149860
Woman	137910	173603	159286
Total	***135107***	***184758***	***151968***
	Total Income		
Man	154351	243915	178077
Woman	150051	207177	184263
Total	***153767***	***229427***	***179461***

Source: Author's Calculation, 2022

The structure of the housing status is observed according to five modalities: owner, free accommodation, tenant, tenant-sale and other modes of occupancy (squat, borrow etc).

The analysis of dwelling status by sex of the head of household is shown in the figure below. The results show that households are mainly homeowners with a higher proportion for male-headed households (94.1% versus 88.6%).

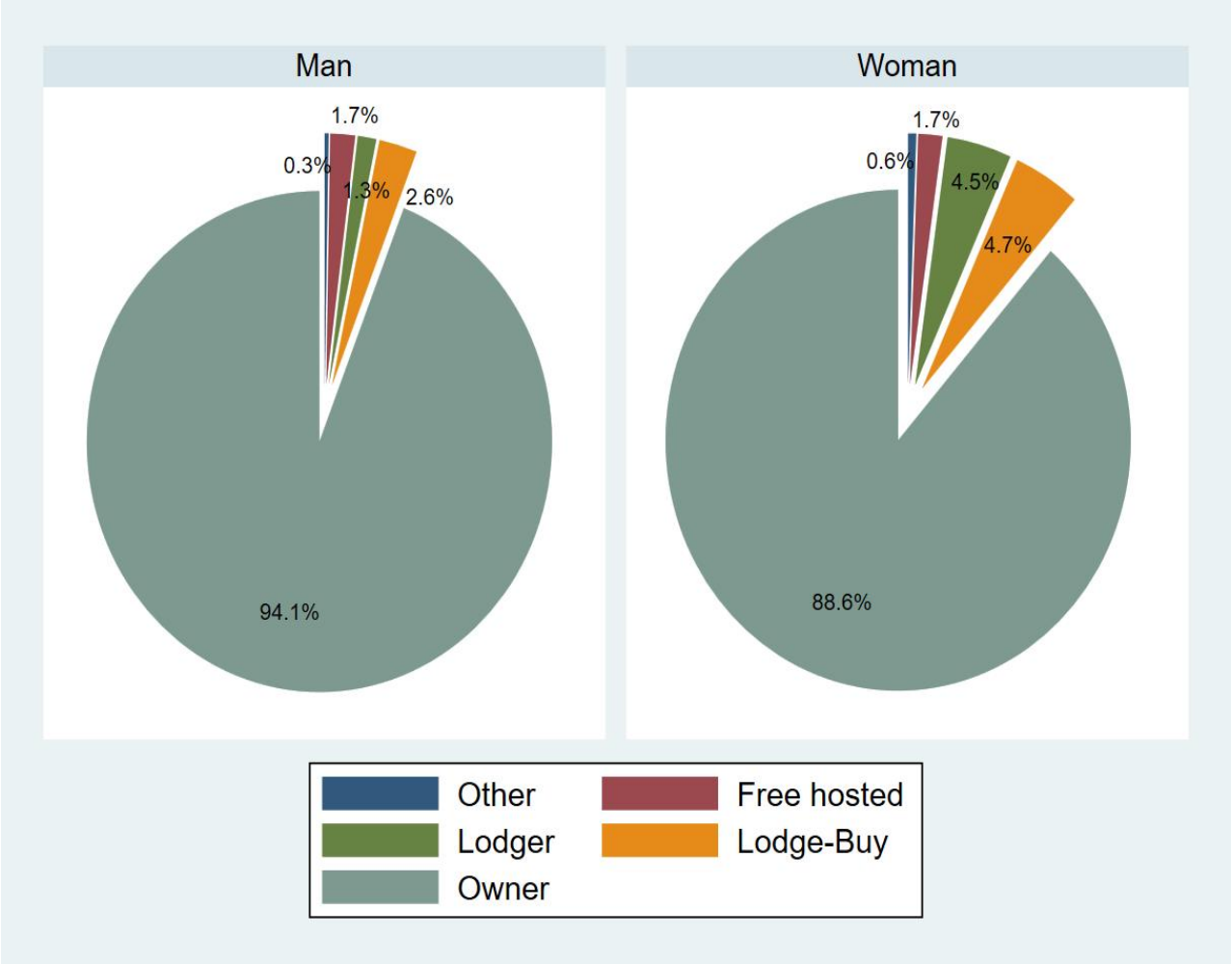
In addition, households headed by women are relatively more numerous at rent (4.5% versus 1.3%). The same is observed for the renting and the selling, where the rate is 4.7% for household headed by women and only 2.6% for households headed by men.

Free accommodation is low, with 1.7% for both male-headed households.

Other modes of occupancy (squatter, borrow etc.) are also low, with 0.3% in male-headed households and 0.6% in female-headed households.

For the most part, among male headed households, only 5.9% (100 – 94.1) do not own their roofs while among female headed households this proportion is 11.4% (100 – 88.6*)*

Figure 17: Dwelling occupancy status by sex of head of household

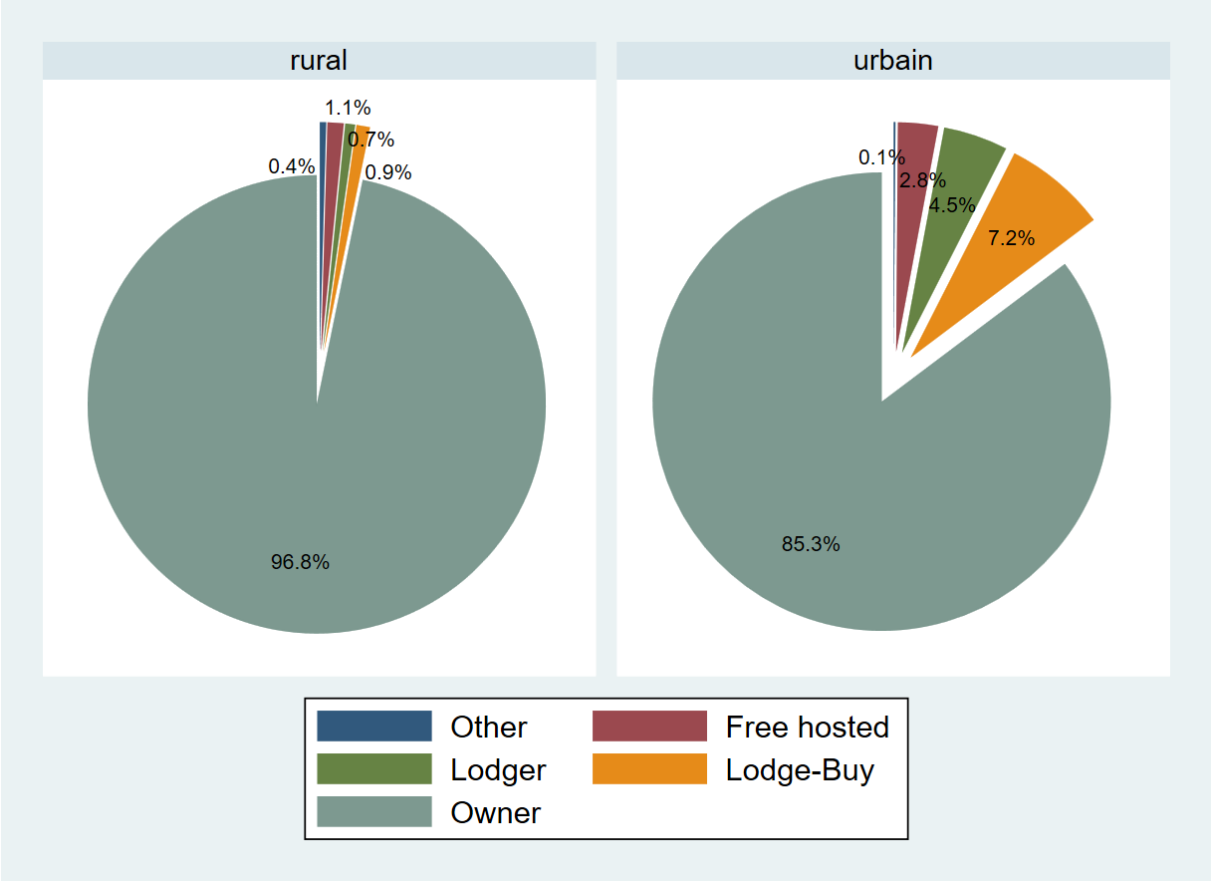


Source: Author, 2022

The distribution of occupation status according to the place of residence is presented in the following graph. The results show that most rural households own their homes (96.8%). In this environment, free accommodation (1.1%), rental (0.7%), hire-for-sale (0.9%) and other modes of occupancy (0.4%) are infrequent.

In urban areas, house owners are relatively lower, at 85.3%. Lodge buy and lodger are also important and concern respectively 7.2% and 4.5% of urban households.

Figure 18: Occupation status by place of residence



Source: Author, 2022

Climate shock variables show the situation of households engaged in agriculture (boader sens), livestock, farming and fishing by detecting events related to:

- crop failure;
- livestock deaths due to disease, lack of water or feed;
- bad fishing seasons

The results are recorded in the table below. For example, among households engaged in cultivation, 3.3% of those headed by men experienced a poor harvest and this affects 3.1% of households headed by women.

In rural areas, crop failure affects 3.1% of households growing crops. The situation is more deplorable in urban areas (where a larger population is concentrated) with 4.8% of poor harvest.

Losses of livestock due to disease, lack of water or food also illustrate the effects of climate change. The results show that among households engaged in animal husbandry, 1.7% of those headed by men are affected by animal losses. 1.6% of households headed by women are concerned. In rural areas, 1.9% of livestock households are affected by livestock losses due to disease, water or feed shortages. This rate is 1.1% in urban areas.

For households engaged in fishing, bad seasons affect 8.3% of male-headed households in urban areas.

Table 3: Effects of Climate Change

	Gender		**Areas**	
	Man	Woman	Rural	Urban
Bad Harvest	3,3%	3,1%	3,1%	4,8%
Livestock deaths	1,7%	1,6%	1,9%	1,1%
Bad fishing season	8,3%	0.0%	0.0%	8,3%

Source : Author's Calculation ,2022

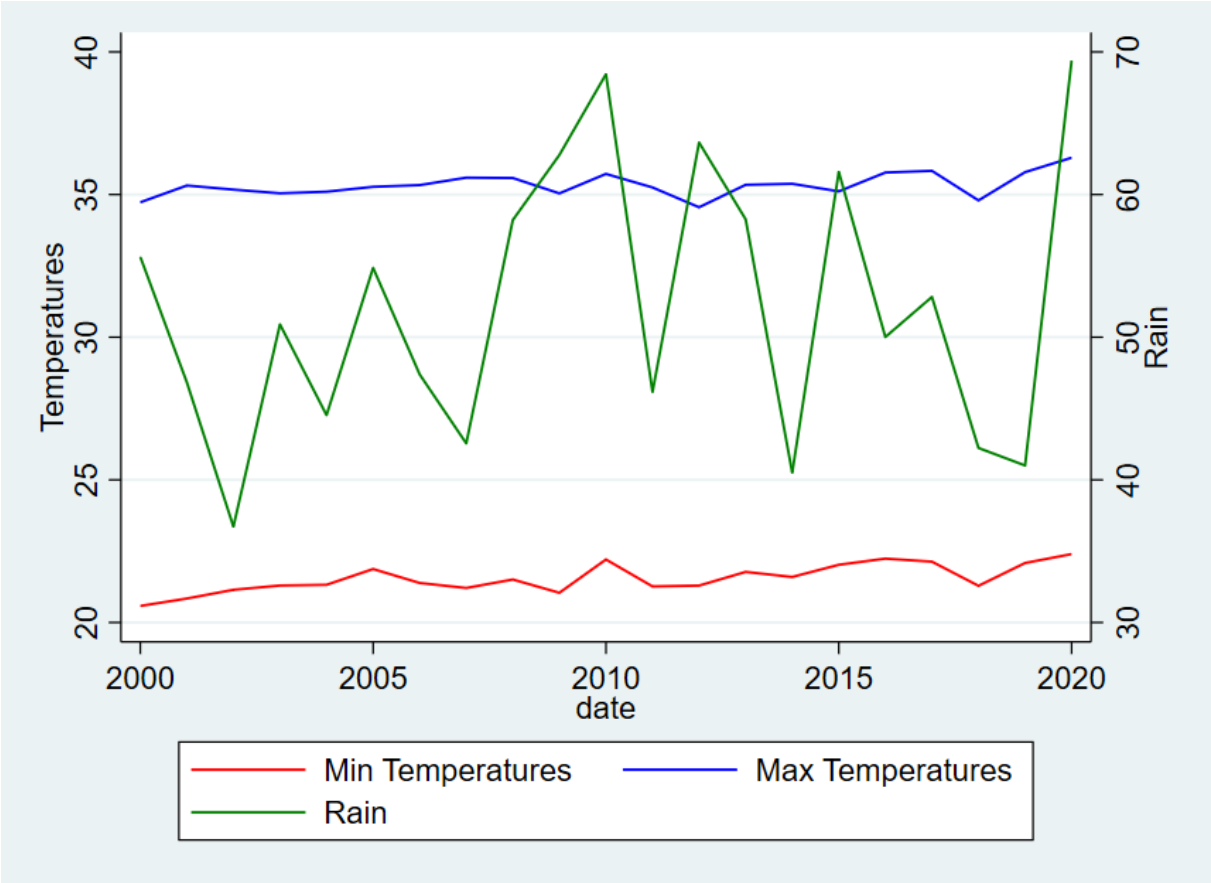
Climate data represent 20-year averages (2000-2020) of rainfall and maximum and minimum temperatures by department. The following figure shows the two-decade trend.

The y-axis for temperatures is plotted on the left and the rainfall axis on the right.

The results show that the minimum temperature increased from 21°C to about 23°C on average over 20 years, an increase of 2°C. As for the maximum temperature, it was around 35°C on average over the 20 years, going up to 37°C in 2020.

Rainfall has changed in a number of ways over the period from 2000 to 2020. The lowest rainfall was recorded in 2002 with an average volume of less than 80 mm. The highest rainfall was recorded in 2010 with 150 mm and in 2015 with 140 mm.

Figure 19: Evolution of 20-'year average climate data



Source : Author ,2022

4.1.2. Exploratory analysis

The exploratory analysis aims to summarize the qualitative information concerning the heads of households through a Multiple Correspondence Analysis (MCA) and to be carried out, by means of a Hierarchical Assending Classification (HAC), a household typology based on summarized information from MCA and some household characteristics such as amounts associated with different income sources, total and food expenditures, and household size.

The results of the Multiple Correspondence Analysis (MCA) are recorded on the graph below.

The factorial plan includes 79.3% of the information: axis 1 accounting for 59.7%. The characteristics of households are divided into three groups.

