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Climate-Smart Agriculture, Climate Risk Vulnerability, and Food Security in Côte d'Ivoire: Exploring the Role of Gender

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Dedication

I dedicate this work to the Almighty God, whose boundless grace and gift of good health have sustained me from the beginning until now.

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Abstract

This dissertation examines the interrelations between Climate-Smart Agriculture (CSA), climate vulnerability, and food security, with a particular focus on gender inequalities in Côte d'Ivoire. Employing econometric techniques and survey data, it analyses farmers' perceptions of climate change, the determinants of CSA practice adoption, and the gender-differentiated effects on food security and vulnerability. Despite growing awareness of climate variability, CSA adoption remains low, with fewer than 20% of households in the Hambol region implementing the majority of the 35 identified practices. Agroforestry emerges as both a widely adopted and effective practice, contributing to food security while supporting climate adaptation and mitigation. However, a lack of awareness regarding CSA benefits remains a major barrier to its uptake. The gender analysis highlights notable disparities: improved seeds increase food security by 33.9% in female-headed households, whereas intercropping improves it by 47.3% in male-headed ones. Overall, CSA practices enhance food security by 41.3%, with respective gains of 29.7% for women and 45.7% for men. Through an endogenous change model, the research demonstrates that adopters experience a 4.84% reduction in vulnerability, compared to a 21% increase among non-adopters. Improved seeds and intercropping reduce vulnerability by 5.76% and 4.5%, respectively, while non-adoption results in increases of 7.54% and 24.74%. Socio-economic factors such as age, household size, and access to healthcare also reduce vulnerability, whereas climate shocks, including droughts and floods, exacerbate it. The combined adoption of CSA practices enhances resilience by diversifying income sources and strengthening adaptive capacities. Policy implications include strengthening meteorological services, providing targeted training, facilitating gender-sensitive credit access, and implementing land reforms to ensure equitable adoption.

Keywords: Perception of climate change; Climate-smart agriculture; Food insecurity; Vulnerability to climate risk; Gender

Résumé

Cette thèse examine les interrelations entre l'Agriculture Intelligente face au Climat (AIC), la vulnérabilité climatique et la sécurité alimentaire, en mettant particulièrement l'accent sur les inégalités de genre en Côte d'Ivoire. En s'appuyant sur des techniques économétriques et des données d'enquête, nous analysons les perceptions des agriculteurs face au changement climatique, les déterminants de l'adoption des pratiques AIC, ainsi que les effets différenciés selon le genre sur la sécurité alimentaire et la vulnérabilité. Malgré une prise de conscience croissante de la variabilité climatique, le taux d'adoption des pratiques AIC demeure faible : moins de 20 % des ménages de la région du Hambol mettent en œuvre la majorité des 35 pratiques identifiées. L'agroforesterie apparaît comme une pratique à la fois largement adoptée et efficace, contribuant à la sécurité alimentaire tout en favorisant l'adaptation et l'atténuation des effets du climat. Cependant, le manque de sensibilisation aux bénéfices de l'AIC constitue un frein majeur à sa diffusion. L'analyse genrée met en évidence des disparités significatives : les semences améliorées augmentent la sécurité alimentaire de 33,9 % dans les ménages dirigés par des femmes, tandis que l'association culturale l'améliore de 47,3 % dans ceux dirigés par des hommes. Globalement, les pratiques AIC renforcent la sécurité alimentaire de 41,3 %, avec des gains respectifs de 29,7 % pour les femmes et de 45,7 % pour les hommes. À travers un modèle de changement endogène, la recherche montre que les adoptants enregistrent une réduction de vulnérabilité de 4,84 %, contre une augmentation de 21 % chez les non-adoptants. Les semences améliorées et l'association culturale réduisent la vulnérabilité de 5,76 % et 4,5 % respectivement, tandis que leur non-adoption entraîne des hausses de 7,54 % et 24,74 %. Des facteurs socio-économiques tels que l'âge, la taille du ménage et l'accès aux soins de santé contribuent à réduire la vulnérabilité, alors que les chocs climatiques, notamment les sécheresses et les inondations, l'aggravent. L'adoption combinée des pratiques AIC améliore la résilience en diversifiant les sources de revenu et en renforçant les capacités d'adaptation. Les implications politiques incluent le renforcement des services météorologiques, la mise en place de formations ciblées, l'accès au crédit sensible au genre, ainsi que des réformes foncières pour assurer une adoption équitable.

Mots-clés : Perception du changement climatique ; Agriculture intelligente face au climat ; Insécurité alimentaire ; Vulnérabilité aux risques climatiques ; Genre

GENERAL INTRODUCTION

Research background

Climate change and variability, caused by the emission of greenhouse gases, present significant environmental threats globally (Abbass et al., 2022; Sorvali et al., 2021; Malhi et al., 2021). Each doubling of carbon dioxide has resulted in temperature increases between 2°C to 4°C since the 1850s (IPCC, 2021). According to the Food and Agricultural Organization of the United Nations (2022), the rise in greenhouse gas emissions made 2021 an exceptionally warm year. Furthermore, the Intergovernmental Panel on Climate Change (2022) highlighted that greenhouse gas emissions and periods of warming by 2021 have heightened the vulnerability of populations worldwide, particularly in African countries. Most of these nations rely on rain-fed agriculture, a major contributor to their gross domestic product (Ngoma et al., 2021). This sector is highly sensitive to climate change threats such as droughts, floods, and the emergence of plant diseases (Pörtner et al., 2022; Chavula & Chilumpha, 2022). Over 95% of African agriculture is rain-fed (Al-Gamal, 2021), including 98% in Côte d'Ivoire (Bogie & Bayala, 2022). More than 50% of people live in rural areas in Sub-Saharan Africa (SSA), making these countries especially vulnerable to the effects of climate change (Al-Gamal, 2021; Bogie & Bayala, 2022).

Climate change impacts agricultural households daily by reducing agricultural income, production, and yield, which exacerbates food insecurity (Ogundari & Onyeaghala, 2021; Chilunjika & Gumede, 2021; Pilo et al., 2018). This exposure increases the vulnerability of people to climate shocks. The vulnerability of SSA populations to climate shocks is evident in the high levels of food insecurity. This insecurity stems from increased greenhouse gas emissions, leading to higher temperatures and reduced rainfall. The number of undernourished people has been rising, with about 282 million residing in Africa (Nugroho et al., 2022). The Food and Agriculture Organization of the United Nations (2019) reported a rise in food insecurity from 2005 to 2019, affecting approximately 57.7 million more people. The World Bank's global hunger index data (2021) shows that many SSA countries face serious food insecurity, with alarming scores ranging from 10.0 to over 30, indicating severe food access issues. Potential losses by 2050 include 5 to 17 percent for crop yields, 10 to 14 percent for cereal production, and fisheries resources, which are crucial for food security (Baptista et al., 2022).

This situation complicates the achievement of Sustainable Development Goal 2 (zero hunger) by 2030 for these countries, including Côte d'Ivoire. The intensification of food insecurity in the region leads to increased malnutrition, loss of human life, particularly among children, and stunting. In 2021, SSA recorded very high numbers of people experiencing severe food insecurity (709.4 million) and undernourishment (260.6 million), resulting from the decline in agricultural yields. To mitigate the vulnerability of agricultural systems to climate change, developing adaptation options is crucial. Climate-smart agriculture (CSA) is one such approach that addresses the challenges of climate change to food security while enhancing agricultural productivity, reducing greenhouse gas emissions sustainably, and ensuring food security (Chandra et al., 2018; FAO, 2010). Implementing CSA strategies can help developing countries, such as those in SSA, boost economic growth and improve livelihoods due to their heavy reliance on agriculture.

The agricultural sector is vital for economic growth and livelihoods in developing countries, particularly in SSA. It remains the primary source of employment and economic growth in these regions (Louhichi et al., 2022; Oyelami et al., 2022), engaging 60 percent of the active population and contributing about 23 percent to the region's GDP (OECD/FAO, 2021). West Africa plays a significant role in this context, as agriculture in these countries contributes substantially to export earnings and is a major income source for communities. In Côte d’Ivoire, the agricultural sector is a key economic pillar, accounting for 22 percent of GDP and 66 percent of export earnings. Agriculture employs about 60 percent of the Ivorian population, according to the Ministry of Agriculture and Sustainable Development and the National Statistics Institute (2020) (Yao et al., 2022). Ivorian agriculture faces similar challenges from climatic shocks. The central and northern regions are particularly prone to droughts, leading to land degradation and infertility due to low rainfall and rising temperatures, which result in increased food insecurity from reduced agricultural yields (Koné et al., 2022; Kouassi et al., 2022; Timité et al., 2022). Southern and western regions face threats from excessive rains, floods, and insect infestations that destroy crops (Aka et al., 2022).

To support the agricultural sector against climate change risks, various programs promote the adoption of adaptation strategies. These initiatives extend across the West African region, including the Global Climate Change Alliance Plus West Africa component (GCCA+WA) and the Comprehensive Africa Agriculture Development Program (CAADP). These programs aim to help agricultural households understand and implement adaptation strategies to improve production levels, combat food insecurity, and enhance rural livelihoods. In Côte d'Ivoire, similar programs, such as the Support Program for the Development of Agricultural Sectors (PADFA), advocate for the implementation of adaptation strategies in regions most affected by climate shocks to boost agricultural production. Additionally, the National Communication on Climate Smart Agriculture (NCCSA), the National Strategy for Disaster Risk Management (NSDRM), and the National Program on Climate Change (NPCC) support PADFA's goals across Côte d'Ivoire, promoting adaptation strategies in all regions affected by climate shocks.

However, Côte d'Ivoire, like many West African countries, faces significant challenges related to climate change, food security, and agricultural sustainability. The food insecurity rate in Côte d'Ivoire remains concerning, with 21.6% of the population experiencing moderate to severe food insecurity in 2022. Rural communities, particularly smallholder farmers who rely on rainfed agriculture, are the most affected. Climate risks exacerbate gender disparities, as women represent nearly 60% of the agricultural workforce but have limited access to land, inputs, credit, and extension services. Despite their crucial role in food production, female farmers own less than 10% of the land and receive only 5% of agricultural credit, reducing their capacity to adopt adaptive strategies.

Climate-Smart Agriculture (CSA) is promoted as a solution to enhance resilience, improve productivity, and ensure food security. However, the adoption of CSA practices remains uneven, with gender playing a critical role in shaping access to information, resources, and decision-making processes. Studies show that only 30% of women farmers in Côte d'Ivoire have access to climate information services, compared to 45% of men. Additionally, while the adoption of improved seeds and conservation agriculture techniques has increased by 15% in the past decade, barriers such as traditional land tenure systems and socio-cultural norms continue to limit women's engagement.

The vulnerability of farm households to climate risks varies significantly based on gender, socio-economic status, and geographical location. In the northern and central regions, where rainfall variability is high, female-headed households report a 25% higher probability of experiencing food shortages compared to male-headed households. Moreover, gendered differences in adaptive capacity influence food security outcomes. Households where women actively participate in decision-making tend to diversify food sources more effectively, reducing the risk of severe food insecurity.

Problem statement

Despite the potential positive impact of Climate-Smart Agriculture (CSA) practices on reducing climate change risks and increasing agricultural food production, smallholder farmers' vulnerability remains high, and food insecurity continues to grow in West Africa, particularly in Côte d'Ivoire (Affoh et al., 2022; Moutouama et al., 2022; Abegunde et al., 2022). The vulnerability of smallholder farmers to climate shocks is defined by their likelihood of being adversely affected, encompassing their exposure to climate shocks, sensitivity (the extent to which they are affected), and their capacity to cope with these shocks. West African countries are particularly vulnerable to climate risk because the majority of their populations depend on livelihood agriculture. Subsistence crops are highly sensitive to climatic extremes such as droughts, which pose significant challenges to farmers who cannot easily cope due to substantial losses in physical, natural, and financial capital (Lokonon, 2018; Njoya et al., 2022; Bedeke, 2022). Studies by Derbile et al. (2022) have shown that 60 percent of Ghana's agricultural food production is vulnerable to increasing droughts, exacerbating the vulnerability of agricultural households. Similarly, Guodaar et al. (2021) emphasized that most Sub-Saharan African (SSA) farmers are vulnerable to increased climatic stresses that reduce their yields, income, and agricultural productivity. Kouman et al. (2022) found that farmers in the northeastern part of Côte d'Ivoire were highly vulnerable to climatic risks such as droughts, rain shortages, and high temperatures due to their heavy reliance on agriculture.

These climatic shocks adversely affect farmers' livelihoods leading to reduced food security. Indeed, the West African region has seen a rise in food insecurity, with 57.3 million undernourished people in 2021, up from 53 million in 2020, and 247.4 million people experiencing severe food insecurity in 2021, compared to 237.2 million in 2020 (FAO, 2022). To mitigate the vulnerability of smallholder farmers to climate risks, several researchers have promoted innovation in the agricultural sector through adaptation strategies that help farmers cope with climate change. Studies emphasize the importance of adaptation strategies such as irrigation, improved seeds, crop diversification, use of organic manure, crop rotation, and agroforestry practices for smallholder farmers in West Africa and Côte d'Ivoire (Timité et al., 2022; Akudugu et al., 2021; Danquah et al., 2022; Anuga et al., 2022). These strategies have been shown to positively impact agricultural performance. For instance, Ndiritu & Muricho (2021) demonstrated that adaptive strategies had a positive impact on food security; farmers in Kenya who had not adopted these practices were more likely to be food insecure. Jambo et al. (2021) found that irrigation positively impacted food security in Ethiopia and contributed to poverty reduction among farmers. Dossou-Yovo & Saito (2021) showed that irrigation use by rice farmers in central Côte d'Ivoire helped maintain and increase yields.

However, some studies highlight the possibility of maladaptation, where strategies implemented by farmers to face climate risks may inadvertently increase their vulnerability. For instance, Pilo et al. (2021) and Bazzana et al. (2022) suggest that certain strategies might lead to increased vulnerability. Consequently, interest has shifted towards CSA practices, which not only help farmers increase production but also contribute to reducing greenhouse gases and increasing resilience to climate shocks. Abegunde et al. (2022) found that CSA practices positively impacted food security among farm households in South Africa. Ngigi & Muange (2022) underscored CSA practices as crucial for mitigating threats to food security in Kenya. Etwire et al. (2022) showed that Ghanaian farmers who adopted adaptive practices had higher yields despite rising temperatures. Recent studies have established the effectiveness of CSA practices in building resilience to climate change and enhancing household food security. Marenya et al. (2020) assessed agricultural technologies such as seed diversification, fertilizer use, and soil and water conservation, finding that each practice positively impacted maize yields and farmers' incomes in Ethiopia. Tesfaye & Tirivayi (2020) analyzed crop diversification's effectiveness on household consumption and welfare in Uganda, noting increased household consumption and diet diversity. Amadu et al. (2020) evaluated CSA performance on maize yields in drought-prone southern Malawi, finding a 53 percent yield increase during severe drought.

Despite the merits of these studies, a critical oversight is their failure to adequately consider gender issues. Achieving Sustainable Development Goals 2 (zero hunger) and 1 (poverty reduction) requires integrating gender into CSA practices in West Africa, particularly in Côte d’Ivoire, as gender disparities limit effective adaptation (FAO, 2022; IPCC, 2022; Ampaire et al. 2020). Both men and women are exposed to climate change impacts and are involved in agriculture, playing vital roles in household food security. Studies show that women often contribute more to food crop production, while men focus more on export crops (De Pinto et al., 2020).

Recognizing the importance of integrating women into agricultural and CSA practices, some authors have begun to address gender approaches in CSA implementation. In Côte d'Ivoire, most studies have focused on assessing food security levels between men and women, highlighting influencing factors. Bazzana & Zhang (2022) found that CSA practices like crop rotation and water conservation increased food security by improving food availability and stability in Ethiopia, though this study did not consider gender. Koudjom (2022) assessed CSA strategies' impact on maize productivity in Togo, noting that married couples (men and women) were more likely to improve food security through increased productivity than unmarried individuals. However, these studies did not compare the impact of CSA adoption by women versus men on food security, a crucial consideration for policymakers to support women's increased adoption of CSA practices, given the still low adoption rates in Côte d’Ivoire.

Although CSA innovations hold potential, many farmers remain reluctant to adopt them. Evidence supports that CSA adoption by rural farmers depends on climate perception and demographic characteristics, but gender perspectives on CSA adoption are insufficiently analyzed. Studies integrating gender factors in CSA adoption have focused more on adoption level differences between men and women, highlighting that women's lower adoption rates stem from a lack of CSA knowledge, climate information, access to finance, and other socio-demographic factors (Abegunde et al., 2022; Bazzana & Zhang, 2022; Agarwal et al., 2021). However, these studies have not assessed the effectiveness of CSA practices adopted by women compared to men, considering CSA pillars. Evaluating the effectiveness of these practices is essential to empower women to contribute to reducing food insecurity and household vulnerability, and to encourage broader CSA adoption.

Research questions

Existing studies on the effectiveness of Climate Smart Agriculture (CSA) in Côte d'Ivoire have inadequately addressed gender differences. Additionally, there is a notable lack of research examining the vulnerability to climate risk while considering CSA practices. Combining these gaps, our primary research question emerges: What is the gender impact of climate-smart agricultural practices on the vulnerability to climate risks and food insecurity in Côte d'Ivoire? This question aims to explore how CSA practices affect men and women differently in terms of their exposure to climate-related risks and their ability to achieve food security, thereby highlighting the necessity for a gender-sensitive approach in agricultural policies and practices. Putting these together our main research question is: what is the gendered impact of climate-smart agricultural practices on the vulnerability to climate risks and food insecurity in Cote d'Ivoire? We further constructed the following three specific questions:

i. **Question 1**: How do farm households perceive climate change, and to what extent do they adopt Climate-Smart Agriculture practices and perceive their effectiveness (smartness)?
ii. **Question 2:** What is the gendered impact of Climate Smart Agriculture strategies' adoption on farm households' food insecurity?
iii. **Question 3**: How does women's adoption of climate-smart agriculture affect farm household vulnerability to climate risk?

Research objectives

This dissertation aims to assess the gendered impact of climate-smart agricultural practices on the vulnerability to climate risks and food insecurity in Côte d'Ivoire. Especially, the research objectives are to:

i. analyze farm households' perception of climate change, the adoption, and the smartness of Climate-Smart Agriculture practices
ii. assess the gendered impact of Climate Smart Agriculture strategies' adoption on farm households' food insecurity
iii. assess the women's adoption of climate-smart agriculture on farm household vulnerability to climate risk

Research hypothesis

To reach the above objectives, we formulate the following hypothesis:

- ➢ (H1): Farm households with a higher awareness of climate change are more likely to adopt Climate-Smart Agriculture (CSA) practices and perceive them as efficient strategies
- ➢ (H2): The adoption of Climate Smart Agriculture by women has a relatively positive impact on household food insecurity compared to men.
- ➢ (H3): Climate-smart agriculture adoption reduces women's vulnerability to climate risk

Thesis defended

Climate-Smart Agriculture (CSA) mitigates climate-related vulnerability and food insecurity by enhancing resilience and adaptive capacity. Grounded in economic and vulnerability frameworks, CSA reduces sensitivity to climate stressors and strengthens adaptive responses through improved practices like agroforestry and conservation agriculture. These interventions support food security by increasing availability, access, utilization, and stability. Economic analyses highlight CSA's potential to optimize welfare under uncertainty, aligning with climate adaptation and sustainable development goals, and positioning CSA as vital for resilient, food-secure farming systems.

Dissertation structure

The dissertation is structured into three main chapters. The first section, titled “General introduction,” consists of the background, problem, research questions, research objectives, and hypothesis. The first chapter focuses on analyzing the farm households’ perception of climate change, adoption, and the smartness of Climate-Smart Agriculture practices. The gendered impact of Climate Smart Agriculture strategies adoption on farm households’ food insecurity is provided in chapter two, while the women’s adoption of climate-smart agriculture impact on farm household vulnerability to climate risk is detailed in chapter three. The general conclusion and policy brief are discussed in the last section.

Chapter 1: CLIMATE CHANGE PERCEPTION, CLIMATE-SMART AGRICULTURE PRACTICES ADOPTION AND SMARTNESS

Abstract

Agricultural sustainability depends on the adaptability and resilience of existing farming systems to climate and environmental change, but little is known about farmers' perceptions of the efficiency of adopting climate-smart practices. This chapter analyses farm households' perception of climate change, the determinants of the choice of the number of adopted practices, and the subjective efficiency and correlation between the most used climate-smart agriculture (CSA) strategies in subsistence agriculture. Zero-inflated Poisson regression and multivariate analysis are employed using data collected from 461 farm households in the Hambol region in Côte d'Ivoire. By inventorying 35 CSA practices, the results reveal that access to climate and meteorological information, as well as funds, marital status, location (department), and education, are the main determinants of the choice of the number of adopted practices. There is a strong complementarity between the most adopted CSA practices. Agroforestry appears as one of the most adopted and effective practices according to interviewees regarding its potential impacts on the CSA's three pillars (food security/productivity, mitigation, and adaptation). The diffusion of climate and meteorological information, combined with funding access facilities and training on CSA implementation, can be key factors in Hambol's agriculture policy.

Keywords: climate change; Adaptation; Climate-smart agriculture; Perception; Smartness

1.1. Introduction

The future of agriculture strongly depends on the ability of existing farming systems to adopt improved technologies and farming practices to meet the significant challenges facing farmers, their farmland, and their products (Zegeye et al., 2022; Kurgat et al., 2020; Lipper et al., 2014; Ogada et al., 2020). However, there appears to be insufficient knowledge about the efficiency of adopting these practices in the countries where these matters (Adeagbo et al., 2023). Climate-smart agriculture practices (CSAPs) are mostly adopted within Sub-Saharan African countries, where farmers remain the most vulnerable group (Ayeni et al., 2023; Ogisi & Begho, 2023). Climate-smart agriculture (CSA) is part of the climate business plan for Africa, according to which 63% of the population of thirty-four sub-Saharan countries have adopted CSA technologies to improve livestock production (World Bank, 2018). In addition, CSAPs related to water management and conservation agriculture have been adopted by 57%, and 53% of the population, respectively.

In sub-Saharan Africa, most households rely on rainfed activities for their income (Atsiaya et al., 2023; Ayeni et al., 2023). Climate shocks and stresses also affect the region and are widely recognized as one of the main factors increasing the propensity of individuals and households to escape or remain in poverty (Herrera et al., 2018). To reduce household vulnerability to climate risks, several researchers have encouraged innovation in the agricultural sector through the implementation of adaptation strategies to help farmers cope with the effects of climate change. Due to uncertainty and imperfect information, many adaptation strategies fail, and some go even further, causing conditions to worsen. Thus, adaptation responses can also deliver maladaptive outcomes, resulting in lock-ins that could exacerbate future climate vulnerabilities (Antwi-Agyei et al., 2018). Lock-ins resulting from maladaptive adaptation responses can have severe long-term consequences for climate vulnerabilities. These lock-ins can perpetuate unsustainable practices and hinder the implementation of more effective and resilient strategies, making it even harder to address and mitigate future climate risks.

Theoretically, CSA practices can be assimilated as innovative agricultural practices that sustainably increase productivity, improve resilience, reduce/remove Greenhouse Gases (GHG), and enhance national food security and sustainable development goals (Newell et al., 2019; Rogers & Ban, 1963). The expected outcomes (vulnerability, productivity, and food security) guide households' decisions to adopt or not adopt any CSAP (Adeagbo et al., 2023; Moutouama et al., 2022; Rankoana, 2016). In addition, the more the farmers perceive changes in climatic conditions, the more they are willing to adopt multiple CSAPs (Moutouama et al., 2022). However, climate change adaptation strategies face several challenges around the world. Negative externalities can be created by financial, informational, technical, infrastructural, institutional, or behavioral challenges (Piggott-McKellar et al., 2020; Sultana, 2010; Müller et al., 2017; Antwi-Agyei et al., 2018).

Moreover, the adoption of agricultural technologies is grounded in a convergence of multiple frameworks, notably the diffusion and acceptance of innovations, reasoned action, creative population pressure, and the theory of induced innovation. The diffusion of innovations theory, as articulated by Rogers (2003), views adoption as a process through which new technologies are communicated over time among members of a social system via specific channels. Within this framework, Davis (1989) contributes the Technology Acceptance Model (TAM), emphasizing that the adoption of a given technology depends primarily on users' perceptions of its usefulness and ease of use. However, these approaches have been criticized for their narrow focus on the intrinsic attributes of technology itself, overlooking broader socio-economic and institutional constraints.

To address this limitation, the Theory of Planned Behavior, developed by Ajzen (1991), introduces a more comprehensive framework that links beliefs, attitudes, perceived norms, intentions, and behaviors. It posits that a farmer's attitude towards adopting a technology is shaped by their behavioral intentions, which in turn are influenced by subjective norms and perceived behavioral control, factors that include structural constraints and social pressures.

Complementing this perspective, Boserup (1965) offers the theory of creative population pressure and induced innovation, suggesting that rising population densities catalyze agricultural intensification. This intensification not only enhances productivity but also drives the adoption of sustainable land management practices as a response to increasing resource scarcity. In addition, the institutionalist perspective, as discussed by Abell et al. (1997), highlights the crucial role of public policies and institutional frameworks in shaping technology adoption. These structures can either facilitate or hinder uptake, depending on how well they align with local socio-economic realities and needs.

Empirically, studies on the adoption and efficiency of climate change adaptation strategies are not unanimous. While some point out the positive impact of these strategies on farm household welfare (Kurgat et al., 2020; Lipper et al., 2014; Ogada et al., 2020; Taylor, 2017; Zougmoré et al., 2016), several highlight their negative impact (Antwi-Agyei et al., 2018; Müller et al., 2017; Piggott-McKellar et al., 2020; Sultana, 2010). Climate-Smart Agriculture (CSA) enhances food security and reduces vulnerability to climate change through multiple mechanisms. First, CSA improves agricultural productivity by promoting resilient crop varieties, conservation agriculture, and efficient water management, ensuring stable food availability. Second, it enhances income diversification via agroforestry, mixed farming, and value chain integration, increasing farmers' financial capacity to access food. Third, CSA fosters adaptation by reducing climate risks through soil conservation, crop rotation, and climate information services, enabling farmers to make informed decisions. Fourth, it supports mitigation by promoting carbon sequestration and reducing greenhouse gas emissions, contributing to long-term ecosystem stability. Lastly, CSA integrates gender-sensitive approaches, ensuring equitable resource access and decision-making, particularly for vulnerable groups. By strengthening resilience, optimizing resource use, and enhancing adaptive capacity, CSA mitigates climate-related shocks, thereby securing food production and livelihoods while reducing vulnerability to climate change.

However, Climate-Smart Agriculture (CSA) adoption may have unintended negative consequences on food security and vulnerability to climate change. First, CSA practices often require high initial investments in technology, knowledge, and inputs, which can be inaccessible to resource-poor farmers, exacerbating income inequality and limiting food access. Additionally, some CSA strategies, such as conservation agriculture or agroforestry, may reduce short-term yields before long-term benefits materialize, increasing food insecurity risks in the transition phase. Furthermore, CSA's reliance on market-based solutions can expose farmers to volatile input and output prices, making them more vulnerable to economic shocks. Socially, the unequal adoption of CSA across gender and socioeconomic groups can marginalize certain farmers, reinforcing structural vulnerabilities. Lastly, CSA’s effectiveness depends on local climatic conditions, and inadequate adaptation to site-specific risks may lead to maladaptation, inadvertently increasing exposure to climate-related shocks rather than mitigating them.

These divergences in the CSAP effects can limit adaptation levels and could be explained by the geographic context in which CSAPs were implemented, farmers' experience, and characteristics. While CSAPs exist in Côte d’Ivoire, most of the practices are not widely adopted. At present, the banana cocoa integration system seems to be the most adopted, covering about 13% of the agricultural land (FAO, 2018). The CSAPs identified by FAO (2018) are adopted at a low level. However, higher adaptation levels might be beneficial to improve agricultural productivity. This sector is the main economic activity in Côte d’Ivoire, contributing 21.2% to the country’s gross domestic product (GDP) and employing 46% of the labor force. In addition, this sector contributes to 12% of the total GHG emissions. The livestock sub-sector contributes 63% of the agricultural emissions, mainly through enteric fermentation (31%) and manure left on pastures (27%). The rest of GHG emissions in the agriculture sector are completed by savanna burning (17%), rice cultivation (5%), and the use of synthetic fertilizers (5%).

Furthermore, CSA implementation in Côte d’Ivoire faces several challenges including lack of capacity building of farmers and limited access to information on available innovations and their provision in an accessible and usable format so that small rural producers can understand and apply them. Nevertheless, several policies, strategies, plans, and programs are being implemented to fight climate change and promote CSA. Of relevance to CSA are the Support Programme for the Development of Agricultural Sectors (PADFA), the National Communication on Climate Smart Agriculture (NCCSA), the National Strategy for Disaster Risk Management (NSDRM), and the National Programme on Climate Change (NPCC). This non-exhaustive list of regional and national initiatives is implemented without categorizing households in terms of their capabilities. In addition, climate-smart agriculture practices must be contextual, and timely. Therefore, the analysis of the adoption and efficiency of climate-smart practices makes sense in this research.

In this way of thought, this chapter aims to assess the perception, adoption, and smartness of climate-smart agriculture practices in Cote d’Ivoire. By this objective, we contribute to the literature in three ways. Firstly, we provide a framework for streamlining household finance for climate change adaptation and resilience in Cote d’Ivoire. The country is characterized by low incomes and still embryonic systems for managing the external effects of pollution and climate control. Secondly, due to the challenges of the local community's perceptions of climate change and its threats (Rankoana, 2016) faced by scientists in assessing CSA, this research considers a wide range of CSA practices and deeply analyzes the adaptation determinants and the efficiency level.

In addition, with many interventions of introducing a variety of technologies and practices in the study area, there has been no published study that analyzes farmers’ adoption of CSAP in the study area. In addition, contrary to previous studies that evaluated CSAP through experts, this work provides results of the evaluation of CSAP by farmers, and this gives an understanding of how the final users of CSAP perceive the practices. In addition, this study deals with Moutouama et al., (2022) limitation by taking into account several socio-demographic characteristics, which allows us to have a larger analysis of determinants

To this end, this chapter employs Zero-inflated Poisson regression and multivariate analysis using data collected from 461 farm households in the Hambol region in Cote d’Ivoire. In addition, we inventory 35 CSA practices, and the results reveal that access to climate and meteorological information, as well as funds, marital status, location (department), and education, are the main determinants of the choice of the number of adopted practices

The remainder of this chapter is organized as follows: section 2 states some statistics on the climate challenge of agriculture development in Cote d’Ivoire, section 3 gives an overview of the literature on the subject; Section 4 is devoted to a detailed description of the methodological approach used to achieve the above-mentioned objective. Finally, before concluding, the empirical results, their econometric analysis, and interpretations are presented in section 6.

1.2.Climate challenges of agricultural development in Côte d'Ivoire

Côte d'Ivoire, a leading agricultural economy in West Africa, faces significant challenges in sustaining its agricultural development amidst intensifying climate change. Agriculture, which contributes over 20% to the national GDP and employs most of the rural population, is heavily reliant on rainfed systems, making it particularly vulnerable to climatic variability. The country has witnessed shifts in rainfall patterns, increasing temperatures, and more frequent extreme weather events, such as droughts and floods, which directly threaten crop yields, livestock productivity, and food security. Staple crops like rice, maize, and yams, along with export-oriented cash crops such as cocoa and coffee, are increasingly at risk. Moreover, these climatic stresses exacerbate land degradation, reduce water availability, and heighten competition for resources. Addressing these challenges requires innovative and climate-resilient agricultural strategies, underpinned by effective policies and sustainable practices tailored to the unique socio-economic and ecological contexts of Côte d'Ivoire. This section states some statistics on the climate challenge of agricultural development in Côte d'Ivoire.

1.2.1. Employment in the agriculture sector

Figure 1 illustrates trends in agricultural employment in Côte d'Ivoire from 1999 to 2022, showing the percentage of total, female, and male employment in the sector. Over the years, the proportion of total employment in agriculture has generally declined, from around 48% in 1999 to 45.6% in 2022, indicating a gradual structural shift in the economy towards other sectors such as industry and services.

The data reveals notable gender disparities. Male employment in agriculture consistently remains higher than female employment, with men accounting for over 50% of agricultural employment throughout the period. In contrast, female employment shows a steady decline, dropping from approximately 46% in 1999 to 38.9% in 2022. This decline suggests that women are increasingly moving out of agriculture, potentially due to limited access to resources, mechanization, or greater opportunities in other sectors.

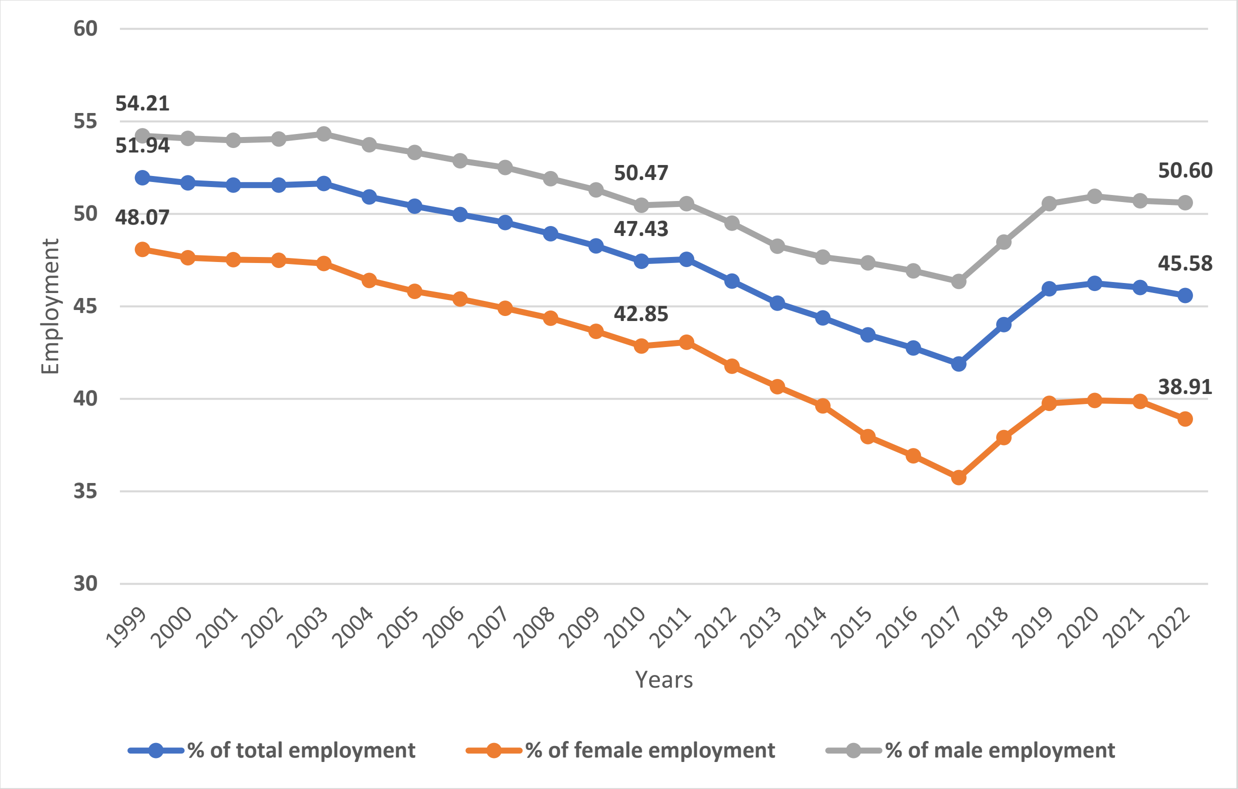

Figure 1: Trends in agricultural employment in Côte d'Ivoire

Data source: Word Bank, 2024

The dip in overall agricultural employment around 2016 and the subsequent recovery could be attributed to specific economic or climatic factors, such as market volatility or extreme weather events impacting agricultural livelihoods. Despite the recovery, female employment did not regain its earlier levels, which might indicate structural barriers or a lack of targeted interventions to support women in agriculture.

Overall, the trends highlight the need for gender-responsive policies that address the constraints women face in the agricultural sector, such as access to land, credit, and technology. Simultaneously, the gradual decline in agricultural employment underscores the importance of diversifying rural livelihoods and investing in sustainable practices to enhance productivity and resilience in the face of economic and climatic challenges.

Figure 2 depicts the proportion of land used for agricultural purposes as a percentage of total land area (blue bars) alongside the contribution of agriculture, forestry, and fishing to GDP as a percentage (orange line) in Côte d'Ivoire from 1999 to 2022. The agricultural land percentage shows a consistent upward trend, increasing from about 61.6% in 1999 to over 73% by 2022. This reflects an expansion in land dedicated to agricultural activities, likely driven by growing demand for food, export crops, and rural livelihoods. However, the intensification of agricultural land use raises concerns about deforestation, biodiversity loss, and sustainability, particularly in the context of climate change and environmental degradation.

On the other hand, the contribution of agriculture, forestry, and fishing to GDP (orange line) fluctuates over time. Starting at 15.2% in 1999, it peaked around 2004 at nearly 18% before generally declining, settling at approximately 15.7% in 2022. This divergence, rising land use but a relatively stagnant or declining GDP contribution, suggests diminishing returns to agricultural expansion. Possible reasons include low productivity, climate-related challenges, or structural changes in the economy, such as the growth of the industry and services sectors.

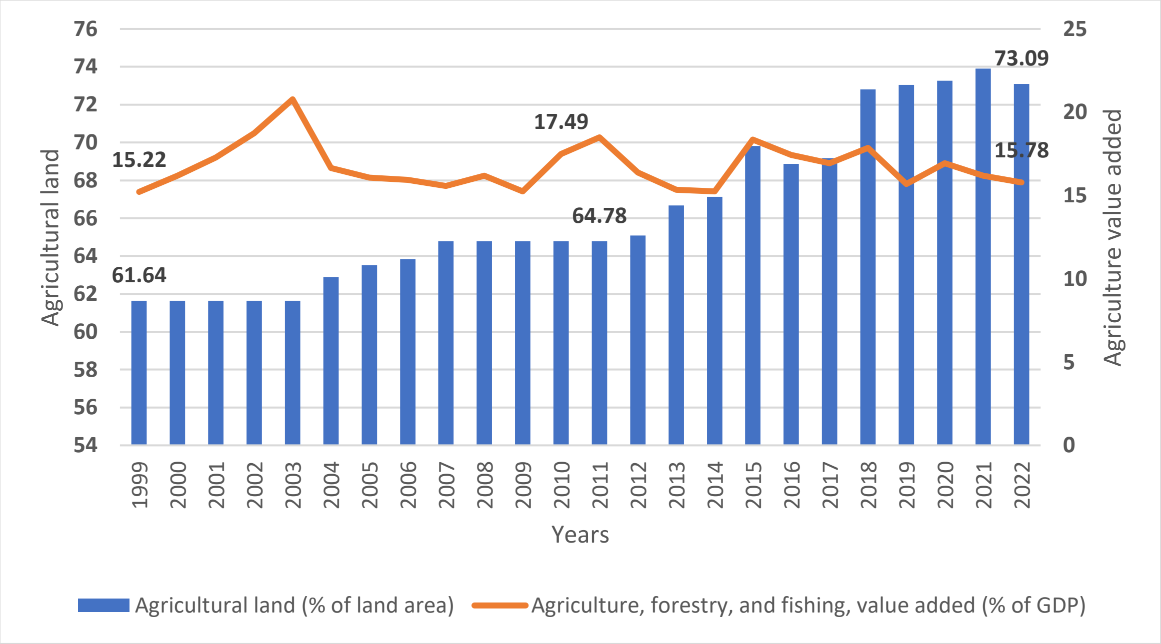

Figure 2: Agriculture's contribution to GDP

Data source: Word Bank, 2024

1.2.2. Climate change and agriculture productivity in Côte d'Ivoire

Figure 3 presents trends in agricultural yields (measured in tens of millions of tons) and average temperature (in degrees Celsius) in Côte d'Ivoire over several decades, from 1988 to 2022. The agricultural yield dynamic indicates a relatively consistent increase in yield over the years. This trend suggests advancements in agricultural practices, such as improved crop varieties, better farming techniques, or increased investments in the agricultural sector. However, periodic fluctuations might reflect the impacts of climate variability, economic factors, or shifts in market demand. The temperature trend represents the average temperature, showing a gradual increase over time. This trend aligns with global patterns of rising temperatures due to climate change. The consistent upward trajectory in temperature poses a potential threat to agricultural productivity, as higher temperatures can stress crops, reduce yields, and exacerbate pest and disease pressures.

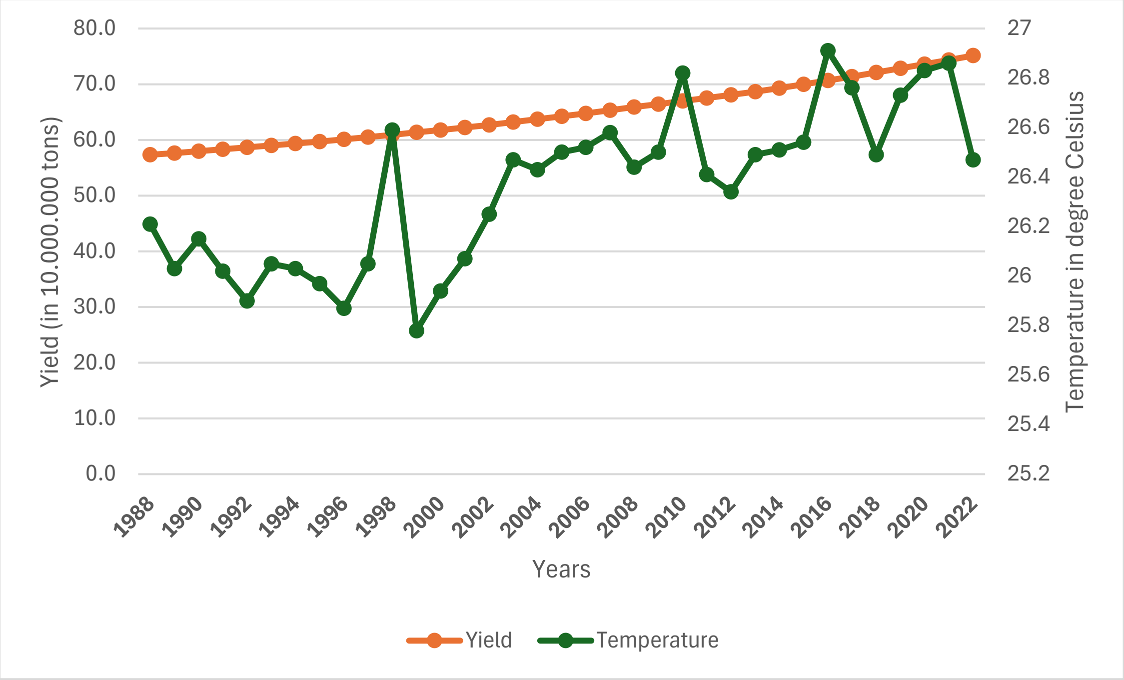

Figure 3: Trends in agricultural yields (measured in tens of millions of tons) and average temperature (in degrees Celsius)

Data source: FAOSTAT, 2025

The precipitation trend shows a gradual decrease over time (**Figure 4**). This trend aligns with global patterns of rising temperatures due to climate change. The consistent downward trajectory in precipitation poses a potential threat to agricultural productivity. While the yield has generally increased, the rising temperatures and decreasing rainfalls present challenges that could hinder further agricultural gains. The resilience of Côte d’Ivoire's agriculture may depend on its ability to adapt to these climatic changes. Without sustainable practices, the gap between yield growth and rising temperatures could widen, leading to long-term productivity losses

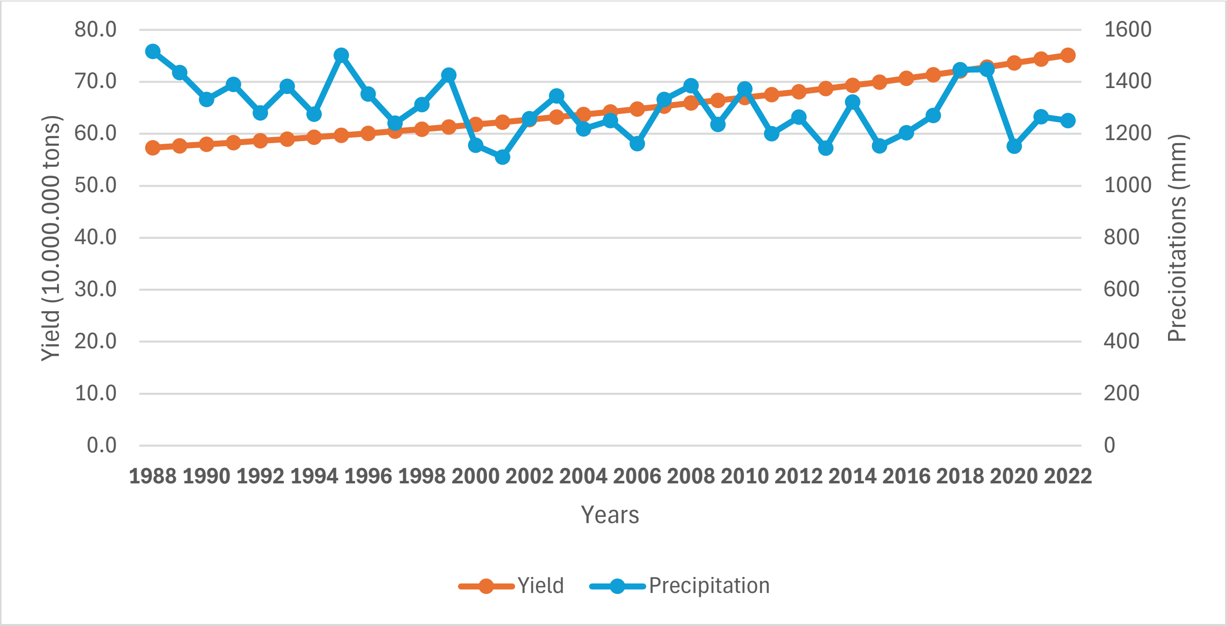

Figure 4: Trends in agricultural yields (measured in tens of millions of tons) and average precipitation (mm)

Data source: FAOSTAT, 2025

1.2.3. Challenges of climate-smart agriculture practices implementation

Climate-smart agriculture (CSA) practices have gained increasing attention worldwide due to their potential to enhance agricultural productivity, improve resilience to climate change, and reduce greenhouse gas emissions. Globally, approximately 9% of agricultural land, equivalent to about 1.5 billion hectares, is under conservation agriculture, one of the core practices of CSA. Precision agriculture, another vital component, is experiencing a growth rate of 12.6% annually and is projected to reach a global market value of $18.5 billion by 2030.

In Côte d'Ivoire, the adoption of CSA practices remains relatively low, with only 10-12% of farmers implementing techniques such as agroforestry and crop diversification as of 2020. However, efforts by the government and international organizations are gradually increasing awareness and adoption rates. Between 2018 and 2022, the Ivorian government allocated $150 million to CSA projects, aiming to train 1 million farmers and provide them with the necessary resources. Agroforestry has been instrumental in enhancing cocoa production, with yields increasing by 15-20% while simultaneously restoring degraded lands and improving biodiversity. Despite these promising developments, significant challenges persist in scaling up CSA practices in Côte d'Ivoire and beyond. Globally, annual investments in CSA need to reach $80 billion by

2030 to achieve food security and climate goals, yet current levels stand at only $20 billion. In sub-Saharan Africa, CSA financing accounts for less than 5% of total agricultural investments, reflecting a substantial funding gap. Private sector involvement in CSA projects is growing, particularly in West Africa, where companies are increasingly investing in sustainable cocoa and coffee production through public-private partnerships. However, these efforts must be significantly expanded to meet the challenges posed by climate change and ensure the widespread adoption of CSA practices.

The implementation of climate-smart agriculture (CSA) practices in Côte d'Ivoire faces several challenges, particularly in investment within the agricultural sector. Despite the recognition of CSA as a critical approach to enhancing agricultural productivity, resilience, and sustainability, the level of financial and institutional support remains insufficient. A major barrier is the limited public and private investment in research and development for climate-resilient crops and technologies. Farmers often lack access to the financial resources needed to adopt CSA practices, such as improved irrigation systems, soil management techniques, and climate-resistant seeds (Beddington et al., 2012). Additionally, access to credit and microfinance for smallholder farmers is often restricted due to high interest rates, lack of collateral, and inadequate financial infrastructure in rural areas (Kouakou et al., 2021).

Infrastructure deficits, such as poor road networks, limited storage facilities, and inadequate access to markets, exacerbate the challenges, making it difficult for farmers to profit from adopting CSA (Jayne et al., 2018). Furthermore, institutional weaknesses, including the lack of coordinated policies and limited extension services, hinder the dissemination of CSA knowledge and best practices to farmers. Many farmers remain unaware of CSA techniques or the long-term benefits they offer, partly due to a shortage of trained agricultural extension officers who could bridge the knowledge gap (Pretty et al., 2011).

Climate-smart agriculture also requires significant upfront investments in technology and training, which are often out of reach for small-scale farmers. The high costs of inputs like organic fertilizers, irrigation equipment, and renewable energy systems for farming further discourage adoption (Lipper et al., 2014). Additionally, the absence of strong public-private partnerships limits the scaling up of CSA initiatives.

Climate change itself poses a direct challenge to CSA implementation by increasing the uncertainty and risks associated with farming. Unpredictable weather patterns, such as erratic rainfall and prolonged droughts, complicate the planning and execution of CSA practices. These factors discourage investment, as both farmers and financial institutions perceive agriculture as a high-risk sector (Thornton et al., 2011).

1.3. State of the art on perception, adoption, and smartness of Climate-Smart Agriculture practices

The conflictual theoretical foundation of the studies on household climate adaptation and living conditions continues to fuel scientific curiosity and political debate (Atsiaya et al., 2023; Ayeni et al., 2023; Khosla et al., 2023). This growing interest is also found in specific subjects such as smallholders' perception of climate change, CSA adoption, and efficiency. Indeed, the lack of theoretical and empirical consensus is the catalyst for this perpetual debate.

Rogers & Ban (1963) discussed the diffusion of agricultural innovations, giving the theoretical framework for analyzing the impacts of adopting innovations in the agricultural system. These technological innovations play a crucial role in improving agricultural productivity, the well-being of producers, and the economy of the food sector (Chavas & Nauges, 2020). Endogenous growth theory sees technical progress as the ultimate driver of long-term growth (Pieri et al., 2018). Therefore, adaptation to climate change is designed to meet farmers' short-term (reducing vulnerability, improving productivity, and food security) and long-term (sustainable agriculture) expectations. The link between climate change-adaptation-vulnerability draws its theoretical foundations from the crossroads of the paradigms of externalities, innovative technology theory (acceptance, willingness to adapt, and diffusion), climate policy, green agriculture, and the capability concept, etc... The theoretical consensus of these paradigms on the gains of the climate policies that seek to increase adaptation or reduce the negative impact of different sources of climate externality (Aryal et al., 2021; Lokonon, 2019) involves the assertion that adaptation policy strengthens household capabilities in terms of productivity, mitigation, and food security. Furthermore, the decision to adopt CSA involves cognitive processes, such as mental accounting (Thaler, 1999), loss aversion (Kahneman & Tversky, 2013), and hyperbolic discounting (Laibson, 1997), which can lead to sub-optimal levels of adoption (Zilberman et al., 2012). In addition, adaptation to climate change can create negative externalities and redouble and shift vulnerability. These types of adaptation strategies are characterized as maladaptation strategies (Antwi-Agyei et al., 2018; Müller et al., 2017; Piggott-McKellar et al., 2020). The river water user for irrigation, upstream and downstream problems, and migrating to a sector from agriculture after selling the land can be a source of redoubling or shifting vulnerability. The river water user for irrigation, upstream and downstream problems, and migrating to a sector from agriculture after selling the land, can be a source of redoubling or shifting vulnerability. The excessive usage of river water for irrigation upstream can lead to reduced water flow downstream, causing water scarcity and affecting ecosystems and livelihoods dependent on the river. Additionally, when land is sold for non-agricultural purposes, it can disrupt traditional farming practices and further exacerbate vulnerability to water scarcity and shifting agricultural patterns. These possible expectations might limit adaptation levels influenced, firstly, by farmers' perception of climate change.

Climate change perception is a complex process that encompasses a range of psychological constructs such as knowledge, beliefs, attitudes, and concerns about if and how the climate is changing (Fierros-González & López-Feldman, 2021; Whitmarsh & Capstick, 2018). Perception is influenced and shaped, among other things, by the individuals’ characteristics (gender, education, age, main activity), their experience, the information that they receive, and the cultural and geographic context in which they live (Adeagbo et al., 2023; Moutouama et al., 2022; Rankoana, 2016). Recent studies found that public perceptions of risk are mostly influenced by cultural worldviews as opposed to empirical and theoretical data, and this is called the cultural theory of risk (Adger et al., 2013; McNeeley & Lazrus, 2014). Cultural theory applied in farmers’ perception of climate change can lead to different results in climate policy. Traditional weather forecasting is a method applied by many indigenous communities worldwide to forecast the weather and guide daily livelihood decisions and climate change adaptation measures (Abegunde, 2017). However, other indigenous people do not perceive the changes in climatic conditions. For instance, 81% of the community in Osun State (Nigeria) believed that climate change is a punishment of the gods (Abegunde, 2017) and 45% of the larger Makueni District (Kenya) believed that droughts were their traditional god’s plan and could not be mitigated (Speranza et al., 2010).

Adaptation strategies are a key means of adjusting to the losses and benefits in the agricultural sector as they relate to coping with the impacts of climate change (Skevas et al., 2022; Wouterse, 2018). In a world with perfect information, complete markets, and adequate incentives, the decision to adopt or implement a particular adaptation measure would simply be a matter of assessing the net benefits of that measure. This is contrary to the context in which smallholder and subsistence farmers in developing countries operate (Castells-Quintana et al., 2018), turning their adaptation decision into a non-automatic or bumpy process. Access to insurance or credit, weather information, property rights, and farmers' perceptions of climate change are some factors in adaptation decisions (Asfawa et al., 2016). Min et al. (2020) assessed farmers' perceptions of climate change in the Mekong region of southern China and showed that most households that had perceived temperature increases had also opted to adopt adaptation strategies.

Assessing CSA effectiveness through its impact on different households' livelihood indicators has been widely investigated empirically. The orthodox analysis underlined the positive impact of adaptation on different household indicators, such as productivity (Tadesse & Ahmed, 2023), food security (Lipper et al., 2014), income and poverty (Ogada et al., 2020), vulnerability to poverty (Aryal et al., 2021). The main thrust of these studies is that adaptation makes it possible to protect against the risks associated with the effects of climate change. Adaptation could improve soil fertility and soil management (use of organic fertilizer, crop rotation, use of soil analysis methods). It helps to against water stress (irrigation, use of improved seed), and plant pests.

Ndiritu & Muricho (2021) showed that adaptive strategies had a positive impact on farmers' food security; those who had not adopted these practices were more likely to be food insecure than those who had adopted them in Kenya. Jambo et al. (2021) showed that irrigation has a potential and positive impact on food security in Ethiopia among farmers in that country. These short-term ricochet effects are stimulating factors for poverty reduction. Thus, few studies underlined the smartness of CSA practices by jointly assessing the achievement of its three objectives (mitigation, adaptation, and productivity or food security). Adeagbo et al. (2023), Gabriel et al. (2023), Moutouama et al. (2022), and Rankoana (2016) suggested that farmers' partnership, sex, age, education, farming experience, farm size, access to credit, and climate information and perception are the main factors influencing the adoption and efficiency of multiple CSAPs. The current paper provides a framework for streamlining household finance for climate change adaptation and resilience in Côte d'Ivoire by considering a wide range of CSA practices and deeply analyzing the adaptation and efficiency level and their factors. This helps future research to overcome the challenges of the local community's perceptions of climate change and its threats (Rankoana, 2016) faced with previous issues in assessing CSA.

1.4. Research materials and methods

1.4.1. Study area and data collection.

The perception of climate change and adoption of climate-smart agricultural practices are both influenced by different factors such as physical vulnerability to climate change (PVCC), household characteristics, and environmental attitudes (Agarwal et al., 2022; Agbenyo et al., 2022; Koudjom et al., 2022). Despite households' environmental attitudinal being a subjective indicator, we used the regional distribution of the PVCC and agriculture households' size to choose the study area among the beneficiary regions of the PADFA program (Programme d'Appui au Développement des Filières Agricole). This program, financed by IFAD (International Fund for Agricultural Development), aims to strengthen smallholder farmers' resilience to climate change. Thus, the program gives new impetus to agricultural development projects that have traditionally focused on improving productivity, while investment in climate-smart practices and post-harvest activities remains low.

Bagoué, Gbêkê, Hambol, Poro, and Tchologo are administrative regions of the PADFA program. While they were selected based on their low productivity in rice, vegetables, and fruits, they are very different in terms of physical vulnerability to climate change. Indeed, Tchologo is identified as the most vulnerable region, and Bagoué is the least vulnerable (FERDI, 2020). Hambol region represents the second most vulnerable to climate change (50.74%). Despite being the second region with a high probability of being negatively affected by climate change, Hambol is a more agricultural region compared to Tchologo. Indeed, the Census of Farmers and Farms Agricultural (REEA, 2017) revealed that the number of farm households in Hambol was 40073, with 65% living in rural areas. The potential negative impacts of climate change within the two most vulnerable regions (Tchologo and Hambol) seem to severely threaten the Hambol population more than Tchologo, since the former is more agricultural and rural. This study is timely, given the urgent need to adapt to climate change. Thus, to provide a framework for optimizing the adoption and efficiency of CSA practices, it seems pertinent to analyze the factors explaining the perception and adoption of CSA practices in a predominantly agricultural and vulnerable region.

This research chose the Hambol administrative region of Côte d'Ivoire as the study site. The region is divided into three departments (Dabakala, Katiola, Niakaramadougou), nineteen sub-prefectures, 88 communal localities, and 213 non-communal localities. Covering an area of 19,122 km square, the Hambol region is in the north-central part of the country.

1.4.2. Sampling technique and sample size

The sample was designed to provide estimates for many indicators in CSA practices adoption and efficiency. Representativeness at the regional, departmental, sub-prefectural, and residential levels was built into the sampling process. In total, the region contains nineteen sub-prefectures, which were divided as soon as possible into two localities (communal and non-communal). The sample selection was based on a three-stage random stratification. This stratification was done to sort each department into sub-prefectures, the latter into localities, and samples were selected independently in each department by a two-stage selection process. In the first stage, 15 sub-prefectures were selected randomly as the primary sampling unit to represent the department size. At the regional and department levels, the sub-prefectures containing communal and non-communal localities were all selected after considering the representativity criterion. The units of these two first selections were mapped below, and the size was the breakdown of the farming households (REEA, 2017) and the population settling in that area during the population and housing census conducted in 2014. The sub-prefectures selected are mapped in **Figure 5**

Since the list of households to be served as the sampling frame is unknown, households were randomly selected in the third stage. In the third stage, a specific household number was selected in each locality. A total of n households was finally selected for the survey, out of which n_1 households were interviewed in the entire region, representing a response rate of $n_1/n * 100$ percent. To calculate n under an unknown population size, we used Cochran's sample size formula. With the margin of error $e = 5\%$, the confidence level Z is 1.96 for the two-tailed test and the default standard deviation p is fixed at 50%. Following recommendations by Johnson (1959), and Miller & Smith (1983) to take a random sample of 10-20% of non-respondents to use in non-respondent follow-up analyses, we account for the likely non-response by adding 20% of n to our sample. Therefore, the sample size is approximatively 461. The data collection involved different module questionnaires which were used to collect a series of information about the households. The first module centered on the household's socioeconomics, including demographics, education, and employment. The second module covered household perception of climate change while the third was focused on CSA practices.

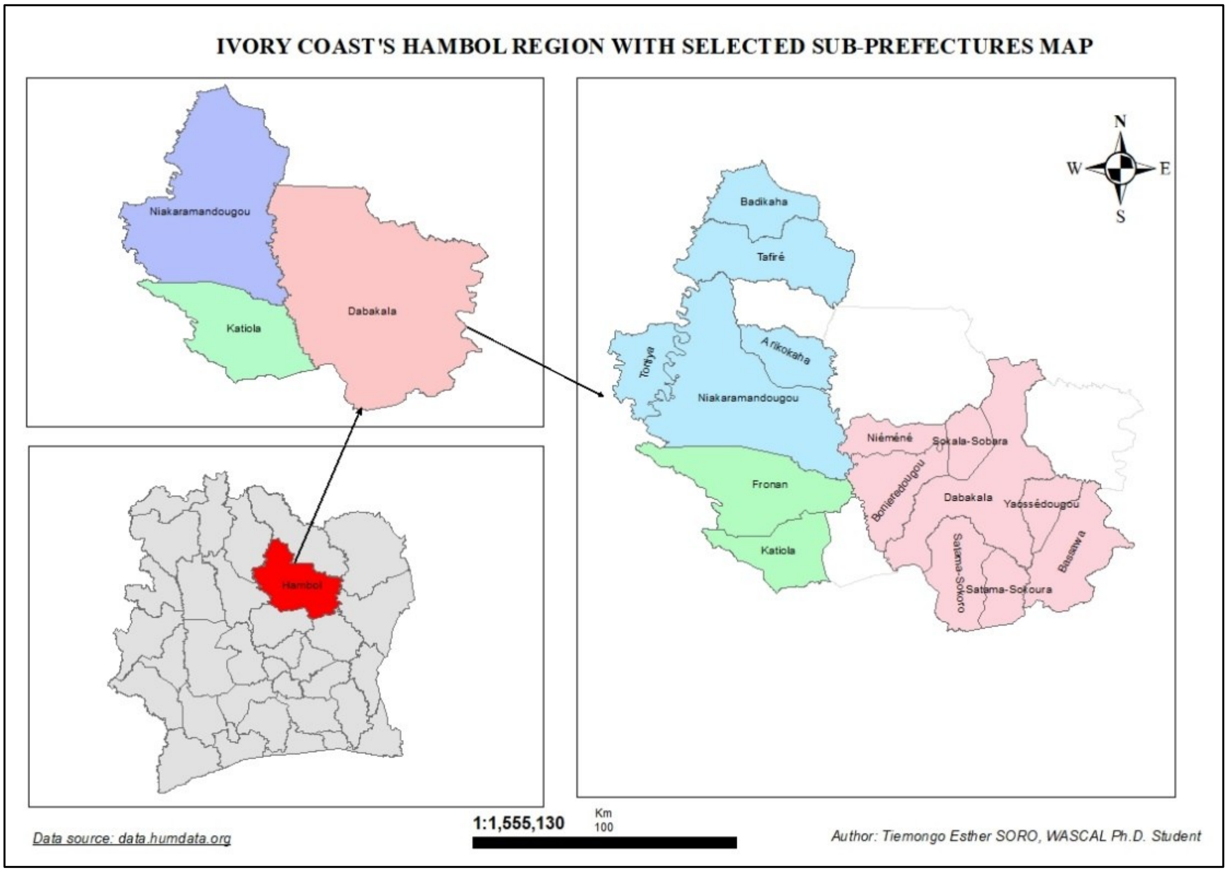

Figure 5: Maps of the study area

1.3.3. Estimating farmers' perception of climate change risks and adoption of CSAPs.

Climate change and variability risks, and their responses can be perceived through several factors such as precipitation, temperature, and meteorologic factors changes over time and farming practices (Khanal et al., 2018). Theoretically, by maximizing the expected utility, a risk-averse farmer i will decide to use the adaptation strategy j, if the expected utility from using the specific adaptation strategy is greater than the one, he/she could have gotten without taking any measure. Assuming that S_j is a nonempty and finite set of available adaptation strategies, a comparative behavior developed by Thurstone (1927) (Equation 1.1) and the probability of adopting strategy j (Equation 1.2), the observable variable which is the decision to adopt an adaptation strategy or not (Equation 1.3) can be rewritten as Equation 1.4.

$$E\big(U(S_1)\big) > E\big(U(S_0)\big) \tag{1.1}$$

$$U_i^* = \psi X_i + \varepsilon_i \tag{1.2}$$

$$U_i = \begin{Bmatrix} 1 \; if \; U_i^* > 0 \\ 0 \; Otherwise \end{Bmatrix} \tag{1.3}$$

$$\begin{gathered} U_{i1}^* = \psi_1 X_{i1} + \varepsilon_{i1} \\ U_{i2}^* = \psi_2 X_{i2} + \varepsilon_{i2} \\ \cdots \\ U_{ij}^* = \psi_j X_{ij} + \varepsilon_{ij} \end{gathered} \tag{1.4}$$

Where $E(U(S_1))$ and $E(U(S_0))$ are the expected utility from adopting strategies S1 and S0 respectively. Note that S0 indicates the absence of any adaptation measure. Ψ is a vector of parameters to be estimated and Xi is a vector of exogenous variables that could affect the farm household's choice of an adaptation strategy and ε stands for the error term. Finally, U_{ij}^* represents the probability that farmer i adopts strategies j.

In addition, the farmer can use more than one adaptation strategy. Therefore, considering the number of strategies adopted by farmers (NS_i) and over-dispersion or under-dispersion and zero excess in the data when dealing with count data we are estimating the n zero-inflated Poisson regression models. By breaking the response variable into two parts, the distribution function of the outcome variable can be stated as follows (Lambert, 1992):

$$NS_i = \begin{Bmatrix} 0 \text{ if farmer i did not take any adaptation strategy; with probability } p_i + (1 - p_i)e^{-\lambda_i} \\ k \text{ if farmer i has taken at least k adaptation strategies; with probability } (1 - p_i)\frac{e^{-\lambda_i}\lambda_,^{NS_i}}{NS_i}); k = 1,2,3, \ldots \end{Bmatrix} \tag{1.5}$$

The mean and variance of zero-inflated Poisson distribution are, respectively, as follows:

$$E(NS_i) = (1 - p_i)\lambda_i \tag{1.6}$$

$$V(NS_i) = (1 - p_i)(\lambda_i + \lambda_i^2)[(1 - p_i)\lambda_i]^2 \tag{1.7}$$

The adoption of more than one adaptation strategy to deal with climate change may suggest a complementarity or substitution effect within the chosen strategies (Ali, 2021). The multivariate model would help capture this behavior. An adaptation strategy j is adopted by the farm household i, if and only if that household perceives an increase in expected reduction of adverse climate impacts on his livelihoods. The utility behind the choice of strategy j is called latent variable. If the Sij stands for a binary response variable of the farm household in choosing strategy j (j = 1,

…, m) within a choice set of adaptation strategies, the probability that a set of responses on all j strategies $Ri = Si$ condition on column of parameters δ, the correlation matrix ξ, and the set of covariates Xij can be set as follows:

$$\Pr(R_i = S_i|\delta,\xi) \equiv pr(S_i|\delta,\xi) = \Lambda_{ij} \dots \Lambda_{i1}\varphi_j(t|0,\xi)dt \tag{1.8}$$

With $\xi = \begin{bmatrix} 1 & \eta_{12}\cdots & \eta_{1m} \\ \vdots & \ddots & \vdots \\ \eta_{1m} & \eta_{2m}\cdots & 1 \end{bmatrix}$;

$S_i = (S_{i1}, \dots, S_{ij})$

Λ_{ij} an interval such that $\Lambda_{ij} = \begin{cases} \left(-\infty,\ X'_{ij} \text{ if } S_{ij} = 1\right) \\ \left[X'_{ij}\delta, \infty\right) \text{ if } S_{ij} = 0 \end{cases}$

and $\varphi_{ij}(t|0,\xi)$ a density function of a j adaptation strategy assumed to be normally distributed. The multivariate probit model in the general form is given as follows:

$$R_{ij} = X'_{ij}\delta_j + \tau_{ij} \tag{1.9}$$

X_{ij} denotes the vector of exogenous predictors that could influence farmers' adoption of a particular farming practice, δ are the regression coefficients, and τ_{ij} stands for the error term.

Following this development, a multivariate probit (MVP) model was also employed to estimate the factors that influenced the perception of changes in multiple climate change factors among smallholder farmers in the study area. The rationale behind the choice of the MVP model is that the model can accommodate the simultaneous estimation of climate factors changes perception by farmers conditional on the explanatory variables. Furthermore, the model allows the error terms of each of the climate factor change perceptions to correlate with one another freely. The tenet of the multivariate model is that the error terms jointly follow a multivariate normal distribution (MVN), with zero mean and variance normalized to unity.