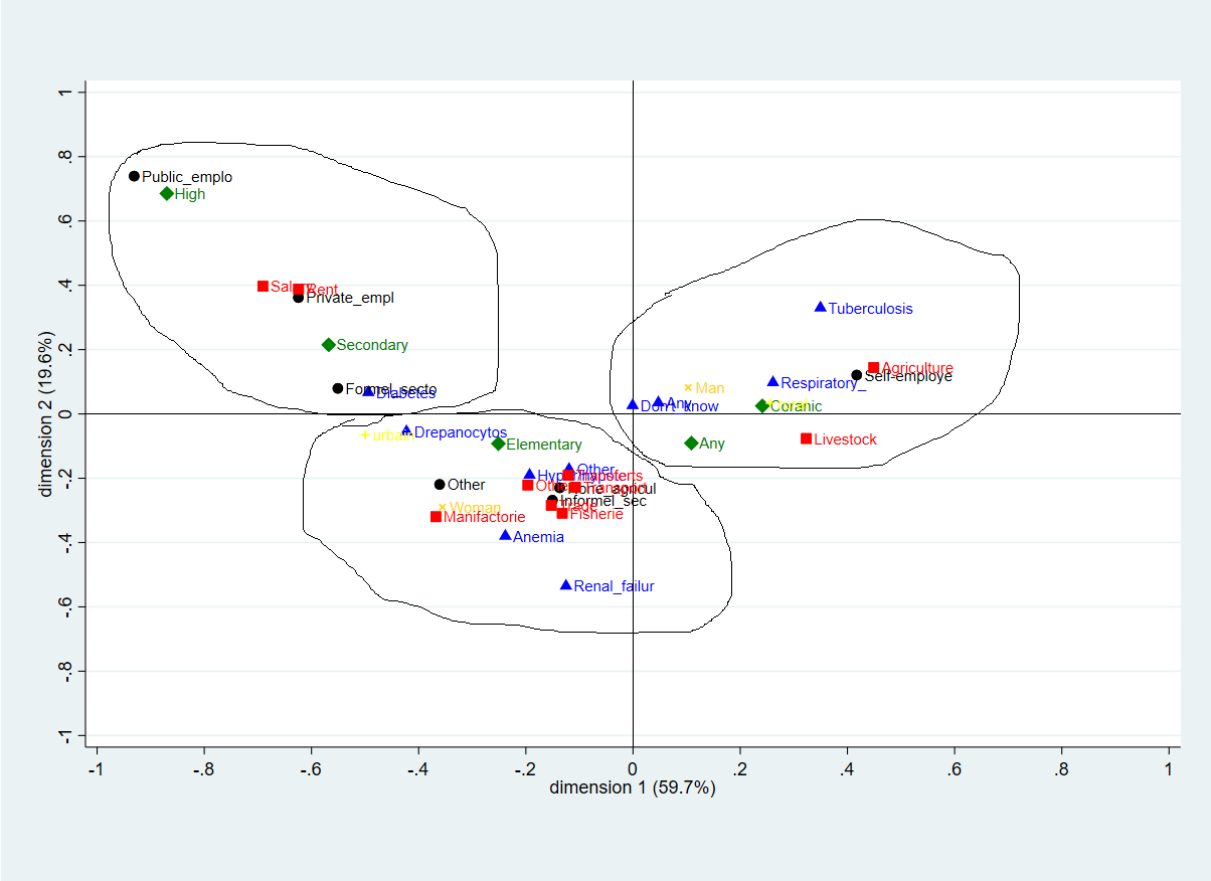
The first group, on the top left, consists of households where the head works in a public institutions or in a private company and have acquired a secondary or higher level of education. Also, in these households, the main sources of income are wages and income from rent.

The second group, as shown in the right-wing block, includes households whose main source of income is agriculture or livestock and whose leader is a man who has only attended the Koranic school and who has chronic disease (tuberculosis, respiratory infection, etc.).

The third group is characterized by households headed by women with an elementary level of education, who work in the informal sector and who generally suffer from sickle cell disease, anaemia, kidney failure or hypo/hypertension. In these households, income is mainly derived from processing, fishing, transfers and trade.

Indeed, in addition to the climatic hazards that can affect fishing conditions, external factors such as the economic conditions of migrants, the evolution of the price of primary products (which are processed by these households) and market conditions.

Figure 20:Multiple Correspondence Analysis



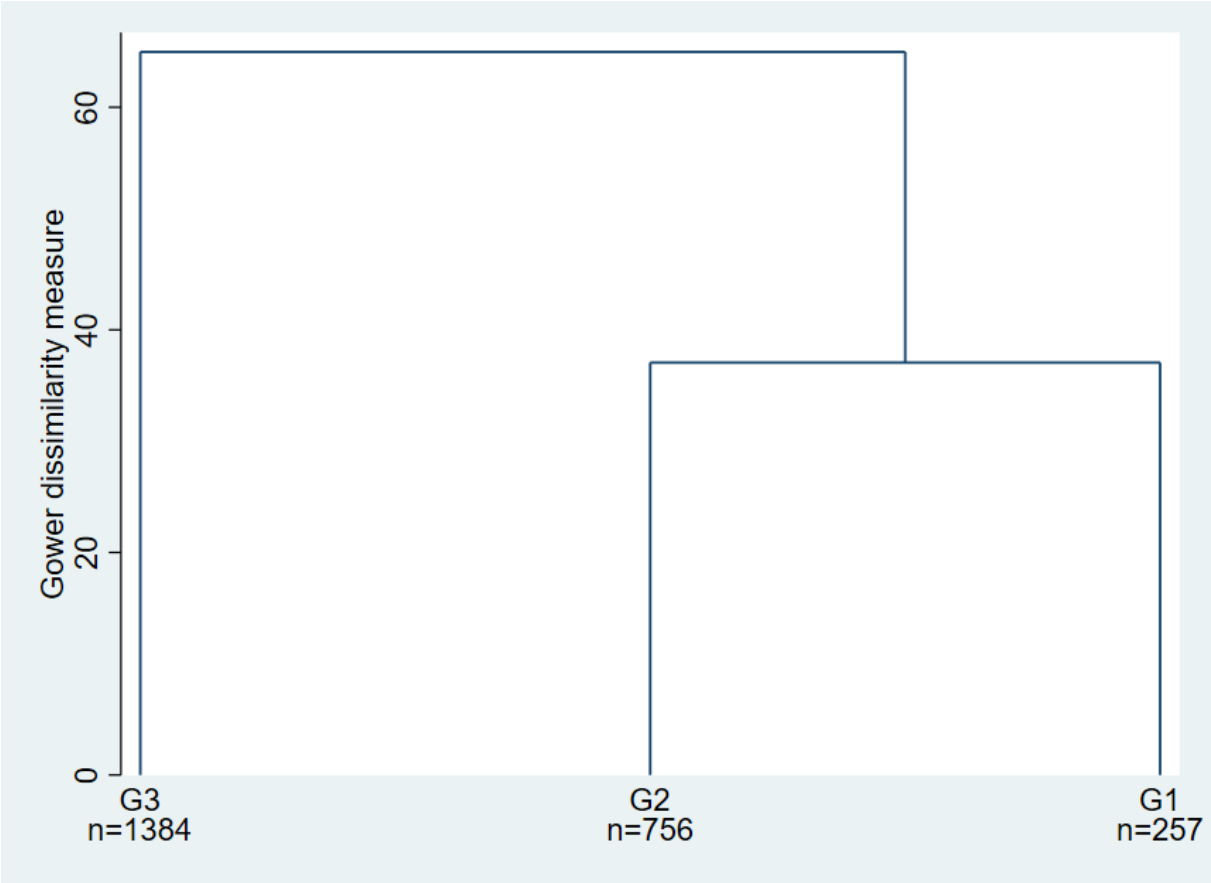
Source: Author, 2022

The two variables concerning the individual's contact details on the two axes (1 and 2) are repeated in the Ascending Hierarchical Classification (AHC) to establish a household typology by adding other characteristics such as the amounts associated with the different sources of

income, total and food expenditure and household size. The results for the Classification dendrogram are shown in the graph below.

The classification was carried out with the distance of dissymmetry of Gower (see appendix). In the light of the results, there are three types of households. To better describe these classes of households, we need to look at the associated income and expenses.

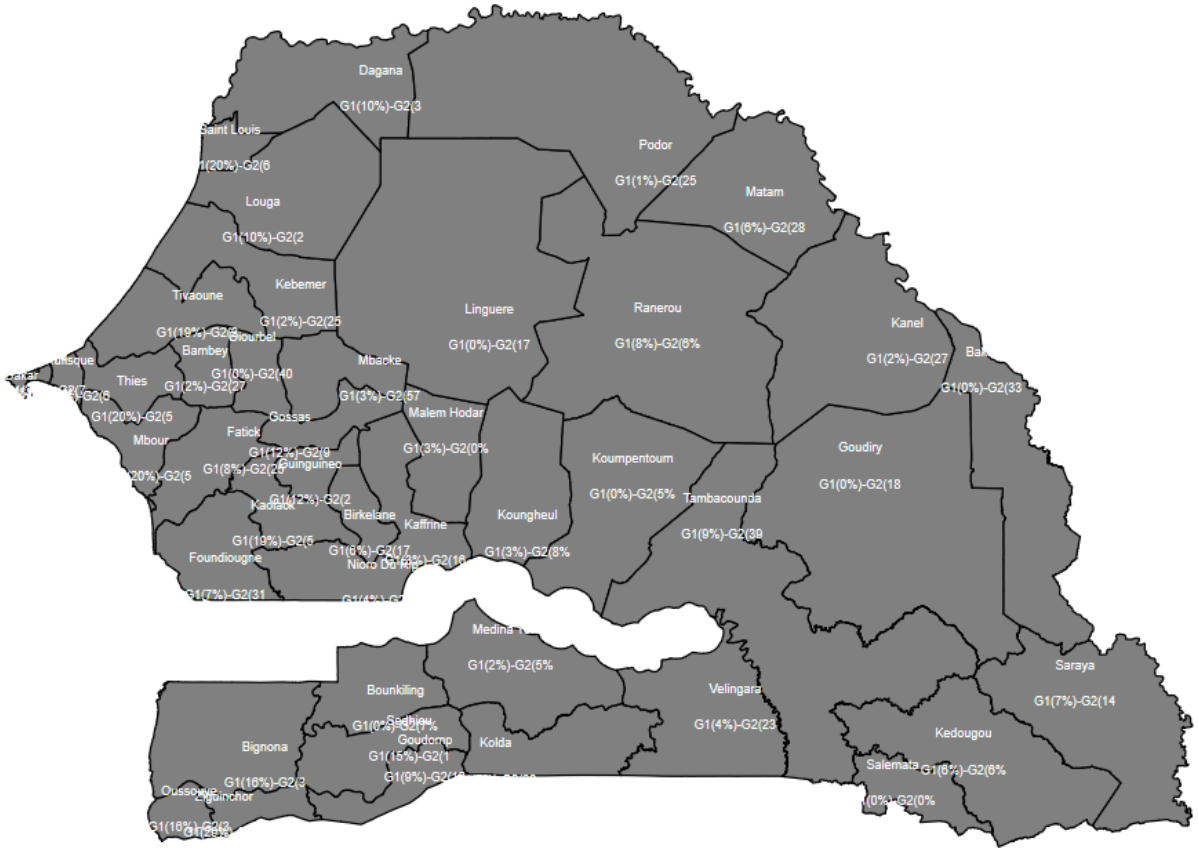
Figure 21: Dendrogram of the classification



Source: Author, 2022

The following graph shows the percentage of households in the G1 and G2 groups (the percentage of the G3 group is deduced from the sum of the percentages of G1 and G2). Households in the G1 group reach 20% around the Dakar region and become weak in the remote regions of Dakar.

Figure 22: Porportion of household classes by departments



Source: Author's, 2022

The table below shows the breakdown of the amounts of the different sources of income and total expenditure on food.

The results show that the hierarchical classification groups have different characteristics.

For the group G3 household's income comes mainly from trade (386944 FCFA) and transfers (326115 FCFA). The second group (G2) households live mainly on incomes from agriculture (290333 FCFA), salaries (255968 FCFA) and transfers (201324 FCFA). For households of group G1, their income is largely supported by salaries (412956 FCFA), other activities (258167 FCFA) and trade (233750 FCFA).

In addition, for the group G3 the total income is 146379 FCFA for 131530 FCFA of total expenditures and 98975 FCFA of food expenditures. The total income of second group (G2) is 166662 FCFA with an average total expenditure of 158311 FCFA and food expenditures of 102660 FCFA. For the households of group G1 households have a total income of 395260 FCFA, a total expenditure of 243372 FCFA and a food expenditure of 150785 FCFA

In view of the descriptions of the classes carried out above, G3 households are considered to be “poor", G2 households to be in the "average" and G1 households to be “rich”.

Table 4: Income and expenditure by household class

	G3	G2	G1	Total
Income per activities				
Agriculture	*96147*	*290333*	*57500*	*106798*
Trade	*386944*	*150561*	*233750*	*229133*
Salary	*148111*	*255968*	*412956*	*337328*
Transferts	*326115*	*201324*	*200000*	*263254*
Transport	*128667*	*116719*	*80000*	*120216*
Others	*75797*	*97440*	*258167*	*97276*
Food expenditure	**98975**	**102660**	**150785**	**105692**
Total expenditure	**131530**	**158311**	**243372**	**151968**
Total income	**146379**	**166662**	**395260**	**179461**

Source : Author’s calculation ,2022

4.1.3. Food insecurity indexes

There are five indexes addressed in this research. Two of these indexes, the Food Consumption Score (FCS) and the Household Dietery Diversity Score (HDDS), measure food security while the other three indexes, Coping Strategy Index (CSI), Houeshold Food Insecurity Access Scale (HFIAS) and Household Hunger Scale (HHS) measure food insecurity.

The calculation of the fives indexes have numerical values

- **The food Consumption Score (FCS)**

To calculate this index, we group the food into eight: main staples, pulses, vegetables, fruits, meat/fish, milk, suger and oil. Each of this group has a specified weight as indicated in the table below:

Table 5: Food Consumption Score estimation

Foods	**Scores**
Main staples	2
Pulses	3
Vegetables	1
Fruits	1
Meat/Fish	4
Milk	4
Sugar	0.5
Oil	0.5

Source: INDDEX Project (2018)

For each group of foods, the associated item is evaluated from 0 to 7 corresponding to the number of days within the week that the household has eaten at least one food in the group. This number of days per week is multiplied by the score and summed up to finaly get the FCS.

FCS = Number of days per week * score of the group

The final index is the numerical variable that is between 0 and 112 (for weighted indexes), and the higher is related to a good situation (Food security).

One of the main limitations of the FCS is that it reflects only one week's consumption and does not capture seasonal variations, food deficit and consumption outside the household.

- **Household Dietery Dievrsity Score (HDDS)**

The following 12 food groups are used to calculate the HDDS indicator:

Table 6: Items for HDDS calculation

A.	Cereals
B.	Roots and tubers
C.	Vegetables
D.	Fruits
E.	Meat, poultry, offal
F.	Eggs
G.	Fish and seafood
H.	Pulses, legumes, nuts
I.	Milk and milk products
J.	Oil/fats
K.	Sugar/honey
L.	Miscellaneous

Source: A. Swindale *et al.* 2006

Each group is a dichotomic variable explained if the household has eaten one food in the group (value 1) or not (value 0) at the day before the survey. The HDDS correspond to the sum of the 12 values:

HDDS = A+B+C+D+E+F+G+H+I+J+K+L

The index is ranged from 0 (bad situation) to 12 (good situation).

The limit of this indicator is that it captures the structure of consumption only over a 24-hour period and therefore, may not properly identify the household food profile. For example, the day before the interveiew may correspond to an event (parties, funerals, movement of certain household members, etc.) which are at the time of a change in household eating behaviour. For example, a wealthy household may limit the consumption of fruit, red meat etc. when children are in holiday in another household. This rich household finds itself with a low level of HDDS which places it in a situation of food insecurity. This household could even have a good FCS value when its consumption had remained normal during the other days of the week.

- **Reduced Consumption Score Indexe (rCSI)**

This index explains, in the past 7 days, if there have been times when the household did not have enough food or money to buy food and how often it happens. The following table describes the item and score used to evaluate the CSI.

Table 7:rCSI item evaluation

	Raw Score	**Universal Severity Weight**	**Weighted Score = Frequency X weight**
A. Rely on less preferred and less expensive foods?	5	1	5
B. Borrow food, or rely on help from a friend or relative?	2	2	4
C. Limit portion size at mealtimes?	7	1	7
D. Restrict consumption by adults in order for small children to eat?	2	3	6
E. Reduce number of meals eaten in a day?	5	1	5
TOTAL HOUSEHOLD SCORE—Reduced CSI			**28**

Source: D. Maxwell, 2008

The final index is the sum of the weighted raw score of all the items. The index is ranged from 0 to 28, and the higher the value, the higher the insecurity of food in the household.

The value of the rCSI of a household does not reflect a situation of insecurity of that household, but makes it possible to compare two households: a household with a high CSI is more insecure than another household with a low rCSI. This is a limitation of this indicator in the measure where certain survival strategies may be circumstantial. For example, following a demonstration, a household could fall back on foods that are less squeaky but acceptable for safety reasons. Similarly, when the household receives people temporarily its consumption could be adjusted under the effect of number (cheaper food).

- **HFIAS is between 0 (no food insecurity) and 27 (higher food insecurity);**

The nine items used in the calculation of this index are presented below.

Table 8: Items for HFIAS calculation

Question	**CODE**
Q1: In the past four weeks, how often did you worry that your household would not have enough food?	*0 = Never* *1 = Rarely (once or twice in the past four weeks)* *2 = Sometimes (three to ten times in the past four weeks)* *3 = Often (more than ten times in the past four weeks)*
Q2: In the past four weeks, how often were you or any household member not able to eat the kinds of foods you preferred because of a lack of resources?	*0 = Never* *1 = Rarely (once or twice in the past four weeks)* *2 = Sometimes (three to ten times in the past four weeks)* *3 = Often (more than ten times in the past four weeks)*
Q3: In the past four weeks, how often did you or any household member have to eat a limited variety of foods due to a lack of resources?	*0 = Never* *1 = Rarely (once or twice in the past four weeks)* *2 = Sometimes (three to ten times in the past four weeks)* *3 = Often (more than ten times in the past four weeks)*
Q4: In the past four weeks, how often did you or any household member have to eat some foods that you really did not want to eat because of a lack of resources	*0 = Never* *1 = Rarely (once or twice in the past four weeks)* *2 = Sometimes (three to ten times in the past four weeks)* *3 = Often (more than ten times in the past four weeks)*
Q5: In the past four weeks, how often did you or any household member have to eat a smaller meal than you felt you needed because there was not enough food?	*0 = Never* *1 = Rarely (once or twice in the past four weeks)* *2 = Sometimes (three to ten times in the past four weeks)* *3 = Often (more than ten times in the past four weeks)*
Q6: In the past four weeks, how often did you or any other household member have to eat fewer meals in a day because there was not enough food?	*0 = Never* *1 = Rarely (once or twice in the past four weeks)* *2 = Sometimes (three to ten times in the past four weeks)* *3 = Often (more than ten times in the past four weeks)*

Q7: In the past four weeks, how often was there ever no food to eat of any kind in your household because of lack of resources to get food?	*0 = Never* *1 = Rarely (once or twice in the past four weeks)* *2 = Sometimes (three to ten times in the past four weeks)* *3 = Often (more than ten times in the past four weeks)*
Q8: In the past four weeks, how often did you or any household member go to sleep at night hungry because there was not enough food?	*0 = Never* *1 = Rarely (once or twice in the past four weeks)* *2 = Sometimes (three to ten times in the past four weeks)* *3 = Often (more than ten times in the past four weeks)*
Q9: In the past four weeks, how often did you or any household member go a whole day and night without eating anything because there was not enough food?	*0 = Never* *1 = Rarely (once or twice in the past four weeks)* *2 = Sometimes (three to ten times in the past four weeks)* *3 = Often (more than ten times in the past four weeks)*

Source:(Coates et al., 2007)

The HFIAS is the sum of the value cooresponding to the modality.

HFIAS = Q1+Q2+Q3+Q4+Q5+Q6+Q7+Q8+Q9

The HFIAS also limits the failure to take into account the execptional events, especially when hosting foreigners on a temporary basis, inducing the household to adopt cheaper food products instead of increasing its spending due to a lack of immediate financial resources. And the length of the reference period, last four weeks, increases the chances of occurrence of execptional events and confers a high value of the HFIAS to a household without it being in a situation of insecurity compared to the FCS or the HDDS.

- **HHS is between 0 (no food insecurity) and 6 (higher food insecurity)**

The items used in the calculation of this indexe are presented below.

Table 9: Items for HHS calculation

Q1: In the past 30 days, how often was there ever no food to eat of any kind in your house because of lack of resources to get food?	*0 = Never* *1 = Sometimes (1 to 1 times)* *2 = Often (more than 10 times)*
Q2: In the past 30 days, how often did you or any household member go to sleep at night hungry because there was not enough food?	*0 = Never* *1 = Sometimes (1 to 1 times)* *2 = Often (more than 10 times)*
Q3: In the past 30 days, how often did you or any household member go a whole day and night without eating anything at all because there was not enough food?	*0 = Never* *1 = Sometimes (1 to 1 times)* *2 = Often (more than 10 times)*

Source: (USAID FANTA Project, 2011)

Finaly, the index is calculated as:

HHS = Q1+Q2+Q3

As for the HFIAS, the HHS also comes up against execptional events or consumption outside households. Indeed, when a household member goes to an event and decides to take his/her meals at that event, the household could reduce its preparation, so that there is not enough for the usual number. This situation does not indicate a situation of food insecurity.

- **Summarized food insecurity index**

A summarized food insecurity indexe is calculated occording to these five indexes. Indeed, the FCS and the HDDS are transformed to insecurities indexes by the complementary values: [112 – FCS] as insecurity version of FCS and [12 – HDDS] the one of HDDS. The resulting summarized indexe is the sum of the five insecurities indexes:

Summarized indexe = (112 – FCS) + (12 – HDDS) + CSI + HFIAS + HHS

This summarized index characterizes the household global food insecurity level: a higher value meaning several food insecurity situation.

The table below shows the food insecurity situation of the three household groups' abtained above with the classification. The results show that, according to all the indexes, the group of rich have better situation, followed by the group of average and the group of poor which have the highest level of food insecurity

Table 10: Household class food insecurity sitituation

Groupe of Household	FCS	HDDS	CSI	HFIAS	HHS	Summarized indexe
Rich (G1)	91.38	8.39	2.64	1.54	0.14	28.56
Average (G2)	84.55	7.91	6.99	4.28	0.61	43.41
Poor (G3)	71.10	6.87	10.30	7.34	0.91	64.59
Global	**77.52**	**7.36**	**8.44**	**5.75**	**0.73**	**54.05**

Source : Author's calculation ,2022

The illustration above shows the results of the ANOVA model that indicates the significance of the difference of FCS level over the household group. The weak value of the p-values show that the model is globaly significant and the difference of FCS level over the groups is also significant.

Figure 23: Difference of FCS over household group

```
. anova FCS groupe
                          Number of obs =      2,397   R-squared     =  0.1263
                          Root MSE      =   20.3808   Adj R-squared =  0.1255

                   Source | Partial SS         df         MS        F     Prob>F
--------------------------+----------------------------------------------------
                    Model |  143716.06          2   71858.029   172.99   0.0000
                          |
                   groupe |  143716.06          2   71858.029   172.99   0.0000
                          |
                 Residual |  994413.79      2,394   415.37752
--------------------------+----------------------------------------------------
                    Total |  1138129.8      2,396   475.01246
```

Source: Author's calculation, 2022

Also, the illustration above shows the results of the ANOVA model that indicates the significance of the difference of HDDS level over the household groupe. The weak value of the p-values shows that the model is globally significant and the difference of HDDS level over the groups is also significant.

Figure 23: Difference of HDDS over household group

```
. anova HDDS groupe

                   Number of obs =      2,397    R-squared     =  0.1146
                   Root MSE      =    1.64353    Adj R-squared =  0.1139

  Source | Partial SS         df         MS        F    Prob>F
---------+----------------------------------------------------
   Model |  837.37137          2   418.68568    155.00  0.0000
  groupe |  837.37137          2   418.68568    155.00  0.0000
Residual |  6466.6395      2,394   2.7011861
---------+----------------------------------------------------
   Total |  7304.0108      2,396   3.0484186
```

Source: Author's calculation, 2022

The illustration above shows the results of the ANOVA model that indicates the significance of the difference of CSI level over the household groupe. The weak value of the p-values shows that the model is globally significant and the difference of CSI level over the groups is also significant.

Figure 24: Difference of CSI over household group

```
. anova CSI groupe

                   Number of obs =      2,397    R-squared     =  0.0408
                   Root MSE      =    12.1671    Adj R-squared =  0.0400

  Source | Partial SS         df         MS        F    Prob>F
---------+----------------------------------------------------
   Model |  15058.109          2   7529.0544     50.86  0.0000
  groupe |  15058.109          2   7529.0544     50.86  0.0000
Residual |  354405.57      2,394   148.03908
---------+----------------------------------------------------
   Total |  369463.67      2,396    154.2002
```

Source: Author's calculation, 2022

The illustration above shows the results of the ANOVA model that indicates the significance of the difference of HFIAS level over the household groupe. The weak value of the p-values shows that the model is globally significant and the difference of HFIAS level over the groups is also significant.

Figure 25: Difference of HFIAS over household group

```
. anova HFIAS groupe

                   Number of obs =      2,397    R-squared     =  0.0981
                   Root MSE      =    6.10775    Adj R-squared =  0.0973

    Source | Partial SS         df         MS        F     Prob>F
-----------+----------------------------------------------------
     Model |  9708.6514          2   4854.3257    130.13  0.0000
    groupe |  9708.6514          2   4854.3257    130.13  0.0000
  Residual |  89307.108      2,394   37.304557
-----------+----------------------------------------------------
     Total |   99015.76      2,396   41.325442
```

Source: Author's calculation, 2022

The illustration above shows the results of the ANOVA model that indicates the significance of the difference of HHS level over the household group. The weak value of the p-values shows that the model is globally significant and the difference of HHS level over the groups is also significant.

Figure 26: Difference of HHS over household group

```
. anova HHS groupe

                   Number of obs =      2,397    R-squared     =  0.0312
                   Root MSE      =    1.38811    Adj R-squared =  0.0304

    Source | Partial SS         df         MS         F    Prob>F
-----------+----------------------------------------------------
     Model |  148.35997          2   74.179984     38.50  0.0000
    groupe |  148.35997          2   74.179984     38.50  0.0000
  Residual |  4612.8891      2,394   1.9268543
-----------+----------------------------------------------------
     Total |  4761.2491      2,396   1.9871657
```

Source: Author's calculation, 2022

The illustration above shows the results of the ANOVA model that indicates the significance of the difference of the synthetic index level over the household group. The weak value of the p-values shows that the model is globally significant and the difference of the synthetic index level over the groups is also significant.

Figure 27: Difference the synthetic index level over household group

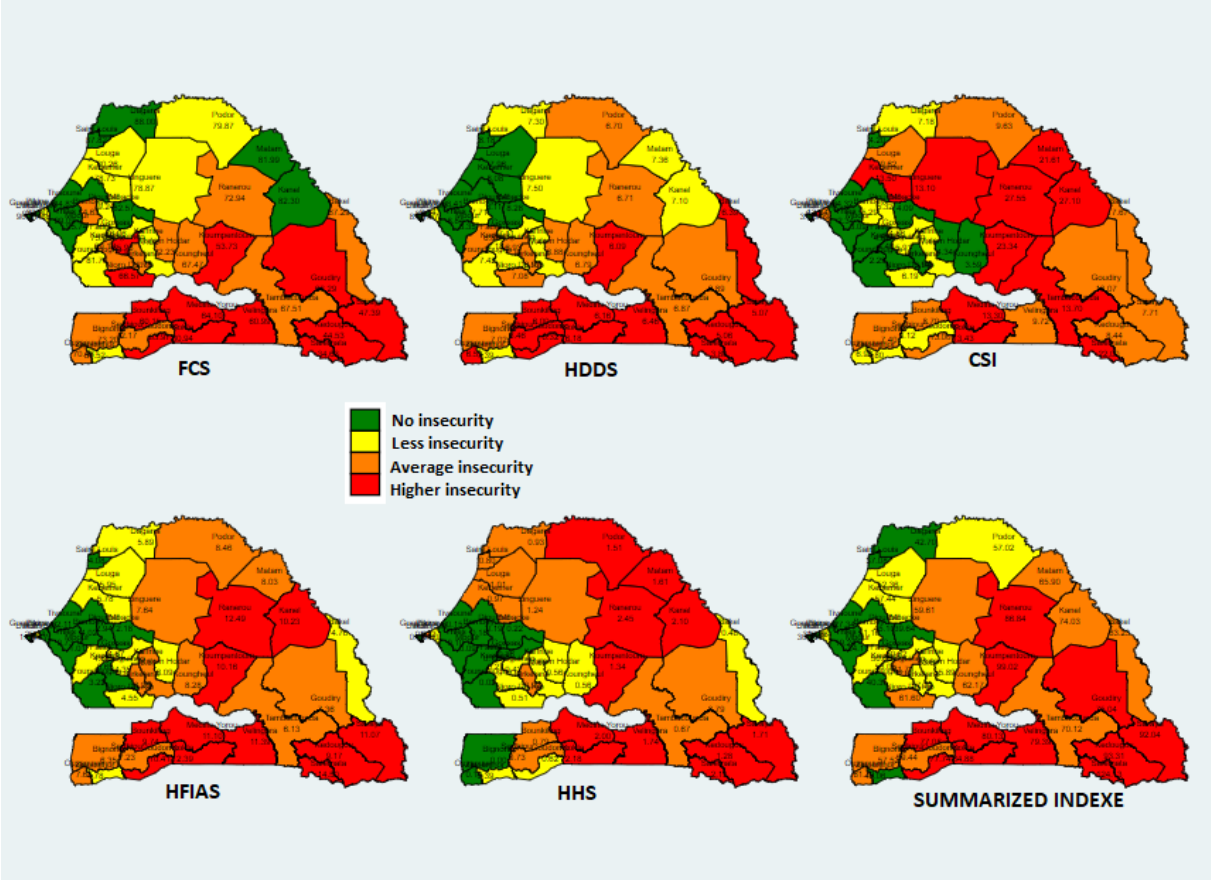
```
. anova synt_ind groupe

                   Number of obs =      2,397    R-squared     =  0.1435
                   Root MSE      =    31.8289    Adj R-squared =  0.1428

    Source | Partial SS         df         MS         F    Prob>F
-----------+----------------------------------------------------
     Model |  406481.56          2   203240.78     200.62  0.0000
    groupe |  406481.56          2   203240.78     200.62  0.0000
  Residual |  2425305.6      2,394   1013.0767
-----------+----------------------------------------------------
     Total |  2831787.2      2,396   1181.8811
```

Source: Author's calculation, 2022

In addition, the food indexes are evaluated by departements using a map to analyse the situation of food insecurity over the differents space of the country. The result is illustrated by the graph below. The food insecurity is more present is the centeral and the Eastern-south of the country

(mainly the regions of Louga, Matam, Tamba, Kedougou, Kolda and Sedhiou). The closest regions of the capital (Dakar) have a good situation.

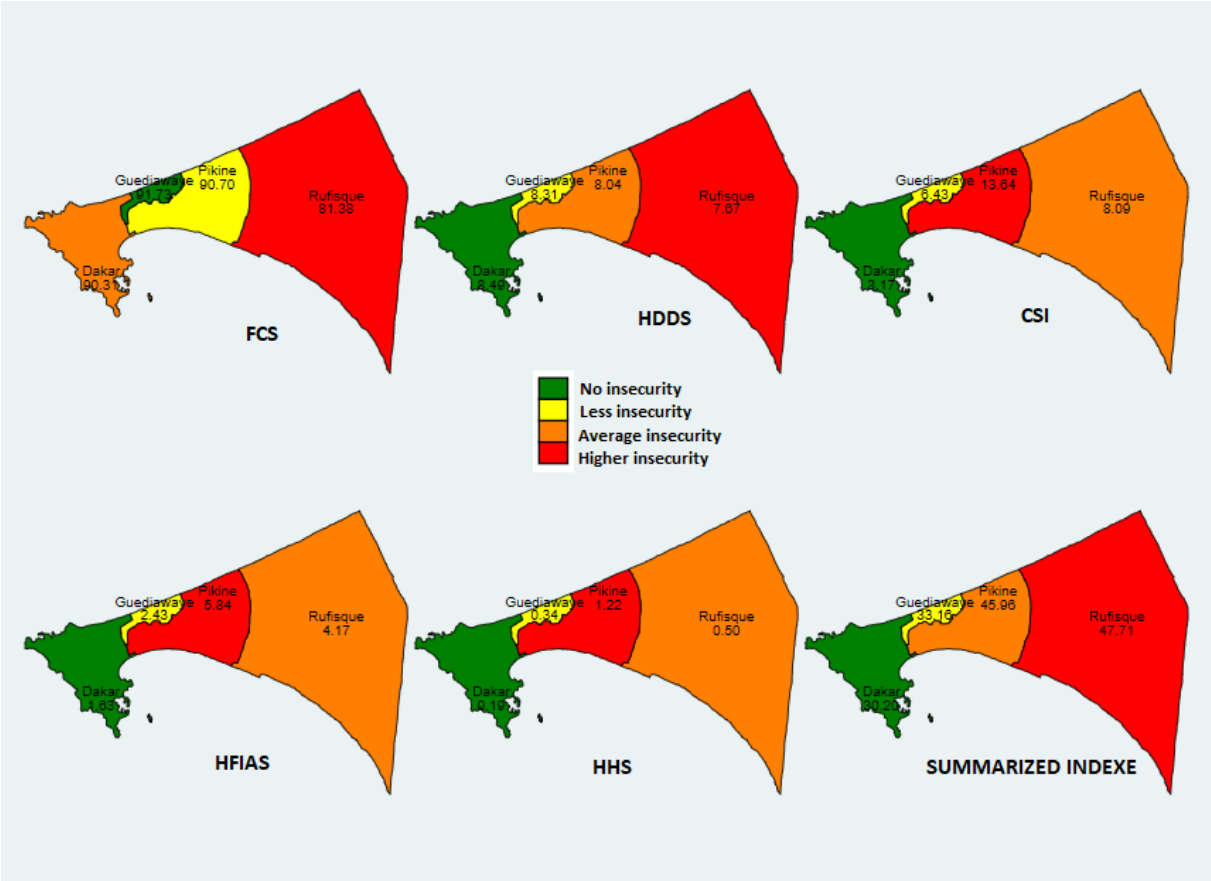
Figure 28: The level of Food Insecurity by departement



Source: Author, 2022

The situation of the capital requires an attention because of its importance in terms of population that is why a focus is made on Dakar as illustrated in the figure below. Globally, the insecurity become important while getting far from the department of Dakar, Rufisque presenting the highest level of food insecurity.