In this study, following Teklewold et al. (2013) and Ojo & Baiyegunhi (2020) we formulate a multivariate model that considers whether the *i*th farmer (*i* = 1,…, *N*) perceives or not the changes in at least one of the climate factors. Those factors are perception in temperature changes over 20 years (P1), perception in precipitation changes over 20 years (P2), perception in meteorologic conditions changes over 20 years (P3), and perception in long rain season changes over 20 years

(P4). Allowing for joint correlation of error terms enables the model to ascertain which climate risk change perceptions are substitutes or complements. Therefore, failure to accommodate correlations among these perceptions into the model will result in bias and inefficient estimates.

1.5. Empirical results

1.5.1. Descriptive results

Departmental repartition shows that 43.38% of surveyed households are from the DABAKALA district, while respondents in the NIAKARAMADOUGOU and KATIOLA districts represent 39.05% and 17.57% of the sample size, respectively **(Table 1)**. The geographic variable is important since the choice of CSA practices may depend on district characteristics and cultural aspects (Ali, 2021). Most of the farmers have at least a basic level of education. Approximately 55% of households' heads have attended at least a professional or alphabetization training. However, literacy is not negligible in the Hambol region regarding the percentage of household heads without education (45%). To assess the effects of different CSA adoption challenges, farmers were asked to report whether funds and facilities, technology defaults, lack of knowledge of practices, and meteorological information constitute any form of adaptation limitation.

On average, 67% of respondents consider funds and facilities as potential causes of increasing the number of CSA practices adopted. Found and facilities access, whether from formal or informal sources, would be a key determinant in explaining the choice of adaptation and the number of practices adopted to deal with climate change effects. Being informed about weather conditions and the existence of adaptation strategies is another key element in technology adoption for climate change adaptation. On average, 42% and 47% of farm households designed respectively the lack of knowledge of practices as an adaptation, and the lack of meteorological prevision information as an adaptation challenge.

Table 1: Descriptive Statistics: Categorical and dummy variables

Variables	**Modalities**	**Frequency (%)**
Education	Without education	45.12
	Professional and Alphabetization	8.03
	Primary	34.92
	Secondary and high-level	11.93
Matrimonial statue	Single	8.46
	Other	91.54
Main activity sector for household headed	Other activity branches	8.68

	Agriculture sector	91.32
Department	DABAKALA	43.38
	NIAKARAMADOUGOU	39.05
	KATIOLA	17.57
Gender	Male	97.61
	Female	2.39
Funds and facilities lack	Not selected	32.54
	Selected	67.46
Technology fault	Not selected	52.93
	Selected	47.07
Lack of knowledge of practices	Not selected	57.92
	Selected	42.08
Lack of meteorological prevision information	Not selected	53.15
	Selected	46.85
Did you hear about climate change?	No, I did not	27.98
	Yes, I heard	72.02

1.5.2. Households’ perception of climate change

Taking the changes in temperature, precipitations, long vegetation seasons, and short vegetation seasons over twenty years, we captured farm households’ perceptions of climate change. **Figure 6** shows that climate change is a phenomenon that is observed in the Hambol region. An investigation into farmers’ experience with eventual changes in rainfall or temperature patterns in the previous two decades shows that 95% and 89% of respondents have experienced respectively changes in these indicators. Moreover, 85.68% of respondents claimed that short vegetation seasons were modified over the two previous decades. Most farm households in Hambol opined that the long vegetation season (84%) has changed over the twenty years. These observations should not only retain policymakers’ attention but should more importantly call for early endogenous and other interventions through the adoption of new technologies to adapt to the new realities of the climate (Ali, 2021). Concerning the changes in temperature and precipitation, 24.27% and 77.52% of households’ heads, respectively declare to observe decreases in these factors. In contrast, 75.73% and 22.48% of households’ heads observed the increases in those factors. In sum, most households perceive a decrease in precipitation and an increase in temperature. However, it is important to note some households' perceptions of changes in precipitation and temperature may not always align with scientific predictions. Factors such as personal experiences, local weather patterns, and subjective biases can influence how individuals perceive and interpret changes in climate variables. Therefore, while most households may perceive a decrease in precipitation and an increase in temperature, it is crucial to consider scientific data and research to obtain a more accurate understanding of climate trends.

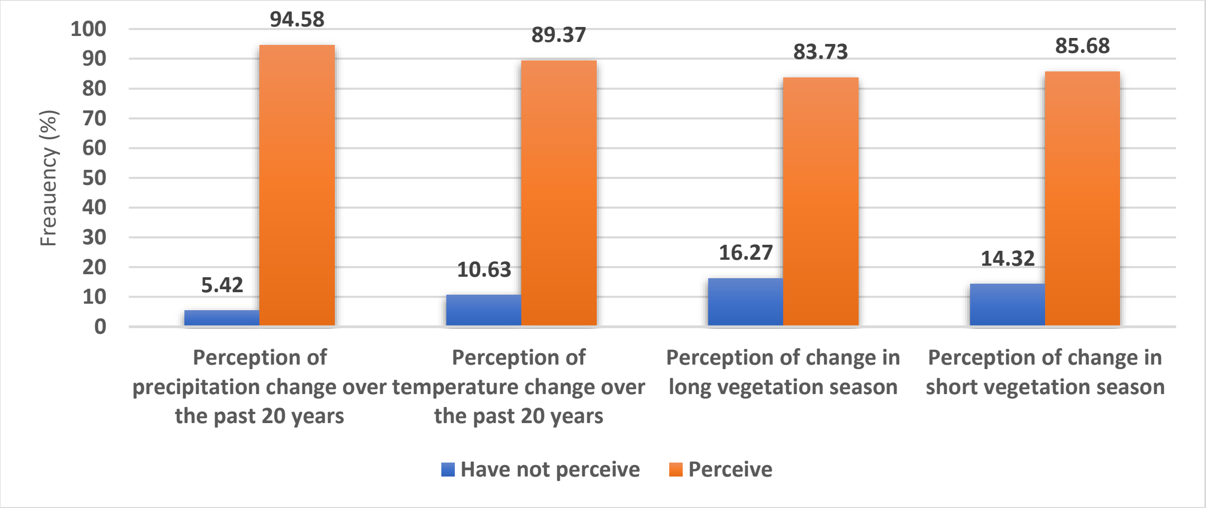

Figure 6: Frequencies of farm households' perception of climate change Hambol region

To understand climate change perception divers, we estimate jointly the probability for farmers to perceive the changes in temperature (P1), precipitation (P2), long rain season (P3), and short rain season (P4) over twenty years by using multivariate probit. The correlation coefficients, Rho_{i1}, Rho_{i2}, and Rho_{i3} indicate that different climate change factors perceptions are complementary (**Table 2**). Indeed, perceiving the changes in temperature increases the farmers' awareness of the modifications in precipitation (0.84), long rain season (0.504), and short rain season duration (0.57). These complementary perceptions of different climate change factors can be leveraged to develop comprehensive and effective climate change mitigation strategies. By recognizing the diverse perspectives and addressing the specific concerns associated with each factor, policymakers can create a more inclusive and impactful approach to tackling climate change. This holistic approach will not only increase the chances of successful mitigation efforts but also foster greater collaboration and cooperation among stakeholders. In addition, the results reveal that farmers' age, education level, and marital status constitute the factors positively associated with their climate change perception. An increase in the household-headed age and education level increases his probability of perceiving the change in climatic conditions. These results are statistically significant not align with Moutouama et al. (2022) conclusions in Benin's case. Authors, by applying the binomial generalized mixed effect models, the authors showed that no socio-demographic factor shapes farmers' perception of climate change in Benin Agro-Ecological Zone IV.

Table 2: Determinants of farm households' perception of climate change in the Hambol region

	(1)	(2)	(3)	(4)
VARIABLES	P1	P2	P3	P4
HH gender (ref: Male)				
Female	4.477	3.483	3.880	0.135
	(312.459)	(445.088)	(183.164)	(0.448)
HH age	0.010	0.016*	0.011*	0.007
	(0.007)	(0.009)	(0.006)	(0.006)
HH Education level (ref: without education)				
Professional and alphabetization	0.152	0.238	-0.349	-0.244
	(0.312)	(0.462)	(0.249)	(0.248)
Primary	0.321*	0.311	0.146	0.326**
	(0.182)	(0.223)	(0.163)	(0.164)
Secondary and high education	0.370	0.495	-0.220	-0.058
	(0.290)	(0.379)	(0.230)	(0.236)
HH marital status (ref: single)				
Married and other	0.046	0.868***	0.246	0.055
	(0.291)	(0.271)	(0.255)	(0.251)
HH principal activity sector (ref: non-agriculture)				
Agriculture	0.247	-3.278	-0.161	-0.039
	(0.314)	(136.172)	(0.284)	(0.275)
HH department (ref: DABAKALA)				
NIAKARAMADOUGOU	0.017	0.138	-0.371*	0.013
	(0.224)	(0.293)	(0.190)	(0.196)
KATIOLA	0.193	0.287	0.213	0.380**
	(0.192)	(0.252)	(0.172)	(0.171)
Constant	0.241	3.096	0.359	0.518
	(0.563)	(136.172)	(0.511)	(0.501)
Observations	461	461	461	461
Rho$_{i1}$		0.841***	0.504***	0.571***
		(0.157)	(0.112)	(0.117)
Rho$_{i2}$			0.576***	0.574***
			(0.127)	(0.107)
Rho$_{i3}$				1.282***
				(0.126)

Standard errors in parentheses; *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Note: perception in temperature changes over 20 years (P1), perception in precipitation changes over 20 years (P2), perception in long rain season changes over 20 years (P3), perception in short rain season changes over 20 years (P4)

1.5.3. Climate change and farm households' technology adoption

Table 3 shows the frequencies of use and subjective efficiency of CSAP. Thirty-five (35) Climate-Smart Agriculture Practices (CSAP)/technologies were compiled from the previous studies (Moutouama et al., 2022) and the Food and Agricultural Organization (FAO) site. **Table 4** compilates the five most used, effective, and the five least used technologies. Solar storage or drying (69.63%); crop rotation (63.77%); intercropping (54.44%); use of no-till technology (35.14%); and agroforestry (32.1%) appeared to be the five most used practices in the study area. Among agricultural practices, only crop rotation and intercropping practices were used by more than 50% of farmers in the Hambol region. Use of soil analysis procedures (4.12%); irrigation (6.72%); drainage (8.03%); and transition from crop to livestock farming (8.68%) come as the fewer agricultural practices used by farmers in Hambol to address the adverse effects of climate change. Livestock practices appear to be used by fewer farmers in Hambol. Indeed, the frequencies of use illustrated in Table 3 show that there is no practice used by more than 10% of interviewed farmers. Agroforestry (32.1%) and forest protection (29.8%) practices are as importantly used as land use and intensification practices. Only three (03) practices were used by more than 50% of the interviewees and no CSAP was used by all the people. The rate of use ranges from 4.12% (Use of soil analysis procedures) to 69.63% (Solar storage or drying).

Additionally, farmers were asked to express how each practice impacts the three pillars (Food security/increased productivity, adaptation, and mitigation) of CSA. Farmers' opinion was collected and recorded into five dimensions (very high, high, less high, less low, and very low). The frequencies of these dimensions for each practice constitute the subjective efficiency. By adding very high and high modalities, according to the Hambol farmers, mechanization of certain crops (83.7%); improved livestock sales calendar (81.82%); agroforestry (76.35%), drip or sprinkler irrigation (71.43%), and solar-powered irrigation (71.43%) appear to be the five most efficient practices to reduce greenhouse gas emissions emission (mitigation). Agroforestry (85.81%), forest protection (78.52%), crop rotation (75.51%), development of rotational grazing and pasture restoration (75%), and intercropping (73.09%) practices for farm households in Hambol constitute the most efficient to adapt to climate change. To improve food security or agriculture productivity, the five most efficient practices are the optimization of the stocking rate (head of cattle per hectare) (81.82%); agroforestry (81.75%); intercropping (80.26%); crop rotation (77.9%); deep urea fertilization (76.47%). Agroforestry constitutes the only CSA practice appearing among the five most used, and efficient for the three pillars. Intercropping and crop rotation practices come in five more used, and subjective efficient for two pillars (Food security/increased productivity, and adaptation).

1.5.4. Determinants of the number and choice of adopted adaptation practices.

Figure 7 shows the left-distributed function of the number of CSAP used by farmers in the study area. Using CSAP to adapt to climate change has become important for agricultural households. The results indicate that only 1.3% of farm households have taken no measure against climate change. Several reasons were given by farmers who were not able to implement CSA practices. The common reasons are linked to the lack of meteorological information, lack of knowledge of CSA practices, lack of water, lack of technical knowledge (technology), lack of funds, and improved seeds. These conclusions are consistent with Ali, (2021). At least 89.89% of households have used more than one and less than ten strategies to adapt to climate change in farming (Figure 2). Adopting several strategies may suggest substitution or complementarity between the practices adopted. Despite the literature underlining that the number adopted by each household may depend on its socio-economic characteristics, the expected farmers' technical efficiency can lead them to increase the number of adopted strategies (Khanal et al., 2018).

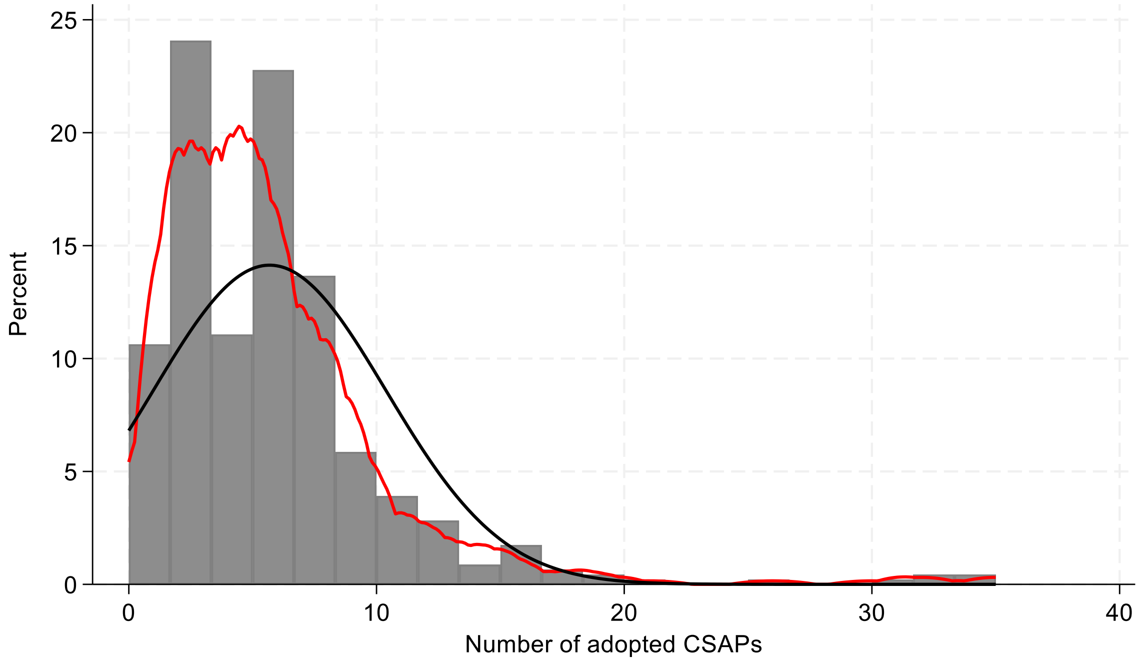

Figure 7: Average number of adaptation strategies adopted by farm households.

Table 3: Implementation and efficiency of adaptation strategies in Hambol region

Climate-smart agriculture practices		**Adoption**	**Subjective efficiency**								
CSAP	**CSA Practices full name**	**The use of CSAP (%)**	**Food security/increased productivity**			**Adaptation**			**Mitigation**		
			Very high	**High**	**Lower**	**Very high**	**High**	**Lower**	**Very high**	**High**	**Lower**
Agricultural practices											
P1	Improved seeds	18.66	20.93	53.49	15.12	12.79	39.53	34.88	8.14	37.21	43.02
P2	Intercropping	50.54	12.45	67.81	14.16	10	63.09	17.17	8.58	57.94	22.32
P3	Crop rotation	63.77	13.95	63.95	13.95	11.56	63.95	1.95	11.56	58.84	18.03
P4	Use of soil analysis procedures	4.12	0	36.84	26.32	0	26.32	26.32	0	31.58	21.05
P5	Reduce excessive application of nitrogen fertilizers	20.17	2.15	47.31	26.88	1.08	51.61	22.58	1.08	50.54	26.88
P6	Expand the use of soil amendments (manure, compost, crop residues, lime, biochar, and various inoculations)	15.62	8.33	40.28	31.94	4.17	51.39	20.83	4.17	48.61	30.56
P7	Changing crops	17.79	1.22	52.44	24.39	2.44	57.32	13.41	0	48.78	34.15
P8	Develop the use of new pest control practices	27.33	5.56	47.62	32.54	5.56	48.41	23.81	3.97	46.03	27.78
P9	Incorporation of crop residues into paddy soil	20.39	4.26	38.3	26.3	6.38	30.85	32.98	3.19	41.49	25.53
P10	Deep urea fertilization	18.44	10.59	65.88	16.47	2.35	70.59	17.65	0	63.53	20
P11	Development of water storage and management processes	10.2	17.02	38.3	34.04	12.77	27.66	27.66	2.13	34.04	34.04
P12	Use of no-till technology	35.14	19.75	44.44	22.84	20.99	37.65	19.14	20.37	31.48	21.6
P13	Irrigation	6.72	16.13	48.39	19.35	16.13	38.71	25.81	12.9	41.94	16.13
P14	Drainage	8.03	18.92	51.35	16.22	16.22	45.95	24.32	13.51	43.24	21.62
P15	Transition from crop to livestock farming	8.68	2.5	30	50	2.5	35	47.5	2.5	27.5	42.5
Livestock practices											
P16	Improvement of breeding systems (breed selection and management of breeding or insemination periods)	7.38	2.94	35.29	35.29	0	32.35	32.35	0	35.29	32.35
P17	Intensification of forage production	2.17	0	50	50	0	60	40	0	60	0
P18	Increased use of feed processing	4.77	0	17.55	36.36	0	45.45	36.36	0	43.48	39.13
P19	Optimizing feed composition and switching to diets	4.99	4.35	65.22	21.74	4.35	47.83	30.43	0	60.87	30.43
P20	Integration of livestock and crop systems	4.99	0	60.87	26.09	0	56.52	17.39	4.76	47.62	26.19
P21	Improved animal health monitoring and disease prevention	9.11	16.67	52.38	21.43	11.9	45.24	23.81	0	40	32
P22	Improved timing of livestock sales	5.42	0	36	36	0	36	40	0	81.82	18.18

P23	Optimization of stocking rates (livestock per hectare) by	2.39	0	81.82	18.18	0	72.73	18.18	10	60	30
P24	Development of rotational grazing and pasture restoration	4.34	15	50	30	0	75	15	2.78	47.22	19.44
Land use and intensification											
P25	Runoff control techniques	15.62	8.33	47.22	23.61	6.64	48.61	15.28	4.55	40.91	27.27
P26	Flood irrigation	4.77	22.73	40.91	18.18	13.64	50	18.18	0	60	10
P27	Drip or sprinkler irrigation	2.17	0	60	20	0	60	10	14.29	57.14	0
P28	Solar-powered irrigation	1.52	14.29	57.14	14.29	14.29	57.14	0	14.29	57.14	14.29
P29	Agricultural mechanization	8.46	17.94	43.59	28.21	12.82	48.72	17.95	0	41.03	25.64
P30	Forest protection	29.28	13.33	60	18.52	18.52	60	17.04	21.48	62.22	8.15
P31	Agroforestry	32.1	24.32	57.43	14.86	28.38	57.43	8.78	24.32	52.03	8.78
Harvesting and processing loss management practices											
P32	Solar storage or drying	69.63	10.59	55.76	23.05	8.72	54.52	26.48	6.54	49.22	27.1
P33	Mechanization of certain crops	8.46	20.51	46.15	23.08	12.82	35.9	28.21	0	28.21	25.64
P34	Improved storage and packaging	32.1	9.46	47.3	22.97	6.76	52.03	24.32	4.73	47.3	27.7
P35	Using plant waste	12.15	16.07	42.86	21.43	8.93	50	17.86	3.57	46.43	14.29

Table 4: Classification of the top 5 CSAP by the frequency of use and agreement for each CSA pillar

Rank	Greenhouse gas emissions mitigation/decrease	Adaptation	Food Security/productivity increase	Most adopted	Least adopted
1	Mechanization of certain crops	**Agroforestry**	Optimization of the stocking rate (head of cattle per hectare)	Solar storage or drying	Use of soil analysis procedures
2	Improved livestock sales calendar	Forest protection	**Agroforestry**	**Crop rotation**	Optimization of stocking rates: head of cattle per hectare Intensification of forage production
3	**Agroforestry**	**Crop rotation**	**Intercropping**	**Intercropping**	Drip or sprinkler irrigation
4	Drip or sprinkler irrigation	Development of rotational grazing and pasture restoration	**Crop rotation**	Use of no-till technology	Solar-powered irrigation
5	Solar-powered irrigation	**Intercropping**	Deep urea fertilization	**Agroforestry**	Use of soil analysis procedures

To capture the determinants of the number of adopted strategies, we perform the zero-inflated Poisson regression and illustrate the results in **Table 5.** The geographic location of farm households is a determinant of the choice of the number of implemented adaptation strategies. Indeed, the expected number of adopted strategies by a farmer in the NIAKARAMADOUGOU and KATIOLA departments is likely to increase compared to a farmer located in the DAKALA department. The results also show that the marital status of the household head is an important factor. Married and other marital status household heads are likely to adopt more adaptation strategies to reduce risks and avoid starvation compared to singles. Similar results were found in Togo, where married household heads are likely to increase the adopted strategies (Ali, 2021) Household head education level and household size are also the accelerator factors in increasing the number of adopted strategies. However, the lack of funds and knowledge of CSA practices is likely to limit the number of adopted strategies.

The inflated model shows that if the subjects were to increase the number of adopted technologies by one point, the probability that women would be in the non-adopters' group would increase. It indicates that male household heads are more likely to adapt to CC compared to females.

The determinants of the choice of the five most adopted practices are assessed by applying the multivariate Probit model, and the results are illustrated in **Table 6**. The arrival of an additional member in the household increases the probability of adopting more practices (Table 5) and of practicing crop rotation (Table 6). The first finding can be explained by the fact that subsistence farming is the main source of income for Hambol households. Inconsistent with the findings of Khanal et al. (2018) in the case of Nepal and Ali (2021) for Togo, this result highlights the efforts made by farmers to increase their productivity and income to maintain the same standard of living with the advent of a new member. The higher level of education of the head of household, his marital status compared to that of a single person, and his involvement in agriculture as a main activity compared to those involved in other activity sectors, increase the likelihood of households adopting a greater number of climate change adaptation strategies (Table 5). Deressa et al. (2011) also demonstrated that education can increase farmers' adaptive capacities, while male-headed households are likely to adapt to climate change compared to women. This evidence is that more educated people are exposed to climate change's adverse impacts on their activities and tend to adopt resistant and high-yielding technologies. Among the most adopted technologies in the study area, higher education tends to increase agroforestry adoption, one of the five climate-smart practices according to farmers.

Table 5: Determinants of the number of adopted technologies: Zero-inflated Poisson regression analysis.

VARIABLES	(1) ZIP regression	Std. errors
HH size	0.024***	(0.003)
Lack of funds (ref: no lack)		
1. Lack	-0.137***	(0.048)
Technology default (ref: no default)		
1. Default	0.183***	(0.051)
Lack of Knowledge of CSA (ref: no lack)		
1. Lack	-0.171***	(0.050)
Lack of meteorological information (ref: no lack)		
1. Lack	-0.064	(0.050)
Knowledge of climate change (ref: don't know)		
1. Known	0.016	(0.049)
HH age	0.000	(0.002)
HH Education level (ref: without education)		
1. Professional and alphabetization	-0.087	(0.077)
2. Primary	0.082*	(0.047)
3. Secondary and high education	0.117*	(0.069)
HH marital status (ref: single)		
1. Married and other	0.577***	(0.117)
HH principal activity sector (ref: non-agriculture)		
1. Agriculture	0.172**	(0.075)
HH department (ref: DABAKALA)		
1. NIAKARAMADOUGOU	0.337***	(0.066)
2. KATIOLA	0.839***	(0.054)
	0.398**	(0.170)
Inflate		
HH gender (ref: Male)		
Female	3.423**	(1.745)
Climate change perception index	3.954**	(1.946)
Constant	-6.084***	(1.290)
Observations	461	

*** p<0.01, ** p<0.05, * p<0.1

The results illustrated in Table 6 show the partial statistical correlations between some CSA practices. Results from the multivariate probit model show that all correlation coefficients between the most used adaptation practices are positive, and some are statistically significant. This implies that the implemented measures to deal with climate change are correlated. The positive sign of different coefficients suggests a complementarity between the most adopted adaptation strategies. Implementing more than a single adaptation strategy would lead a farm household to smooth its consumption needs and avoid starvation due to climate uncertainty.

Table 6: Determinants of adoption of the five most used adaptation strategies

VARIABLES	(1) CSA32	(2) CSA3	(3) CSA2	(4) CSA12	(5) CSA11
HH size	0.012	0.033**	0.012	0.012	-0.005
	(0.013)	(0.013)	(0.013)	(0.012)	(0.014)
Lack of funds (ref: no lack)					
1. Lack	-0.645***	0.014	0.016	-0.170	0.213
	(0.176)	(0.157)	(0.161)	(0.165)	(0.170)
Technology default (ref: no default)					
1. Default	0.621***	-0.128	-0.003	0.516***	0.472***
	(0.170)	(0.156)	(0.165)	(0.165)	(0.176)
Lack of Knowledge of CSA (ref: no lack)					
1. Lack	-0.198	-0.424***	-0.192	-0.285*	-0.030
	(0.171)	(0.156)	(0.161)	(0.162)	(0.166)
Lack of meteorological information (ref: no lack)					
1. Lack	-0.656***	0.583***	0.059	0.027	0.142
	(0.167)	(0.151)	(0.154)	(0.164)	(0.171)
Knowledge of climate change (ref: don't know)					
1. Known	0.256	0.154	-0.160	0.021	0.124
	(0.167)	(0.151)	(0.155)	(0.161)	(0.175)
HH gender (ref: Male)					
Female	-0.023	-0.491	0.538	0.142	0.757
	(0.481)	(0.411)	(0.397)	(0.435)	(0.475)
HH age	0.003	-0.002	0.008	0.009*	0.005
	(0.006)	(0.005)	(0.005)	(0.005)	(0.006)
HH Education level (ref: without education)					
1. Professional and alphabetization	-0.164	-0.269	-0.094	-0.078	0.258
	(0.252)	(0.234)	(0.256)	(0.247)	(0.255)
2. Primary	0.185	0.028	0.088	0.164	0.509***
	(0.164)	(0.153)	(0.156)	(0.159)	(0.171)
3. Secondary and high education	-0.136	0.118	-0.028	-0.232	0.350
	(0.236)	(0.227)	(0.235)	(0.242)	(0.247)
HH marital status (ref: single)					
1. Married and other	1.475***	0.405	0.688***	0.508	0.099
	(0.291)	(0.268)	(0.260)	(0.362)	(0.331)
HH principal activity sector (ref: non-agriculture)					
1. Agriculture	-0.130	0.410*	0.626**	-0.224	0.355
	(0.264)	(0.237)	(0.271)	(0.237)	(0.250)
HH department (ref: DABAKALA)					
1. NIAKARAMADOUGOU	-0.412**	-0.826***	-1.499***	0.706***	0.732***
	(0.203)	(0.188)	(0.201)	(0.206)	(0.224)
2. KATIOLA	-0.114	-0.490***	-1.343***	1.516***	1.541***
	(0.185)	(0.176)	(0.178)	(0.191)	(0.198)
Constant	-0.448	-0.411	-0.815*	-2.112***	-2.750***
Observations	461	461	461	461	461

	(0.522)	(0.473)	(0.493)	(0.548)	(0.561)
Rho$_{i1}$		0.103	0.156*	0.328***	0.054
		(0.082)	(0.087)	(0.090)	(0.090)
Rho$_{i2}$			0.400***	0.230***	0.188**
			(0.083)	(0.081)	(0.086)
Rho$_{i3}$				0.276***	0.169*
				(0.088)	(0.088)
Rho$_{i4}$					0.200**
					(0.088)

Standard errors in parentheses; *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Note: CSA32 (Solar storage or drying); CSA3 (Crop rotation); CSA2 (Intercropping); CSA12 (Using no-till technology); CSA11 (Agroforestry)

The results show that there is a positive correlation between crop rotation, intercropping, and agroforestry. Theoretically, not only is this result approved to improve the sustainability of agriculture (Martin et al., 2016; Ryschawy et al., 2014; Thierfelder et al., 2018), but it also implies that combining these practices suggests a complementarity that may lead to higher expected utility from the farming business. Crop rotation and intercropping help to reduce soil erosion and compaction, while agroforestry helps to increase soil fertility and improve water infiltration. All these practices help to improve the overall sustainability of the agricultural system. They also help to reduce the number of resources needed to maintain productivity and increase crop yields. Additionally, these practices can help reduce the effects of climate change. Implementing crop rotation in organic farming systems led to increased soil fertility, reduced pest and disease pressure, and improved crop yields. Similarly, agroforestry practices, such as intercropping trees with crops, have been successful in providing multiple benefits such as improved soil structure, increased biodiversity, and enhanced water retention. Other studies found the substitution between adopted practices with similar methods (Aryal et al., 2021; Soglo & Nonvide, 2019). Indeed, Soglo & Nonvide (2019) found that there was a substitution between crop and livestock integration systems and the use of improved varieties and tree plantations among specific maize farmers in the coastal zone of Benin. Aryal et al. (2021) found a substitution between nonfarm adaptation strategies implemented by smallholder farmers in the case study of coastal Bangladesh.

1.6. Conclusion

The chapter assessed smallholder farmers' perception of climate change and Climate-Smart Agriculture (CSA) adoption factors and efficiency in the Hambol region in Côte d'Ivoire. The results revealed that in the Hambol region, farmers are aware of climate change. Thirty-five (35)

CSAPs were inventoried in the area, but most were less used by farmers (Twenty-five CSAPs were used by less than 20% of interviewees). There is a complementarity between farmers' perceptions of climate factors changes such as temperature, precipitation, meteorologic conditions, and long rain seasons over twenty years. The use of CSAP was determined by education level, gender, marital status, and departmental location. Even though most farmers are aware of climate change and could enumerate constraints linked to the lack of meteorological information, knowledge of CSA practices, water, technical knowledge (technology), funds, and improved seeds in the area, only a few CSAPs were widely used by farmers. This may be the result of a lack of knowledge that the CSAP could be effective for them. Even though most farmers agreed with the statement that CSAP increases crop productivity and income and contributes to adaptation and mitigation for almost all CSAP, the percentage of those who think that the impact of CSAP on the three pillars is very little is not negligible. Training on CSAP will help farmers to better understand the essential CSAP and how CSAP contributes to each CSA pillar. This is critical for the adoption of CSAP and will contribute to the increase in the area's resilience to climate change.

For a successful investment policy in climate change adaptation, access to meteorological information, knowledge of CSA practices, water, funds, and improved seeds would be key components. In addition, regular training of farmers (technical knowledge) on different practices and access to advisory services could enhance farmers' adaptive capacity and ensure the effectiveness of implemented practices. Future research on households' willingness to adopt might further provide incentive policies to accelerate the CSA practices adoption to sustain agriculture in Côte d'Ivoire.

Chapter 2: GENDERED IMPACT OF CLIMATE-SMART AGRICULTURE STRATEGIES ADOPTION ON FARM HOUSEHOLDS' FOOD SECURITY

Abstract

This second chapter examines the impact of Climate-Smart Agriculture (CSA) practices, particularly improved seeds, and intercropping on household food insecurity in Côte d'Ivoire. Using data from the 2018 Harmonized Survey on Living Conditions of Households (EHCVM-2018), the analysis employs an extended ordered probit model to account for selection bias and endogeneity in CSA adoption decisions. The results indicate that CSA adoption significantly influences food security outcomes, but its effects vary by gender and region. Female-headed households benefit more from improved seeds, increasing their probability of food security by 33.9%, while intercropping has a stronger positive effect for male-headed households, raising their food security probability by 47.3%. The combined adoption of CSA practices further improves food security, increasing the probability by 41.3% for the full sample, 29.7% for women, and 45.7% for men. To maximize the benefits of CSA and address existing disparities, several policy actions are necessary. Region-specific CSA strategies should be implemented, prioritizing drought. Policymakers must implement holistic approaches that combine CSA promotion with institutional and socio-economic support to create a more resilient and food-secure agricultural sector.

Keywords: CSA, Food insecurity, gender, adaptation

2.1. Introduction

Despite the potential positive impact of Climate-smart Agriculture (CSA) practices on reducing climate change risks and increasing agricultural food production, smallholder farmers' vulnerability remains high, and food insecurity is still growing in West Africa, particularly in Côte d'Ivoire (Affoh et al., 2022; Moutouama et al., 2022; Abegunde et al., 2022). However, these practices have been significantly adopted in Sub-Saharan Africa. Indeed, according to the climate business plan for Africa in line with the development of climate-smart agriculture, 63, 57, and 53% of the relative population among thirty-four sub-Saharan countries adopted, respectively climate-smart agriculture technologies on the improvement of livestock production: water management, and conservation agriculture (World Bank, 2018). However, the West African region has recorded a possible increase in food insecurity, with 57.3 million undernourished people in 2021, compared to 53 million in 2020, and 247.4 million people in a situation of severe food insecurity in 2021, compared to 237.2 million in 2020 (FAO, 2022).

Climate change, by increasing temperature and precipitation, hurts agricultural productivity. In addition, this occurs in a situation characterized by low land productivity and harsh weather conditions. That phenomenon results in low yield, food insecurity risk, and a higher probability of poverty (Herrera et al., 2018). Therefore, adaptation strategies are considered potential factors that can help households limit losses and damages related to climate change and ensure that the impacts will not overwhelm societies and ecosystems (Schipper, 2020). But planning adaptation is an exercise in uncertainty, and built on imperfect information, many adaptation strategies fail, and some go even further, creating conditions that worsen the situation. Thus, adaptation responses can also deliver maladaptive outcomes, resulting in lock-ins that could exacerbate future climate vulnerabilities (Antwi-Agyei et al., 2018).

Indeed, climate change could fall beyond farmers' experience, some studies draw attention to the possibility of maladaptation. These include the study by Pilo et al (2021) and Bazzana et al. (2022), who show that some strategies implemented by farmers to face climate risks may increase their vulnerability. Thus, climate change scientists' interest has shifted toward climate-smart agriculture practices. CSA practices are not only a strategy for farmers to increase their production, but they also contribute to the reduction of greenhouse gases from the agricultural sector and increase farmers' resilience to climate shocks. Abegunde et al. (2022) have shown that the main way to combat climate change is to engage in CSA practices and have also found that these practices have had a positive impact on the food security of farm households in South Africa. Ngigi & Muange (2022) highlighted CSA practices as key to curbing the threats posed by climate change to food security in Kenya. Etwire et al. (2022) showed that the proportion of farmers who adopted adaptive practices in Ghana had higher yields than non-adopters despite the temperature increase.

Given the importance of the mainstreaming of women in the agricultural sector and in the implementation of CSA practices, some authors have taken into account the gender approach to the implementation of CSA practices. Most studies conducted in Côte d'Ivoire have focused on assessing the level of food security between men and women, with an emphasis on the factors that influence it. Bazzana & Zhang's (2022) study has highlighted that CSA practices such as crop rotation and water conservation increase food security by increasing food availability, and self-sufficient food, food stability in Ethiopia, but this study omitted gender. Koudjom (2022) assessed the impact of these strategies on maize productivity in Togo using a couple of married men and women; he found that married women and men are more likely to increase their food security through increased food productivity than those who are not married. However, these studies did not assess the impact of women's adoption compared to men's on food security, which we believe is important as it could be a channel for policymakers to provide women with the means to increase their adoption of CSA practices because of the level of adoption which is still low in Cote d'Ivoire. Despite the potential of CSA innovations, many farmers are reluctant to adopt them. Existing evidence supports the fact that CSA adoption by rural farmers depends on climate perception and demographic characteristics. However, gender perspectives on CSA adoption are not sufficiently analyzed. Several studies that have integrated the gender factor in the adoption of CSA practices have focused more on the difference between the level of adoption of CSA by men and women. They have highlighted that the low level of adoption by women can be explained by a lack of knowledge about CSA, a lack of climate information, a lack of access to finance, and other socio-demographic factors (Abegunde et al., 2022; Bazzana & Zhang, 2022; Agarwal et al., 2021).

In this way of thinking, this research assesses the gendered impact of Climate Smart Agriculture strategies' adoption on farm households' food insecurity in Côte d'Ivoire. This chapter explores the impact of Climate-Smart Agriculture (CSA) practices, specifically improved seeds and intercropping, on household food insecurity in Côte d'Ivoire. Using data from the 2018 EHCVM survey, an extended ordered probit model corrects for selection bias and endogeneity in CSA adoption. Findings reveal that CSA significantly enhances food security, with effects differing by gender and region. Female-headed households gain the most from improved seeds, increasing food security by 33.9%, while intercropping benefits male-headed households more, raising their food security probability by 47.3%. Combining both practices further boosts food security, with overall increases of 41.3%, 29.7% for women, and 45.7% for men.

The remainder of this chapter is organized as follows: section 2 states some statistics on the food security in Cote d'Ivoire, section 3 gives an overview of the literature on the subject; Section 4 is devoted to a detailed description of the methodological approach used to achieve the above-mentioned objective. Finally, before concluding, the empirical results, their econometric analysis, and interpretations are presented in section 6.

2.2. Current situation on food security in Côte d'Ivoire

Côte d'Ivoire has made economic progress in recent years, but food insecurity remains a significant challenge, particularly in rural areas. Approximately 34.8% of the population lives below the poverty line, and regions in the north and central-west report stunting rates of around 30% due to chronic malnutrition (WFP, 2024). In 2024, cereal production reached 3.3 million tonnes, about 7% above the five-year average. However, despite this growth, around 922,000 people faced acute food insecurity during the lean season (FAO, 2024). Food access remains constrained due to climate shocks, price volatility, and regional conflicts. Additionally, the arrival of over 67,000 asylum seekers from Burkina Faso has further strained resources in northern communities (WFP, 2024).

To combat these challenges, Côte d’Ivoire has implemented initiatives such as the National Multisectoral Nutrition Plan, aiming to improve nutrition and reduce malnutrition. The World Food Programme (WFP) is also providing school meals to over 145,000 children and supporting smallholder farmers to enhance local food production (WFP, 2024). Despite these efforts, food insecurity persists, driven by poverty, climate shocks, and limited agricultural resources. Strengthening sustainable agriculture and nutrition-focused policies remains crucial for improving food security in the country. This section highlights some statistics on food security trends in Côte d'Ivoire.

2.2.1. Food security trends in Cote d’Ivoire

2.2.1.1. Food availability

The average dietary energy requirement for Côte d’Ivoire has shown a consistent upward trend over the years, increasing from 2,188 kcal per capita per day in 2000 to 2,245 kcal per capita per day in 2023 **(Figure 8**). This gradual rise reflects changes in the population's caloric needs, which could be driven by a combination of demographic growth, improved agricultural productivity, and shifts in dietary patterns. It may also indicate the increasing demands of a population experiencing economic growth, urbanization, and diversification in food consumption habits.

The data suggests progress in aligning food production and availability with the dietary needs of the population. However, meeting these rising energy requirements remains a critical challenge. Regional disparities persist, with rural areas and vulnerable groups often facing significant barriers to accessing adequate food. Factors such as poverty, food price volatility, and climate-related shocks exacerbate these challenges, leaving many households food insecure despite national-level improvements in dietary energy requirements.

Given the agricultural reliance of Côte d'Ivoire's economy, addressing these challenges requires a multifaceted approach. Investments in climate-resilient agricultural practices, improved food distribution systems, and targeted nutritional interventions are essential to ensure that all segments of the population can meet their dietary energy requirements. Policies aimed at increasing food availability must be coupled with measures to enhance affordability and access, especially for low-income and marginalized communities.

The steady increase in dietary energy requirements underscores the need for sustained efforts to bridge the gap between caloric needs and actual food consumption. This requires integrating food security strategies with broader socioeconomic development goals, ensuring that rising dietary needs are met without exacerbating inequalities or overburdening natural resources.

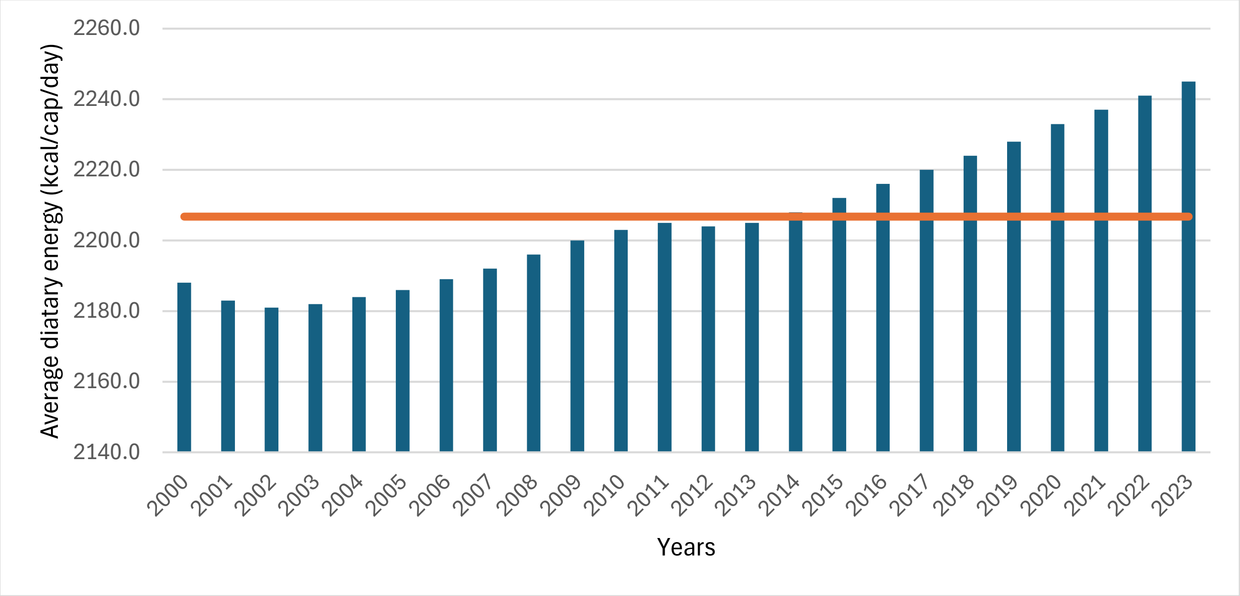

Figure 8: Trends of the average dietary energy requirement (kcal/cap/day)

Data source: FAOSTAT, 2025

2.2.1.2. Food accessibility

The prevalence of undernourishment in Côte d'Ivoire, illustrated in **Figure 9,** has shown a clear downward trend over the years, indicating significant progress in reducing food insecurity. From a high of 20.9% in the 2001-2003 period, the prevalence steadily declined to 9.6% by 2021-2023.

This reduction reflects improvements in agricultural production, food availability, and access, alongside economic growth and targeted interventions addressing food insecurity.

Notably, the decline in undernourishment was most pronounced between 2009-2011 and 2015-2017, when the prevalence dropped from 16.6% to 11.9%. This period coincides with increased national and international efforts to improve agricultural practices, enhance food distribution systems, and address poverty, particularly in rural areas. However, despite these gains, the prevalence slightly increased from 8.8% in 2019-2021 to 9.6% in 2021-2023, likely reflecting the impacts of global disruptions such as the COVID-19 pandemic and regional climate challenges.

While Côte d'Ivoire has made commendable progress in reducing undernourishment, the persistence of nearly one-tenth of the population still experiencing inadequate nutrition underscores the need for continued investments in sustainable agriculture, poverty reduction, and resilience-building against economic and climatic shocks. These efforts are crucial to ensuring that food security improvements reach the most vulnerable populations and remain resilient in the face of future challenges.

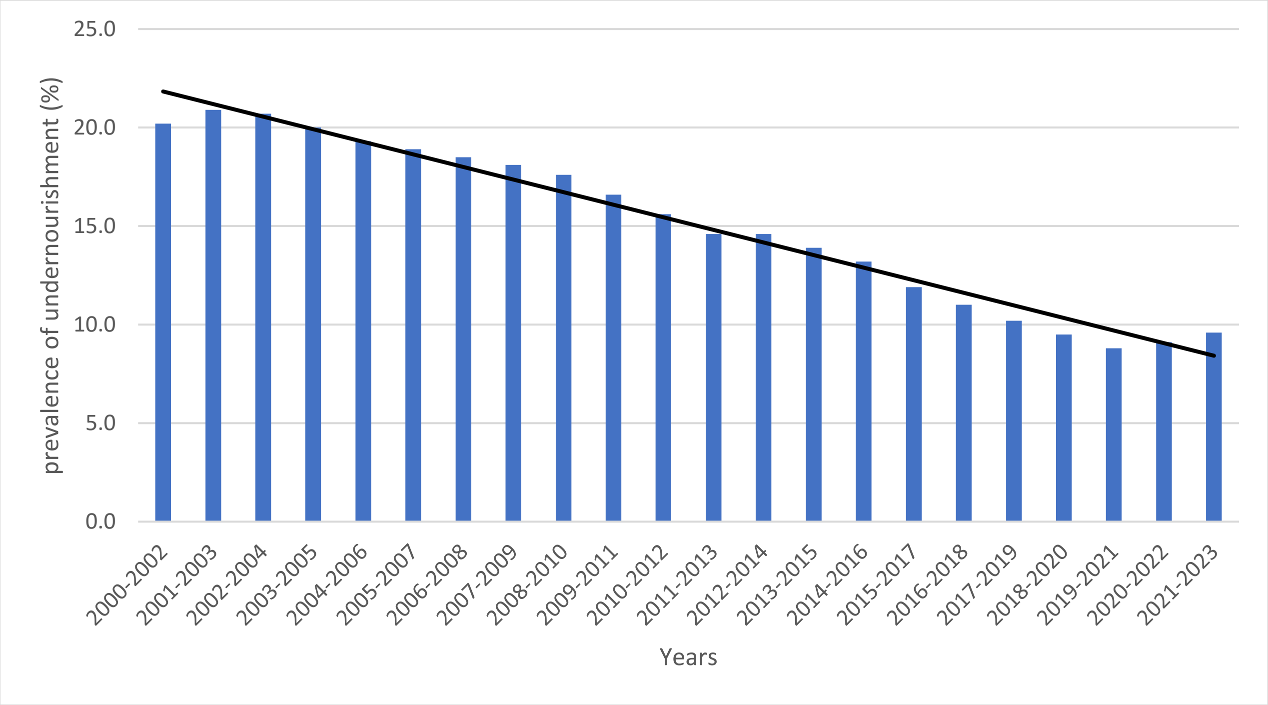

Figure 9: Trends of the prevalence of undernourishment (percent) (3-year average)

Data source: FAOSTAT, 2025

2.2.2.2. Food utilization

Access to safely managed drinking water and sanitation services in Côte d'Ivoire, illustrated in **Figure 10,** has shown gradual but significant improvement over the years, reflecting progress in public health infrastructure and basic service provision. The percentage of the population using safely managed drinking water services increased steadily from 23% in 2000 to 44% in 2022. This nearly doubled access indicates enhanced efforts to improve water infrastructure, expand coverage, and ensure quality standards in urban and rural areas.

Similarly, access to safely managed sanitation services, though progressing at a slower pace, also improved from 10% in 2000 to 17% in 2022. Despite this increase, the low overall percentage highlights a significant gap in sanitation coverage, particularly in rural and underserved communities. The disparity between water and sanitation access suggests a need for more targeted investments and initiatives to address the lag in sanitation facilities, which are critical for improving public health and reducing waterborne diseases.

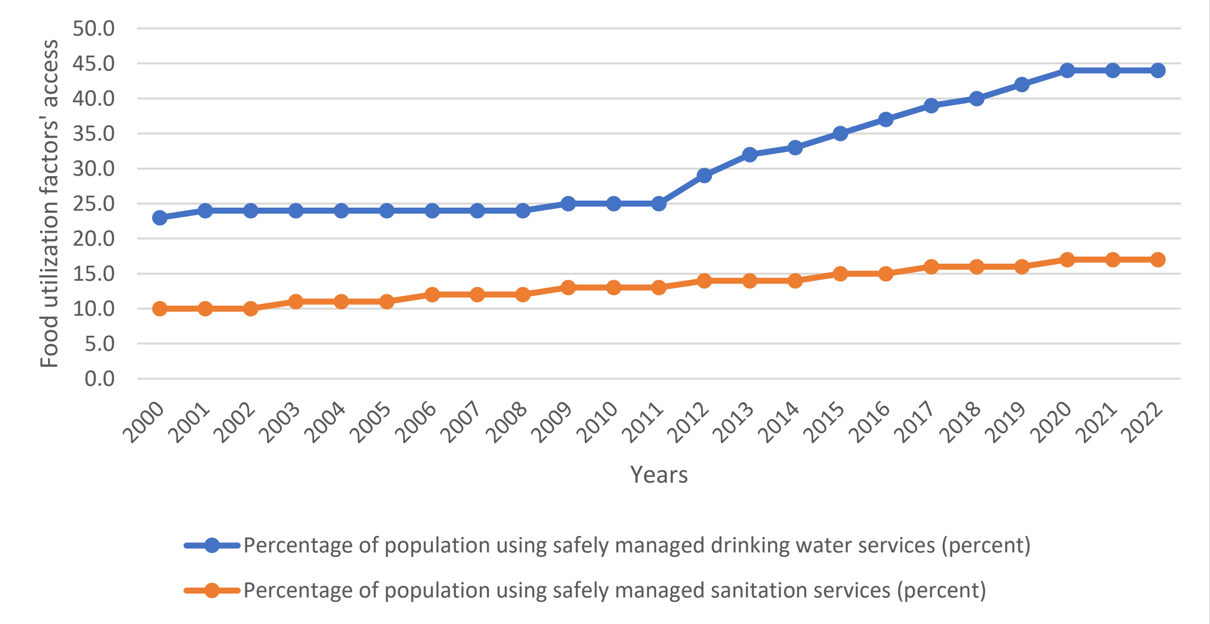

Figure 10: Trends of the population with access to safe drinking water and sanitation services

Data source: FAOSTAT, 2025

These advancements align with Côte d'Ivoire's commitments to the Sustainable Development Goals (SDGs), particularly Goal 6, which aims for universal access to clean water and sanitation by 2030. However, challenges such as population growth, urbanization, and climate change place additional pressure on existing infrastructure. To sustain and accelerate progress, the country must prioritize integrated water resource management, enhance sanitation service delivery, and strengthen community engagement to ensure equitable access for all, especially in marginalized areas.

The health and nutritional status of Côte d'Ivoire's population, particularly children and women, has undergone significant changes from 2000 to 2022, as indicated by **Figure 11**. The percentage of children under 5 years of age who are stunted has shown a marked decrease, dropping from 32.6% in 2000 to 20.2% in 2022. This decline highlights progress in addressing chronic malnutrition, likely due to improved healthcare access, nutrition programs, and efforts to combat poverty and food insecurity.

Conversely, the percentage of children under 5 who are overweight remained relatively low but stable, fluctuating between 4.9% in 2000 and 2.6% in 2022. While this may suggest limited issues with childhood overweight, the slight increase in recent years signals a need for continued monitoring of dietary habits and physical activity levels among children to prevent future health complications.

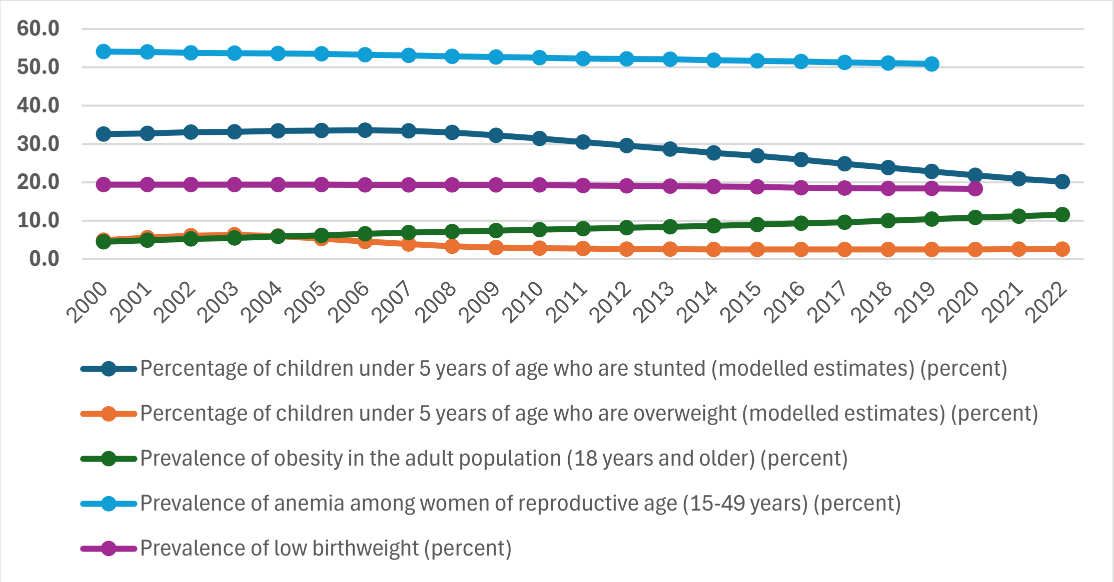

Figure 11: Trends of the health and nutritional status of Côte d'Ivoire's population

Data source: FAOSTAT, 2025

In adults, the prevalence of obesity has nearly tripled, rising from 4.5% in 2000 to 11.6% in 2022. This trend reflects shifting dietary patterns, urbanization, and sedentary lifestyles, emphasizing the need for public health campaigns promoting balanced diets and regular physical activity to prevent related non-communicable diseases.

The prevalence of anemia among women of reproductive age has seen only a modest decrease, from 54.1% in 2000 to 50.9% in 2019, indicating that anemia remains a persistent challenge. Factors such as limited access to micronutrient-rich foods, inadequate healthcare, and high rates of infectious diseases may contribute to this slow progress. Addressing anemia requires targeted nutritional interventions, including iron supplementation and education on dietary diversification. Lastly, the prevalence of low birth weight has gradually declined, from 19.4% in 2000 to 18.3% in 2020, suggesting improvements in maternal health and prenatal care. However, the rate remains high, underscoring the importance of continued focus on maternal nutrition and healthcare access to ensure better birth outcomes.

2.2.2.3.Food stability

The per capita food supply variability in Côte d'Ivoire from 2000 to 2023 shows significant fluctuations, reflecting the instability in food availability over time (**Figure 12**). Starting at 31 kcal per capita per day in 2000, variability rose to a peak of 38 kcal in 2002 before decreasing steadily to its lowest level of 4 kcal in 2009. This decline likely indicates improvements in food supply stability during the late 2000s, possibly due to better agricultural policies, increased food production, or enhanced distribution systems.

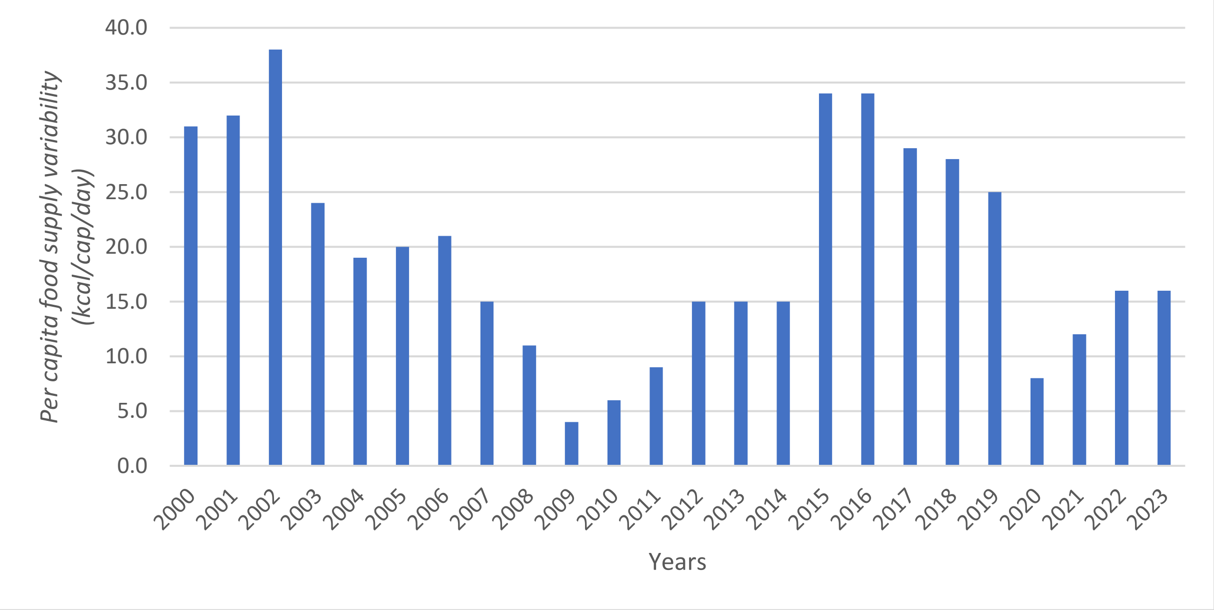

Figure 12: Trends of the per capita food supply variability (kcal/cap/day)

Data source: FAOSTAT, 2025

However, variability increased again in the mid-2010s, reaching 34 kcal per capita per day in 2015 and 2016, which could have been influenced by economic challenges, climate-related shocks, or disruptions in food systems. A subsequent decline to 8 kcal in 2020 suggests renewed efforts to stabilize the food supply, possibly aided by international support and government interventions. Nevertheless, the variability rose again to 16 kcal by 2022 and 2023, highlighting persistent vulnerabilities in the food supply chain.

The value of food imports as a percentage of total merchandise exports in Côte d'Ivoire has demonstrated relative stability over the years, with some fluctuations reflecting economic and trade dynamics (**Figure 13**). Between 2000 and 2007, this percentage remained steady at 9%, indicating a consistent balance between food imports and merchandise exports during this period.

Starting in 2008, there was a gradual increase, with the value reaching 11% by 2009-2011 and peaking at 13% in 2010-2013. This rise likely corresponds to growing food import needs driven by population growth, changing consumption patterns, or disruptions in domestic food production. Afterward, the percentage declined slightly to 10% in 2013-2015 but remained relatively steady at 11-13% from 2014 onward, reflecting continued reliance on food imports despite efforts to boost local agricultural production.

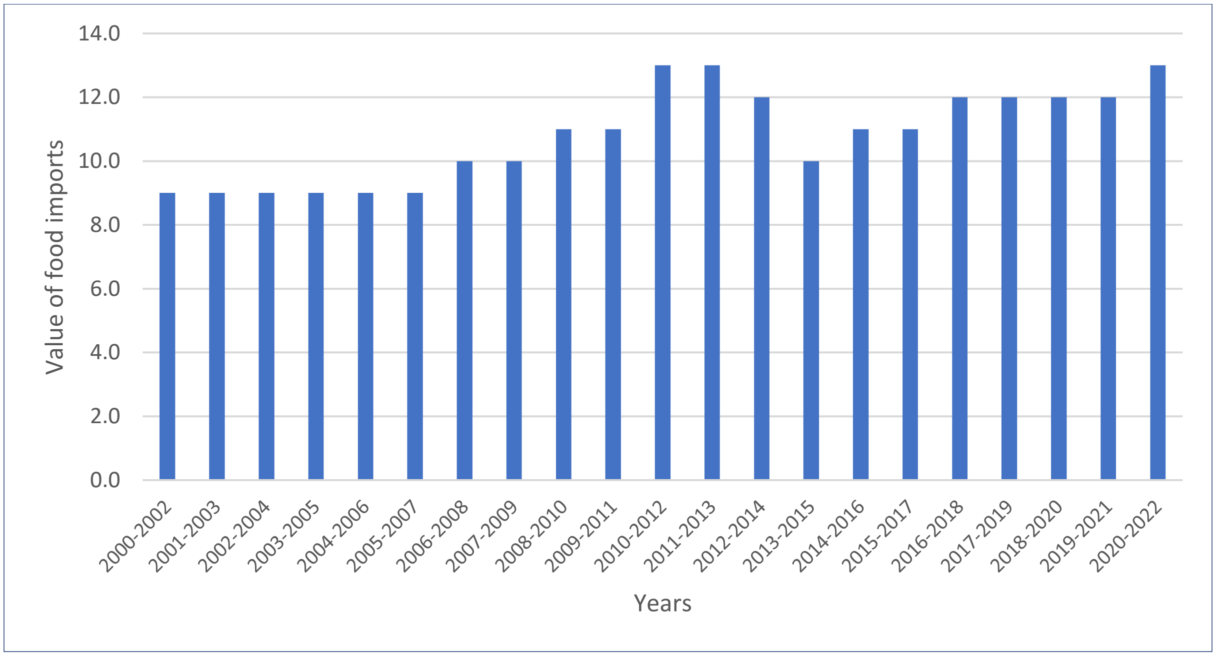

Figure 13: Trends of the value of food imports in total merchandise exports (percent) (3-year average)

Data source: FAOSTAT, 2025

These fluctuations underscore the ongoing challenges Côte d'Ivoire faces in ensuring consistent food availability for its population. Factors such as climate change, political instability, and global market dynamics likely play a role in driving variability. Addressing these issues requires sustained investment in climate-resilient agriculture, robust infrastructure for food storage and distribution, and policies aimed at reducing market volatility. Ensuring a stable food supply is critical for achieving food security and supporting the nation's overall economic and social development. The persistent proportion of food imports in total exports underscores the country's vulnerability to global trade and price fluctuations. A significant portion of merchandise exports is likely comprised of raw agricultural commodities, making the economy susceptible to external shocks. To address this, Côte d'Ivoire must prioritize agricultural diversification, invest in local food production capacity, and enhance value addition in export sectors. Reducing dependence on food imports is critical for achieving long-term food security and strengthening economic resilience.

2.2.2. Food insecurity in Côte d'Ivoire

2.2.2.1. Vulnerability of food sector in Côte d'Ivoire

The vulnerability of Côte d'Ivoire's food sector, illustrated in **Figure 14**, as measured from 1995 to 2021, highlights fluctuations influenced by various economic, environmental, and policy factors. Starting at 0.625 in 1995, the vulnerability index showed a slight decline until 1999, reflecting some resilience during this period. However, vulnerability began increasing from 2000, peaking at 0.660 in 2007-2008, possibly due to global food crises, regional instability, or climate-related challenges affecting agricultural output and food security.

After 2008, vulnerability fluctuated but generally trended downward, with significant improvements noted between 2012 (0.615) and 2014 (0.599). This period might align with increased investments in agricultural resilience, better governance, or favorable climatic conditions. However, progress plateaued in subsequent years, with the index stabilizing around 0.602 from 2017 to 2021, indicating persistent structural challenges in fully safeguarding the food sector from external shocks.

The variations in the food sector's vulnerability underscore the need for sustained efforts in enhancing resilience. Key measures include investing in climate-smart agriculture, improving food storage and distribution systems, and diversifying food production. Strengthening the agricultural value chain and implementing robust policies to mitigate the market and climate risks are critical for reducing the sector's susceptibility to future shocks.

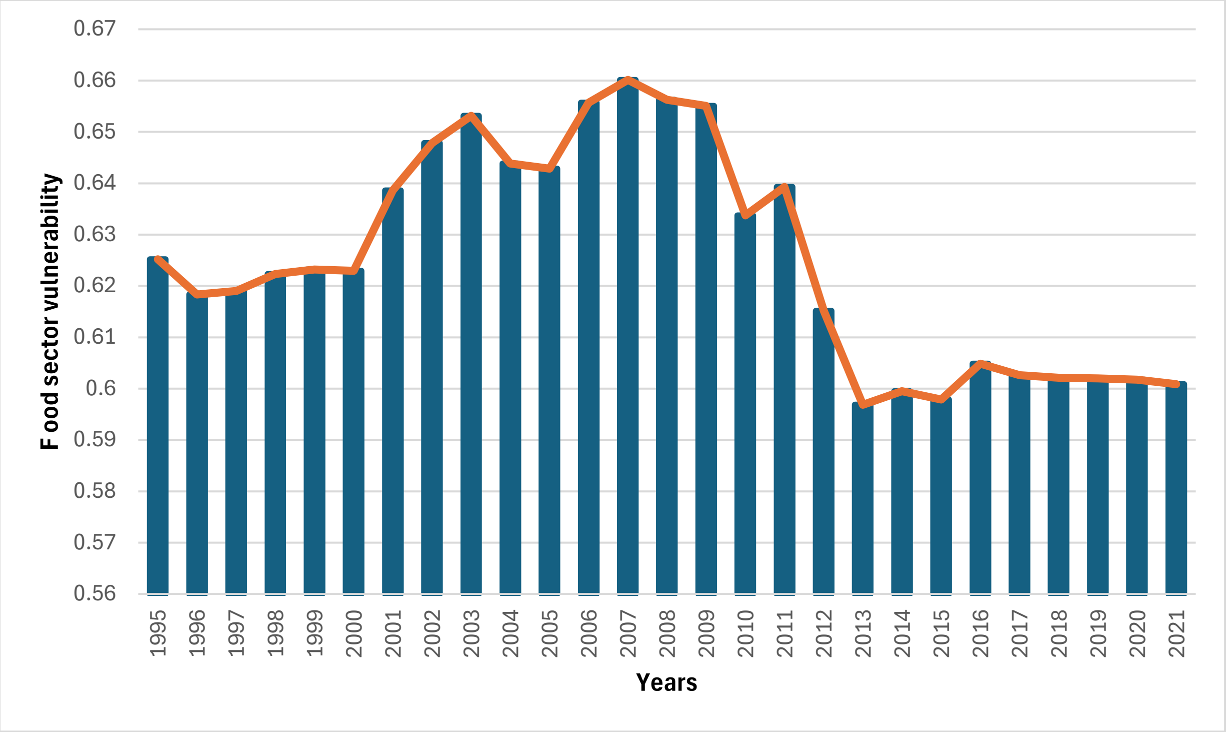

Figure 14: Trends of the food sector vulnerability

Data source: Notre Dame Gain, 2025

2.2.2.2. Food insecurity severity in Côte d’Ivoire

Figure 15 presents the prevalence of severe food insecurity in Côte d’Ivoire, based on a 3-year average, which shows a steady upward trend between 2014-2016 and 2020-2022, followed by a slight decline in 2021-2023. Among the female adult population, severe food insecurity rose from 6.3% in 2014-2016 to a peak of 9.5% in 2020-2022, before slightly dropping to 9.1% in 2021-2023. Similarly, the prevalence in the total population increased from 6.2% to 9.4% over the same peak period, with a decrease to 8.9% in the latest recorded period. Male adults show a comparable pattern, rising from 6.2% to 9.3% and then decreasing to 8.8%.

From 2014 to 2023, food insecurity in Côte d’Ivoire, both moderate/severe and severe, showed an upward trend with slight recent improvements (**Figure 16**). The prevalence of moderate or severe food insecurity among females rose from 34.0% in 2014-2016 to a peak of 40.9% in 2020-2022, before slightly decreasing to 39.4% in 2021-2023. For males, it increased from 34.1% to 41.0%

during the same peak period, then declined to 39.3%. Similarly, the total population experienced an increase from 34.1% to 41.0%, followed by a reduction to 39.4%

Figure 15: Trends of the food insecurity severity in Côte d'Ivoire

Data source: FOASTAT, 2025

These trends highlight the persistent challenges in food access, exacerbated by economic, social, and climatic factors. The recent decline suggests the initial impacts of interventions, but the overall high levels of food insecurity underscore the need for sustained efforts to enhance food systems, address gender disparities, and build resilience against future shocks. These trends may reflect the persistent challenges in addressing food insecurity, exacerbated by factors such as economic instability, climate variability, and global disruptions (e.g., the COVID-19 pandemic). The higher prevalence among women highlights gender disparities in access to food resources, likely linked to socio-economic inequalities and traditional household roles.