Figure 29: The level of Food Insecurity in Dakar



Source: Author, 2022

4.2 Modeling food insecurity indexes

The different econometric specifications made in this section attempt to show the characteristics of the different indexes of food insecurities discussed above. More explicitly, the aim is to explain each of the five indicators using an econometric model with explanatory variables as total agricultural income (agri), salary, transfer amount, donations income (donations), household size (hhsize) , total agricultural land areas (areas), environment (milieu), main source of income (srev), the gender of the head of household (q116c), the household membership class (group), the average volume of rainfall (rain) over the last 20 years, the mean minimum (tmin) and maximum (tmax) temperatures.

The grouped nature of the data conduct to use the multilevel model. Indeed, the climatic information relating to the temperature (minimum and maximum) and the rainfall relate to the departments. They are therefore common to all households of the same department.This constitutes the first level of the model.In each department a sample of household is considered with information according to their characteristics, their expenditures, their income.ect.This

second stage is the second level of the model.Also, the few number of observations in some departments may result in the violation of the assumptions of the multilevel linear model (that are the same from the linear model). Therefore, the multilevel generalized linear model is used in all the following estimations.

This model fits multilevel mixed-effects generalized linear models of the form:

$$\boldsymbol{g\{E(y|X,u)\} = X\beta + Zu, \quad y \sim F}$$

Where $\boldsymbol{y}$ is the n×1 vector of responses from the distributional family $\boldsymbol{F}$, $\boldsymbol{X}$ is an n×p covariate matrix for the fixed effects β, and $\boldsymbol{Z}$ is the n × q covariate matrix for the random effects $\boldsymbol{u}$. The Xβ + Zu part is called the linear predictor, and it is often denoted as $\boldsymbol{\eta}$.

The function $\boldsymbol{g(\cdot)}$ is called the link function and is assumed to be invertible such that:

$$\boldsymbol{E(y|X,u) = g^{-1}(X\beta + Zu)}$$

The choice between fixed or random effect is made by using the specification test of hausman as shown in the table below for the FCS model. The highest value of the p_value, 0.7006, suggested to use the random effects model. The specification test for the other models is illustrated in annex.

Figure 30: Hausman test of model specification

```
Test of H0: Difference in coefficients not systematic

   chi2(10) = (b-B)'[(V_b-V_B)^(-1)](b-B)
            =   7.26
Prob > chi2 = 0.7006
(V_b-V_B is not positive definite)
```

Source: Author's Calculation, 2022

The food insecruty indexes modelling is illustrated in the table below. The results show that the food consumption score increases significantly (at the 5% level) with agricultural income, wages and the amount of transfers received by the household. Farm income, wages and transfers help to improve the food situation of households.

At the 10% level, the food consumption score increases with income from trade and decreases with the amount of donations. Thus, an increase in donations in a household indicates a low level of food consumption score, and thus food insecurity.

Also, the food consumption score of a household increases significantly by 7.319 if that household resides in urban rather than rural areas. The food situation with regard to the food consumption score is therefore, significantly worse in rural areas.

In addition, a household's food consumption score increases significantly by 4.610 if the main source of income is trade compared to agriculture. Also, the food consumption score increases (relative to agriculture) by 7.471 if the main source of household income is salary and by 11.499 if the main source of income is transportation. Thus, in comparison with agriculture, the main source of income that guarantees a good food situation of the household, from the point of view of the food consumption score, is first transport, then wages and finally trade.

According to household classes and compared to the situation where the household would be rich (group 1), the food diversity score is significantly reduced by 3.476 if the household is average (group 2) and by 5.443 if the household is poor (group 3). Thus, compared to wealthy households, the food situation as measured by the food consumption score is worse for middle-class households and even worse for poor-class households.

Compared to climate variables, a 1mm increase in the 20-year average rainfall volume significantly reduced the household food consumption score by 0.236. Similarly, a 1°C increase in the 20-year average of the minimum (maximum) temperature significantly reduces the household food consumption score by 3.830 (0.296, respectively). The 20-year average of the minimum temperature has a greater effect on the FCS compared to the effects of the mean volume of rainfall and the maximum temperature.

The results of the modelisation of HDDS show that the household food diversity score increases significantly (at the 5% level) with the salary and the amount of transfers received by the household. Thus, wages and transfers help to diversify food in the household, and help to improve the food situation.

At the 10% level, the household food diversity score increases with income from trade and household size and decreases with the amount of donations.

Also, for a household, the food diversity score increases significantly by 0.584 if that household resides in urban rather than rural areas. The household food diversity score is therefore, significantly lower in rural areas, showing a better food situation in terms of diversity in urban areas compared to rural areas.

In addition, for a household, the household food diversity score increases significantly by 0.515 if the main source of income is trade compared to agriculture. Also, the household food diversity score increases by 0.655 if the main source of household income is salary (compared to agriculture) and by 0.785 if the main source of income is transport rather than agriculture. Transport is therefore, the activity that offers a better food situation in terms of nutritional diversity, than wages and trade.

On the other hand, compared to the situation where the household would be rich (group 1), the food consumption score is significantly reduced by 0.399 if the household is poor (group 3). This latter class of households thus has a less ideal net situation in terms of food diversity compared to households in the rich class. For a 10% significance level, the food diversity score of a middle-class household (group 2) is reduced by 0.287 compared to the rich class (group 1). In relation to climate variables, only the effect of the minimum temperature is significant. For this purpose, a 1°C increase in the 20-year average of the minimum temperature reduces the household food diversity score by 0.356. The increase in the minimum temperature worsens the household's food situation, particularly in terms of nutritional diversity.

The results of the modelisation of the CSI show that the consumption score index decreases significantly (at the 5% level) with income from transfers and trade. The Consumption Score Index measures the food shortages experienced in the household over the course of a week. Thus, the amount of transfers and income from trade help to improve the household's food situation by reducing the consumption score index.

Moreover, at the 10% level, the consumption score index reduces agricultural income and wages. Also, at the 10% level, the consumption score index of a household decreases by 1.858 if that household resides in urban rather than rural areas. The consumption score index is therefore, significantly higher in rural areas.

In addition, the consumption score index of a household decreases significantly by 4.413 if the main source of income is wages rather than agriculture, and decreases by 3.694 if the main source of income of the household is transport compared to agriculture. Thus, compared to agriculture, wages are the best source of income allowing the household to avoid situations of lack of food, thus improving the food situation.

Compared to climate variables, a 1 mm increase in the 20-year average rainfall volume significantly reduces the household consumption score index by 0.042. Similarly, a 1°C increase in the 20-year average of the minimum temperature significantly increases the

household consumption score index by 3.631.Thus, an increase in rainfall allows the household to limit the absence of food while the increase in the minimum temperature makes the household's food situation difficult.

The results of the HFIAS Modelling show that the scale of the household food access index decreases significantly (at the 5% level) with transfers, income from trade and household size. This indicator measures the difficulties related to access to food. Thus, transfers received by the household, income from trade and household size contribute to improving access to food.

At the 10% level, the scale of the household food access index decreases with agricultural income.

The scale of a household's food access index decreases significantly by 1.619 if that household resides in urban rather than rural areas. The scale of the household food access index is therefore, significantly higher in rural areas, showing a difficulty of food access in these areas compared to urban areas.

The scale of the household food access index decreases significantly by 2.529 if the main source of income is wages compared to agriculture. Also, it decreases (compared to agriculture) by 2.362 if the main source of household income is transport. Transport and wages are in order of importance, the main sources of activities that facilitate access to food in the household. At the 10% level, the fact that trade is the main source of income leads to a reduction in the scale of the household's food access index compared to the situation where the main source would be agriculture.

According to household classes and compared to the situation where the household would be rich (group 1), the scale of the household's food access index increases significantly by 1.472 if the household is average (group 2) and by 1.836 if the household is poor (group 3). Since the score measures difficulties of access, households in group 3 (poor households) have more difficult food situation, those in group 2 (average households) a little difficult, compared to group 1 (rich households).

Compared to climate variables, a 1 mm increase in the 20-year average rainfall volume significantly increases the household food access index scale by 0.041. A 1°C increase in the 20-year average of the minimum temperature significantly increases the household food access index scale by 1.175. The 20-year average of the minimum temperature has a greater effect on the HFIAS compared to the effects of the average volume of rainfall and the maximum

temperature. The increase in rainfall and the minimum temperature contribute to exacerbating the difficulties of access to food.

The average of the maximum temperature over 20 years is significant at the 10% level and leads to an increase of 0.077 of the HFIAS over a variation of +1°C.

The results of the HHS Modelling show that only transfer income has a significant and negative effect on the household's hunger score, thus improving the household's food situation. In addition, the household hunger score decreases significantly by 0.285 if the main source of income is wages compared to agriculture. When wages are the main source of income, hunger is less present in the household, which improves the food situation.

According to household classes and compared to the situation where the household would be rich (group 1), the household hunger score is significantly increased by 0.233 if the household is average (group 2) and by 0.207 if the household is poor (group 3). Here although the food situation is paltry compared to the group of wealthy households, the group of poor households is a little better off.

Compared to climate variables, a 1 mm increase in the 20-year average volume of rainfall, significantly reduced the household hunger score by 0.004 and a 1°C increase in the 20-year average of the minimum temperature significantly increased the household hunger score by 0.079. The 20-year average of the minimum temperature thus tends to accentuate food insecurity with regard to HHS while the increase in rainfall contributes to reducing hunger in the household.

The results of the summarized food insecurity index modelling show that the synthetic index decreases significantly (at the 5% level) with agricultural income, wages and the amount of transfers received by the household and income from trade. So, household food security is improved by wages, transfers and trade.

Moreover, at the 10% level, the synthetic index decreases the size of the household.

Also, the synthetic index decreases significantly by 29.686 if the household resides in urban rather than rural areas. The level of food insecurity is therefore significantly higher in rural areas than in urban areas.

In addition, the synthetic index decreases significantly by 52.450 if the main source of income is wages in comparison to agriculture. Also, the synthetic index decreases by 48.535 if the main

source of household income is transport relative to agriculture. Wages and transfers, as the main sources of income, help to improve the household's food situation.

In relation to climate variables, only the minimum temperature is significant. Thus, a 1°C increase in the 20-year average of the minimum temperature significantly increases the hunger index, thus increasing the household's level of insecurity.

In the end, the results found above are intuitive. Indeed, it is well known in the literature that rainfall instability and extreme temperatures negatively affect agricultural harvests and lead to a decrease in food supply (Badolo F., 2013). This confirms our results on the FCS which is negatively impacted by pluviometry and extreme temperatures (minimum and maximum). For the other indicators, only the effect of the minimum temperature remained intuitively significant in accordance with the theory. Rainfall is measured here on the volume and not on the variables, hence sometimes unexpected effects on the indicators. As for the maximum temperature, it can be observed over a short period during the year, so that its effect on food insecurity is not significant.

Moreover, it is clear that income, regardless of the source, reduces the level of food insecurity. Thus, the results showed that agricultural incomes, wages, transfers and income from household trade activities reduce household food insecurity across all indicators. Transfers having a significant impact on all indicators, a result conhérents with regard to empirical theory.

The negative effect of grants on indicators is due to the fact that aid has generally taken place in cases of extreme poverty or obvious food insecurity. Consequently, the increase in donations leads to an increase in food insecurity as the households eligible for social assistance are those who are vulnerable (examples of family security grants). While donations improve the situation within households, the number of vulnerable and dependent households is not reduced. Furthermore, in a situation where all vulnerable households receive donations, an increase in donations (in number) means an increase in the number of vulnerable households. It would also be argued that food insecurity is more pronounced in rural areas than in urban areas, in line with the literature.

Although the results according to the sex of the head of household are not significant, the information remains interesting. In fact, women-led households are diversifying their food more. In contrast, outside of food diversity, food insecurity is more prevalent among women-led households. This can be partly explained by the land problem, as women's access to land is weak.

Table 11: Food insecurities Indexes modeling

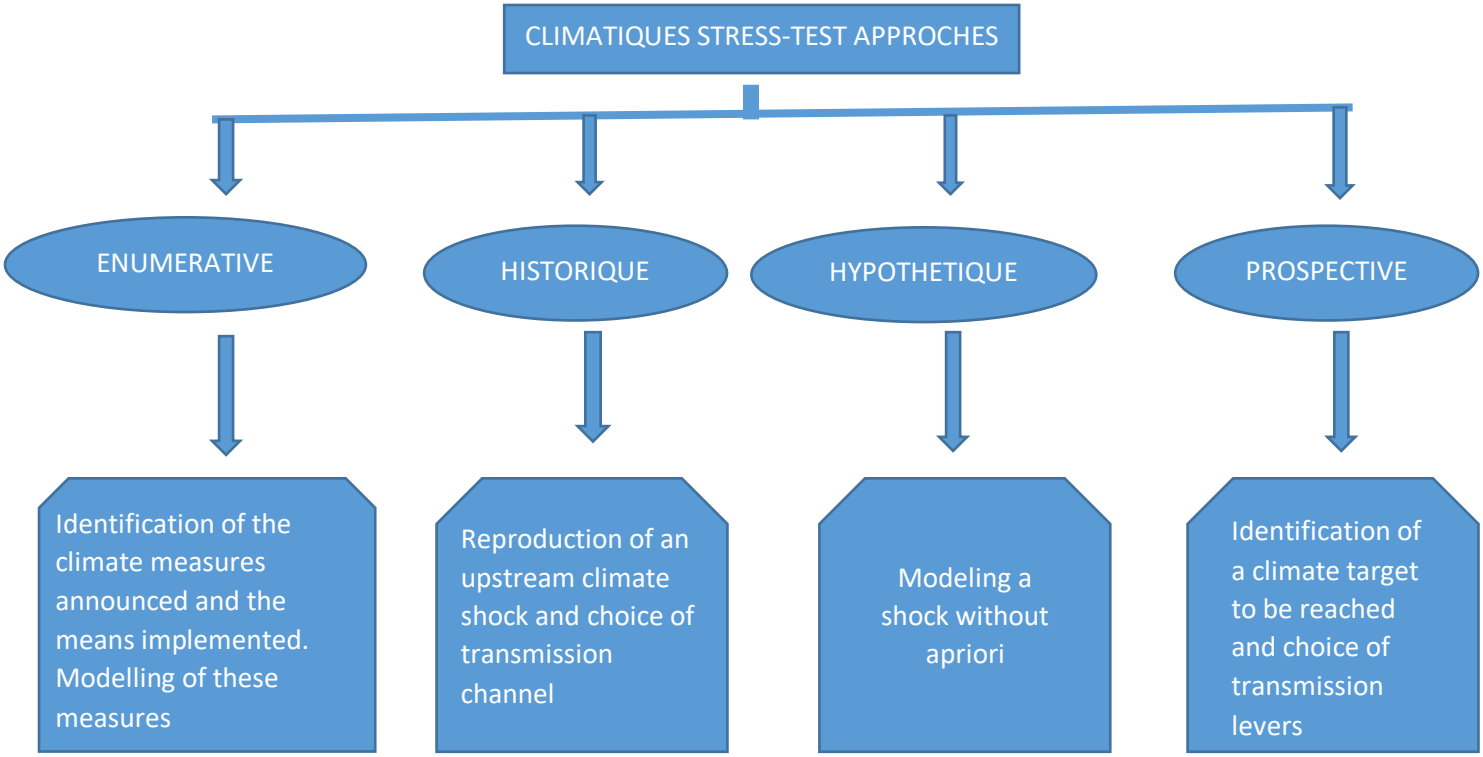
Variables	FCS	HDDS	CSI	HFIAS	HHS	SYNTHETIC
agriculture	.00001144**	6.062e-07	-4.897e-06	-3.116e-06	-4.030e-08	-.00006073*
salary	4.802e-06*	5.319e-07**	-1.805e-06	-5.737e-07	-6.992e-08	-.0000248*
transfert	.00004003***	2.500e-06*	-.00002003**	-.00001039**	-1.951e-06**	-.00024237***
donation	-.00002719	-1.006e-06	3.587e-06	8.261e-06	1.204e-06	.00004712
trade	.00001766	1.325e-06	-.00001105**	-6.879e-06**	NA	-.00013293***
household size	.11613155	.01021378	-.04631417	-.10826345***	NA	-.7104993
agricultural land areas	.01452625	NA	NA	NA	NA	.03191831
Gender						
Woman	-.18703784	0.05274346	.59089344	.02027259	.00565938	5.084731
milieu						
urbain	7.3193173***	.58360933***	-1.8577552	-1.6193179***	-.08907783	-29.685967***
Source of income						
Trade	4.6098061*	.51490097***	-.07058398	-.72566407	-.1175755	-5.3530012
Salary	7.4714155***	.65514458***	-4.4315372**	-2.5292596***	-.28516271*	-52.450103***
Transferts	1.7124344	.44447041	-.88612245	-.82117549	-.03655433	-15.003962
Transport	11.499123***	.78542282***	-3.6943503***	-2.3620293***	-.13528413	-48.535495**
Others	1.1357994	.12451417	.36777172	-.24788256	.09413682	4.1867341
groupe						