The recent decline in 2021-2023 may indicate the initial impact of recovery efforts, including targeted food security interventions and policy adjustments. However, the rates remain alarmingly high, signaling the need for continued action to reduce severe food insecurity. Key measures include strengthening social safety nets, promoting equitable access to resources, and investing in sustainable agricultural practices to build resilience against future shocks.

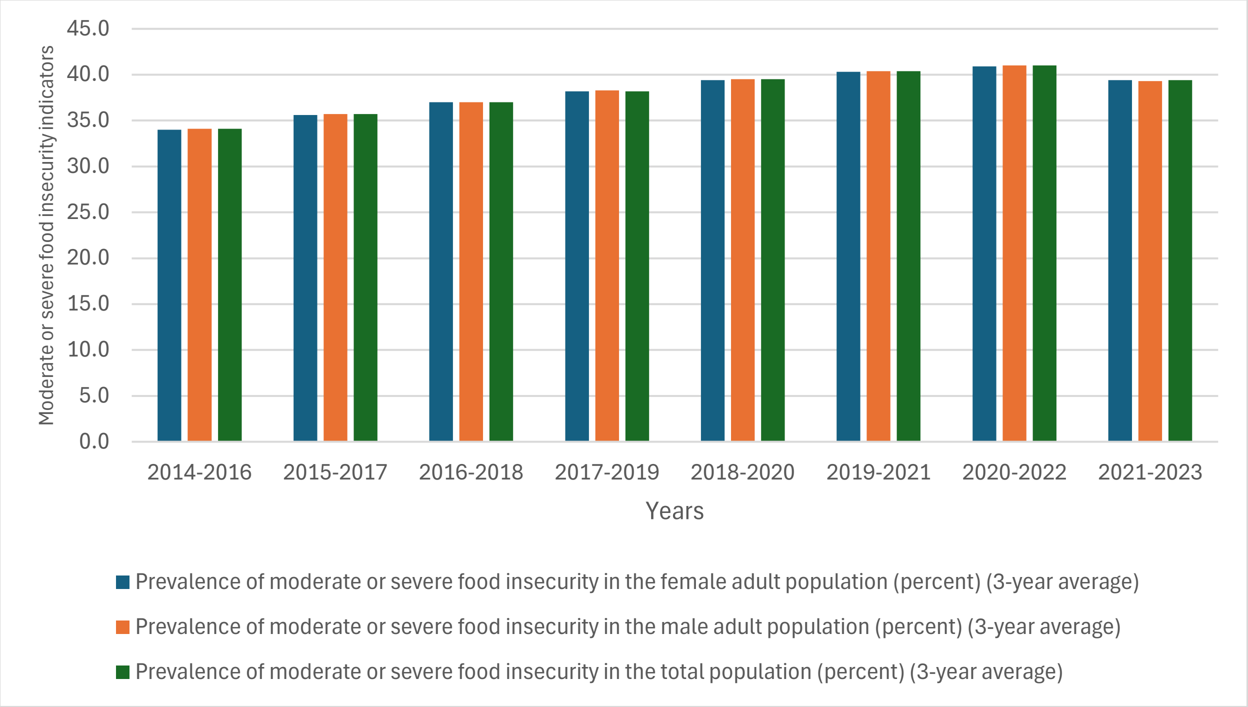

Figure 16: Trends of moderate or severe food insecurity in Côte d'Ivoire

Data source: FOASTAT, 2025

2.2.3. Programs and policies against food insecurity in Côte d'Ivoire

The fight against food insecurity in Côte d'Ivoire has been supported by numerous programs, initiatives, and policies over the years, addressing the multifaceted drivers of hunger and malnutrition. Despite substantial efforts, food insecurity persists in various forms, particularly among vulnerable groups, such as women, children, and rural communities. This section examines key initiatives aimed at improving food security in Côte d'Ivoire, highlighting their strengths, challenges, and gaps while suggesting paths for improvement.

Côte d'Ivoire's food security policies have traditionally focused on improving agricultural productivity as a cornerstone of addressing hunger. Programs such as the National Rice Development Strategy and support for cocoa and coffee production have been instrumental in boosting staple crop yields and export revenues. These initiatives have successfully positioned Côte d'Ivoire as one of the leading agricultural exporters in sub-Saharan Africa. However, they have also created an over-reliance on export-oriented cash crops, often at the expense of food crops. The focus on cash crops has resulted in insufficient diversification of agricultural systems, leaving the country vulnerable to global market volatility and limiting the availability of diverse and affordable food for local populations (FAO, 2020).

To mitigate these challenges, the government launched initiatives such as the Agricultural Investment Program (PNIA), which prioritizes infrastructure development, rural financing, and access to agricultural inputs. While PNIA has contributed to increased agricultural production, challenges remain in ensuring equitable access to these resources. Many smallholder farmers, particularly women, still lack access to critical inputs such as seeds, fertilizers, and credit. Gender disparities in land ownership and decision-making further exacerbate these issues, preventing women, who make up a significant portion of the agricultural workforce, from fully participating in and benefiting from these programs (World Bank, 2021).

Food security efforts in Côte d'Ivoire have also been supported by international organizations. The World Food Programme (WFP), for instance, has implemented school feeding programs that provide free meals to children in underserved areas, improving both nutrition and school attendance. These programs have been highly effective in addressing immediate food needs and promoting human capital development. However, their sustainability remains questionable, as they rely heavily on external funding. Integrating school feeding programs into national budgets and strengthening local food supply chains to support these initiatives could enhance their long-term impact (WFP, 2022).

Nutrition-specific interventions, such as the National Multisectoral Nutrition Plan (PNMN), have been launched to tackle malnutrition and improve dietary quality. These efforts have shown positive outcomes, particularly in reducing child stunting and anemia among women of reproductive age. Yet, progress has been uneven, with rural and low-income communities benefiting less from these programs. Inadequate funding and weak coordination between sectors such as health, agriculture, and education hinder the effective implementation of nutrition-focused policies. Strengthening intersectoral collaboration and increasing financial commitments are necessary to ensure these programs reach the most vulnerable populations (UNICEF, 2020).

Climate-smart agriculture (CSA) has emerged as a key component of recent food security strategies in Côte d'Ivoire, addressing the growing challenges posed by climate change. The adoption of CSA practices, such as improved seeds, agroforestry, and intercropping, has demonstrated potential for increasing agricultural resilience and reducing food insecurity. However, CSA adoption remains limited, particularly among smallholder farmers, due to high initial costs, limited awareness, and inadequate technical support. Scaling up CSA requires targeted subsidies, farmer education programs, and stronger public-private partnerships to enhance accessibility and uptake (FAO, 2021).

Social protection measures, such as cash transfer programs, have also been employed to combat food insecurity by increasing household purchasing power. These initiatives have provided critical support during periods of economic hardship, such as the COVID-19 pandemic. However, coverage remains limited, with many vulnerable households excluded due to administrative inefficiencies and a lack of accurate targeting mechanisms. Expanding social protection coverage and integrating food security objectives into broader social safety nets could improve their effectiveness (World Bank, 2022).

Côte d'Ivoire's policies have made strides in integrating food security into broader development strategies, such as the National Development Plan (PND). These frameworks aim to reduce poverty and promote sustainable economic growth, with food security as a central component. While the PND has brought attention to structural issues like rural infrastructure and market access, implementation gaps persist. Weak institutional capacity and limited budget allocations for food security programs often undermine the impact of these policies. Addressing these systemic weaknesses requires increasing public investment in the agricultural sector, particularly in rural areas, and ensuring that food security policies are adequately resourced and prioritized (African Development Bank, 2020).

In addition to national efforts, Côte d'Ivoire has participated in regional initiatives such as the Comprehensive Africa Agriculture Development Programme (CAADP) and the Economic Community of West African States (ECOWAS) Regional Agricultural Policy. These frameworks aim to promote regional food security and market integration. However, regional collaboration faces challenges, including trade barriers, insufficient infrastructure, and differing national priorities. Strengthening regional coordination and harmonizing policies could enhance the effectiveness of these initiatives, ensuring that Côte d'Ivoire and its neighbors benefit from collective efforts to address food insecurity (NEPAD, 2021).

Despite these efforts, significant gaps remain in addressing the root causes of food insecurity in Côte d'Ivoire. High levels of poverty, limited access to education and healthcare, and persistent gender inequalities continue to undermine food security outcomes. Additionally, the dual challenges of population growth and climate change are placing increasing pressure on natural resources and food systems. To address these challenges, a more integrated approach is needed, combining short-term measures to address immediate food needs with long-term strategies to build resilience and sustainability.

Investing in smallholder farmers, who are the backbone of the country's agricultural sector, is essential for achieving food security. Providing affordable credit, agricultural inputs, and technical training can enhance productivity and resilience. Addressing gender disparities through policies that promote women's empowerment and land ownership is also critical, as women play a central role in food production and household nutrition.

Furthermore, improving rural infrastructure, such as roads, storage facilities, and irrigation systems, can reduce post-harvest losses and enhance market access. Strengthening local food supply chains and promoting value addition in agricultural products can boost incomes and reduce reliance on imports. Integrating climate adaptation into agricultural policies and investing in research and innovation are also key to addressing the long-term impacts of climate change on food security.

In sum, while Côte d'Ivoire has made progress in addressing food insecurity through various programs, initiatives, and policies, significant challenges remain. Strengthening coordination between sectors, increasing public investment, and addressing systemic inequalities are critical for achieving sustainable food security. Regional collaboration and international support will also play a vital role in enhancing the country's resilience to future food security challenges. By adopting a comprehensive and inclusive approach, Côte d'Ivoire can build a more sustainable and equitable food system that ensures food security for all its citizens.

2.3. Literature review on the impacts of CSA on food security due to gender disparities

Climate change poses a significant threat to agricultural systems, with profound implications for global food security. Climate-Smart Agriculture (CSA), a set of strategies to enhance productivity, resilience, and mitigation, has been identified as a critical approach to addressing these challenges. However, the effectiveness and adoption of CSA strategies are mediated by various socio-economic factors, particularly gender dynamics, which shape access to resources, decision-making processes, and labor allocation within farm households. As Kristjanson et al. (2017) noted, gender plays a pivotal role in mediating the adoption of CSA practices and their outcomes, influencing the food security of farm households in multifaceted ways. This literature review critically examines the gendered impacts of CSA adoption on food insecurity, drawing on both theoretical frameworks and empirical evidence from recent studies.

Disparities due to gender in access to resources such as land, credit, and extension services have been widely documented as barriers to the adoption of CSA practices. Women, who make up a significant proportion of the agricultural workforce in developing regions, often face systemic inequities that hinder their ability to engage in climate-resilient farming. For instance, Doss et al. (2018) highlight that women typically have smaller landholdings and less access to agricultural inputs compared to men, limiting their capacity to implement CSA strategies that require significant initial investments. Similarly, Meinzen-Dick et al. (2019) emphasize the importance of gender-responsive agricultural extension services, noting that the lack of tailored training and information for women farmers often results in lower adoption rates of CSA practices among female-headed households.

The impact of CSA adoption on food security is deeply gendered, reflecting the distinct roles and responsibilities of men and women in household food production and consumption. Research by Beuchelt and Badstue (2013) illustrates that while CSA practices such as conservation agriculture and agroforestry can enhance household food availability and income, their benefits are often unevenly distributed within households. Men are more likely to control the proceeds from market-oriented CSA practices, whereas women are primarily responsible for ensuring household food and nutritional security. This intra-household dynamic can limit the extent to which CSA adoption translates into improved food security outcomes for all household members, particularly children.

Empirical studies also reveal that CSA adoption can have both positive and negative impacts on women's well-being and food security. For example, a study by Quisumbing et al. (2021) in sub-Saharan Africa found that women's participation in agroforestry programs led to increased dietary diversity and reduced food insecurity, largely due to their control over the use of income generated from tree products. However, the labor-intensive nature of some CSA practices, such as soil conservation and water management, often increases women's workload, exacerbating time poverty and reducing their capacity to engage in other productive or caregiving activities. These findings underscore the need to consider labor implications and ensure that CSA interventions do not disproportionately burden women.

Theoretical frameworks on gender and food security provide valuable insights into the pathways through which CSA strategies affect household food outcomes. Sen's (1981) entitlement theory, for example, highlights the role of resource access and control in shaping food security. Applying this framework, Farnworth et al. (2016) argue that gendered inequalities in resource ownership and decision-making power can constrain women's ability to benefit from CSA interventions, even when these strategies are designed to enhance household resilience to climate shocks. Similarly, Kabeer's (1999) empowerment framework emphasizes the importance of agency and choice in addressing food insecurity, suggesting that interventions must actively promote women's participation and leadership in agricultural decision-making.

Case studies from various regions illustrate the diverse gendered impacts of CSA adoption. In Ethiopia, Tessema et al. (2019) found that adopting drought-resistant crop varieties significantly improved food security in male-headed households, while female-headed households faced persistent barriers to access to credit and extension services. In India, Agarwal (2020) documented the benefits of participatory approaches to CSA, such as farmer field schools, which increased women's adoption rates and enhanced household food security. However, these programs often struggled to overcome entrenched socio-cultural norms that limited women's decision-making power over agricultural resources. These examples highlight the importance of context-specific and gender-sensitive approaches to CSA implementation.

Policy and programmatic interventions play a critical role in addressing the gendered barriers to CSA adoption and ensuring equitable food security outcomes. Gender-sensitive CSA programs that provide targeted support for women, such as access to credit, training, and technology, have shown promising results. For instance, the work of Njuki et al. (2016) demonstrates that initiatives integrating gender considerations into value chain development can enhance women's economic empowerment and improve nutritional outcomes at the household level. Similarly, microfinance schemes tailored to women farmers, as highlighted by Muricho et al. (2021), have been effective in enabling the adoption of labor-saving and productivity-enhancing CSA technologies.

Despite these advances, significant gaps and challenges remain in the literature and practice. Many studies fail to disaggregate data by gender, limiting the understanding of the nuanced impacts of CSA adoption on different household members. Moreover, there is a lack of longitudinal studies examining the long-term gendered impacts of CSA on food security and resilience. Intersectionality, which considers the interplay of gender with other social categories such as age, ethnicity, and class, is also underexplored in the context of CSA. Future research should address these gaps by developing robust methodologies for measuring gender impacts and evaluating the scalability of gender-sensitive CSA interventions.

2.3. Methodological approach

2.3.1. Theoretical framework

The theoretical framework for analyzing the determinants of food security is based on the farm household utility model developed by Strauss et al. (1986). This theoretical framework was chosen as experience shows that it adequately models the behavior of households in developing countries, particularly those in Sub-Saharan Africa. This theoretical framework is widely used in the literature to understand the determinants of household food security (Feleke et al., 2003). Rural households are both consumers and producers of agricultural products they grow (A.deJanvry, 1991). The producer-consumer model starts with the following utility function:

$$U_i = U(x_i, l_i(Z_i)) \tag{2.1}$$

Where U_i is a strictly quasi-concave, twice differentiable utility function, x_i is a vector of consumption demand of the nth household consisting of food goods x_a and non-food goods c_{na}, l_i constitutes the leisure demand (time available not devoted to work) by the household and Z_i is a vector of socio-demographic characteristics that serve to shift the utility surface in the utility-consumption-leisure space. This implies that household characteristics can affect its utility.

Based on the above definition, consumption demand for goods is rewritten as follows:

$$x_i = x(x_a, x_{na}) \tag{2.2}$$

Households are essentially net consumers. One part of their food consumption would therefore come from their own production or home production (C_d), and the other from market purchases (C_m). Taking this assumption into account, the food consumption function can be written as follows:

$$x_a = x_a(C_d, C_m) \qquad 2.3$$

By introducing the second (2.2) and third (2.3) equations into the first (2.1) and rearranging, we obtain the utility equation, which we write as follows:

$$U_i = U\{[(C_d, C_m), x_{na}], l_i(Z_i)\} \tag{2.4}$$

A fundamental assumption of this model is the separability of markets, i.e., that household decisions concerning production on the one hand and consumption on the other can be treated as if they were made sequentially. Under this assumption, production decisions are made first and then used to allocate income between consumption of goods and leisure. In this context, only production decisions can influence consumption decisions. Moreover, these households are subject to certain production, income, and time constraints (Ogundari, 2017). This hypothesis further assumes that household food security often depends on production variables, but not vice versa (Feleke et al., 2003).

The household, as producer and consumer, is assumed to maximize its utility from the consumption of these goods, subject to agricultural production, income, and time constraints (Lopez,1986) specified respectively as follows:

$$G(Q_d, L, A^0, K^0) = 0 \tag{2.5}$$

$$P_d(Q_d - C_d) - P_m C_m - P_{na} x_{na} - S\left(L - l_f\right) + N = 0 \tag{2.6}$$

$$T = l_f + l \tag{2.7}$$

Under the assumption that technology is exogenous, G(.) is an implicit food production function, Q_d representing the quantity of goods produced by the agricultural household, L the total labor input allocated to agricultural activities, A^0 the household's fixed land quantity, and K^0 the fixed capital stock. Additionally, P_d represent the prices of food products produced by the household, $Q_d - C_d$ the surplus of locally produced food is marketed, P_m the price of food items purchased on the market, P_{na} the price of non-food items, S the wage rate in the economy, and N non-agricultural income; T represents the total available time of the household, divided between labor and leisure, and denotes the household's labor supply for agricultural activities.

The time and income constraints can be combined into a single constraint by introducing the time constraint (2.6) into the income constraint (2.7) as follows:

$$P_d(Q_d - C_d) - P_m C_m - P_{na} x_{na} - S(L - T + l) + N = 0 \tag{2.8}$$

By expanding and rearranging equation (2.8), we obtain the following equation (2.9):

$$P_m C_m + P_{na} x_{na} + P_d C_d + Sl = P_d Q_d + ST + N - SL \tag{2.9}$$

On the left-hand side, the equation represents household expenditures, while the right-hand side represents household income. Expenditures include the value of market-purchased food products

($P_m C_m$), non-food expenditures ($P_{na} x_{na}$), the value of self-produced goods purchased within the farm ($P_d C_d$), and leisure expenditures. Household income comprises the value of agricultural products ($P_d Q_d$), the value of time endowment (ST), the value of labor used SL , and N, the non-agricultural income.

After introducing and simplifying all constraints, the household's problem becomes:

$$Max\ U\{[(C_d\ , C_m), x_{na})], l_i\ (\ Z_i)$$

$$S/C \tag{2.10}$$

$$P_m C_m + P_{na} x_{na} + P_d C_d + Sl = P_d Q_d + ST + N - SL$$

Defining $\pi = P_i Q_d - SL$ as an agricultural profit, the Lagrangian associated with this program can be formulated as follows:

$$\text{L} = U\{[(C_d\ , C_m), x_{na})], l_i\ (\ Z_i)\} + \mu(\pi + ST + N - P_m C_m - P_{na} x_{na} - P_d C_d - Sl)$$

Applying first-order conditions yields the following system:

$$\begin{cases} \dfrac{\partial \text{L}}{\partial Cm} = Um - \mu\ P_m = 0 \\ \dfrac{\partial \text{L}}{\partial x_{na}} = U_{na} - \mu P_{na} = 0 \\ \dfrac{\partial \text{L}}{\partial C_d} = U_{Cd} - \mu P_{Cd} = 0 \\ \dfrac{\partial \text{L}}{\partial l} = U_l - \mu S = 0 \\ \dfrac{\partial \text{L}}{\partial L} = \mu \dfrac{\partial \pi}{\partial L} = 0 \\ \dfrac{\partial \text{L}}{\partial \mu} = \pi + N - P_m C_m - P_{na} x_{na} - P_d C_d - Sl \end{cases}$$

The solution L^* of the proft maximization is independent of the rest of the system. Considering labor as a factor, we can express:

$$\frac{\partial \text{L}}{\partial L} = \mu \frac{\partial \pi}{\partial L} = 0 \rightarrow \mu \left(P_d \frac{\partial \pi}{\partial L} - S\right) = 0 \rightarrow P_d \frac{\partial \pi}{\partial L} - S = 0$$

Thus, we obtain the optimal values of L (L^*) and Q (Q^*) as functions of the parameters P and S as follows:

$$L^* = L^* \ (Pi, S, A^0, K^0) \tag{2.11}$$

$$Q^* = Q^* \ (Pi, S, A^0, K^0) \tag{2.12}$$

The agricultural profit is then given by: $\pi^* = P_d Q^* - SL^*$

The maximization constraint becomes: $P_m C_m + P_{na} B_{na} + P_d C_d + Sl = \pi^* + ST + N$

The total household income, which influences consumption decisions, is the sum of agricultural profit π^*, non-agricultural income (N), and the value of time endowment:

$$Y^* = ST + \pi^* \ (Pd, S, A^0, K^0) + N \tag{2.13}$$

The Lagrangian is then expressed as:

$$\llcorner = U\{[(C_d \ , C_m), x_{na})], l_i \ (Z_i)\} + \mu(\pi^* + ST + N - P_m C_m - P_{na} x_{na} - P_d C_d - Sl) \tag{2.14}$$

Applying first-order conditions to Lagrangian (2.14) allows us to determine the optimal consumption of food goods (x_a) from both self-production and the market. This relationship can be specified as follows:

$$x_a = (P_d, \ P_m, P_{na}, S, Y^* \ ) \tag{2.15}$$

We observe that food consumption demand is influenced by food and non-food prices, wages, and household income. The latter is determined by household production activities, meaning that changes affecting production also alter income, subsequently influencing consumption decisions. Consequently, we integrate socio-demographic factors into equation (2.15), rewriting the demand for food goods as:

$$x_a = [P_d, \ P_m, P_{na}, S, Y^* \ (Pd, S, A^0, K^0, N), Z_i] \tag{2.16a}$$

According to Ogundari (2017), household food demand (β_a) can be considered a measure of household food security (SA) and is expressed as follows:

$$SA = [FCS \ , PI, DDI, FIS \ldots] \tag{2.16b}$$

SA represents a vector of various household food security indicators. According to Smith & Subandoro (2007), Omonona & Grace (2007), Lokosang et al. (2011), Obayelu (2013), Pangaribowo et al. (2013), and Ogundari (2017), this vector could include the Food Consumption Score (FCS), Production Index (PI), Dietary Diversity Index (DDI), or the Food Insecurity Index (FIS). However, price data as a determinant of SA is unavailable in our database. Consequently, we reparametrize the relationship between food security and its determinants using a reduced form of equation 2.16a, excluding prices in consideration of 2.16b:

$$FIS = [\, Y^{*}\ (A^0, K^0, N), Z_i] \tag{2.17}$$

Equation 2.17 enables us to determine the effects of variables other than price on household food security. This procedure, which analyzes the effects of economic and socio-demographic variables, is widely used in the literature (Broussard, 2019).

2.3.2. Model specification and estimation technique

In this study, the Food Insecurity Index (FIS), based on equation 1.1 above, is used to assess household food insecurity. This variable is defined as:

$$Food\ insecurity\ class = \begin{cases} 1\ if\ food\ secure \\ 2\ if\ mild\ food\ insecure \\ 3\ if\ moderate\ food\ insecure \\ 4\ if\ severe\ food\ insecure \end{cases}$$

The choice of this variable is due to its availability in the database. Given the ordered nature of their different categories, the appropriate estimation method is an ordered multinomial model. Nonetheless, adopting climate-smart agriculture practices is not random and may be subject to selection bias and endogenous to each farm household decision. Indeed, these problems must be considered to avoid biased estimates. Thus, this research assesses the effect of CSA on food insecurity through an extended ordered probit regression (Mounirou & Lokonon, 2022***)***. The general form of the model is as follows (Wooldridge 2010):

$$y_i^* = x_i\beta + \delta A_i + \varepsilon_i$$

$$A_i^* = \begin{cases} 1\ if\ \alpha Z_i + \eta_i > 0 \\ 0\ otherwise \end{cases}$$

with y capturing the level of household food security, A is the binary treatment variable (CSA adoption); 1 if yes, and 0 if no, x and z represent the vectors of explanatory variables, β and γ are the parameters associated with the explanatory variables to be estimated, μ and ε are the error terms. These error terms follow a bivariate normal distribution with a mean of 0 and have the following correlation structure: $corr(\mu, \varepsilon) = \rho$. Thus, the treatment variable is endogenous if and only if $\rho \neq 0$. The average treatment effect (ATE) for each category of food insecurity is computed based on the estimation results.

2.3.3. Data and descriptive statistics for the sample

The data used in this chapter are provided by Côte d'Ivoire's Harmonized Survey on Living Conditions of Households in 2018 (EHCVM-2018). It contains the necessary information for welfare measurement in different dimensions, including consumption expenditure and adaptation decisions. The survey was conducted using multi-stage stratified random sampling. Two questionnaires are used in the survey: one that covers access to social services like education, health, and socio-economic characteristics, and another that includes household revenues, consumption, and expenditures. The survey covered 6923 Ivorian households. We assess the impacts of adopting climate-smart agriculture (CSA) practices on households' food insecurity.

The analysis of food insecurity distribution based on CSA practices reveals notable differences across farming strategies and gender (**Table 7**). Farmers using improved seeds show higher food security (20.74%) than those using conventional seeds (11.97%), and the Chi-square test (16.46) confirms statistical significance. Monoculture farmers exhibit greater food security (17.56%) than intercropping farmers (15.15%), but intercropping is associated with higher severe food insecurity (8.67% vs. 5.22%). Adoption of both CSA practices (CSA1 & CSA2) leads to mixed outcomes: non-adopters have the highest food security (23.25%) but also high severe food insecurity (8.27%), while adopters have lower food security (9.45%) but reduced severe food insecurity (5.62%). Among women, improved seeds are linked to higher food security (21.64%) but also higher severe food insecurity (16.04%). Intercropping benefits women more (17.41% food secure) compared to monoculture (8.33%), and the Chi-square test (10.891) confirms statistical significance. CSA adoption in women is associated with increased food security (15.42%) but also slightly higher severe food insecurity (13.68%). In contrast, men benefit more from improved seeds (20.62% food security), and monoculture provides greater food security (18.80%) than intercropping (14.84%). The Chi-square test (50.216) confirms a strong association. CSA adoption among men results in lower severe food insecurity (4.53%), though non-adopters show the highest food security

(25.00%). Overall, CSA adoption seems to influence food insecurity differently for men and women.

Table 7: Food insecurity distribution

		Food insecurity level				Test of difference
Variables	Modalities	Food secure	Mild	Moderate	Severe	Chi2
Full sample						
Type of seeds	Conventional	11.97	7.46	10.01	4.62	16.460***
(CSA1)	Improved	20.74	17.03	18.91	9.28	
Type of cultivation	Monoculture	17.56	12.46	14.38	5.22	70.007***
(CSA2)	Intercropping	15.15	12.03	14.54	8.67	
CSA1 and CSA2	Non-adopters	23.25	16.57	19.69	8.27	40.499***
	Adopters	9.45	7.91	9.23	5.62	
Female sample						
Type of seeds	Conventional	4.10	3.86	6.72	2.24	5.217
(CSA1)	Improved	21.64	19.78	25.62	16.04	
Type of cultivation	Monoculture	8.33	5.85	8.83	3.11	10.891**
(CSA2)	Intercropping	17.41	17.79	23.51	15.17	
CSA1 and CSA2	Non-adopters	10.32	8.58	12.31	4.60	9.496**
	Adopters	15.42	15.05	20.02	13.68	
Male sample						
Type of seeds	Conventional	13.03	7.94	10.46	4.94	15.650***
(CSA1)	Improved	20.62	16.66	18.00	8.36	
Type of cultivation	Monoculture	18.80	13.35	15.13	5.51	50.216***
(CSA2)	Intercropping	14.84	11.25	13.33	7.79	
CSA1 and CSA2	Non-adopters	25.00	17.65	20.69	8.76	20.298***
	Adopters	8.65	6.95	7.77	4.53	

*** p<0.01, ** p<0.05, * p<0.1

The food insecurity distribution across agroecological zones in Côte d'Ivoire highlights notable regional disparities (**Figure 17**). The full sample shows that 32.71% of households are food secure, while 13.89% experience severe food insecurity. The Centre region has one of the lowest levels of food security (31.17%), with a relatively high rate of severe food insecurity (15.49%), suggesting that while a few households are fully food secure, extreme food insecurity is also widespread. In the Centre-Ouest, food security is slightly lower (25.3%), and the region also experiences a higher rate of severe food insecurity (22.4%), indicating a significant disparity between food-secure and food-insecure households. The Nord region shows a higher food security rate (30.67%), but a relatively high proportion of households are in the mild (28.56%) and moderate (29.87%) food insecurity categories, while severe food insecurity remains moderate (10.89%). This pattern suggests that although food security is better in this region, a significant portion of the population still faces moderate food insecurity. The Sud-Est region has a higher food security rate (35.95%) but still shows moderate (30.92%) and mild (21.47%) levels of food insecurity, while its severe food insecurity rate is relatively low (11.66%). The Sud-Ouest region has the highest food security rate (44.41%) and one of the lowest severe food insecurity rates (8.72%), indicating better conditions compared to other regions.

These regional disparities are influenced by differences in agroecological conditions, farming systems, and livelihood opportunities. The Nord region, with its higher food security, benefits from drier agroecological conditions that support extensive livestock farming and drought-resistant crops. The Centre and Centre-Ouest, with relatively lower food security and higher severe food insecurity, are characterized by a mix of cash crops and food production, making them more vulnerable to climate shocks and price volatility. The Sud-Est and Sud-Ouest, benefiting from coastal and forested agroecological zones, show moderate food security but lower severe food insecurity, likely due to diversified agricultural activities and better access to markets. These findings underscore the need for region-specific interventions, with tailored support for regions facing both high food insecurity and extreme vulnerability to shocks.

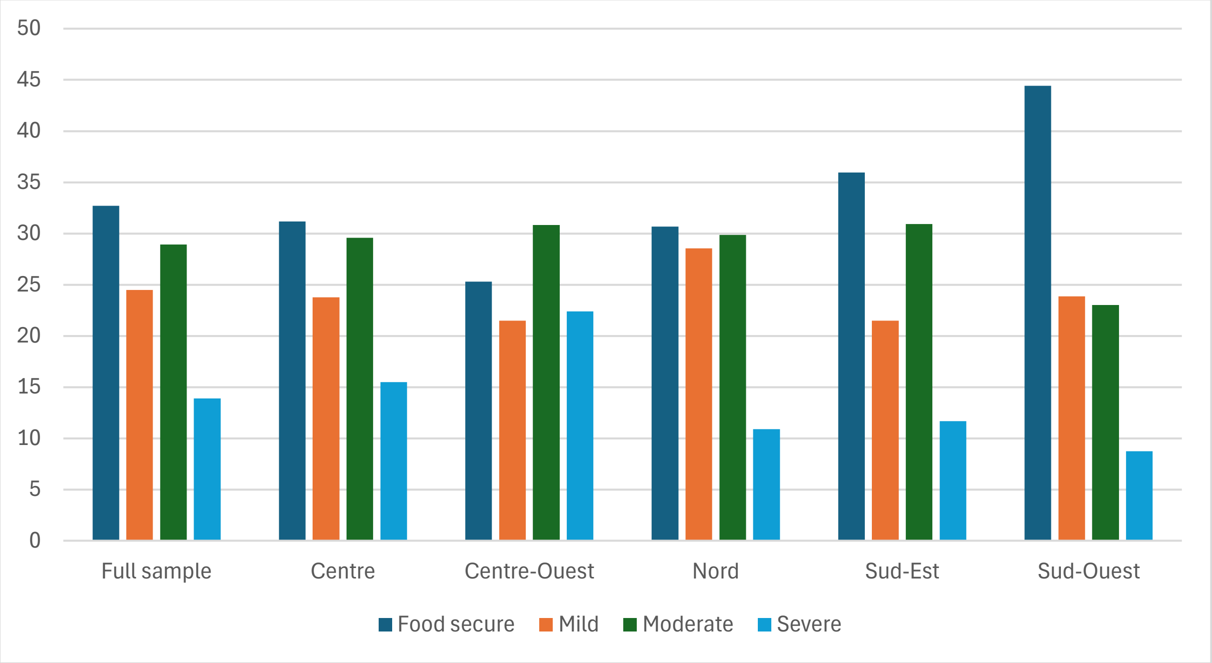

Figure 17: Distribution of food insecurity within agroecological zones

2.4. Results and discussion

2.4.1. Effect of the use of improved seed on household food insecurity: gender analysis

The results summarized in **Table 8** highlight the impact of improved seed (CSA1) adoption on food insecurity in Côte d'Ivoire, showing gendered differences and the role of household characteristics, climate shocks, and land tenure. Gender influences food insecurity, as female-headed households are more vulnerable, but CSA1 adoption reduces this disparity (-0.126 for adopters vs. -0.174 for non-adopters). This aligns with Doss (2001) and Fisher and Carr (2015), who noted that climate-smart technologies can help reduce gendered food insecurity when combined with financial support.

Household size does not significantly impact food security, but the number of equivalent adults reduces food insecurity for CSA1 adopters (-0.072 full sample, -0.073 males), supporting Tittonell and Giller (2013), who argued that CSA practices reduce dependence on household size for food production. Cultivated land area is a significant determinant of food security for non-adopters (-0.027 full sample, -0.033 males), but its effect weakens for adopters (-0.003 full sample, -0.002 males), suggesting that CSA1 adoption enables households to achieve food security even on smaller plots. This corroborates Meinzen-Dick et al. (2019), who emphasized the role of secure land tenure and improved farming techniques in reducing land dependency.

Education does not have a significant effect, implying that access to CSA1 and other agricultural innovations may play a larger role than formal schooling in ensuring food security, which contrasts with Ali et al. (2015), who found that education increases technology adoption. Credit access has a complex effect: female-headed non-adopters with access to credit experience worse food insecurity (-0.256), but for female adopters, access to credit significantly improves food security (-0.554), suggesting that credit is only effective when combined with productivity-enhancing investments, consistent with Khandker and Samad (2014).

Climate shocks play a major role in food insecurity, as flooding significantly increases food insecurity among female-headed non-adopters but is mitigated by CSA adoption, confirming Dercon (2004) and Arslan et al. (2014), who found that climate adaptation reduces vulnerability to flooding. However, drought negatively impacts all groups, including CSA adopters (0.194 full sample, 0.177 males), contradicting Pretty et al. (2018), who suggested that CSA enhances drought resilience. This discrepancy may be due to the need for additional water management strategies, as highlighted by Barrett et al. (2011).