average	-3.4757425**	-.28764878	.83322606	1.4718065***	.23303556***	15.061737
poor	-5.4431791***	-.39956227**	1.3438062	1.8355866***	.20705677*	19.207913
rain	-.23610921***	-.01524122	-.04219959***	.04072799***	-.00370633***	-.08183577
tmin	-3.8296171***	-.35642599*	3.630835***	1.1752397***	.07911343**	40.06495***
tmax	-.29566541*	.0022453	.22314714	.07712864	-.01987283	1.9027007
_cons	179.3572***	15.355364*	-73.322989***	-22.556909***	NA	-771.31427***

Source: Author's calculation , 2022 Legend: * p<0.05; ** p<0.01; *** p<0.001

4.3 Food insecurity prevention in climate changes

In addition to these estimates, climatic variations were simulated on the basis of scenarios based on values from the literature(Florian JACQUETIN, 2021). To represent a climate scenario applicable to a stress test, several approaches can be applied. To this end, approaches such as enumerative, historical, hypothetical or prospective (or normative) may apply to a climate stress-test. The following diagram describes the principle of these different approaches.



Source:(Florian JACQUETIN, 2021)

In this modelling, the prospective approach will be adopted to apply a climate crisis simulation scenario. The transmission channel will be mainly the variables of minimum and maximum temperature and precipitation to analyse the effects on food insecurity indexes. According to the literature, Sub-Saharan Africa warmed by 1.1°C, up to 1.4°C in April, while the average duration of the rainy season decreased by 19% in Senegal from 1950 to 1980 (AMMA-2050. 2018). The variables relating to the volume of rainfall and the duration of the rainy season can be used as a proxy for each other.

Thus, since we have (in our secondary data) the mean temperature (minimum and maximum) and the average volume of rainfall over 20 years (2000 to 2020), the values presented above

will be considered at two-thirds (67%) of their values to form the scenarios, because of the part of 20 years into 30 years period:

- 12.73% (19% x 0.67) decrease in average rainfall;
- 0.737°C (1.1°C x 0.67) increase in mean minimum temperature;
- 0.938°C (1.4°C x 0.67) increase in mean maximum temperature.

Preventive measures simulated here taking into account the effects of climate change. This increase will be applied separately to income from different activities (agriculture, trade, transfers and services). The basis of household expenditure will be simulated by a decrease in the cost of total expenditure. Government action is supported by the family social grant for the poor and salaries.

The Government of Senegal allocates a lump sum of XOF 25,000 to poor households per quarter, or XOF 8,330 per month in line with a social stock exchange policy. In addition, the State has raised wages in several sectors of the economy, following trade union demands. These increases range from 75,000 to 250.000 XOF. Thus, in the simulations, farm incomes will be increased in the same way as the social stock exchanges will be 8,330 XOF and transfers will also be similarly increased to salaries with an amount of 75,000 XOF

I. Prevention of the effect of the variation of temprature and precipitation on the FCS

The table below shows the results of the simulation of the effects of climate change on the FCS and its prevention channels. The results show that the difference in the level of FCS of households is 14.7% due to the particularities of the departments in particular in terms of rainfall and minimum and maximum temperature.

An increase of 12.73% in the 20-year average of the volume of rainfall leads to a decrease in the FCS of 1.721% and the 20-year average increase in the minimum temperature of 0.737°C reduces the FCS by 2.822% and the 20-year average increase in the maximum temperature of 0.938°C reduces the FCS by 0.277%. These combined effects show a 4.821% decline in FCS.

Taking into account the combined effect of climate change, an increase in agricultural income of 8,330 XOF makes it possible to offset the climate effects on the FCS and leads to an increase of 0.095% in the FCS. Similarly, the increase in the amount of transfers of 75,000 XOF also increases the FCS by 3.003% despite the effects of climate change. This increase in transfers combined with that of agricultural income increases the FCS by 3.098% despite the effects of climate change.

In terms of public policies, a salary increase of 75,000 XOF also allows to correct the effects of climate change with an increase of 0.36% on the FCS. On the other hand, social assistance alone accentuates the effects of climate change by further widening the FCS deficit.

However, the increase in salaries combined with the social grants allow a mitigation of the effects of climate change and increase the FCS by 0.134%.

Table 12: The simulation of the variation of temprature and precipitation on household's FCS

		Coefficient	Std. err.	[95% conf.	interval]
Differences	ICC	14.7	0.019	0.114	0.187
Climate changes effets	Rain	-1.721	0.137	-1.991	-1.452
	Minimal temp	-2.822	0.262	-3,336	-2.309
	Max temperature	-0.277	0.131	-0.533	-0.021
	Grouped	-4.821	0.354	-5,516	-4.126
HH income increase	Agricole income	0.095	0.037	0.023	0.167
	Transfert	3.003	0.487	2.048	3.957
	Grouped	3.098	0.475	2.167	4.029
Government Politics	Salary	0.360	0.141	0.085	0.636
	Donations	-0.226	0.135	-0.491	0.038
	Grouped	0.134	0.185	-0.228	0.496

Source : Author's Calculation, 2022

II. Prevention of the effect of the variation of temprature and precipitation on the HDDS

The estimates in this section focus on the simulation of the effects of climate change on HDDS and the channels for preventing these effects. The results show that the difference in HDDS level of households is due to 5.1% differences in rainfall and minimum and maximum temperature among departments.

A 12.73% increase in the 20-year average rainfall volume results in a 0.11% decrease in HDDS. The 20-year average increase in the minimum temperature of 0.737°C reduces the HDDS by 0.268% and the 20-year average increase in the maximum temperature of 0.938°C reduces the HDDS by 0.002%. These combined effects show a decrease in HDDS of 0.376%.

These combined effects of climate change accompanied by an increase in agricultural income of 8330 XOF leads to an increase of 0.005% in the HDDS. Similarly, the increase in the amount of transfers of 75,000 XOF also increases the HDDS by 0.187% despite the effects of climate change. The combined effects of rising farm income and transfers raise the HDDS by 0.193% despite the effects of climate change.

In terms of public policies, a salary increase of 75,000 XOF also allows to correct the effects of climate change with an increase of 0.04% on the HDDS. On the other hand, social assistance alone contributes to further widening the HDDS deficit.

However, the increase in wages combined with the social grants allow a mitigation of the effects of climate change and increase the HDDS by 0.032%.

Table 13: Simulation of the effect of the variation of temprature and precipitation on the HDDS

		Coefficients	**Std. err.**	**[95% conf.**	**interval]**
Differences	ICC	5,100	0.058	0.005	0.359
Climate changes effets	Rain	-0.111	0.111	-0.328	0.105
	Minimal temp	-0.263	0.131	-0.520	-0.005
	Max temperature	-0.002	0.095	-0.189	0.184
	Grouped	-0.376	0.094	-0.560	-0.191
HH income increase	Agricole income	0.005	0.004	-0.002	0.013
	Transfert	0.187	0.087	0.016	0.359
	Grouped	0.193	0.086	0.024	0.361
Government Politics	Salary	0.040	0.014	0.013	0.066
	Donations	-0.008	0.013	-0.035	0.018
	Grouped	0.032	0.019	-0.006	0.069

Source : Author's Calculation, 2022

III. Prevention of the effect of the variation of temprature and precipitation on the CSI

In this section, the estimates focus on the simulation of the effects of climate change on the CSI and the prevention channels for these effects. The results show that the difference in household CSI level is due to 15.1% differences in rainfall and minimum and maximum temperature among departments.

A 12.73% decrease in the 20-year average rainfall volume results in a 0.308% increase in CSI. The 20-year average increase in the minimum temperature of 0.737°C increases the CSI by 2.676% and the 20-year average increase in the maximum temperature of 0.938°C increases the CSI by 0.209%. These combined effects show a decrease in the CSI of 3.193%.

These combined effects of climate change accompanied by an increase in agricultural income of 8330 XOF led to a decrease of 0.041% in the CSI. Similarly, the increase in the amount of transfers of 75,000 XOF also reduces the CSI by 1,502% despite the effects of climate change. The combined effects of rising farm income and transfers raise the CSI by 1,543% despite the effects of climate change.

In terms of public policies, a salary increase of 75,000 XOF also allows to correct the effects of climate change with a reduction of 0.135% on the CSI. On the other hand, social assistance alone contributes to further widening the deficit by increasing the CSI.

However, the increase in wages combined with the social grants allow a mitigation of the effects of climate change and increase the CSI by 0.106%.

Table 14: Simulation of the effect of the variation of temprature and precipitationon the CIS

		ICC	Std. err.	[95% conf.	interval]
Differences	ICC	15,1	0.029	0.103	0.216
Climate changes effets	Rain	0.308	0.075	0.160	0.455
	Minimal temp	2,676	0.288	2,112	3,240
	Max temperature	0.209	0.137	-0.060	0.479
	Grouped	3,193	0.235	2,732	3,654
HH income increase	Agricole income	-0.041	0.022	-0.084	0.002
	Transfert	-1,502	0.497	-2,476	-0.528
	Grouped	-1,543	0.497	-2,518	-0.568
Government Politics	Salary	-0.135	0.074	-0.280	0.009
	Donations	0.030	0.080	-0.128	0.187
	Grouped	-0.106	0.078	-0.257	0.046

Source: Author's Calculation, 2022

IV. Prevention of the effect of the variation of temprature and precipitation on the HFIAS

In this section, the estimates focus on the simulation of the effects of climate change on the HFIAS and the prevention channels for these effects. The results show that the difference in household HFIAS level is due to 12.6% differences in rainfall and minimum and maximum temperature among departments.

A 12.73% increase in the 20-year average rainfall volume results in a 0.297% increase in the HFIAS. The 20-year average increase in the minimum temperature of 0.737°C increases the HFIAS by 0.866% and the 20-year average increase in the maximum temperature of 0.938°C increases the HFIAS by 0.072%. These combined effects show a fall in the HFIAS of 1.235%.

These combined effects of climate change accompanied by an increase in agricultural income of 8,330 XOF led to a decrease of 0.026% in the HFIAS. Similarly, the increase in the amount of transfers by XOF 75,000 also reduces the HFIAS by 0.779% despite the effects of climate change. The combined effects of rising farm income and transfers raise the HFIAS by 0.805% despite the effects of climate change.

In terms of public policies, a salary increase of 75,000 XOF also allows to correct the effects of climate change with a reduction of 0.043% on the HFIAS. On the other hand, social assistance alone contributes to further widening the deficit by increasing the HFIAS.

However, the increase in wages combined with the social exchanges allow a mitigation of the effects of climate change and increase the HFIAS by 0.026%.

Table 15: Simulation of the effect of the variation of temprature and precipitation on the HFIAS

		ICC	Std. err.	[95% conf.	interval]
Differences	ICC	12,6	0.018	0.095	0.165
Climate changes effets	Rain	0.297	0.047	0.205	0.389
	Minimal temp	0.866	0.131	0.610	1,122
	Max temperature	0.072	0.038	-0.002	0.147
	Grouped	1,235	0.132	0.977	1,494
HH income increase	Agricole income	-0.026	0.014	-0.053	0.001
	Transfert	-0.779	0.243	-1,256	-0.303
	Grouped	-0.805	0.243	-1,281	-0.329

	Salary	-0.043	0.032	-0.106	0.020
Government Politics	Donations	0.069	0.078	-0.085	0.223
	Grouped	0.026	0.065	-0.102	0.153

Source: Author's Calculation, 2022

V. Prevention of the effect of the variation of temprature and precipitation on the HHS

In this section, the estimates focus on the simulation of the effects of climate change on HHS and the prevention channels for these effects. The results show that the difference in HHS level of households is due to 15.8% differences in rainfall and minimum and maximum temperature among departments.

A 12.73% decrease in the 20-year average rainfall volume results in a 0.027% increase in HHS. The 20-year average increase in the minimum temperature of 0.737°C increases the HHS by 0.058% and the 20-year average increase in the maximum temperature of 0.938°C increases the HHS by 0.019%. These combined effects show a decrease in HHS of 0.104%.

These combined effects of climate change accompanied by an increase in agricultural income of 8,330 XOF offset the effects of climate change on the HHS. Similarly, the increase in the amount of transfers of 75,000 XOF also reduces the HHS by 0.146% despite the effects of climate change. The combined effects of rising farm income and transfers reduce the HHS by 0.147% despite the effects of climate change.

In terms of public policies, an increase in wages of 75,000 XOF also allows to correct the effects of climate change with a reduction of 0.005% on the HHS. On the other hand, social assistance alone contributes to further widening the deficit by increasing the HHS.

The increase in wages combined with social grants does not allow a mitigation of the effects of climate change due to the opposite effect of social assistance on the HHS.

Table 16: Simulations of the effect of the variation of temprature and precipitation on the HHS

		ICC	Std. err.	[95% conf.	interval]
Differences	ICC	15,8	0.030	0.109	0.225
Climate changes effets	Rain	0.027	0.007	0.013	0.041
	Minimal temp	0.058	0.018	0.023	0.093
	Max temperature	0.019	0.012	-0.005	0.043
	Grouped	0.104	0.034	0.036	0.172
HH income increase	Agricole income	0.000	0.003	-0.007	0.006
	Transfert	-0.146	0.047	-0.239	-0.054
	Grouped	-0.147	0.047	-0.239	-0.054
Government Politics	Salary	-0.005	0.004	-0.013	0.003
	Donations	0.010	0.016	-0.021	0.041
	Grouped	0.005	0.016	-0.026	0.035

Source: Author's Calculation

VI. Prevention of the effect of the variation of temprature and precipitation on the synthetic indexe

The synthetic indicator is an overall measure of food insecurity. Thus, in this section, the simulations carried out are analysed as re-uses of the estimates made above.

The results show that the difference in the level of food insecurity of households is due to 16.2% differences in rainfall and minimum and maximum temperature among departments.