Health service access improves food security, particularly for male-headed households (-0.241 non-adopters, -0.128 adopters), consistent with Masset et al. (2012), who found that healthcare access boosts labor productivity and food security. The weaker effect for women may indicate structural barriers, as noted by Quisumbing et al. (2015). Marital status and rural residency have mixed effects, with married women non-adopters facing higher food insecurity, but experiencing reduced food insecurity upon CSA adoption, indicating that marital stability may provide food security benefits when combined with improved agricultural practices.

Table 8: Effect of the use of improved seed (CSA1) on household food insecurity

	Full sample		Female sample		Male sample	
	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	CSA1=0	CSA1=1	CSA1=0	CSA1=1	CSA1=0	CSA1=1
Gender of HH (0F/1M)	-0.174*	-0.126**				
	(0.099)	(0.057)				
Age of HH	-0.001	-0.002	-0.003	0.001	0.000	-0.002*
	(0.002)	(0.001)	(0.005)	(0.003)	(0.002)	(0.001)
Household size	-0.048	0.045	-0.101	0.026	-0.027	0.044
	(0.042)	(0.028)	(0.085)	(0.063)	(0.045)	(0.031)
Number of equivalent adults	0.072	-0.072*	0.208	-0.026	0.038	-0.073*
	(0.058)	(0.039)	(0.127)	(0.088)	(0.061)	(0.043)
Cultivated land area	-0.027***	-0.003*	-0.026**	-0.008	-0.033***	-0.002*
	(0.008)	(0.001)	(0.011)	(0.007)	(0.008)	(0.001)
Education of HH (educated)	0.039	-0.010	-0.176	-0.087	0.036	0.001
	(0.045)	(0.036)	(0.115)	(0.086)	(0.047)	(0.039)
Credit access (have access)	0.104	0.078	-0.256**	-0.554*	0.110	0.137
	(0.142)	(0.105)	(0.122)	(0.314)	(0.147)	(0.109)
Health service access (have access)	0.171**	0.100**	-0.257**	-0.059	0.241***	0.128**
	(0.074)	(0.049)	(0.107)	(0.093)	(0.079)	(0.054)
Flooding experience	0.203	0.042	1.091**	0.496**	0.155	-0.009
	(0.140)	(0.086)	(0.474)	(0.202)	(0.139)	(0.091)
Drought experience	0.194***	0.165***	0.381**	-0.074	0.177***	0.189***
	(0.058)	(0.042)	(0.180)	(0.117)	(0.059)	(0.044)
Disability (apt)	0.163*	0.289***	0.170	0.049	0.150	0.342***
	(0.091)	(0.065)	(0.170)	(0.113)	(0.096)	(0.073)
Marital status of HH (Married)	-0.049	-0.104**	0.126	-0.146*	-0.075	-0.054
	(0.073)	(0.052)	(0.137)	(0.084)	(0.079)	(0.062)
Residential area (Rural)	0.004	0.026	0.273**	-0.088	-0.020	0.046
	(0.058)	(0.046)	(0.125)	(0.091)	(0.061)	(0.051)
CSA1: Endogenous treatment						
Soil type (ref: Sandy)						
1. Silty		-0.308***		-0.183**		-0.301***
		(0.052)		(0.093)		(0.056)
2. Clay		-0.318***		-0.109		-0.323***
		(0.046)		(0.091)		(0.050)
3. Glacis and other		0.010		-0.490***		0.061
		(0.079)		(0.168)		(0.082)
Soil fertility						
1. Moderate		-0.200***		-0.324***		-0.189***
		(0.043)		(0.075)		(0.048)
2. Poor		-0.362***		-0.324**		-0.372***
		(0.078)		(0.155)		(0.083)

1. Land ownership (owners)	-0.328***	-0.258**	-0.311***
	(0.049)	(0.121)	(0.050)
Constant	0.961***	1.436***	0.878***
	(0.050)	(0.142)	(0.052)
corr(e.Eq2, e.Eq1)	0.324**	0.955***	0.307*
	(0.162)	(0.040)	(0.184)
Observations	6,760	804	5,956

Standard errors in parentheses; *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Note: CSA1=0 (Non-adopters) ; CSA1=1 (Adopters)

The correlation coefficient suggests that CSA adoption is not entirely random but influenced by household characteristics, particularly for female adopters, reinforcing Giller et al. (2017), who emphasized the importance of tailored interventions. The findings confirm that improved seed adoption improves food security but does not fully eliminate gender disparities or vulnerability to climate shocks. To maximize its impact, CSA1 must be integrated with secure land tenure, targeted credit programs, and soil fertility management, as recommended by Pretty et al. (2018).

2.4.2. Effect of intercropping practice on household food insecurity: gender analysis

The results of the analysis examine the effects of intercropping (CSA2) on household food insecurity in Côte d'Ivoire, with a gender-disaggregated approach (**Table 9**). The findings reveal several important relationships between household characteristics and food insecurity outcomes. In the full sample, female-headed households are significantly less food insecure when they adopt intercropping compared to non-adopters, with a coefficient of -0.118 at the 1% significance level. This suggests that intercropping has a stronger positive effect on reducing food insecurity in female-headed households. This aligns with previous studies (Doss, 2018; Quisumbing et al., 2014), which found that female farmers often invest more in food security and nutrition-related expenditures when they have access to productive agricultural practices.

The negative and significant coefficient for household head age in the adopter group (-0.002 for adopters) suggests that older household heads experience slightly lower food insecurity when they adopt intercropping. This is consistent with the literature (Bezu & Holden, 2014), which argues that experienced farmers are more likely to adopt climate-smart practices effectively.

Household size is not significantly associated with food insecurity across groups, but the coefficient is negative for female-headed adopters. This suggests that larger female-headed households may struggle more with food insecurity despite intercropping adoption, possibly due to higher dependency ratios (Agarwal, 2019). Credit access appears to have a gendered effect.

While it is positive and significant for male-headed adopters, it is strongly negative for female-headed adopters (-0.764). This finding aligns with Fletschner & Kenney (2011), who argue that women often face greater challenges in accessing and utilizing credit effectively due to institutional and social barriers. Access to health services significantly reduces food insecurity among male-headed households (0.147 for non-adopters and 0.086 for adopters), but not for female-headed households. This may indicate that male-headed households are better able to translate health access into productive outcomes (Doss & Morris, 2001).

Table 9: Effect of the use of intercropping practice (CSA2) on household food insecurity in Cote d'Ivoire

	Full sample		Female sample		Male sample	
	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	CSA2=0	CSA2=1	CSA2=0	CSA2=1	CSA2=0	CSA2=1
Gender of HH (0F/1M)	-0.023	-0.118***				
	(0.061)	(0.042)				
Age of HH	0.000	-0.002**	-0.003	0.001	0.000	-0.003***
	(0.001)	(0.001)	(0.005)	(0.003)	(0.001)	(0.001)
Household size	0.003	0.015	0.002	-0.061	0.001	0.026
	(0.022)	(0.024)	(0.127)	(0.065)	(0.022)	(0.026)
Number of equivalent adults	-0.014	-0.015	0.053	0.091	-0.016	-0.031
	(0.030)	(0.033)	(0.178)	(0.089)	(0.030)	(0.035)
Cultivated land area	-0.001	-0.005	0.004	-0.016*	-0.001	-0.005
	(0.001)	(0.004)	(0.005)	(0.009)	(0.001)	(0.003)
Education of HH (educated)	-0.002	0.015	-0.112	-0.039	0.004	0.018
	(0.029)	(0.027)	(0.160)	(0.095)	(0.029)	(0.028)
Credit access (have access)	0.061	0.106	-0.041	-0.764**	0.061	0.161**
	(0.088)	(0.081)	(0.448)	(0.349)	(0.088)	(0.078)
Health service access (have access)	0.132***	0.045	-0.206	-0.133	0.147***	0.086**
	(0.042)	(0.039)	(0.195)	(0.104)	(0.043)	(0.041)
Flooding experience	0.036	0.059	0.639*	0.470*	0.009	0.019
	(0.069)	(0.080)	(0.351)	(0.282)	(0.069)	(0.081)
Drought experience	0.116***	0.092***	-0.035	0.074	0.115***	0.097***
	(0.035)	(0.034)	(0.180)	(0.150)	(0.036)	(0.034)
Disability (apt)	0.095*	0.254***	-0.118	0.210	0.109**	0.270***
	(0.051)	(0.055)	(0.166)	(0.149)	(0.053)	(0.059)
Marital status of HH (Married)	-0.053	-0.052	-0.240	-0.071	-0.036	-0.033
	(0.046)	(0.038)	(0.164)	(0.092)	(0.047)	(0.045)
Residential area (Rural)	0.024	-0.001	0.165	-0.038	0.019	-0.000
	(0.036)	(0.036)	(0.163)	(0.107)	(0.037)	(0.038)
CSA2: Endogenous treatment						
Soil type (ref: Sandy)						
1. Silty		0.058**		0.014		0.075***
		(0.026)		(0.108)		(0.027)

2. Clay	-0.007	0.029	0.006
	(0.026)	(0.103)	(0.027)
3. Glacis and other	-0.183***	-0.322	-0.142***
	(0.046)	(0.219)	(0.047)
Soil fertility			
1. Moderate	-0.136***	-0.156*	-0.133***
	(0.022)	(0.084)	(0.023)
2. Poor	-0.217***	-0.604***	-0.186***
	(0.047)	(0.185)	(0.047)
1. Land ownership (owners)	-0.063**	-0.306**	-0.048
	(0.030)	(0.130)	(0.030)
corr(e.hhintercroping	0.892***	0.734***	0.916***
	(0.030)	(0.141)	(0.028)
Constant	0.133***	1.006***	0.028
	(0.034)	(0.130)	(0.035)
Observations	6,760	804	5,956

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Note: CSA1=0 (Non-adopters) ; CSA1=1 (Adopters)

The findings generally align with existing literature on gender and food security in climate-smart agriculture (CSA). Previous studies (Meinzen-Dick et al., 2019; Mutenje et al., 2019) have found that women benefit from CSA adoption but face additional barriers such as limited access to credit, markets, and decision-making power. The strong negative impact of credit constraints on female-headed households in this study further reinforces this argument. Additionally, the results confirm that CSA practices can enhance food security, but their effectiveness depends on household characteristics such as land ownership, credit access, and exposure to climate shocks. The findings on soil fertility and land quality align with previous work by Pretty et al. (2018), which emphasized the need for integrated soil management alongside CSA adoption.

2.4.3. The combined effect of the use of organic fertilizer and intercropping practice on household food insecurity: gender analysis

The results in **Table 10** provide insights into the impact of the combined adoption of improved seeds and intercropping on household food insecurity, with a particular focus on gender differences. Several key variables emerge as significant in explaining household food insecurity among adopters (CSA=1) and non-adopters (CSA=0). Household gender shows a negative and significant effect among adopters, suggesting that female-headed households adopting Climate-Smart Agriculture (CSA) practices experience lower food insecurity than male-headed households. This aligns with findings by Doss (2018), who highlighted that when women adopt improved agricultural technologies, they tend to allocate resources more efficiently, enhancing food security at the household level.

The age of the head of household has a significant negative effect among male adopters, indicating that older male household heads adopting CSA practices experience reduced food insecurity. This may be due to accumulated farming experience, as noted by Abebaw and Haile (2013), who found that older farmers are more likely to adopt sustainable agricultural practices that improve productivity. Household size has a weakly significant positive effect for male adopters, suggesting that larger households that adopt CSA practices may struggle with food security. This is consistent with Frelat et al. (2016), who argued that larger households require more food resources, which can counterbalance the benefits of improved agricultural practices.

Table 10: The combined effect of the use of organic fertilizer and intercropping practice on household food insecurity

	Full sample		Female sample		Male sample	
	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	CSA=0	CSA=1	CSA=0	CSA=1	CSA=0	CSA1=1
Gender of HH	-0.061	-0.115**				
	(0.063)	(0.056)				
Age of HH	-0.001	-0.002	-0.004	0.002	-0.001	-0.004**
	(0.001)	(0.001)	(0.005)	(0.003)	(0.001)	(0.002)
Household size	-0.008	0.051	-0.054	-0.030	-0.002	0.065*
	(0.025)	(0.034)	(0.102)	(0.070)	(0.025)	(0.038)
Number of equivalent adults	0.003	-0.069	0.143	0.026	-0.011	-0.085
	(0.034)	(0.047)	(0.142)	(0.097)	(0.034)	(0.052)
Cultivated land area	-0.002	-0.004	0.001	-0.015*	-0.002	-0.003
	(0.001)	(0.004)	(0.005)	(0.009)	(0.001)	(0.004)
Education of HH (educated)	0.005	0.021	-0.114	-0.050	0.009	0.036
	(0.030)	(0.040)	(0.130)	(0.101)	(0.030)	(0.042)
Credit access (have access)	0.065	0.112	-0.103	-0.761**	0.071	0.204**
	(0.093)	(0.109)	(0.468)	(0.336)	(0.094)	(0.104)
Health service access (have access)	0.160***	0.016	-0.200	-0.087	0.190***	0.049
	(0.045)	(0.053)	(0.139)	(0.115)	(0.046)	(0.057)
Flooding experience	0.061	0.035	0.624*	0.461	0.041	-0.036
	(0.076)	(0.107)	(0.351)	(0.292)	(0.076)	(0.109)
Drought experience	0.134***	0.137***	0.107	0.024	0.129***	0.149***
	(0.036)	(0.050)	(0.175)	(0.150)	(0.037)	(0.050)
Disability (apt)	0.166***	0.287***	-0.074	0.216	0.183***	0.310***
	(0.056)	(0.076)	(0.156)	(0.164)	(0.058)	(0.085)
Marital status of HH (Married)	-0.049	-0.088*	-0.094	-0.122	-0.050	-0.047
	(0.047)	(0.054)	(0.137)	(0.099)	(0.050)	(0.066)
Residential area (Rural)	0.019	-0.024	0.099	-0.039	0.018	-0.024
	(0.038)	(0.053)	(0.128)	(0.117)	(0.039)	(0.057)
CSA: Endogenous treatment						
Soil type (ref: Sandy)						
1. Silty		-0.071*		-0.154		-0.035

	(0.037)	(0.103)	(0.037)
2. Clay	-0.109***	-0.052	-0.091**
	(0.036)	(0.094)	(0.038)
3. Glacis and other	-0.248***	-0.407*	-0.187***
	(0.058)	(0.227)	(0.061)
Soil fertility			
1. Moderate	-0.197***	-0.271***	-0.193***
	(0.027)	(0.080)	(0.029)
2. Poor	-0.410***	-0.496***	-0.397***
	(0.061)	(0.176)	(0.066)
1. Land ownership (owners)	-0.227***	-0.362**	-0.203***
	(0.044)	(0.160)	(0.047)
corr(e.improvedseeds_	0.732***	0.723***	0.781***
	(0.066)	(0.193)	(0.069)
Constant	-0.104**	0.879***	-0.266***
	(0.050)	(0.163)	(0.055)
Observations	6,760	804	5,956

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Note: CSA=0 (Non-adopters); CSA=1 (Adopters)

Access to credit is significantly negative among female adopters, but significantly positive among male adopters. This suggests that while male farmers benefit from credit access, female farmers may face structural constraints that limit their ability to translate credit into food security gains, as observed by Kabeer (2016). Women often have less control over financial resources, limiting their ability to make independent farming decisions. Access to healthcare is significantly positive for non-adopters and male non-adopters, indicating that better healthcare access is associated with greater food security. This could be due to healthier household members being able to work more productively, as found in the study by Fanzo et al. (2020), which emphasized the link between health services and agricultural productivity.

Exposure to drought has a strong positive effect across all groups, with significance at the 1% level, showing that drought conditions exacerbate food insecurity regardless of CSA adoption. This finding is consistent with Wossen et al. (2018), who found that drought exposure significantly reduces farm productivity and household food security. Disability status also has a significant positive effect across all groups, indicating that households with disabled members face higher food insecurity. This is consistent with the findings of Groce et al. (2011), who argued that households with disabled members have lower income-generating capacity and higher dependency burdens.

2.4.4. Average treatment effects

We have calculated the average treatment effects of improved seeds (CSA1), intercropping (CSA2), and their combined adoption on food insecurity across different gender groups. The probability of being food secure significantly increases with the adoption of these Climate-Smart Agriculture (CSA) practices, but the magnitude of the impact varies by gender and type of practice (**Table 11**).

For improved seeds (CSA1), the probability of being food secure increases by 0.126 for the full sample, but this effect is not statistically significant. However, for female-headed households, the effect is much stronger and highly significant, indicating that women benefit more from improved seeds than men. This suggests that female farmers may use improved seeds more effectively to enhance food security, possibly due to their preference for crops that contribute directly to household nutrition, as suggested by Beuchelt and Badstue (2013).

Intercropping (CSA2) has an even stronger impact, significantly increasing the probability of food security by 0.449 for the full sample. The impact is positive and significant for both men and women, but it is particularly strong for male-headed households. This aligns with findings from Thierfelder et al. (2017), who showed that intercropping improves soil fertility and increases yields, thus enhancing food security. The significant effect for female-headed households suggests that women also benefit from intercropping, although not to the same extent as men. This may be due to differences in access to complementary resources such as land, labor, or extension services.

The combined adoption of improved seeds and intercropping (CSA1 and CSA2) has the strongest impact, increasing the probability of food security by 0.413 for the full sample. The effect is positive and significant for both men and women, confirming that combining CSA practices leads to greater improvements in food security. This result is consistent with studies by Giller et al. (2015), who found that integrating multiple sustainable agricultural practices generates higher productivity and resilience.

The probability of experiencing mild food insecurity increases significantly with improved seeds alone, particularly for women, but decreases slightly with the combined adoption (-0.030 for the full sample). This suggests that while improved seeds alone might help reduce severe food insecurity, they may not be sufficient to eliminate mild food insecurity unless combined with intercropping. This aligns with the findings of Mutenje et al. (2016), who showed that single interventions often provide limited benefits, whereas integrated strategies offer more comprehensive food security improvements.

Moderate food insecurity declines significantly across all CSA adoption categories, indicating that these practices effectively reduce vulnerability to food shortages. The strongest reduction is observed for the combined adoption (-0.166 for the full sample, -0.178 for males), highlighting the importance of synergy between improved seeds and intercropping. This is in line with the work of Snapp et al. (2010), who found that combining CSA practices reduces yield variability and stabilizes food availability.

Table 11: Average treatment effects (ATE)

	Improved seeds (CSA1)			Intercropping (CSA2)			CSA1 and CSA2		
	Full sample	Female	Male	Full sample	Female	Male	Full sample	Female	Male
Pr(Food secure)	0.126	0.339***	0.108	0.449***	0.264***	0.473***	0.413***	0.297***	0.457***
	(0.087)	(0.018)	(0.102)	(0.014)	(0.064)	(0.013)	(0.040)	(0.093)	(0.041)
Pr(Mild)	0.062***	0.154***	0.061***	0.006	0.104***	-0.012	-0.030**	0.070**	-0.055***
	(0.015)	(0.018)	(0.014)	(0.007)	(0.026)	(0.007)	(0.013)	(0.026)	(0.015)
Pr(Moderate)	-0.705***	0.114**	-0.062*	-0.086***	-0.050	-0.089***	-0.166***	-0.092*	-0.178***
	(0.027)	(0.051)	(0.035)	(0.017)	(0.064)	(0.018)	(0.009)	(0.055)	(0.008)
Pr(Severe)	-0.117	-0.608***	-0.106	-0.369***	-0.317**	-0.372***	-0.217***	-0.275*	-0.224***
	(0.074)	(0.059)	(0.079)	(0.026)	(0.131)	0.026	(0.029)	(0.149)	(0.029)

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Severe food insecurity also declines, particularly for female-headed households. For example, female farmers adopting improved seeds experience a substantial reduction in severe food insecurity, whereas for males, the effect is smaller and not significant. This suggests that female-headed households are more vulnerable to extreme food insecurity but also benefit more when adopting CSA practices. This supports the findings of Meinzen-Dick et al. (2019), who emphasized that gender-responsive agricultural interventions can have transformative impacts on women’s food security.

Overall, these results confirm that CSA adoption improves food security, with the greatest benefits observed when multiple practices are combined. However, the gender-differentiated impacts highlight the need for targeted support to ensure that both male and female farmers can maximize the benefits of CSA. The findings are consistent with previous literature, which emphasizes that while CSA adoption can enhance food security, its effectiveness depends on gender dynamics, resource access, and complementary investments in extension services and credit facilities.

2.4.5. The combined effect of the use of organic fertilizer and intercropping practice on household food insecurity: regional analysis

The results highlight the regional differences in the impact of adopting organic fertilizer and intercropping (CSA) on household food insecurity, considering various household characteristics (**Table 12**). The effect of CSA adoption varies significantly across regions, indicating that local conditions play a crucial role in determining food security outcomes.

In the Centre region, CSA adoption does not have a significant effect on food insecurity, as shown by the non-significant coefficient. However, in the Centre-Ouest, CSA adoption significantly improves food security, suggesting that intercropping and organic fertilizer use are highly beneficial in this region. This result aligns with the findings of Giller et al. (2015), who emphasized that the success of sustainable agricultural practices depends on soil and climatic conditions. In contrast, the Nord region shows a significant negative effect, implying that CSA adoption might not be effective in reducing food insecurity in this region. This finding is consistent with the study by Wossen et al. (2018), which found that CSA adoption in semi-arid areas is less effective due to climate variability and limited soil fertility improvements. The Sud-Est region shows a positive but non-significant effect, while in the Sud-Ouest, CSA adoption reduces food insecurity significantly, confirming the effectiveness of CSA practices in humid regions with more favorable agroecological conditions.

Household gender (Gender of HH) plays a crucial role in food security outcomes across regions. In the Centre-Ouest, female-headed households experience improved food security with CSA adoption, but in other regions, female-headed households are more food insecure (-0.733 in Nord, -0.490 in Sud-Ouest). This pattern supports the findings of Doss (2018), who highlighted that women's food security outcomes are highly dependent on resource access, including land, credit, and agricultural extension services.

The age of the household head (Age of HH) hurts food insecurity in the Nord and Sud-Ouest, suggesting that older household heads may have more farming experience and better coping mechanisms against food shortages. This is consistent with the findings of Abebaw and Haile (2013), who noted that age positively influences agricultural decision-making and resilience. Household size (Household size) does not show a significant effect in most regions, except for the Sud-Ouest, where larger households experience slightly higher food security. This supports the argument by Frelat et al. (2016) that larger households can have a labor advantage in agricultural production, particularly in regions with more land availability.

Cultivated land area (Cultivated land area) has a significant negative effect in the Centre-Ouest and Sud-Ouest, indicating that larger landholdings may not always lead to better food security. This result is in line with Holden and Ghebru (2016), who found that land tenure security and land quality play a more crucial role than land size in ensuring food security.

Education of the household head (Education of HH) has a significant positive effect on food security in the Nord and Centre-Ouest, suggesting that educated farmers are more likely to adopt improved agricultural practices and manage resources efficiently. This aligns with the findings of Beuchelt and Badstue (2013), who emphasized the role of education in improving agricultural technology adoption. Credit access does not show a significant effect in any region, indicating that financial support alone may not be sufficient to improve food security without complementary interventions such as extension services and infrastructure development. This is consistent with Kabeer (2016), who highlighted that access to credit needs to be accompanied by financial literacy and market access. Health service access is positively associated with food security in Nord (0.158), suggesting that access to healthcare improves household resilience and labor productivity. This supports the findings of Fanzo et al. (2020), who emphasized the interconnection between health and food security.

Exposure to drought (Drought experience) increases food insecurity in the Nord and Sud-Ouest, reflecting the vulnerability of these regions to climate shocks. This is in line with the study by Wossen et al. (2018), which found that drought exposure significantly reduces farm productivity and household food security. Overall, the results confirm that the combined adoption of organic fertilizer and intercropping has mixed effects on food insecurity across regions, emphasizing the importance of context-specific agricultural policies. While CSA adoption significantly improves food security in the Centre-Ouest and Sud-Ouest, it appears less effective in the Nord, where climate and soil conditions may limit its benefits. These findings support previous literature emphasizing that CSA interventions must be tailored to regional characteristics, considering gender dynamics, land tenure, education, and climate vulnerability.

Table 12: The combined effects of the use of organic fertilizer and intercropping practice on household food insecurity: regional analysis

	Centre		Centre-ouest		Nord		Sud-est		Sud-ouest	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
VARIABLES	Eq1	Eq2	Eq1	Eq2	Eq1	Eq2	Eq1	Eq2	Eq1	Eq2
CSA	-0.471		2.143***		-2.142***		0.771		-1.924**	
	(0.990)		(0.221)		(0.163)		(0.503)		(0.774)	
Gender of HH	-0.248	-0.168***	0.533***	-0.270***	-0.733***	-0.325***	0.199	-0.253***	-0.490***	-0.179***
	(0.186)	(0.037)	(0.143)	(0.047)	(0.106)	(0.042)	(0.201)	(0.062)	(0.182)	(0.058)
Age of HH	-0.002	-0.001	-0.001	-0.000	-0.004**	-0.002**	-0.001	0.002	0.003	0.002**
	(0.003)	(0.001)	(0.002)	(0.001)	(0.002)	(0.001)	(0.003)	(0.001)	(0.003)	(0.001)
Household size	0.087	0.037	-0.045	0.017	-0.017	-0.006	0.092	-0.045*	0.036	0.034*
	(0.067)	(0.028)	(0.055)	(0.024)	(0.036)	(0.016)	(0.078)	(0.027)	(0.071)	(0.019)
Number of equivalent adults	-0.109	-0.062	0.068	-0.026	-0.013	-0.005	-0.090	0.038	-0.042	-0.042
	(0.097)	(0.038)	(0.076)	(0.033)	(0.049)	(0.022)	(0.101)	(0.035)	(0.097)	(0.026)
Cultivated land area	-0.000	-0.000	0.020	-0.013***	-0.001	-0.000	-0.013	-0.008*	-0.043***	-0.007**
	(0.002)	(0.001)	(0.012)	(0.005)	(0.001)	(0.000)	(0.011)	(0.005)	(0.013)	(0.003)
Education of HH (educated)	0.038	-0.046	0.073	-0.018	0.127**	0.070***	-0.045	0.049	0.024	0.027
	(0.084)	(0.031)	(0.059)	(0.024)	(0.064)	(0.026)	(0.078)	(0.031)	(0.070)	(0.020)
Credit access (have access)	-0.245	-0.105	-0.112	0.121	-0.003	-0.032	-0.309	0.119	-0.162	-0.019
	(0.237)	(0.099)	(0.218)	(0.075)	(0.153)	(0.065)	(0.217)	(0.091)	(0.204)	(0.076)
Health service access (have access)	-0.161	-0.002	-0.062	0.056	0.158**	0.036	0.124	0.072	0.115	0.034
	(0.103)	(0.041)	(0.108)	(0.037)	(0.080)	(0.031)	(0.118)	(0.046)	(0.107)	(0.035)
Flooding experience	0.263	-0.004	0.098	0.004	0.027	0.017	0.134	-0.028	0.002	0.017
	(0.230)	(0.094)	(0.185)	(0.065)	(0.101)	(0.045)	(0.259)	(0.097)	(0.233)	(0.064)
Drought experience	0.008	-0.010	-0.070	0.043	0.137**	0.042*	0.001	0.024	0.338**	-0.019
	(0.094)	(0.040)	(0.066)	(0.027)	(0.061)	(0.025)	(0.127)	(0.056)	(0.143)	(0.028)
Disability (apt)	0.218	-0.071	0.163	-0.012	-0.004	-0.054	0.074	-0.030	0.334**	0.068
	(0.163)	(0.053)	(0.125)	(0.046)	(0.122)	(0.040)	(0.146)	(0.059)	(0.132)	(0.043)
Marital status of HH (Married)	-0.104	-0.058	-0.008	0.021	-0.001	0.009	-0.260*	-0.016	-0.204*	-0.031
	(0.093)	(0.036)	(0.090)	(0.037)	(0.087)	(0.038)	(0.135)	(0.051)	(0.105)	(0.033)
Residential area (Rural)	0.003	0.072*	0.056	-0.003	0.152**	0.045*	0.023	0.102***	-0.123	0.009
	(0.117)	(0.044)	(0.071)	(0.028)	(0.068)	(0.027)	(0.113)	(0.033)	(0.105)	(0.030)

Soil type		-0.045***		0.038		0.001		-0.025		0.018*
		(0.015)		(0.027)		(0.004)		(0.018)		(0.010)
Soil fertility		-0.032		0.022*		-0.035*		0.011		-0.052***
		(0.048)		(0.012)		(0.021)		(0.026)		(0.013)
landownership		-0.153**		-0.009		-0.008		-0.185***		-0.115*
		(0.060)		(0.039)		(0.011)		(0.038)		(0.060)
var(e.Eq2, e.Eq1)	0.200***		0.193***		0.194***		0.177***		0.107***	
	(0.005)		(0.006)		(0.004)		(0.007)		(0.007)	
corr(e.Eq2, e.Eq1)	0.304		-0.924***		0.938***		-0.233		0.619**	
	(0.436)		(0.110)		(0.074)		(0.225)		(0.261)	
Constant		1.173***		0.473***		0.716***		0.618***		0.361***
		(0.087)		(0.078)		(0.070)		(0.101)		(0.084)
Observations	1,065	1,065	1,518	1,518	2,139	2,139	815	815	1,216	1,216

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Note: CSA=0 (Non-adopters) ; CSA=1 (Adopters)

2.5. Conclusion and policy implications

This chapter examines the impact of Climate-Smart Agriculture (CSA) practices, particularly improved seeds and intercropping, on household food insecurity in Côte d'Ivoire. Using data from the 2018 Harmonized Survey on Living Conditions of Households (EHCVM-2018), the analysis employs an extended ordered probit model to account for selection bias and endogeneity in CSA adoption decisions. The model estimates the effect of CSA on food security, controlling for socio-economic characteristics, climate shocks, and regional factors. The results indicate that CSA adoption significantly influences food security outcomes, but its effects vary by gender and region. Female-headed households benefit more from improved seeds, increasing their probability of food security by 33.9%, while intercropping has a stronger positive effect for male-headed households, raising their food security probability by 47.3%. The combined adoption of CSA practices further improves food security, increasing the probability by 41.3% for the full sample, 29.7% for women, and 45.7% for men. However, the effects are not uniform across regions. CSA adoption significantly enhances food security in the Sud-Ouest, whereas in the Centre-ouest, it has a positive impact, likely due to harsh climatic conditions and poor soil fertility. Structural barriers such as limited access to credit and land ownership disproportionately affect female farmers. Credit access significantly reduces food insecurity for male adopters, but for female adopters, access to credit negatively impacts food security (-0.761), suggesting that financial constraints remain a major obstacle. Exposure to climate shocks exacerbates food insecurity, with drought increasing food insecurity across all groups (0.134 for the full sample), confirming that CSA adoption alone is insufficient to mitigate climate risks without complementary adaptation strategies.

To maximize the benefits of CSA and address existing disparities, several policy actions are necessary. Region-specific CSA strategies should be implemented, prioritizing drought-resistant crops and soil fertility improvements in the Nord while expanding CSA adoption support in the Centre and Centre-Ouest. Gender-responsive policies must enhance women's access to land, credit, and agricultural extension services to bridge the gender gap in food security outcomes. Credit schemes tailored to smallholder farmers should be developed, with a focus on reducing borrowing constraints for women. Investments in rural infrastructure, including roads and storage facilities, would strengthen market access and reduce post-harvest losses. Climate adaptation strategies, such as improved irrigation systems and early warning mechanisms, should be integrated with CSA adoption to enhance resilience to droughts and floods. Expanding agricultural extension services and farmer education programs will also be crucial in increasing CSA awareness and adoption. Public-private partnerships should be promoted to scale CSA technologies, while nutrition-sensitive agricultural policies should ensure that CSA adoption translates into improved dietary diversity and overall well-being.

These findings underscore the transformative potential of CSA in reducing food insecurity in Côte d'Ivoire but highlight the need for targeted interventions to address gender disparities, climate risks, and financial constraints. Policymakers must implement holistic approaches that combine CSA promotion with institutional and socio-economic support to create a more resilient and food-secure agricultural sector. This research highlights the importance of considering gender disparities in fostering the impacts of CSA practices on food security however, it fails to integrate social relationships and the dynamic aspects of these strategies. Further research can rely on agent-based analysis modeling, which takes into account the relationships that the farm household has with market agents through prices, and agricultural cooperatives through the adoption of practices and group work, and sees the impact of all this on the food security of the farm household.

Chapter 3: IMPACT OF WOMEN’S ADOPTION OF CLIMATE-SMART AGRICULTURE ON FARM HOUSEHOLD VULNERABILITY TO CLIMATE RISK

Abstract

While climate change cannot be compartmentalized by region, religion, caste, or creed, it does pose a real risk of widening the gender gap in less developed countries. Adoption of climate-smart agriculture (CSA) practices is necessary to build women’s resilience to climate risk. The objective of this paper is to assess the impact of women’s adoption of climate-smart agriculture on farm household vulnerability to climate risk in Côte d'Ivoire. We employ the endogenous switching approach on Côte d’Ivoire’s Harmonized Survey on Living Conditions of Households in 2018. The results show that age positively affects the probability of adopting improved seeds and intercropping. Moreover, floods, drought, and being married compared to being single increase women’s vulnerability to climate risk while the age of households headed by women, household size, and health access statistically reduce women’s vulnerability to climate risk. On average, adopters of improved seeds and intercropping systems (CSA1CSA2) have a 4.84% decline in the vulnerability index, whereas their counterparts showed a 21% rise in the vulnerability index. In addition, adopters of improved seeds (CSA1), and intercropping indicated a 5.76%, and 4.5% fall in the vulnerability index, respectively, whereas their counterparts revealed a 7.54%, and 24.74% rise in the vulnerability index, respectively. Implementing policy measures that increase farm households headed by women's adaptive capacity is critical. These measures can empower women to effectively respond to climate change, enhance their resilience, and contribute to the achievement of Sustainable Development Goal 13.

Keywords: Vulnerability to climate risk, climate-smart agriculture, women, adaptation

3.1. Introduction

Although climate change cannot be compartmentalized by region, religion, caste, or creed, it does pose a real risk of widening the gender gap in less developed countries (Bryan et al., 2024; Eastin, 2018; Yadav & Lal, 2018). Climate change exacerbates existing gender inequalities in poorer countries by increasing the vulnerability of women in agricultural households (Masson et al., 2019;

Memon, 2020). Indeed, different stakeholders in different regions perceive the impacts of climate change differently, and the extent of vulnerability depends on different rights, roles, and responsibilities (Yadav & Lal, 2018). Males and females are not fundamentally different based on biological sex (Annecke, 2002), but rather socially constructed roles, behaviors, attributes, and relative power. Across cultures and between them, gender perceptions vary widely. There is unequal access to power and resources for men and women in every culture (FAO, 2011). In a climate change situation, women are disproportionately more vulnerable than men due to these gendered aspects (Daoud, 2021; Denton, 2002; Mujere, 2016). As women's traditional roles in agriculture are heavily impacted by climate change, such as decreased crop yields and increased water scarcity, their economic and social status becomes even more precarious, widening the gender gap.

Nevertheless, women's adoption of climate-smart agriculture (CSA) can lead to increased resilience and reduced vulnerability of farm households to climate change (Rahman, 2013). By implementing sustainable farming practices, such as crop diversification, soil conservation, and efficient water management, women can enhance the productivity and sustainability of their farms, ensuring stable income and food security even in the face of changing climate conditions (Annecke, 2002; Yadav & Lal, 2018). In addition, by implementing sustainable farming practices, women can improve the quality and quantity of their agricultural products, leading to higher market value and increased income. Furthermore, climate-smart agriculture can create new economic opportunities for women, such as participating in value-added processing activities or accessing markets that prioritize sustainable and climate-friendly products. These practices can also help to reduce poverty and gender inequality, as women are often the primary caregivers in their families and are more likely to be affected by climate change. Sustainable farming practices can also help conserve natural resources, such as water, soil, and biodiversity.

While women play an important role in the Ivorian economy, they are vulnerable to discrimination that hinders their ability to be resilient to different shocks. In the food crops sub-sector of agriculture, women represent 90% of the actors, which employs 85% of the active agricultural population. Women are also involved in rearing small cattle, processing, and marketing by-products, and account for two-thirds of the agricultural workforce. Contextually, Afrobarometer, (2022) showed that men are more likely to complete secondary education (44% vs. 39%) and post-secondary education (19% vs. 11%) than women, and the latter are more likely to lack formal education (19%) than the former (13%) in Côte d'Ivoire. In addition to owning a bank account (20% vs. 28%), Ivorian women also lack access to land and opportunities. Indeed, gender inequality in Côte d'Ivoire not only affects women's access to education and basic resources but also hampers their economic opportunities. Limited access to land and opportunities further restricts women from participating fully in the workforce, hindering their potential for economic growth and empowerment.

Gender inequalities may impede women’s abilities to access the necessary resources to adopt CSA, or they may not be able to take advantage of the benefits of climate-smart agriculture if they are not knowledgeable about the technology (Ayeb-Karlsson et al., 2020; Cutter, 2017; Jordan, 2019; Masson et al., 2019; Memon, 2020; Ngcamu, 2023; Tanjeela & Rutherford, 2018). The scarcity of fuel wood, water, and fodder in rural areas disrupts the lives of women the most. Even so, women are also effective agents of change since they use their coping strategies and livelihood strategies to cope with climate change (Israel & Sachs, 2013; Mujere, 2016; Yadav & Lal, 2018). As anthropogenic climate change worsens, women in arid and semi-arid countries struggle even harder and suffer more. As a result, climate change must be understood in a gendered manner. Without CSA's benefits and resilience, these women may struggle to adapt to changing weather patterns and face greater challenges in maintaining their agricultural livelihoods. Several successful initiatives in Côte d'Ivoire have promoted women's adoption of climate-smart agriculture.

For example, the "Women in Agriculture" program provides training and resources to women farmers, empowering them to implement sustainable farming practices that are resilient to climate change. Another initiative called "Women's Agricultural Cooperatives" supports women in forming cooperatives, enabling them to access financing and resources for climate-smart agriculture projects. In addition to increasing women's adoption of climate-smart agriculture, these initiatives have also reduced farm household vulnerability to climate change in Côte d'Ivoire. By equipping women farmers with the necessary knowledge, skills, and resources, these programs have enhanced the resilience of farm households, enabling them to better cope with the adverse effects of climate change and ensure food security for their families. However, despite the success of these initiatives, accessing gender equity for CSA projects remains a significant challenge in Côte d'Ivoire. However, agriculture sustainability remains treated by some difficulties encountered in rural villages such as lack of rain (81.1%), lack of funding (81.1%), crop diseases (86.4%), damage from predators (82.2%), and drought (82.2%) according to the Census of Farmers and Agricultural Exploitations 2015/2016 (REEA, 2017).

The observed gender inequalities and agricultural challenges occur in a context characterized by regional vulnerability. According to the Foundation for Studies and Research on International Development, the physical vulnerability to climate change was distributed from 51.49 (Grands Ponts) to 48.46 (Tonkpi) in 2018. 25 of the 34 regions have a physical vulnerability to climate change of 50% or more, indicating a high general level of vulnerability. The five most vulnerable regions were Grand Ponts (51.49), Abidjan (51.02), Tchologo (50.88), Hambol (50.74), and Bounkani (50.70). In this context, the research question is: Does women's adoption of climate-smart agriculture impact farm household vulnerability to climate risk in Côte d'Ivoire? Limited access to credit, lack of collateral, and gender biases within financial institutions often hinder women's ability to secure funding for their agricultural ventures. Addressing these barriers and promoting gender-inclusive financing mechanisms will be crucial in further empowering women and advancing climate-smart agriculture in the country.

We aim to assess the impacts of women's adoption of CSA on farm household vulnerability to climate risk in Côte d'Ivoire. By applying an endogenous switching approach, we further analyze the determinants of women's adoption of CSA and farm household vulnerability to climate risk regarding the CSA adoption decision. This method is used to deal with selection bias and endogeneity failures due to adaptation decisions. By this objective, we evaluate the specific strategies (improved seeds and intercropping) that enable women to effectively cope with climate shocks and reduce their vulnerability. This would provide a comprehensive understanding of the role that women play in protecting the environment and their capacity to adapt to the challenges posed by climate change.

Using the endogenous switching approach on Côte d'Ivoire's 2018 Harmonized Survey on Living Conditions of Households, results reveal that age increases the likelihood of adopting improved seeds (CSA1) and intercropping (CSA2), while factors like floods, droughts, and being married heighten women's vulnerability. Conversely, female-headed households' age, larger household sizes, and better health access reduce vulnerability. Adopting CSA practices significantly lowers climate vulnerability. Households using both improved seeds and intercropping see a 4.84% decrease in their vulnerability index, compared to a 21% rise for non-adopters. Improved seeds alone reduce vulnerability by 5.76%, and intercropping lowers it by 4.5%, while non-adopters experience increases of 7.54% and 24.74%, respectively. These findings underscore the importance of expanding CSA adoption to enhance resilience and reduce climate-related risks.

The remainder of this paper is organized as follows: Section 2 gives an overview of the literature on the subject; Section 3 is devoted to a detailed description of the methodological approach used to achieve the above-mentioned objective. Finally, before concluding, the empirical results, their econometric analysis, and their economic interpretations are presented in section 4.

3.2. Current situation of climate vulnerability in Côte d'Ivoire

3.2.1. Country's vulnerability to climate change

The data on climate change vulnerability in Côte d'Ivoire from 1995 to 2021 illustrated in **Figure 18** indicates a complex interaction of factors including capacity, exposure, and sensitivity. Vulnerability to climate change remained relatively stable, with values fluctuating slightly but generally ranging between 0.48 and 0.50 over the years. This indicates ongoing susceptibility to climate risks, although changes in the contributing factors, capacity, exposure, and sensitivity reflect varying degrees of resilience and adaptation over time.

Capacity, which reflects the ability to cope with and adapt to climate change, steadily improved from 0.71 in 1995 to a peak of 0.74 in 2007, suggesting enhanced adaptive mechanisms, possibly due to economic growth, infrastructural development, or policy interventions. However, after 2007, capacity began declining, falling to 0.68 by 2021, which could point to emerging challenges such as economic constraints, population pressures, or limited implementation of climate adaptation strategies.

Exposure remained constant at 0.45 throughout the entire period, indicating that the country's geographic and climatic conditions continue to present consistent risks. These include susceptibility to floods, droughts, and other climate-related hazards that are intrinsic to the region.

Sensitivity, which measures the degree to which systems are affected by climate exposure, showed more fluctuation. It peaked at 0.36 in 2000 before gradually declining to approximately 0.33-0.34 by 2021. This decrease suggests some reduction in underlying vulnerabilities, possibly due to improvements in health, education, or agricultural practices, though the variability indicates that progress has been uneven.

While there has been some progress in mitigating climate vulnerability through increased capacity and reduced sensitivity, the decline in capacity after 2007 and the unchanged exposure highlight persistent risks. Addressing these challenges will require sustained investments in adaptive capacity, more targeted policies to reduce exposure and sensitivity, and comprehensive climate adaptation strategies.

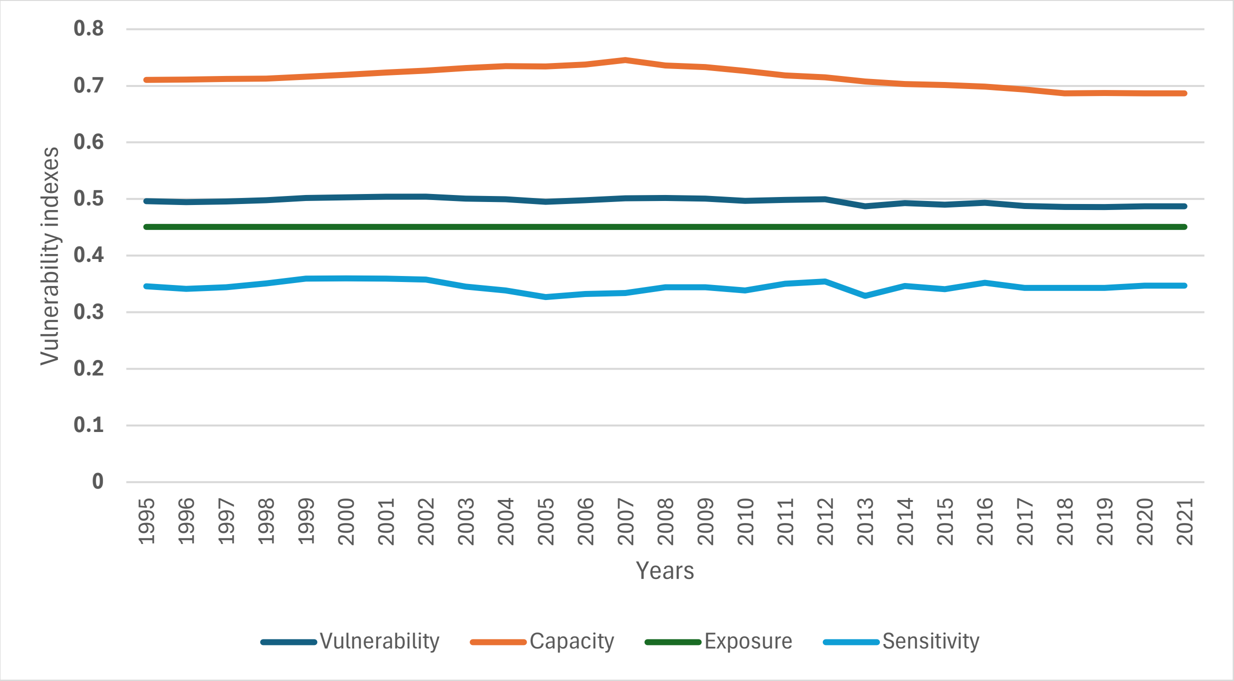

Figure 18; Trends of the country's vulnerability to climate change

Data source: Notre Dame Gain, 2025

3.2.2. Subnational physical vulnerability to climate change

Figure 19 outlines the Physical Vulnerability to Climate Change Index (PVCCI) developed by the Foundation for studies and Research on International Development (FERDI), which evaluates a region's vulnerability by focusing on two primary categories: risks associated with progressive shocks and risks from the intensification of recurrent shocks. Each category is subdivided into contributing factors with assigned weights to reflect their relative importance in determining vulnerability.

Progressive shocks include flooding due to sea level rise or melting glaciers and increasing aridity, each carrying a weight of 1/5. Flooding risk is assessed through the share of flood areas and the size of likely sea level rise, each weighted at 1/10. Aridity is measured by the share of dry lands and trends in temperature and rainfall, with temperature and rainfall trends weighted at 1/20 each. Recurrent shocks are divided into risks related to rainfall, temperature, and storms, all also weighted at 1/5. Rainfall risks are evaluated based on rainfall levels and trends in rainfall instability, each weighted at 1/10. Temperature-related risks include baseline temperature levels and temperature instability trends, both with weights of 1/10. Finally, storm-related risks consider storm intensity and changes in storm intensity, each also weighted at 1/10.

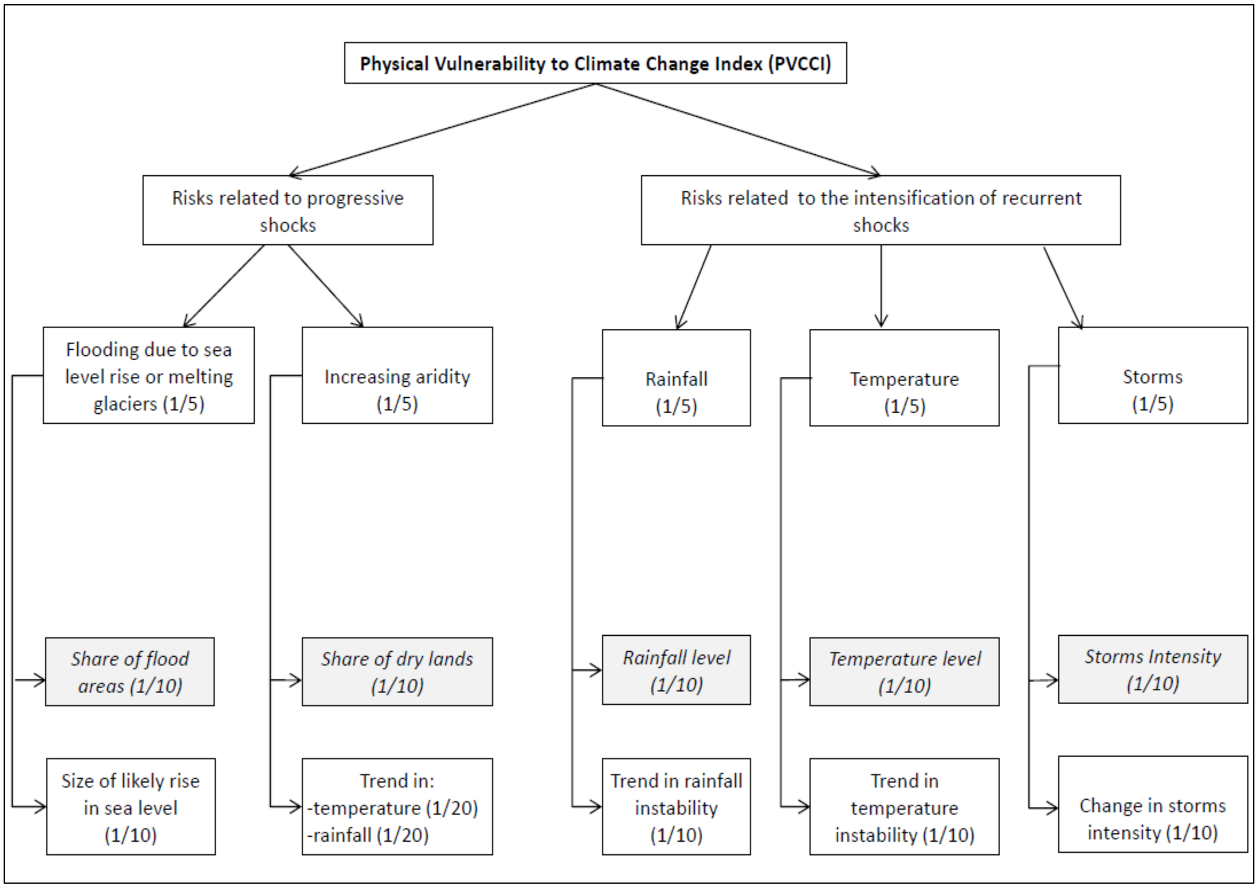

Figure 19; Diagram of the Physical Vulnerability to Climate Change Index (PVCCI)

Source: Foundation for studies and Research on International Development, (2018)

The framework provides a comprehensive approach to assessing climate vulnerability by integrating both gradual and sudden environmental changes. By assigning weights to each contributing factor, the model highlights the critical dimensions of physical vulnerability, guiding targeted interventions to mitigate climate change risks and enhance resilience.

The PVCCI score of 46.01 in 2018 reflects moderate vulnerability to climate change, primarily driven by high sensitivity to temperature (68.84) and rainfall variability (65.20) (**Figure 20**). These factors highlight significant risks related to rising temperatures and irregular rainfall patterns, which impact agriculture, water resources, and ecosystems. Increasing aridity (39.91) contributes moderately to the vulnerability while flooding due to sea-level rise or high rainfall (0.32) plays a minimal role.

The Physical Vulnerability to Climate Change Index (PVCCI) rankings for various regions in Côte d'Ivoire highlight varying levels of vulnerability to climate risks across the country (**Figure 21**). The highest PVCCI values are observed in Grands Ponts (51.49), followed by Abidjan (51.02) and Tchologo (50.88), indicating these regions face the greatest physical vulnerabilities to climate change. These regions are likely exposed to a combination of factors such as flooding, aridity, or recurrent climate shocks, which heighten their risk profiles.

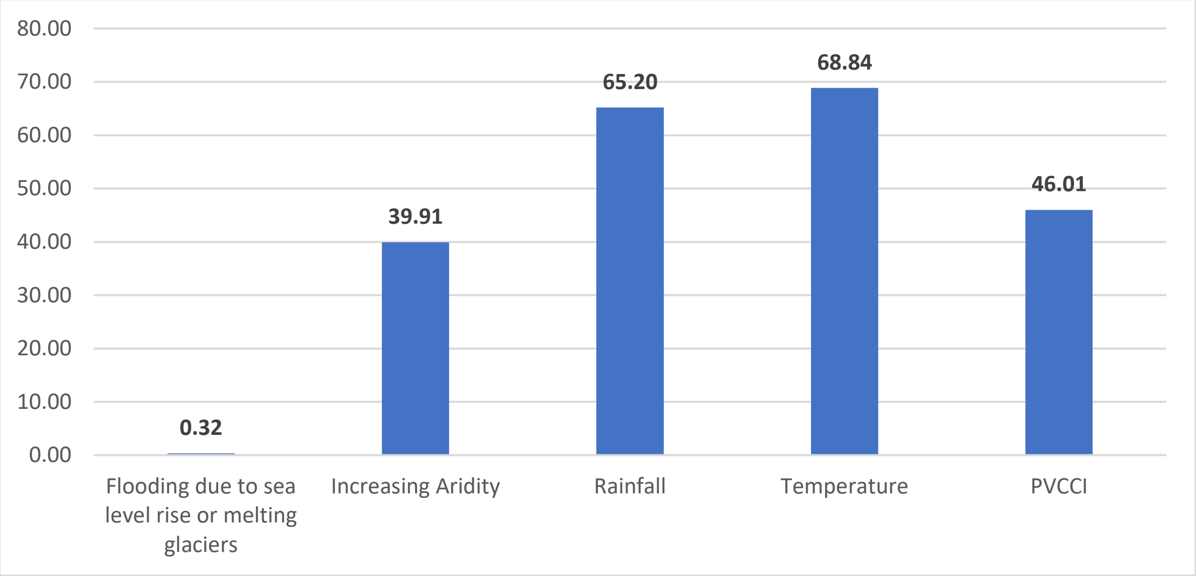

Figure 20: Physical Vulnerability to Climate Change Index (PVCCI) and its dimensions

Data source: Foundation for Studies and Research on International Development (2018)

Regions like Tonkpi (48.46), SAN-PEDRO (48.80), and Cavally (48.85) exhibit the lowest PVCCI scores, suggesting relatively lower vulnerability compared to other regions. However, even the lowest-ranked regions maintain PVCCI values close to 50, signaling that climate change poses a significant risk nationwide. The majority of regions, including Bounkani (50.70), Gbeke (50.69), and Yamoussoukro (50.64), have PVCCI values clustered around 50, indicating moderate vulnerability. These values reflect exposure to a mix of progressive and recurrent climate shocks, underpinned by regional characteristics such as infrastructure, land use, and population dynamics. Overall, the PVCCI data underscores the importance of region-specific strategies to address climate vulnerabilities in Côte d'Ivoire. High-risk regions like Grand Ponts and Abidjan require targeted interventions to mitigate flooding and other acute risks, while regions with moderate or lower vulnerability could benefit from preventative measures to build resilience and adapt to future climate challenges.

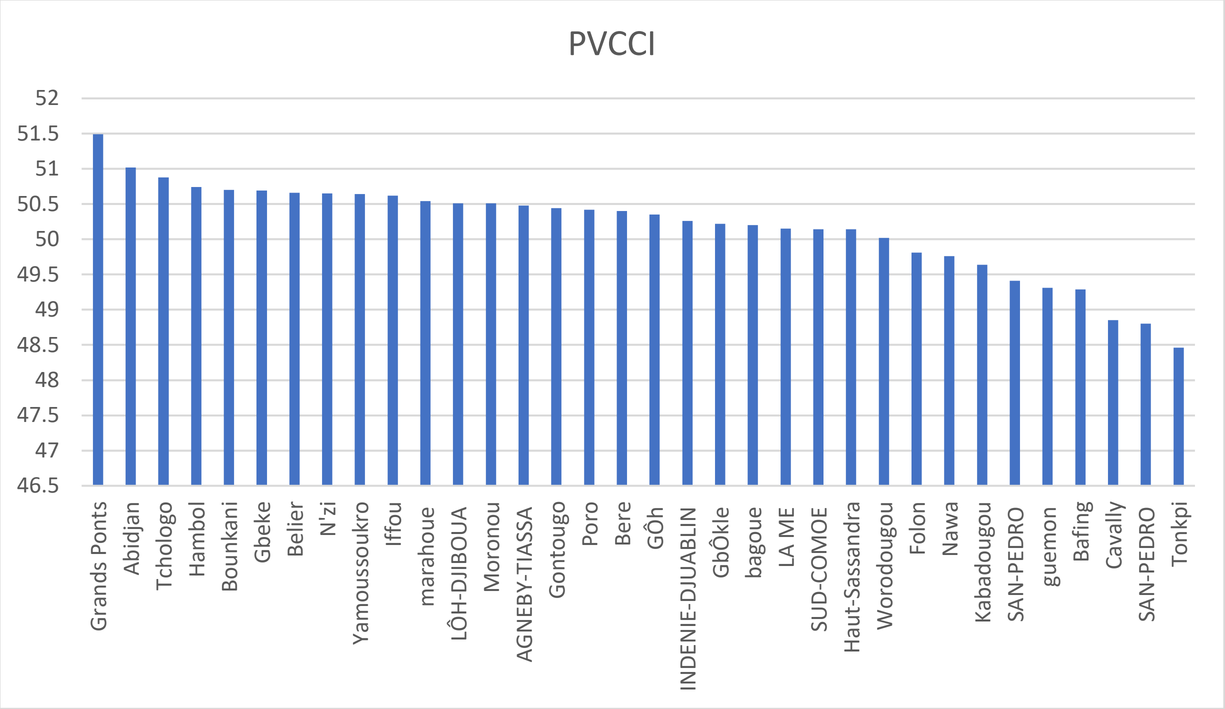

Figure 21: Regional distribution of Physical Vulnerability to Climate Change Index (PVCCI)

Data source: Foundation for studies and Research on International Development, (2018)

3.2.3. Sectoral vulnerability to climate change in Côte d'Ivoire

The data on sectoral vulnerability to climate change in Côte d'Ivoire reveals critical insights into the levels and trends of vulnerability across five key sectors, food, habitat, health, infrastructure, and water, from 1995 to 2021 (**Figure 22**). Each sector's trajectory reflects specific challenges and opportunities for targeted interventions to enhance resilience and adapt to the impacts of climate change.

The food sector exhibits consistently high vulnerability, with values fluctuating between 0.62 and 0.66 over the years. The peak vulnerability of 0.66 in 2007 reflects significant susceptibility to climate risks, such as droughts, floods, and shifts in temperature that affect agricultural productivity. Although a slight decline in vulnerability is observed post-2010, the sector remains one of the most exposed to climate variability. Enhancing resilience in the food sector requires a focus on promoting climate-smart agriculture (CSA) practices, such as drought-resistant crops, efficient irrigation systems, and sustainable farming techniques. Expanding access to agricultural insurance and improving rural infrastructure, such as roads and storage facilities, can also mitigate risks and reduce post-harvest losses, contributing to greater food security.

The habitat sector shows moderate and relatively stable vulnerability over time, with values remaining close to 0.61. This indicates persistent risks to housing and urban infrastructure, particularly in regions prone to flooding and extreme weather events. While recent declines suggest some improvements in urban planning and disaster preparedness, more needs to be done to enhance resilience. Key measures include investing in flood-resistant housing designs, improving land-use planning, and expanding access to affordable and safe housing in rural and urban areas. Policies that enforce construction standards and integrate climate risk assessments into urban development plans will further strengthen this sector's adaptive capacity.

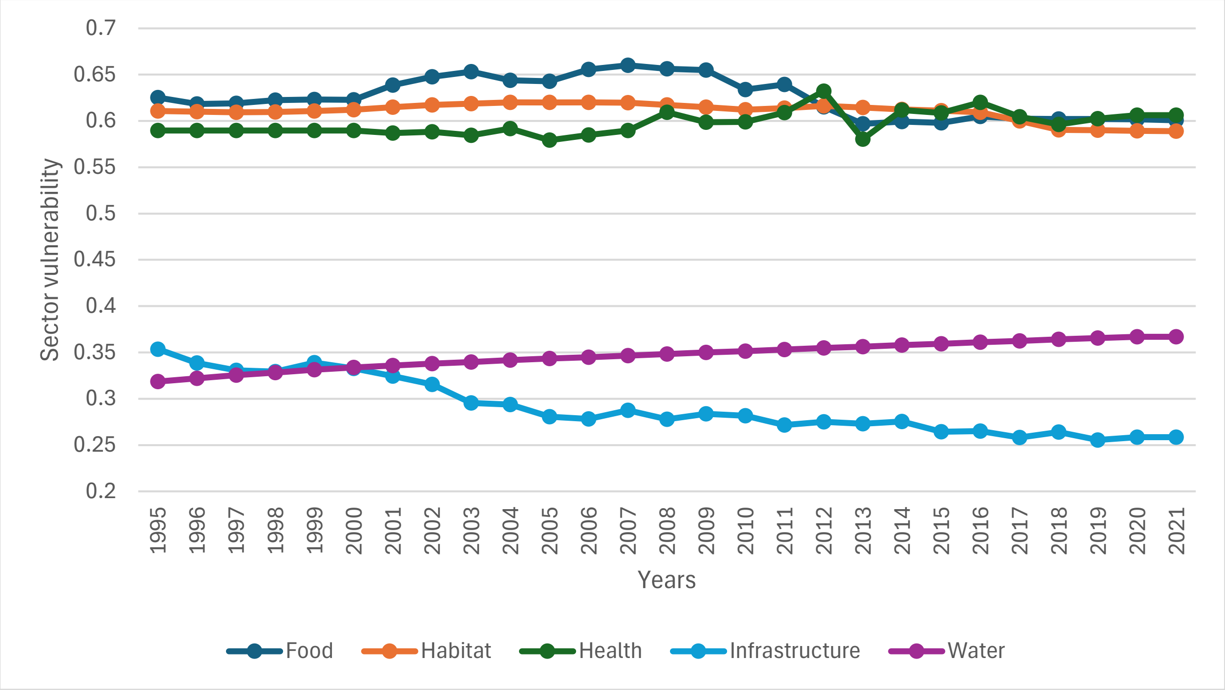

Figure 22: Trends of the different sector vulnerability to climate change

Data source: Notre Dame Gain, 2025

The health sector demonstrates a complex pattern of vulnerability, with significant fluctuations over the years. Vulnerability declined slightly between 1995 and 2005 but increased sharply after 2010, peaking at 0.63 in 2012. This rise likely corresponds to the growing burden of climate-related health risks, such as heat stress, waterborne diseases, and vector-borne diseases like malaria. Addressing these vulnerabilities requires bolstering the healthcare system's capacity to respond to climate-induced health challenges. Investments in early warning systems for disease outbreaks, expanding access to healthcare in rural areas, and integrating climate considerations into public health policies are critical. Additionally, targeted health campaigns to raise awareness about climate-sensitive diseases can improve community-level preparedness.

The infrastructure sector shows the lowest levels of vulnerability among the five sectors, with a steady decline from 0.35 in 1995 to 0.26 by 2021. This trend suggests gradual improvements in infrastructure resilience, likely driven by investments in transportation, energy, and public works. However, rural areas remain disproportionately vulnerable due to inadequate infrastructure and limited access to essential services. Enhancing resilience in this sector requires sustained investments in climate-resilient infrastructure, such as flood-proof roads, robust energy grids, and disaster-resistant public facilities. Strengthening infrastructure in rural areas is particularly important to reduce disparities and ensure equitable access to resources.

The water sector exhibits steadily increasing vulnerability, rising from 0.32 in 1995 to 0.37 in 2021. This trend reflects growing pressures on water resources due to climate change, population growth, and insufficient water management systems. Increasing variability in rainfall patterns and prolonged dry spells exacerbate water scarcity, affecting agriculture, drinking water supply, and sanitation. To address these challenges, Côte d'Ivoire must prioritize integrated water resource management (IWRM) by improving water storage infrastructure, promoting efficient irrigation techniques, and protecting watersheds. Expanding access to clean drinking water and ensuring the equitable distribution of water resources are also critical to reducing vulnerability in this sector.

The interconnected nature of vulnerabilities across these sectors underscores the need for integrated and cross-sectoral approaches to climate adaptation. For instance, improving water management systems directly supports food security and public health, while resilient infrastructure benefits all sectors. Expanding financial support for adaptation projects, enhancing institutional capacities, and fostering community-based approaches are essential for ensuring sustainable outcomes. Gender-responsive policies are also crucial, as women often face disproportionate climate risks, particularly in the food and water sectors.

2.2.4. Programs and policies against women's vulnerability to climate change in Côte d'Ivoire

Efforts to address women's vulnerability to climate change in Côte d'Ivoire have gained momentum in recent years, as gender disparities remain a critical factor in climate resilience. Women, especially in rural areas, are disproportionately affected by climate impacts due to limited access to resources, restricted decision-making power, and greater reliance on climate-sensitive sectors like agriculture. Programs, policies, and initiatives aimed at reducing women's vulnerability to climate change have yielded some progress, but challenges persist in achieving equitable outcomes and empowering women to become agents of resilience.

Côte d'Ivoire has integrated gender considerations into its national climate strategies, such as the National Adaptation Plan (NAP) and the Nationally Determined Contributions (NDCs) under the Paris Agreement. These frameworks recognize the need to enhance women's adaptive capacity and reduce gender inequalities in accessing resources and opportunities. However, despite their gender-sensitive language, implementation often lags due to insufficient funding, weak institutional coordination, and limited involvement of women in decision-making processes. For these policies to have a meaningful impact, greater emphasis must be placed on translating commitments into concrete actions, with clear monitoring and evaluation mechanisms to track progress (UNDP, 2021).

Programs promoting Climate-Smart Agriculture (CSA) have shown potential for reducing women's vulnerability, as many women are involved in agriculture. CSA practices, such as improved seeds, intercropping, and agroforestry, can help female farmers adapt to climate variability and enhance food security. Initiatives like the Agricultural Investment Program (PNIA) and partnerships with international organizations such as the FAO and World Bank have sought to improve women's access to agricultural inputs, training, and markets. While these programs have increased awareness of CSA practices, their impact is constrained by systemic barriers such as unequal land ownership, limited credit access, and cultural norms that restrict women's participation in decision-making. Addressing these barriers requires gender-specific interventions, including subsidies for women farmers, land tenure reforms, and inclusive extension services (FAO, 2020).

Social protection programs, such as cash transfers and microfinance initiatives, have also been employed to reduce women's vulnerability to climate change. These programs aim to enhance household resilience by increasing income stability and access to financial resources. In Côte d'Ivoire, projects like the Social Safety Net Program, supported by the World Bank, have provided financial assistance to vulnerable households, including women-led ones. However, coverage remains limited, and the targeting mechanisms often exclude the most marginalized women, such as those in remote areas or informal economies. Expanding these programs and ensuring gender-responsive targeting criteria are critical to maximizing their effectiveness in addressing women's vulnerability (World Bank, 2022).

Access to education and training plays a vital role in empowering women to adapt to climate change. Initiatives like the Gender and Climate Change Strategy (GCCS) aim to build women's capacity through education, vocational training, and awareness campaigns on climate adaptation practices. While these initiatives have increased knowledge and skills among some women, their reach is often limited to urban or semi-urban areas, leaving rural women with minimal support. Moreover, traditional gender roles often limit women’s time and opportunities to participate in training sessions. To overcome these challenges, programs should incorporate flexible and locally tailored approaches, such as mobile training units or community-based learning platforms, to reach women in remote areas (UN Women, 2020).

Health programs addressing climate-related vulnerabilities have also targeted women, as they are more susceptible to health risks from climate change, such as waterborne diseases, heat stress, and malnutrition. The National Health Development Plan includes strategies to improve access to healthcare services, particularly in rural areas. Additionally, initiatives such as the Global Alliance for Clean Cookstoves aim to reduce indoor air pollution, which disproportionately affects women and children. While these programs have contributed to reducing health-related vulnerabilities, gaps remain in ensuring equitable healthcare access and addressing the specific needs of women, such as reproductive health services and support during climate-related crises (WHO, 2020).

International partnerships and funding mechanisms have played a crucial role in supporting gender-responsive climate initiatives in Côte d’Ivoire. Organizations such as the Green Climate Fund (GCF) and the United Nations Development Programme (UNDP) have funded projects that integrate gender considerations into climate adaptation and mitigation efforts. For example, GCF-supported programs have provided technical and financial assistance to women farmers, helping them adopt sustainable practices and build resilience. However, the reliance on external funding raises questions about the sustainability of these initiatives once donor support ends. Strengthening domestic financing and integrating gender considerations into national budgets are essential for ensuring the longevity of these programs (GCF, 2021).