A 12.73% decrease in the 20-year average rainfall volume leads to an increase in food insecurity by 0.597%. The increase in the 20-year average of the minimum temperature of 0.737°C increases the level of food insecurity by 29.528% and the increase in the 20-year average of the maximum temperature of 0.938°C increases the level of food insecurity by 1.785%. These combined effects include an increase in the level of food insecurity by 31,909%.

These combined effects of climate change accompanied by an increase in agricultural income of 8,330 XOF offset the effects of climate change and lead to a decrease in food insecurity of 0.509%. Similarly, the increase in the amount of transfers of 75,000 XOF also reduces food insecurity by 18,177% despite the effects of climate change. The combined effects of rising

farm income and transfers reduce the level of food insecurity by 18,683% despite the effects of climate change.

In terms of public policies, an increase in wages of 75,000 XOF also allows to correct the effects of climate change with a reduction of 1.86% on the level of food insecurity. On the other hand, social assistance alone contributes to further widening the deficit by increasing food insecurity.

The increase in wages combined with social grants allows a mitigation of the effects of climate change with a reduction of food insecurity of 1.468%.

Table 17: Simulation on the synthetic Indexe

	Level	Coefficients	Std. err.	[95% conf.	interval]
Differences	ICC	16,2	0.033	0.107	0.237
Climate changes effets	Rain	0.597	2,187	-3,689	4,883
	Minimal temp	29,528	7,276	15,266	43,789
	Max temperature	1,785	2,806	-3,714	7,284
	Grouped	31,909	7,726	16,766	47,052
HH income increase	Agricole income	-0.506	0.210	-0.917	-0.095
	Transfert	-18,177	4,167	-26,345	-10.010
	Grouped	-18,683	4,174	-26,864	-10.503
Government Politics	Salary	-1,860	0.945	-3,713	-0.007
	Donations	0.393	1,339	-2,232	3,017
	Grouped	-1,468	1,666	-4,732	1,797

Source: Author's Calculation, 2022

To promote household resilience to the effects of climate change and reduce the level of food insecurity, it is necessary to limit social grants in favour of a good agricultural policy allowing to increase the agricultural income and to revise the labour laws by increasing the minimum wage both in the public and private sectors. It is also important to regulate the availability of money transfers by migrants, by reducing transfer costs, in order to have an appreciable increase in the amounts received by households, since this source of income has a greater impact than agricultural wages and incomes on all the indicators studied.

General Conclusion

The issue of food insecurity is a priority in all countries, especially those in the developing countries. Food insecurity is a function of availability, access, use and stability that is determined by combining these three dimensions. It is important to distinguish between insecure and vulnerable households. To do this, a combinatorial analysis is performed to summarize information on household characteristics using multiple correspondence analysis (MCA). The summarized information was attached to the hierarchical classification model to obtain a household typology. Thus, three types of households have been distinguished: poor, middle and rich.

The characteristics of households differ according to the typology. For the group of poor households, income is mainly from trade. Households in the middle group derive their income from agriculture whereas the income of households in the rich group is mainly derived from wages.

However, for food security indicators such as the Food Consumption Score (FCS) and the Household Food Diversity Score (HDDS), the wealthy household group have higher scores, followed by the group of average households and then of poor households, with the lowest scores. These two indicators illustrate a good food situation for the rich group compared to that of the middle and poor groups with the most insecure food situation. The situation is the same for food insecurity indicators such as the consumption score index (CSI), the household food access index scale (HFIAS) and the household hunger score (HHS) for which the rich group has a lower score behind the middle group, the poor group having the highest score. Thus, all the indicators used show the same results on the food situation of household groups: the group of the rich are more food secure while the poor are more food insecure.

In addition, a mapping of the food situation by department showed that the capital (Dakar) and its immediate surroundings (Thiès and Louga, Diourbel) have better food security compared to remote areas (Tambacounda and Kédougou).

Also, the synthetic index of food insecurity formed from the five indicators used here, shows that migrant transfer and trade are more consistent in significantly reducing the level of household food insecurity while the minimum temperature significantly increases food insecurity. Food insecurity is higher in rural areas than in urban areas.

The results of the simulation of the effects of climate change (changes in climate and minimum and maximum temperatures) have disproportionate consequences depending on the index studied. Indeed, the FCS decreases by an average of 4.8 points due to the effect of climate

change on rainfall and on minimum and maximum temperatures. Despite these climate effects, a simultaneous increase in agricultural income and transfers increases FCS and thus reduces the level of food insecurity. Similarly, a combined increase in salaries and donations increases the FCS by 0.13 points.

For the household food diversity score (HDDS), the effects of climate change led to a reduction of 0.38%. A simultaneous increase in agricultural income and transfers increases HDDS by 0.19%, despite the effects of climate change and thus reduces the level of food insecurity. Similarly, a combined increase in salaries and donations increases the HDDS by 0.03%.

For the CSI, climate change leads to a 3.19% increase in the score and the combined increase in agricultural income and transfers helps dissipate the effects of climate change and reduces the CSI by 1.54%, which improves the food situation of households. The simultaneous increase in salaries and donations also reduces the CSI by 0.1%

Thus, farm income and transfers are better suited to prevent the effects of climate change on food insecurity.

Recommandations

Simulations of the effects of climate change show a fragility of household food security. Adjustment measures for agricultural income and transfers and government actions (wages and grants (social assistance)) are thus adaptation measures to prevent severe food insecurity as the effects of climate change manifest themselves over time. Thus, in the light of the results on the modelling of indicators of food insecurity and the simulations carried out, the following recommendations are made:

- ✓ Protect the trade activities of households by rehabilitating or creating commercial trading spaces nearby their settlements;
- ✓ Facilitate and encourage the creation of agricultural spaces in a broad sense in rural areas to boost agricultural production;
- ✓ Promote territorial equity for a socio-economic balance of localities;
- ✓ Organize transfers of migrants and support beneficiary households for more efficiency in spending by directing the transfers received towards more profitable and structural investments;
- ✓ To support the agricultural sector as a whole by means of almost complete mechanization of crops, health and nutritional protection of livestock, diversification of fisheries (aquaculture);
- ✓ To protect workers' wages both in the public and private sectors and to introduce periodic pay increases according to seniority;
- ✓ To limit social aid and replace it with agricultural investment (farming, stock farming, fishing, forestry etc.).

Future works to study

The results obtained in this study had a number of constraints that would have made the results more robust and general. The main limitation is the nature of the data. The ideal situation would have been to have panel data on a sample of households in each department as well as data on temperature and rainfall over a period of at least 20 years. There are also food losses (post-harvest, losses in arboriculture, loss of livestock, etc.) that the study could not measure in order to consider the full potential of local production for achieving the objective of self-sufficiency and food security. Also, given the importance of trade in the results, the study could have measured the effectiveness of weekly markets in the development of household trade activities.Thus, the most relevant research perspectives that are part of improving this research

project are:the impact of current agricultural projects on food security indicators and nutrition;analysis of the evolution of the gap between production (taking into account exports) and imports for a monitoring of food self-sufficiency which is also an indicator of food security; the collection of adaptation techniques to climate change implemented by producers spontaneously; the measurement of food losses related to agricultural production, livestock and fishing, in order to upgrade production by proposing adequate measures; the effectiveness of domestic spending in households receiving migrant transfers in order to propose a more efficient use of this source of household income in the fight against food insecurity; the role of weekly markets in the development of household trade activities.

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Annex

I. Hausman Test of model specification

Under the null hypothesis, the model's specification take acoount the random effets:

$$\boldsymbol{y = c + X\beta + Zu + \epsilon}$$

With $\boldsymbol{E(y|X,u) = g^{-1}(X\beta + Zu)}$

If the random effets is rejected, the specification become:

$$\boldsymbol{y = c + X\beta + \epsilon}$$

With $\boldsymbol{E(y|X,u) = E(y|X) = g^{-1}(X\beta)}$

, the null hypothesis is that the individual-level effects are adequately modeled by a random-effects model:

H0:

Table 18:Test de Spécification de Hausman pour le FCS

	Coefficients (b) fixed_fcs	(B) rand_fcs	(b-B) Difference	sqrt(diag(V_b-V_B)) Std. err.
agri_sl	.274508	.2915805	-.0170725	.0044418
salary_sl	.2677607	.2701054	-.0023447	.0028829
transfert_sl	.2897468	.2928056	-.0030588	.0023393
gift_sl	-.1086671	-.1109386	.0022715	.0032279
trade_sl	.3598437	.3616951	-.0018513	.0031223
hhsize_sl	.0685622	.0678379	.0007243	.0029048
area_sl	.0663049	.0695842	-.0032794	.0049951
2.q116c	-.2204861	-.2174673	-.0030187	.0277341
2.milieu	6.54918	6.418836	.1303441	.1168279
srev				
2	3.820261	3.960793	-.140532	.0985351
3	6.48722	6.643187	-.1559668	.1007858
4	1.282443	1.300508	-.0180651	.1045588
5	10.16243	10.24942	-.086993	.1003343
6	.7778472	.8930819	-.1152347	.0913074
groupe				
2	-2.915507	-2.955485	.0399779	.0435107
3	-4.523778	-4.75097	.2271916	.0713083

b = Consistent under H0 and Ha; obtained from **xtreg**.
B = Inconsistent under Ha, efficient under H0; obtained from **xtreg**.

Test of H0: Difference in coefficients not systematic

chi2(16) = (b-B)'[(V_b-V_B)^(-1)](b-B)
= 116.23
Prob > chi2 = 0.0000
(V_b-V_B is not positive definite)

Table 19:Test de spécification de Hausman pour le HDDS

	Coefficients (b) fixed_hdds	(B) rand_hdds	(b-B) Difference	sqrt(diag(V_b-V_B)) Std. err.
agri_sl	.1482196	.1633941	-.0151745	.005179
salary_sl	.2885166	.2926572	-.0041406	.0035652
transfert_sl	.1760052	.180615	-.0046099	.0028401
gift_sl	-.0495677	-.0476974	-.0018703	.0039639
trade_sl	.2660546	.2762856	-.010231	.0037838
hhsize_sl	.0591894	.0585712	.0006182	.0033333
2.q116c	.4331267	.4732845	-.0401579	.0327952
2.milieu	5.716553	5.428978	.2875747	.1361633
srev				
2	4.300346	4.60116	-.3008138	.1136956
3	5.622421	5.922891	-.3004708	.1174991
4	3.995372	4.043134	-.0477617	.1221882
5	6.920803	7.152198	-.2313946	.1169005
6	.6926529	1.051912	-.3592587	.106131
groupe				
2	-2.498057	-2.558051	.059994	.0527149
3	-3.366449	-3.570877	.2044283	.0837841

b = Consistent under H0 and Ha; obtained from **xtreg**.
B = Inconsistent under Ha, efficient under H0; obtained from **xtreg**.

Test of H0: Difference in coefficients not systematic

chi2(15) = (b-B)'[(V_b-V_B)^(-1)](b-B)
= 21.91
Prob > chi2 = 0.1101
(V_b-V_B is not positive definite)

Table 20:Test de spécification de Hausman pour le CSI

	Coefficients (b) fixed_csi	(B) rand_csi	(b-B) Difference	sqrt(diag(V_b-V_B)) Std. err.
agri_sl	-.2346122	-.2475883	.0129761	.0058081
salary_sl	-.1938894	-.2010291	.0071397	.0043413
transfert_sl	-.2645886	-.2664225	.0018339	.0031188
gift_sl	.0142541	.011075	.0031791	.0047429
trade_sl	-.4298736	-.4359173	.0060437	.0043768
hhsize_sl	-.0506299	-.0515669	.000937	.0033657
2.q116c	.7989103	.8641496	-.0652393	.0403294
2.milieu	-3.680633	-3.643541	-.0370927	.1340981
srev				
2	.2529628	.062218	.1907448	.1153105
3	-7.20212	-7.414921	.2128007	.1208929
4	-2.017535	-2.194552	.1770175	.1281042
5	-5.728786	-6.027125	.2983387	.130066
6	1.202568	.9736578	.2289106	.1091003
groupe				
2	1.723133	1.739897	-.0167639	.0663519
3	1.986418	2.069347	-.0829296	.0931652

b = Consistent under H0 and Ha; obtained from **xtreg**.
B = Inconsistent under Ha, efficient under H0; obtained from **xtreg**.

Test of H0: Difference in coefficients not systematic

chi2(15) = (b-B)'[(V_b-V_B)^(-1)](b-B)
= 0.80
Prob > chi2 = 1.0000
(V_b-V_B is not positive definite)

Table 21:Test de spécification de Hausman pour le HFIAS

	Coefficients			
	(b) fixed_hfias	(B) rand_hfias	(b-B) Difference	sqrt(diag(V_b-V_B)) Std. err.
agri_sl	-.312186	-.3300201	.017834	.
salary_sl	-.1259496	-.1399832	.0140335	.
transfert_sl	-.3099088	-.3208042	.0108954	.
gift_sl	.1410086	.1383844	.0026242	.
trade_sl	-.5829927	-.600938	.0179453	.
hhsize_sl	-.2514605	-.2501744	-.0012861	.0026233
2.q116c	.0567154	.0838569	-.0271415	.
2.milieu	-5.551999	-5.331312	-.2206868	.1546891
srev				
2	-2.387091	-3.075607	.6885157	.0973016
3	-9.009424	-9.818756	.8093317	.
4	-2.615935	-3.010341	.3944059	.
5	-8.46561	-9.296762	.8311515	.
6	-.5435339	-1.272406	.7288726	.0447965
groupe				
2	5.521251	5.492639	.0286116	.
3	6.36895	6.47802	-.1090704	.

b = Consistent under H0 and Ha; obtained from **xtreg**.
B = Inconsistent under Ha, efficient under H0; obtained from **xtreg**.

Test of H0: Difference in coefficients not systematic

chi2(15) = (b-B)'[(V_b-V_B)^(-1)](b-B)
= -29.07

Warning: chi2 < 0 ==> model fitted on these data
fails to meet the asymptotic assumptions
of the Hausman test; see **suest** for a
generalized test.

Table 22:Test de spécification de Hausman pour le HHS

	Coefficients (b) fixed_hhs	(B) rand_hhs	(b-B) Difference	sqrt(diag(V_b-V_B)) Std. err.
agri_sl	-.0001835	-.0009755	.000792	.0001021
salary_sl	-.0027392	-.0030865	.0003472	.
transfert_sl	-.0154803	-.0157729	.0002926	.
gift_sl	.0069868	.0070761	-.0000894	.
2.q116c	.0006798	.0033853	-.0027055	.
2.milieu	-.1017275	-.0864498	-.0152777	.0086512
srev				
2	-.0961977	-.1241403	.0279426	.0072449
3	-.2637611	-.2914519	.0276908	.0063446
4	-.0114959	-.0266949	.015199	.0056465
5	-.1352765	-.1613266	.0260501	.0023781
6	.1093904	.0844861	.0249042	.00588
groupe				
2	.2395591	.2374918	.0020673	.
3	.2046378	.209767	-.0051292	.0023038

b = Consistent under H0 and Ha; obtained from xtreg.
B = Inconsistent under Ha, efficient under H0; obtained from xtreg.

Test of H0: Difference in coefficients not systematic

chi2(13) = (b-B)'[(V_b-V_B)^(-1)](b-B)
= 1388.42
Prob > chi2 = 0.0000
(V_b-V_B is not positive definite)

Table 23:Test de spécification de Hausman pour le Score synthétique

	Coefficients (b) fixed_synt	(B) rand_synt	(b-B) Difference	sqrt(diag(V_b-V_B)) Std. err.
agri_sl	-.2730962	-.2932542	.020158	.
salary_sl	-.241404	-.2481047	.0067007	.
transfert_sl	-.2991178	-.3036508	.0045331	.
gift_sl	.0914053	.0913983	6.99e-06	.
trade_sl	-.4308511	-.4374146	.0065635	.
hhsize_sl	-.0973457	-.0968871	-.0004586	.0017636
area_sl	-.0072284	-.013277	.0060486	.
2.q116c	.3274855	.3550365	-.027551	.
2.milieu	-5.887028	-5.738951	-.1480768	.0958034
srev				
2	-2.670019	-2.947681	.2776618	.0629076
3	-7.409305	-7.722365	.31306	.0224808
4	-1.895451	-2.033396	.1379452	.
5	-8.991176	-9.293159	.3019828	.
6	-.1530897	-.4355781	.2824884	.0343997
groupe				
2	3.177516	3.211304	-.0337884	.
3	4.309565	4.526001	-.2164364	.

b = Consistent under H0 and Ha; obtained from **xtreg**.
B = Inconsistent under Ha, efficient under H0; obtained from **xtreg**.

Test of H0: Difference in coefficients not systematic

chi2(16) = (b-B)'[(V_b-V_B)^(-1)](b-B)
= 655.91
Prob > chi2 = 0.0000
(V_b-V_B is not positive definite)

II. Annex A : Food Consumption Score

$$FCS = agri + salary + transfert + gift + trade + hhsize + area + i.gender + i.milieu + i.srev + i.groupe + rain + tmin + tmax$$

Table 24:Modélisation of FCS

Mixed-effects GLM — Number of obs = 2,397
Family: Gaussian
Link: Identity
Group variable: dep — Number of groups = 45

Obs per group:
min = 8
avg = 53.3
max = 110

Integration method: ghermite — Integration pts. = 7

Wald chi2(19) = 1309.15
Log pseudolikelihood = -10286.279 — Prob > chi2 = 0.0000
(Std. err. adjusted for 45 clusters in dep)

FCS	Coefficient	Robust std. err.	z	P>|z|	[95% conf.	interval]
agri	.0000114	4.40e-06	2.60	0.009	2.82e-06	.0000201
salary	4.80e-06	1.88e-06	2.56	0.010	1.13e-06	8.48e-06
transfert	.00004	6.49e-06	6.16	0.000	.0000273	.0000528
gift	-.0000272	.0000162	-1.68	0.093	-.0000589	4.55e-06
trade	.0000177	9.43e-06	1.87	0.061	-8.27e-07	.0000361
hhsize	.1161315	.088919	1.31	0.192	-.0581465	.2904096
area	.0145263	.0155264	0.94	0.349	-.0159049	.0449574
q116c						
Woman	-.1870378	1.075183	-0.17	0.862	-2.294357	1.920281
milieu						
urbain	7.319317	1.572866	4.65	0.000	4.236557	10.40208
srev						
Trade	4.609806	2.236915	2.06	0.039	.2255334	8.994079
Salary	7.471415	1.667614	4.48	0.000	4.202953	10.73988
Transferts	1.712434	1.882476	0.91	0.363	-1.97715	5.402019
Transport	11.49912	2.241681	5.13	0.000	7.10551	15.89274
Others	1.135799	2.269128	0.50	0.617	-3.31161	5.583209
groupe						
2	-3.475743	1.2163	-2.86	0.004	-5.859646	-1.091839
3	-5.443179	1.573585	-3.46	0.001	-8.52735	-2.359009
rain	-.2361092	.0188458	-12.53	0.000	-.2730464	-.199172
tmin	-3.829617	.3552113	-10.78	0.000	-4.525819	-3.133416
tmax	-.2956654	.1393077	-2.12	0.034	-.5687035	-.0226273
_cons	179.3572	9.322969	19.24	0.000	161.0845	197.6299
dep						
var(_cons)	51.76608	6.959094			39.77547	67.37135
var(e.FCS)	300.7003	18.0238			267.3705	338.1851

Source: **Author's calculation**

III. Annex B : Household Dietary Diversity Score

The household dietary diversity score is modelled here with the specification presented above:

$$HDDS = agri + salary + transfert + gift + trade + hhsize + i.gender + i.milieu + i.srev + i.groupe + rain + tmin + tmax$$

Table 25:Modélisation of HDDS

Mixed-effects GLM — Number of obs = 2,397
Family: Gaussian
Link: Identity
Group variable: dep — Number of groups = 45

Obs per group:
min = 8
avg = 53.3
max = 110

Integration method: ghermite — Integration pts. = 7

Wald chi2(18) = 552.10
Log pseudolikelihood = -4334.2687 — Prob > chi2 = 0.0000
(Std. err. adjusted for 45 clusters in dep)

HDDS	Coefficient	Robust std. err.	z	P>|z|	[95% conf.	interval]
agri	6.06e-07	4.61e-07	1.31	0.189	-2.98e-07	1.51e-06
salary	5.32e-07	1.81e-07	2.94	0.003	1.77e-07	8.87e-07
transfert	2.50e-06	1.16e-06	2.15	0.032	2.18e-07	4.78e-06
gift	-1.01e-06	1.61e-06	-0.63	0.532	-4.16e-06	2.15e-06
trade	1.33e-06	7.01e-07	1.89	0.059	-4.90e-08	2.70e-06
hhsize	.0102138	.0054862	1.86	0.063	-.0005391	.0209666
q116c						
Woman	.0527435	.0954266	0.55	0.580	-.1342893	.2397762
milieu						
urbain	.5836093	.1108973	5.26	0.000	.3662547	.800964
srev						
Trade	.514901	.1494892	3.44	0.001	.2219074	.8078945
Salary	.6551446	.1504989	4.35	0.000	.3601721	.9501171
Transferts	.4444704	.298959	1.49	0.137	-.1414785	1.030419
Transport	.7854228	.2302158	3.41	0.001	.3342082	1.236637
Others	.1245142	.1817795	0.68	0.493	-.2317672	.4807955
groupe						
2	-.2876488	.1586556	-1.81	0.070	-.5986081	.0233105
3	-.3995623	.1465571	-2.73	0.006	-.686809	-.1123156
rain	-.0152412	.01516	-1.01	0.315	-.0449543	.0144718
tmin	-.356426	.1781827	-2.00	0.045	-.7056578	-.0071942
tmax	.0022453	.1014302	0.02	0.982	-.1965543	.2010449
_cons	15.35536	5.987847	2.56	0.010	3.6194	27.09133
dep						
var(_cons)	.1149871	.1391841			.0107233	1.233021
var(e.HDDS)	2.12392	.1256113			1.891459	2.38495

Source: Author's Calculation

IV. Annex C : Reduced Consumption Score Index

$$CSI = agri + salary + transfert + gift + trade + hhsize + i.gender + i.milieu + i.srev + i.groupe + rain + tmin + tmax$$

Table 26:Modélisation of CSI

```
Mixed-effects GLM                               Number of obs     =      2,397
Family: Gaussian
Link:   Identity
Group variable: dep                             Number of groups  =         45

                                                Obs per group:
                                                              min =          8
                                                              avg =       53.3
                                                              max =        110

Integration method: ghermite                    Integration pts.  =          7

                                                Wald chi2(18)     =    1034.16
Log pseudolikelihood = -9130.9991               Prob > chi2       =     0.0000
                                (Std. err. adjusted for 45 clusters in dep)
```

CSI	Coefficient	Robust std. err.	z	P>|z|	[95% conf.	interval]
agri	-4.90e-06	2.65e-06	-1.85	0.064	-.0000101	2.94e-07
salary	-1.81e-06	9.85e-07	-1.83	0.067	-3.73e-06	1.25e-07
transfert	-.00002	6.62e-06	-3.02	0.002	-.000033	-7.05e-06
gift	3.59e-06	9.65e-06	0.37	0.710	-.0000153	.0000225
trade	-.000011	3.68e-06	-3.00	0.003	-.0000183	-3.84e-06
hhsize	-.0463142	.0501353	-0.92	0.356	-.1445775	.0519492
q116c						
Woman	.5908934	.5852274	1.01	0.313	-.5561313	1.737918
milieu						
urbain	-1.857755	1.030683	-1.80	0.071	-3.877857	.1623462
srev						
Trade	-.070584	1.495572	-0.05	0.962	-3.001852	2.860684
Salary	-4.431537	1.477618	-3.00	0.003	-7.327615	-1.535459
Transferts	-.8861224	1.903832	-0.47	0.642	-4.617565	2.845321
Transport	-3.69435	1.094255	-3.38	0.001	-5.839051	-1.549649
Others	.3677717	1.319323	0.28	0.780	-2.218055	2.953598
groupe						
2	.8332261	.7107755	1.17	0.241	-.5598683	2.22632
3	1.343806	1.066412	1.26	0.208	-.7463223	3.433935
rain	-.0421996	.0103026	-4.10	0.000	-.0623924	-.0220068
tmin	3.630835	.3904853	9.30	0.000	2.865498	4.396172
tmax	.2231471	.1464356	1.52	0.128	-.0638614	.5101557
_cons	-73.32299	7.696631	-9.53	0.000	-88.40811	-58.23787
dep						
var(_cons)	20.29057	3.358157			14.66957	28.06538
var(e.CSI)	114.3676	16.22818			86.60075	151.0373

Source: Author's Calculation

V. Annex D: Household Food Insecurity Access Scale

The HFIAS expresses the occurrence and frequency of events marking a difficulty in accessing food. To estimate it, the following model is used:

$$HFIAS = agri + salary + transfert + gift + trade + hhsize + i.gender + i.milieu + i.srev + i.groupe + rain + tmin + tmax$$

Table 27: Modélisation du HFIAS

```
Mixed-effects GLM                               Number of obs     =      2,397
Family: Gaussian
Link:   Identity
Group variable: dep                             Number of groups  =         45

                                                Obs per group:
                                                              min =          8
                                                              avg =       53.3
                                                              max =        110

Integration method: ghermite                    Integration pts.  =          7

                                                Wald chi2(18)     =     711.76
Log pseudolikelihood = -7455.7191               Prob > chi2       =     0.0000
                                (Std. err. adjusted for 45 clusters in dep)
```

HFIAS	Coefficient	Robust std. err.	z	P>|z|	[95% conf.	interval]
agri	-3.12e-06	1.63e-06	-1.91	0.056	-6.31e-06	8.30e-08
salary	-5.74e-07	4.28e-07	-1.34	0.181	-1.41e-06	2.66e-07
transfert	-.0000104	3.24e-06	-3.20	0.001	-.0000167	-4.04e-06
gift	8.26e-06	9.42e-06	0.88	0.381	-.0000102	.0000267
trade	-6.88e-06	2.15e-06	-3.19	0.001	-.0000111	-2.66e-06
hhsize	-.1082634	.0262746	-4.12	0.000	-.1597607	-.0567662
q116c						
Woman	.0202726	.3209447	0.06	0.950	-.6087674	.6493126
milieu						
urbain	-1.619318	.3828109	-4.23	0.000	-2.369613	-.8690224
srev						
Trade	-.7256641	.4355083	-1.67	0.096	-1.579245	.1279165
Salary	-2.52926	.4821888	-5.25	0.000	-3.474332	-1.584187
Transferts	-.8211755	.6531617	-1.26	0.209	-2.101349	.4589979
Transport	-2.362029	.5756973	-4.10	0.000	-3.490375	-1.233683
Others	-.2478826	.4858664	-0.51	0.610	-1.200163	.7043981
groupe						
2	1.471807	.3517999	4.18	0.000	.7822913	2.161322
3	1.835587	.364529	5.04	0.000	1.121123	2.55005
rain	.040728	.0064271	6.34	0.000	.0281311	.0533249
tmin	1.17524	.177095	6.64	0.000	.8281399	1.522339
tmax	.0771286	.040701	1.90	0.058	-.0026438	.1569011
_cons	-22.55691	3.878418	-5.82	0.000	-30.15847	-14.95535
dep						
var(_cons)	4.061391	.5824217			3.066258	5.379488
var(e.HFIAS)	28.27562	2.67572			23.48892	34.03778

Source: Author's Calculation

VI. Annex E : Household Hunger Scale

The model used to estimate the HHS indexe is explained as follow:

$$HHS = agri + salary + transfert + gift + trade + hhsize + i.gender + i.milieu + i.srev + i.groupe + rain + tmin + tmax$$

Table 28:Modeling the HHS

```
Mixed-effects GLM                               Number of obs     =      2,397
Family: Gaussian
Link:   Identity
Group variable: dep                             Number of groups  =         45

                                                Obs per group:
                                                              min =          8
                                                              avg =       53.3
                                                              max =        110

Integration method: ghermite                    Integration pts.  =          7

                                                Wald chi2(16)     =     458.64
Log pseudolikelihood = -3988.0204               Prob > chi2       =     0.0000
 ( 1)  [HHS]_cons = 0
                                (Std. err. adjusted for 45 clusters in dep)
```

HHS	Coefficient	Robust std. err.	z	P>|z|	[95% conf.	interval]
agri	-4.03e-08	3.90e-07	-0.10	0.918	-8.05e-07	7.25e-07
salary	-6.99e-08	5.52e-08	-1.27	0.205	-1.78e-07	3.83e-08
transfert	-1.95e-06	6.29e-07	-3.10	0.002	-3.18e-06	-7.18e-07
gift	1.20e-06	1.87e-06	0.64	0.520	-2.47e-06	4.88e-06
q116c						
Woman	.0056594	.0700889	0.08	0.936	-.1317124	.1430312
milieu						
urbain	-.0890778	.0854363	-1.04	0.297	-.2565298	.0783742
srev						
Trade	-.1175755	.1132836	-1.04	0.299	-.3396072	.1044562
Salary	-.2851627	.1225396	-2.33	0.020	-.525336	-.0449895
Transferts	-.0365543	.1825991	-0.20	0.841	-.394442	.3213334
Transport	-.1352841	.1446742	-0.94	0.350	-.4188404	.1482722
Others	.0941368	.1259133	0.75	0.455	-.1526487	.3409224
groupe						
2	.2330356	.0700414	3.33	0.001	.095757	.3703142
3	.2070568	.0906542	2.28	0.022	.0293777	.3847358
rain	-.0037063	.0010049	-3.69	0.000	-.0056759	-.0017367
tmin	.0791134	.0241286	3.28	0.001	.0318223	.1264045
tmax	-.0198728	.0130926	-1.52	0.129	-.0455339	.0057883
_cons	0	(omitted)				
dep						
var(_cons)	.293827	.0535516			.205568	.4199792
var(e.HHS)	1.561986	.1986554			1.217363	2.004168

Source: Author's Calculation

VII. Annex F: Synthetic Indexe of Food Insecurity

The synthetic indexe is specified with the following model:

$$SYN = agri + salary + transfert + gift + trade + hhsize + area + i.gender + i.milieu + i.srev + i.groupe + rain + tmin + tmax$$

Table 29: Modeling the Synthetic Indexe of Food Insecurity

```
Mixed-effects GLM                               Number of obs     =      2,397
Family: Gaussian
Link:   Identity
Group variable: dep                             Number of groups  =         45

                                                Obs per group:
                                                              min =          8
                                                              avg =       53.3
                                                              max =        110

Integration method: mvaghermite                 Integration pts.  =          7

                                                Wald chi2(19)     =     229.93
Log likelihood = -14820.931                     Prob > chi2       =     0.0000
```

synt_ind2	Coefficient	Std. err.	z	P>|z|	[95% conf.	interval]
agri	-.0000607	.0000252	-2.41	0.016	-.00011	-.0000114
salary	-.0000248	.0000126	-1.97	0.049	-.0000495	-9.76e-08
transfert	-.0002424	.0000556	-4.36	0.000	-.0003513	-.0001335
gift	.0000471	.0001607	0.29	0.769	-.0002679	.0003622
trade	-.0001329	.00003	-4.44	0.000	-.0001917	-.0000742
hhsize	-.7104993	.4021689	-1.77	0.077	-1.498736	.0777372
area	.0319183	.1865145	0.17	0.864	-.3336433	.39748
q116c						
Woman	5.084731	6.699234	0.76	0.448	-8.045526	18.21499
milieu						
urbain	-29.68597	7.157157	-4.15	0.000	-43.71374	-15.6582
srev						
Trade	-5.353001	8.40224	-0.64	0.524	-21.82109	11.11509
Salary	-52.4501	11.12903	-4.71	0.000	-74.26261	-30.6376
Transferts	-15.00396	13.63208	-1.10	0.271	-41.72235	11.71443
Transport	-48.5355	17.35963	-2.80	0.005	-82.55974	-14.51125
Others	4.186734	9.535099	0.44	0.661	-14.50172	22.87518
groupe						
2	15.06174	11.77224	1.28	0.201	-8.011424	38.1349
3	19.20791	12.41725	1.55	0.122	-5.129456	43.54528
rain	-.0818358	.2999692	-0.27	0.785	-.6697646	.5060931
tmin	40.06495	9.873036	4.06	0.000	20.71415	59.41574
tmax	1.902701	2.991125	0.64	0.525	-3.959796	7.765197
_cons	-771.3143	226.1048	-3.41	0.001	-1214.472	-328.1569
dep						
var(_cons)	2538.785	613.1939			1581.374	4075.839
var(e.synt_ind2)	13153.12	383.7219			12422.13	13927.11

```
LR test vs. linear model: chi2(4) = 243.89                    Prob > chi2 = 0.0000
```

VIII. Annex G: Questioinner

A. MODULE COMMUNAUTAIRE

Les informations collectées dans ce module portent sur la commune et ne comporte qu'une seule section.

Q1	Région	|__|__|
Q2	Département	|__|__||__|__|
Q3	Commune	|__|__||__|__|
Q4	Milieu de résidence *Urbain 1* *Rural 2*	|__|
Q5	Nombre de quartier/village dans la commune	
Q6	Température moyenne annuelle de la commune en 2018 ?	
Q7	Température moyenne annuelle de la commune en 2017 ?	
Q8	Volume de la pluviométrie annuelle de la commune en 2018 ?	
Q9	Volume de la pluviométrie annuelle de la commune en 2017 ?	

B. MODULE MENAGE

Les informations collectées dans cette partie portent sur le ménage. Elle est répartie en xx sections

1.7. SECTION I : CARACTERISTIQUES ET CONDITIONS DE VIE DU MENAGE

Q10	**Sexe du chef de ménage** *1. masculin* *2. féminin*	|__|			|__|__| |__|
Q11	**Age du chef de ménage**				
Q12	**Statut matrimonial** Marié(e) monogame …1 Marié(e) polygame …..2 Divorcé(e)/veuf(ve) ….3 Célibataire ……..4 Autre à préciser……..5	|__|			|__|

Q13	**Niveau d'instruction du chef de ménage** *Aucun …0* *élémentaire….1* *Moyen/Secondaire …2* *Supérieur …3* *Coranique uniquement…..4*				
Q14	**Le chef de ménage souffre-t-il de handicap** Non …….0 Physique uniquement…….1 Mental uniquement…….2 Physique et mental ……3 Autre à préciser …..4	|__|			|__|

Q15	**Le chef de ménage souffre-t-il de maladie chronique** NON.....0 Diabète ……..1 Hyper/hypotension …2 Drépanocytose…3 VIH/sida…4 Tuberculose…….5 Cancer …6 Insuffisance rénale … 7 Autre à préciser…….8 ……				
Q16	**Taille du ménage (nombre de personnes membres du ménage)**	|__|__||__|			|__||__|
Q17	**Nombre de femmes total**				
Q18	**Nombre total d'enfants 6-59 mois**	|__||__|			|__||__|
Q19	**Nombre de filles 6-59 mois**				
Q20	**Nombre de femmes enceintes**	|__||__|			|__||__|
Q22	**Nombre de femmes allaitantes**				

Q23	**Quel est le principal composant des murs du logement du ménage ?** Paille …1 Palme/Bambou …2 Bois/Planche…3 Terre…4 Semi-dur …5 Pierre…6 Brique …7 8 = Autre à préciser …8	|__|			|__|

	…….				
Q24	**Quel est le principal composant du toit du logement du ménage ?** Tôle …1 Tuile …2 Terre…3 Paille …4 Dalle …5 Bois/Planche …6 Tente …7 Autre à préciser…8 ……..				
Q25	**Quel est le principal composant du sol des habitats ?** Ciment …1 Carrelage …2 Terre battue/sable …3 Bois/Planche ….4 Bambo/palme Autre	|__|			
Q26	**Quel est le statut d'occupation du ménage ?** Propriétaire Locataire Locatiare/acheteur Hébergé gratuitement Autre				

Q27	**Quelle est la principale source d'eau de boisson du ménage** Robine d'eau courante Forage à pompe Puits Marigot, rivière, ruisseau, pluies Autre à préciser	
Q28	**Quelle est la principale source d'énergie pour la cuisson dans le ménage ?**	

Q29	**Principale source d'éclairage du ménage ?**	

Q30 **Combien de biens fonctionnels possède le ménage ?**

N°	***Biens***	***Nombres***
1	Radio	|___|___|
2	Téléviseur	|___|___|
3	Livebox(internet)	|___|___|
4	Décodeur de chaine téléviseur	|___|___|
5	Climatiseur	|___|___|
6	Machine à laver	|___|___|
7	Machine à coudre	|___|___|
8	Réfrigérateur/congélateur	|___|___|
9	Fourneau Jambar	|___|___|
10	Ligne téléphone fixe	|___|___|
11	Téléphone portable	|___|___|
12	Voiture	|___|___|
13	Moto/Motocyclette	|___|___|
14	Vélo/Bicyclette	|___|___|
15	Tracteur	|___|___|
16	Charrette	|___|___|
17	Charrue	|___|___|
18	Semoir	|___|___|
19	Pirogue	|___|___|
20	Filets	|___|___|
21	Motopompe	|___|___|
22	Maisons	|___|___|
23	Parcelle de terrain	|___|___|

Q31	Le ménage possède-t-il du bétail/volaille ?	

Q32 Si Oui, indiquer le nombre

Bétail	Bovin	Ovin	Caprin	Equin	Asin	Porcin	Camelin	Volaille
Nombre	|__|__|	|__|__|	|__|__|	|__|__|	|__|__|	|__|__|	|__|__|	|__|__|

Q33	Comparativement à la campagne agricole de 2017, comment appréciez-vous la production de 2018 pour chacune des spéculations suivantes : mil, maïs, sorgho, riz, fonio, niébé, arachide et manioc ? Code : **Largement moins bonne …1 ;** **Moins bonne…2 ;** **Pareille…3 ;** **Meilleure….4 ;** **Largement meilleure …5 ;** **Non concerné (le ménage ne cultive pas la spéculation) ……8**	

Spéculation	code
Mil	
Mais	
Sorgho	
Riz	
Fonio	
Niébé	
Arachide	
Maroc	

Q34	**Environ combien de mois de consommation la production cumulée de 2018 des céréales mil, maïs, sorgho, riz et fonio de cette année pourrait-elle assurer ?**	|___||___|
Q35	**Quelle est la principale céréale consommée par le ménage au cours des 12 derniers mois?** *Code :* *Mil……..1* *Mais……..2* *Sorgho…….3* *Riz……..4* *Fonio……5*	|___|
	Quelle est la principale source de provenance de la céréale la plus consommée par le ménage au cours des 12 derniers mois ?	|___|

Q36	***Code :*** *Propre production…1* *Dons sociaux…2* *Achats (marchés/boutiques) ……..3* *Autre à préciser …8* **…….** **si réponse 1, 2 ou 8 aller à Q227**	

Q37	**Si la principale source d'approvisionnement en céréales est « achat (marché/ boutique) », quelle est distance entre le village/quartier et le marché/boutique ?** *Moins d'un km……1* *Entre 1 et 5 km ……..2* *Plus de 5km ……..3*	|___|
Q38	**Au cours de l'année 2018, le ménage a-t-il eu des difficultés pour se nourrir ?** Sinon, allez à la section suivante	
Q39	**Si oui, quels sont les mois pendant lesquels le ménage a eu des difficultés pour se nourrir ?** *NOTE: si non partout aller à la section suivante non…0 ; oui …1*	

Janv. 18	**Fév. 18**	**Mars 18**	**Av 18**	**Mai 18**	**Juin 18**	**Juil. 18**	**Aout 18**	**Sept 18**	**Oct. 18**	**Nov. 18**	**Déc. 18**
|___|	|___|	|___|	|___|	|___|	|___|	|___|	|___|	|___|	|___|	|___|	|___|

Q40	**Quelle est la principale raison de ces difficultés?** **<u>code</u>** *Récolte insuffisante…1* *Manque de revenus ….2* *Absence de céréales locales sur les marchés …3* *Prix des denrées trop élevés …4* *Baisse du prix du bétail ….5* *Marchés physiquement inaccessibles (sécurité, inondations, etc.)…6 Autres à préciser …7* ……	|___|

1.8. SECTION II : DEPENSES ET REVENUS

Dépenses

Q41	**Évaluer les dépenses du ménage** (il faut éviter le double emploi. Une dépense doit être prise en compte une seule fois)		
	Types de dépenses	**Au cours des 30 derniers jours précédant le passage de l'agent enquêteur** (mettre zéro si la dépense n'est pas effectuée)	**Au cours des 12 derniers mois** (mettre zéro si la dépense n'est pas effectuée)
1	Alimentation (céréales, viande, poisson, thé, café, sucre, huile, condiments, boissons, etc.)	|___||___||___||___||___||___|	|___||___||___||___||___||___|
2	Eau, électricité	|___||___||___||___||___||___|	|___||___||___||___||___||___|
3	Transport	|___||___||___||___||___||___|	|___||___||___||___||___||___|
4	Santé (soins, consultations, médicaments, médecine traditionnelle, etc.)	|___||___||___||___||___||___|	|___||___||___||___||___||___|
5	Éducation	|___||___||___||___||___||___|	|___||___||___||___||___||___|
6	Logement	|___||___||___||___||___||___|	|___||___||___||___||___||___|
7	Communication (Téléphones fixes, mobiles)	|___||___||___||___||___||___|	|___||___||___||___||___||___|
8	Autres dépenses à préciser …….. ;	|___||___||___||___||___||___|	|___||___||___||___||___||___|

Revenus

Q42	**Quelles sont les trois principales sources de revenus du ménage (par ordre d'importance)?**			
	Principales sources	**origine**	**Montant en FCFA**	**périodicité**
1	**1ère source de revenu**	|___|		|___|
2	**2ème source de revenu**	|___|		|___|
3	**3ème source de revenu**	|___|		|___|
	Code origine du revenu Pas d'autre source de revenu .....0 (passez à la section suivante) Vente de produits agricoles ……..1 Vente de produits miniers ……..2 Vente de bétail ou produits d'élevage ….3 Vente des produits de la pêche ……4 Vente des produits de la chasse/cueillette…..5 commerce ……6 salaire du public……7 salaire du privé……8 Artisanat……9 Transport……10 Transfert d'argent des migrants……11 Autres (préciser)…….12			**Code Périodicité** Journalière ….……1 Mensuelle ……..…2 Trimestrielle……..3 Annuelle…….4

1.9. SECTION III : CONSOMMATION ALIMENTAIRE DU MENAGE

Q43	Hier, combien de repas ont été pris par les membres du ménage âgés de 5 ans ou plus ?	|___||___|
Q44	Hier, combien de repas ont été pris par les membres du ménage âgés de 6-59 mois ?	|___||___|
Q45	habituellement, combien de repas quotidiens prennent les membres du ménage âgés de 5 ans ou plus ?	|___||___|

Q46	habituellement, combien de repas quotidiens prennent les membres du ménage âgés de 6-59 mois ? ?	|___||___|

Q47 Combien de jours durant les 7 derniers jours, les membres de votre ménage ont consommé les aliments suivants et comment ces aliments ont été acquis ?

(Utilisez les codes à droite, écrire 0 pour les produits non consommés les 7 derniers jours et si nécessaire noter la source des aliments)

	Produits alimentaires	**Q47.1- Nombre de jours de Consommation durant les 7 derniers jours ?** *Si 0 jour, ne pas préciser le mode d'acquisition*	**Q47.2- Source principale des aliments consommés ?** (Inscrire le code correspondant) **<u>Code des sources</u>** Propre production (végétale, animale)...1 Pêche/Chasse …..2 Collecte/Cueillette…..3 Emprunt /achat à crédit……..4 Achat en comptant…5 Troc……..6 Travail contre nourriture ….7 Don (famille/amis/voisins/communauté…..8 Aide alimentaire (ETAT, ONG/UN…….9
1.	Riz	|___|	|___|
2.	Pâtes alimentaire, pain/galette et/ou beignets, pain	|___|	|___|
3.	**Racines, tubercules** : pomme de terre, igname, manioc, patate douce et/ou autres tubercules	|___|	|___|
4.	**Autre Céréales** : sorgho, mil, maïs	|___|	|___|
5.	**Légumineuse/noix** : haricots, niébé, arachides, lentille, soja, et/ou autre noix	|___|	|___|

6.	**Légumes oranges** (légumes riches en vitamine A): (la carotte, le poivron rouge, la citrouille, la patate douce orange, etc.)	|___|	|___|
7.	**Les légumes à feuilles vertes (**épinards, le brocoli, l'amarante et / ou d'autres feuilles vert foncé, les feuilles de manioc etc.)	|___|	|___|
8.	**Autres légumes** (oignons, tomates, concombre, radis, haricots verts, petits pois, laitue, etc.)	|___|	|___|
9.	**Fruits oranges** (des fruits riches en vitamine A): mangue, la papaye, l'abricot, pêche etc.)	|___|	|___|
10	**Autres fruits** (banane, pomme, citron, mandarine)	|___|	|___|
11	**Viande/abats/volaille** (viande en grande quantité et non comme condiment)	|___|	|___|
12	**Poisson/Fruits de mer (en grande quantité)**	|___|	|___|
13	**Œufs**	|___|	|___|
14	**Lait et Autres produits laitiers :** Lait frais/ aigri, yaourt, fromage, autre produits laitiers SAUF margarine / beurre ou de petites quantités de lait pour le thé / café	|___|	|___|
15	**Huile/gras/beurre :** huile végétale, palme,	|___|	|___|

	5 beurre de karité, margarine, autres gras/huile		
1	**Sucre ou produits sucré :** sucre**,** miel, confiture, beignets, bonbons, biscuits, 6 pâtisseries, gâteaux et autres produits sucrés, (boissons sucrées),	|___|	|___|
1	**Condiments/Épices :** thé, café/cacao, sel, ail, épices, levure/poudre à pâte, tomate/sauce 7 piquante, viande ou poisson comme condiments, autres condiments y compris petite quantité de lait pour le thé/café	|___|	|___|

1.10. SECTION IV : Chocs et stratégies d'adaptation

Q48	Au cours des 6 derniers mois, le ménage a-t-il été confronté aux chocs suivants :(lister les chocs)				
	Chocs	Non ..0 Oui …1		**Chocs**	Non ..0 Oui …1
1	Hausse de prix d'intrants agricoles (semences, engrais, matériel agricole)	|___|	10	Inondations	|___|
2	Hausse de prix de denrées alimentaires à consommation courante	|___|	11	Incendie	|___|
3	Baisse du prix des produits vendus par le ménage	|___|	12	Pluies insuffisantes	|___|
4	Invasion d'insectes ou d'oiseaux ravageurs	|___|	13	Pluies hors saison	|___|
5	Maladies de plantes	|___|	14	Conflits/insécurité	|___|
6	Maladie/accident d'un membre du ménage	|___|	15	Perte de revenus (perte d'emploi, interruption de transferts)	|___|
7	Décès d'un membre du ménage qui était contributeur aux dépenses du ménage	|___|	16	Pénurie d'eau	|___|
8	vol	|___|	17	Autre choc à préciser	|___|
9	Maladies /Morbidité/Mortalité animales	|___|			

Stratégies d'adaptation

Q49	**Au cours des 7 derniers jours, le ménage a-t-il eu à recourir à l'une des stratégies suivantes à cause de difficultés alimentaires :** ***(lister les stratégies une à une. Si la stratégie n'est pas adoptée, inscrire 0 au nombre de jour)***	**Fréquence (en nb de jours de 0 à 7)**
1	Consommer des aliments moins appréciés, moins chers	|___|
2	Emprunter des aliments ou dépendre de l'aide de proches (amis, voisins, collègues, parents, etc.)	|___|
3	Diminuer la quantité des repas	|___|
4	Acheter des aliments à crédit	|___|
5	Réduire la consommation des adultes en faveur des enfants	|___|
6	Passer une journée sans prendre un repas par manque de moyens	|___|
7	Envoyer les membres du ménage aller manger ailleurs	|___|
8	Travailler contre de la nourriture	|___|
9	Mendier	|___|
10	Consommer les semences de la prochaine campagne agricole	|___|