Despite these efforts, systemic challenges persist in reducing women's vulnerability to climate change. Land tenure insecurity remains a major obstacle, as women often lack formal ownership or control over land, limiting their ability to invest in long-term adaptation measures. Similarly, women’s limited representation in decision-making processes at local and national levels undermines their ability to influence policies and programs that affect their lives. Addressing these issues requires legal and institutional reforms to promote gender equality in land rights and governance structures. Additionally, cultural and social norms that reinforce gender inequalities must be challenged through education and advocacy campaigns (World Bank, 2021).

Climate change exacerbates existing gender disparities, making it essential to adopt a holistic approach to addressing women’s vulnerability. Integrating gender considerations across all sectors, agriculture, health, education, and social protection, can create synergies and maximize the impact of interventions. For example, combining CSA programs with social protection measures and access to healthcare can simultaneously enhance women’s adaptive capacity, economic stability, and overall well-being. Similarly, fostering partnerships between government, civil society, and the private sector can leverage resources and expertise to scale up successful initiatives.

In sum, Côte d’Ivoire has made progress in incorporating gender considerations into its climate policies and programs, but significant challenges remain in addressing women’s vulnerability to climate change. While initiatives in agriculture, social protection, education, and health have provided important support, their impact is often limited by systemic barriers such as unequal access to resources, land tenure insecurity, and cultural norms. To achieve meaningful progress, greater emphasis must be placed on empowering women through targeted interventions, legal reforms, and inclusive decision-making processes. Strengthening domestic financing and fostering partnerships can ensure the sustainability of gender-responsive climate initiatives, enabling Côte d’Ivoire to build a more equitable and resilient society.

3.3. Literature review on the implications of climate-smart agriculture adoption by women for farmers’ vulnerability to climate risks

Agriculture in general and developing countries are facing the challenges of climate change, and smart farming practices offer a promising solution (Abdulai & Huffman, 2014; Kurgat et al., 2020; Ogisi & Begho, 2023; Sanogo et al., 2023; Verma et al., 2023). Tadesse & Ahmed, (2023) identified several factors that influence the adoption of climate-smart agriculture in Ethiopia which are the age of the head of the household, gender, household size, education level, distance from land, size of the farm, farming system, source of income from the farm, and off-farm income. Moreover, Ogisi & Begho, (2023) support the widely held view that smart farming practices can mitigate climate-induced effects, but they didn't consider gender factors in their analysis. The gender gap can lead to unequal access to resources and opportunities, which can have a significant effect on the success of smart farming practices (Agarwal et al., 2022; Koudjom et al., 2022; Ogisi & Begho, 2023; Sultana, 2010). It is therefore important to consider gender when assessing the impact of climate change on rural households.

Aryal et al., (2014) examined the ability of male and female farmers to adopt mitigation and adaptation technologies in response to climate change. They concluded that larger landholdings are positively associated with the adoption of CSAs, regardless of the gender of the household head. Based on a multivariate probit model, Nchanji et al. (2022) analyzed gender differences in access to and use of CSA in 14 villages in Malawi's Dedza district. In addition to promoting climate-sensitive and gender-sensitive agricultural technologies, they recommend training that would build capacity. Using data collected from key decision-makers, both men and women, Gumucio et al. (2019) examined how women's empowerment can contribute to the development of CSA practices related to the use of trees on farms in a climate-smart village. According to Agarwal et al. (2022), knowledge of CSA practices, male out-migration, education, and income affect the determinants of male out-migration and adoption of CSAs. They found that the knowledge gap between men and women was smaller among adopters. This means that by empowering women, they can gain the knowledge and resources necessary to adopt CSAs, which can help reduce carbon emissions and also help to increase crop yields. Women can also provide support to other women in adopting these practices, which can help to spread the benefits of climate-smart agriculture. According to Barooah et al. (2023) village cooperatives and self-help groups can help women access farming information and adopt climate-smart practices. (Assefa & Gebrehiwot (2023) reported that climate change had greater impacts on female-headed households, as they lacked control over resources, income, and technology.

Researchers have shown that adaptation strategies are a better way to reduce the vulnerability of smallholder farmers to climate shocks (Lokonon, 2019; Oo et al., 2018). Oo et al. (2018) found in Pyapon District, a delta region in Myanmar, that some areas were highly exposed, severely affected, and had a very low capacity to cope with climate shocks. The study highlighted that adaptation strategies implemented in some localities have reduced the sensitivity of farmers. Furthermore, Lokonon (2019) assessed the vulnerability of communities in the Niger Basin in Benin and showed that climate change affected the vulnerability of these communities strongly because they are very exposed, so adaptation strategies were recommended to reduce this vulnerability. However, these studies did not consider adaptation strategies by women on their vulnerability. Moreover, Lokonon & Pilo (2021) also found that women who had access to land in Benin had an improved consumption score compared to those who did not. However, these studies did not associate the adoption of CSA practices with women's access to land.

Nevertheless, the studies of De Pinto et al. (2020) have shown that the implementation of crop diversification by women in Bangladesh contributed to their empowerment because of the increase in agricultural production. Asongu et al. (2022) showed the importance of women's involvement in policies that aim to reduce the vulnerability of agrarian households to climate risks in 169 countries. They concluded that women have a strong hand in protecting the environment so their involvement would reduce the vulnerability of people to climate shocks. However, this study did not show whether this would enable women to cope with climate shocks by reducing their vulnerability. Further research should be conducted to evaluate the specific strategies and resources that enable women to effectively cope with climate shocks and reduce their vulnerability. This would provide a comprehensive understanding of the role that women play in protecting the environment and their capacity to adapt to the challenges posed by climate change. Potential research methods to evaluate women's coping strategies could include conducting interviews or surveys with women in communities affected by climate shocks to gather qualitative data on their experiences and coping mechanisms. Additionally, quantitative research could involve analyzing existing data sets to identify correlations between women's involvement in environmental protection and their ability to cope with climate shocks.

In this study, we will analyze how women in Côte d'Ivoire can reduce their vulnerability to climate shocks by adopting CSA practices to fill the gaps, since few studies have explored this topic. Existing research worldwide has shown that women are disproportionately affected by climate shocks, as they often bear the brunt of the resulting food and water insecurity, increased workload, and limited access to resources. By adopting Climate-Smart Agriculture (CSA) practices, women can enhance their resilience and reduce their vulnerability to these shocks, ultimately bridging the knowledge gap and paving the way for more inclusive and sustainable development.

3.4. Modeling the impact of climate-smart agriculture practices on women's vulnerability to climate risks

Following (Asongu et al., 2022; Daoud, 2021; Denton, 2002; Lokonon, 2019; Mujere, 2016; Oo et al., 2018; Rahman, 2013; Yadav & Lal, 2018) several studies applied different methods to assess the role of women's adaptation to climate-smart agriculture (CSA) practices in improving their outcomes (productivity, income, food security, poverty, vulnerability to climate change or poverty. Ordinary least squares and simple comparison methods produce biased estimations, while decomposition methods, despite providing a richer description than linear regressions, since the entire conditional distribution of the variable of interest can be studied and not just its average, they do not allow for attributing the effect obtained to the adaptation decision. Dealing with selection bias, endogeneity, and heterogeneity failures, this paper applies the Endogenous Switching Regression (ESR) method to assess the adaptation decision factor and simultaneously the impact of this decision on women's vulnerability to climate risk.

3.4.1. Climate-smart agriculture practices adoption

Estimating the impact of climate change adaptation decisions on agricultural production, productivity, household income, and vulnerability to poverty using the least squares method can result in biased estimates (Lokonon, 2019). Indeed, this method uses the adaptation decision as an exogenous variable, but ignoring its potential endogeneity is a source of selection bias. This combined problem of systematic heterogeneities between those who adapt and those who do not, and the existence of unobservable characteristics or innate abilities that influence both the decision to adopt and the productivity of the farm or asset holding by households, is addressed in this article using the endogenous switching regression (ESR). This method is commonly used in the decision-making literature (Adego et al., 2019; Di Falco et al., 2011; Etwire et al., 2022; Martey et al., 2019). Following Ali et al. (2023) and Aseres et al. (2019), let A_h^* be the latent variable that indicates the hth rural household headed by women's behavior in adopting CSA practices j relative to not adopting. This latent variable is given as follows:

$$A_h^* = \alpha Z_h + \eta_h \text{ such that } A_h = \begin{cases} 1 & if\ A_h^* > 0 \\ 0 & otherwise \end{cases} \tag{3.1}$$

Where Z_h is a vector of covariates that influence adoption decisions. CSA practices include improved seeds and intercropping. There is a belief within the literature that households' characteristics in terms of demography and capital endowments affect both vulnerability and adaptation decisions. η_{jh} is the random disturbance term.

3.4.2. Measurement of household vulnerability to climate change (VCC) and adaptation impacts

In the economic literature, vulnerability refers to the probability that an individual, household, or society will have a level of well-being below a reference point, at some point in the future (Dercon, 2005; Feeny & McDonald, 2015; Herrera et al., 2018; Lokonon, 2019) . There are three main approaches to assessing vulnerabilities in the economic literature: vulnerability as expected poverty (VEP), vulnerability as expected utility (VEU), and vulnerability as uninsured exposure to risk (VER). They all construct a model that predicts a measure of well-being. VER is a vulnerability of agricultural livelihoods to climate shocks and is a function of exposure, sensitivity, and adaptive capacity (Ali et al., 2023; Lokonon, 2019). Exposure indicators characterize the frequency of extreme events, the extent of land erosion and sea-level rise, and changes in temperature and rainfall. Sensitivity is the degree to which a farm-based livelihood system is affected by climate shocks. Adaptive capacity is the ability of an agricultural livelihood system to cope with climate shocks, take advantage of opportunities, or respond to consequences.

Following Ali et al. (2023); Lokonon's (2019) and IPCC's (2007) suggestions, both socioeconomic and biophysical variables, were used to determine the vulnerability index of households headed by women. This index is specified as follows:

$$Vulnerability\ (VCC_h) = Adaptive\ capacity\ - (Sensitivity + Exposure) \tag{3.2}$$

$$VCC_h = \sum_{i=1}^{n} w_i Ac_{ih} - \left[\sum_{i=1}^{n} w_i Sen_{ih} + \sum_{i=1}^{n} w_i Exp_{ih}\right]$$

Where Ac, Sen, and Exp are indicators of adaptive capacity, sensitivity, and exposure, respectively. w_i is the weight (explained variation) associated with each indicator of each vulnerability dimension. For Principal Component Analysis (PCA) used to compute the vulnerability index, nominal and ordinal variables are transformed using an optimal scaling technique. After selecting components and estimating vulnerability indicators for each household, Kaiser's eigenvalue criterion is applied. PCA assigns weights to indicators without assuming a latent variable structure. **Figure 23** illustrates the indicators included in each vulnerability index and the potential CSA practices.

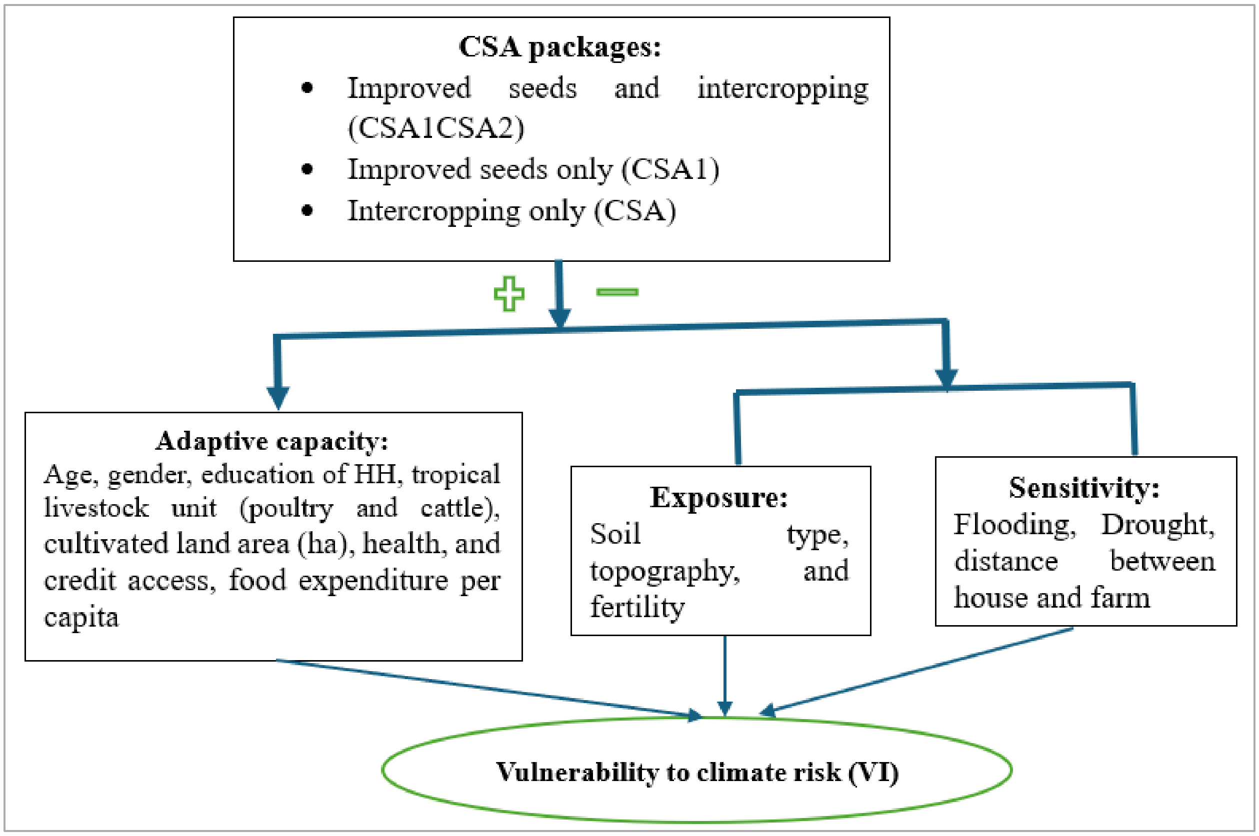

Figure 23: Conceptual framework of the vulnerability to climate risk assessment

This conceptual framework is grounded in the widely accepted IPCC framework, which defines vulnerability as a function of exposure, sensitivity, and adaptive capacity (IPCC, 2014). At its core, the model explores how the adoption of Climate-Smart Agriculture (CSA) packages, specifically improved seeds, intercropping, or a combination of both, can influence household vulnerability. These CSA interventions are posited to strengthen adaptive capacity while potentially reducing sensitivity and exposure. Adaptive capacity incorporates socio-economic and demographic factors such as age, gender, and education of the household head, livestock ownership (measured in Tropical Livestock Units), cultivated land area, access to credit and health services, and food expenditure per capita, elements known to influence resilience to climate stress (Vincent, 2007; Deressa et al., 2009). Exposure reflects the environmental and agro-ecological context, including soil type, fertility, and topography, which shape the extent to which households face climate hazards (Thornton et al., 2006). Sensitivity captures household-level susceptibility to shocks, such as flooding, drought, and logistical challenges like the distance between house and farm, which can limit timely responses to climate events (Smit and Wandel, 2006). This integrated framework enables a nuanced understanding of how CSA adoption may mediate vulnerability in heterogeneous farming contexts.

The impact of adaptation on vulnerability, taking adaptation as a dummy variable, might yield biased estimates because it assumes that adaptation is exogenously determined, while it is potentially endogenous (Di Falco et al., 2011). The sample selection bias problem is another potential econometric challenge because adopters may have systematically different characteristics from the non-adaptors. To handle the inconsistency estimation issue of the effect of adaptation on households' vulnerability, we estimate a simultaneous equations model by employing the endogenous switching regression model with full information maximum likelihood, which simultaneously estimates the two equations - the selection and outcome equations. Based on their adaptation decision, this method partitions households into two groups. It expresses each outcome function, the expected values of the error terms, and the comparison of the predicted vulnerability and its change due to adaptation of climate change strategies. Regarding the outcome function, given the households' decision to adopt, the vulnerability is specified as follows:

$$Regime\ 1: VCC_{Ah} = X_{Ah}\beta_A + \varepsilon_{Ah}\ if\ A_h = 1 \tag{3.3}$$

$$Regime\ 2: VCC_{Nh} = X_{Nh}\beta_N + \varepsilon_{Nh}\ if\ A_h = 0 \tag{3.4}$$

The error terms η_h, ε_{Ah} and ε_{Nh} are assumed to have a trivariate normal distribution, with zero mean; respective variance σ_η^2, σ_A^2 and σ_N^2 and covariance $Cov(\varepsilon_A, \varepsilon_N) = \sigma_{AN}$, $Cov(\varepsilon_A, \eta) = \sigma_{A\eta}$ and $Cov(\varepsilon_N, \eta) = \sigma_{N\eta}$. Because of the correlation between $\eta_h$and ε_{Ah}; $\eta_h$and ε_{Nh} the expected value of ε_{Ah} and ε_{Nh} conditional on the sample selection is non-zero given as:

$$E[\varepsilon_{Ah}|A_h = 1] = \sigma_{A\eta}\frac{\varphi(Z_h\alpha)}{\phi(Z_h\alpha)} = \sigma_{A\eta}\lambda_{Ah} \text{ and } E[\varepsilon_{Nh}|A_h = 0] = \sigma_{N\eta}\frac{\varphi(Z_h\alpha)}{\phi(Z_h\alpha)} = \sigma_{N\eta}\lambda_{Nh} \tag{3.5}$$

where $\varphi(.)$ is the standard normal probability density function, and $\phi(.)$ is the standard normal cumulative density function. The terms λ_{Ah} and λ_{Nh} refer to the inverse Mills ratio evaluated at $Z_h\alpha$ and are incorporated into outcome equations to account for sample selection bias. To compare the two groups of households, the expected vulnerabilities to climate risk regarding their adaptation decision are expressed as:

$$E[VCC_{Ah}|A_h = 1] = X_{Ah}\beta_A + \sigma_{A\eta}\lambda_{Ah}\ and\ E[VCC_{Nh}|A_h = 0] = X_{Nh}\beta_N + \sigma_{N\eta}\lambda_{Nh} \tag{3.6}$$

Similarly, the expected value of the adaptor had the household chosen not to adopt $E[VCC_{Nh}|A_h = 1]$, and the expected value of the non-adaptor had the household chosen to adapt $E[VCC_{Ah}|A_h = 0]$ are given, respectively, as:

$$E[VCC_{Nh}|A_h = 1] = X_{Ah}\beta_N + \sigma_{N\eta}\lambda_{Ah} \; and \; E[VCC_{Ah}|A_h = 0] = X_{Nh}\beta_A + \sigma_{A\eta}\lambda_{Nh} \quad (3.7)$$

The treatment effects due to the adoption of climate change adaptation strategies (TT) and the effect of the treatment (adaptation) on the untreated (non-adapted) (TU) for the household that did not adapt can be calculated respectively as the difference between $E[VCC_{Ah}|A_h = 1]$ and $E[VCC_{Nh}|A_h = 1]$ and between $E[VCC_{Nh}|A_h = 0]$ and $E[VCC_{Ah}|A_h = 0]$:

$$TT = E[VCC_{Ah}|A_h = 1] - E[VCC_{Nh}|A_h = 1] = X_{Ah}(\beta_A - \beta_N) + \left(\sigma_{A\eta} - \sigma_{N\eta}\right)\lambda_{Ah} \quad (3.8)$$

$$TU = E[VCC_{Nh}|A_h = 0] - E[VCC_{Ah}|A_h = 0] = X_{Nh}(\beta_N - \beta_A) + (\sigma_{N\eta} - \sigma_{A\eta})\lambda_{Nh}$$

The vulnerability to climate risk may be less for households that decided to adopt than those that did not. This will occur because of unobservable household characteristics. Following di Falco et al., (2011), Khanal et al., (2018) for the group of households that decided to adopt ($BH1$), this heterogeneity effect is measured as the difference between $E[VCC_{Ah}|A_h = 1]$ and $E[VCC_{Ah}|A_h = 0]$. For the group of households that decided not to adopt ($BH2$), this effect is the difference between $E[VCC_{Nh}|A_h = 1]$ and $E[VCC_{Nh}|A_h = 0]$.

$$BH1 = E[VCC_{Ah}|A_h = 1] - E[HVCC_{Ah}|A_h = 0] = (X_{Ah} - X_{Nh})\beta_{Ah} + \sigma_{A\eta}(\lambda_{Ah} - \lambda_{Nh}) \quad (3.9)$$

$$BH2 = E[VCC_{Nh}|A_h = 1] - E[VCC_{Nh}|A_h = 0] = (X_{Ah} - X_{Nh})\beta_{Nh} + \sigma_{N\eta}(\lambda_{Ah} - \lambda_{Nh})$$

3.3.2. Data, and descriptive statistics for the sample

The data used in this paper are provided by Côte d'Ivoire's Harmonized Survey on Living Conditions of Households in 2018 (EHCVM-2018). It contains the necessary information for welfare measurement in different dimensions, including consumption expenditure and adaptation decisions. The survey covered 6923 Ivorian households. We used the subsample of 820 farm households headed by women to assess the determinants and impacts of adopting climate-smart agriculture (CSA) practices on households' vulnerability to climate risk. Descriptive statistics illustrated in **Tables 13** and **14** show that, on average, vulnerability is 0.28. As shown in Table 1, the majority of households (57.32%) have a vulnerability index between 0.26 and 0.50. Besides this, the average vulnerability index of sample households headed by women is 0.252, 0.312, 0.282, 0.274, and 0.316 for the Centre, Centre-west, North, South-east, and South-west agroecological zones, respectively. The statistics imply that households in South-west and Centre-west agroecological zones are more vulnerable than those in the Centre and South-east. Moreover, 53.74% of sample households headed by women in the Centre agroecological zone are found to have a vulnerability index below 0.25, which suggests that the zone is less vulnerable than other zones. In contrast, 73.05% and 68.15% of sample households headed by women in the Centre-west and South-west agroecological zones, respectively, are found to have a vulnerability index beyond 0.25, which suggests that the zones are more vulnerable than other zones.

Table 13: Vulnerability Index distribution of sample households by agroecological zones

		Agroecological zones				
Vulnerability index	Total	Centre	Centre-west	North	South-east	South-west
[0-0.25]	330	158	45	68	38	21
[0.26-0.50]	470	132	115	120	61	42
[0.51-0.75]	20	4	7	4	2	3
[0.76-1]	0	0	0	0	0	0
Total	820	294	167	192	101	66
Mean	0.279	0.252	0.312	0.282	0.274	0.316

In addition to the aggregate descriptive analysis, we apply the student's t-test and Pearson's chi-square tests to our quantitative and qualitative variables, respectively, to test if farm households headed by women significantly differ by adaptation status. The results compiled in Table 2 show that the average vulnerability to poverty for adopters was 0.01 higher than that of non-adaptors. There are significant differences between adaptors and non-adaptors in terms of household size, number of equivalent adults, cultivated land area, residential area, perception of soil fertility, and land exploited ownership when improved seeds and intercropping are jointly used.

There are usually five members in a household headed by a woman. Most farmers do not have access to health services (82.38%) or credit (98.54%). Limited access to health services and credit in the farming community can be attributed to a variety of factors, including geographic isolation, lack of financial literacy, and the absence of formal banking institutions in rural areas. Additionally, gender inequality and discrimination further exacerbate the challenges faced by women farmers, making it even more difficult for them to access essential services and financial resources. Women in Côte d'Ivoire who adopt CSA packages are younger than those who do not adopt, implying age concerns in adopting CSA packages. Sandy soil is exploited by 50.85% of households headed by women, while 20.85%, 24.27%, and 4.02% exploit silty, clay, and glacis soils, respectively. Sandy soil farmers using improved seeds represent 43.54%, while 37.20%

practice intercropping. According to chi 2 statistics, there is a correlation between disability and intercropping practice. The correlation between disability and intercropping practice suggests that farmers with disabilities may face additional challenges in implementing intercropping techniques. This correlation highlights the need for inclusive agricultural practices that consider the needs and abilities of all farmers, regardless of disability status, to ensure equal access to resources and opportunities in the farming community. Chi 2 statistics indicate a correlation between land ownership and the adoption of CSA practices. One possible reason could be that landowners have more control over their resources and are therefore more likely to invest in sustainable agricultural practices. Additionally, landowners may have greater access to financial resources and support systems that enable them to implement CSA practices effectively.

Figure 24, which presents kernel density estimates for different Climate-Smart Agriculture (CSA) packages, provides a visual representation of the distribution of adoption rates or impacts of various CSA strategies. The density curves illustrate how different practices, such as improved seeds (CSA1), intercropping (CSA2), and the combination of both (CSA1CSA2), are adopted and their effects on key variables like agricultural productivity or climate vulnerability. Peaks in the curves indicate the most common levels of adoption or impact, while the spread reflects variability across households or regions. For instance, a narrow and high peak may suggest consistent impacts or concentrated adoption, while a broader curve highlights diverse effects or adoption patterns. Comparing the KDE curves for each CSA package allows for an understanding of their relative effectiveness and reach. Such visualizations are crucial for identifying which practices are more widely adopted or impactful, offering valuable insights to guide targeted interventions and policies for improving food security and resilience to climate change.

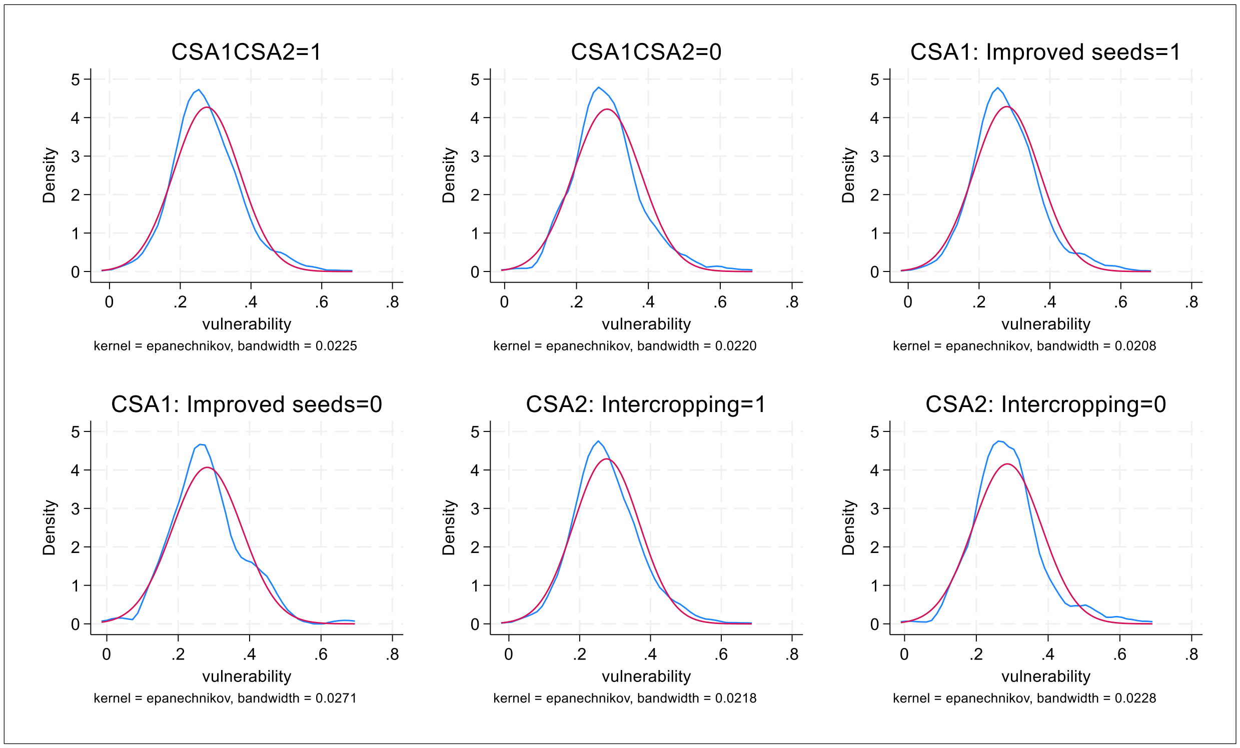

Figure 24: Kernel density estimates for different CSA packages

3.4. Results and discussion

As a response to the instrumental variables needed in the method, we rely on a falsification test to determine the statistical validity of our instruments. To be considered valid, an instrument must significantly influence the adaptation decision, but not the vulnerability to climate risks. According to **Table 15**, land exploited ownership can be used to select adaptation strategies, but it has no significant effect on the vulnerability of households to climate change. Additionally, intercropping practices and the use of improved seeds are complementary. By maximizing land utilization and increasing overall crop productivity, intercropping can enhance the benefits of improved seeds. With intercropping, different crops are grown together to maximize resource utilization, such as sunlight, water, and nutrients, resulting in higher yields and better pest and disease resistance.

Table 16 reports the full information maximum likelihood (FIML) estimates of the endogenous switching regression model for women's vulnerability to climate risk. Using different climate-smart agriculture packages, the first three columns report the results of practicing intercropping and growing improved seeds (CSA1CSA2). The outcome equation indicating the impact of adaptation decisions on households' vulnerability is provided in each sample by column (2) for non-adaptors and column (3) for adaptors. The correlation coefficients (ρ) between the residuals of the adaptation decision selection equation and outcome equations are significantly different from zero according to the result of the likelihood ratio test $\rho 1 = \rho 2 = 0$. Statistically, a significant correlation coefficient suggests that the joint estimate based on endogenous switching regression was more efficient than separate regressions, suggesting that the two equations regarding the choice of adaptation strategies cannot be estimated separately and are not independent.

3.4.1. Determinants of climate-smart agriculture practices adoption

Column (1) in **Table 16** illustrates the determinants of adopting simultaneously improved seeds (CSA1) and an intercropping system (CSA2). The results show that age positively affects the probability of adopting improved seeds and intercropping. One reason for this is that older farmers often have more experience and knowledge of agricultural practices, making them more open to trying new techniques such as using improved seeds and intercropping. Additionally, older farmers may have a greater level of financial stability, allowing them to invest in these innovations. This result is in line with Khanal et al's (2018) in Nepal and Martey et al's (2019) in Ghana findings where authors showed that older farmers may have established networks and relationships within the farming community, which can provide them with access to information and resources related to improved seeds and intercropping. In contrast, increasing the number of equivalent adults in the household and exploited land area decreases women's likelihood of adopting improved seeds and intercropping. One potential reason for the negative impact of exploited land areas on adoption could be that households with larger land areas may already be engaged in intensive agricultural practices or have complex cropping systems. Implementing new practices such as improved seeds and intercropping may require additional resources, time, and effort, which could be perceived as burdensome or risky for households with already high levels of land exploitation. The negative effect of the number of equivalent adults suggests that households with fewer adults may be more likely to take on the risk of trying new agricultural practices, as they may have more resources available to cover the extra costs associated with them. Furthermore, it may be the case that households with fewer adults may be less reliant on land and thus have more flexibility to try new technologies. Considering improved seeds and intercropping as separate strategies did not change the sign of different significant determinants as shown in columns (4) and (7), respectively.

3.4.1. Determinants of women's vulnerability to climate risk

An interesting finding illustrated in **Table 16** is the signs and significances of the covariance terms ρ_A and ρ_N. The results show that the covariance term for the adopters is statistically significant, indicating that self-selection occurred in adaptation. Thus, adaptation to climate change may not have the same effect on the non-adopters, if they choose to adopt (Abdulai & Huffman, 2014; Lokshin & Sajaia, 2004) Moreover, the differences in the coefficients of the women's vulnerability to climate risk equation between the households suggest the presence of heterogeneity in the sample.

Considering improved seeds and intercropping systems as a CSA package, floods, drought, disability, being married compared to single, exploiting other soil types compared to sandy, and non-good soil fertility increase women's vulnerability to climate risk. Indeed, columns (2) and (3) in Table 16 show that floods and drought increase women's vulnerability to climate risk. Women are often the primary producers of food, and when floods or droughts occur, their ability to produce food is reduced. Being married compared to being single increases women's vulnerability to climate risk. Married women may face additional challenges to climate risk compared to single women. In many societies, married women often have greater responsibilities in terms of household and caregiving duties, which can limit their ability to adapt to and recover from climate-related events. This can further exacerbate their vulnerability to floods and droughts, as they may have less time and resources to allocate toward food production and resilience-building measures. Sandy soil and good soil fertility have certain qualities that make them less vulnerable to climate change. Sandy soil has larger particles, which allows for better drainage and reduces the risk of waterlogging during heavy rainfall. Additionally, sandy soil tends to warm up more quickly in the spring, allowing for earlier planting and longer growing seasons. Non-good soil fertility, on the other hand, is typically rich in organic matter and nutrients, providing better conditions for plant growth and resilience to climate fluctuations.

Age of households headed by women, household size, and health access statistically reduce women's vulnerability to climate risk. In larger households, women have access to more resources and support systems, which can help them cope with climate-related challenges. For example, in the event of a natural disaster, women in larger households may have more people to help with evacuation or to share the burden of recovery tasks. Additionally, larger households may have more income-generating opportunities, providing women with greater economic resilience in the face of climate shocks. Access to health care for women plays a crucial role in reducing their vulnerability to climate change. Studies have shown that when women have access to reproductive health services, they have better control over their reproductive choices, which in turn leads to lower population growth rates (Rahman, 2013). This helps in mitigating the strain on the environment and reducing the impact of climate change. Taking improved seeds and intercropping as separate CSA practices show the robustness of these results. Indeed, columns (5) and (6) (for improved seeds practices), and columns (8) and (9) (for intercropping practices) confirm the conclusions discussed earlier. However, it is important to note that relying on larger households as a means of support may not always be feasible or desirable for women. In some cases, women may not have access to larger households or may prefer to live in smaller, more independent arrangements. Additionally, larger households may also come with their challenges, such as increased conflict or competition for resources. Therefore, it is crucial to consider a range of strategies and interventions that can support women's resilience to climate change, including access to education, and economics.

Table 14: Descriptive statistics

Variables		**Sample**	**Decision stage**								
			Improved seeds and intercropping			**Improved seeds**			**Intercropping**		
Continuous variables		**Mean**	**Non-adopters**	**Adopters**	**Test of difference**	**Non-adopters**	**Adopters**	**Test of difference**	**Non-adopters**	**Adopters**	**Test of difference**
Vulnerability index		0.279	0.285	0.275	0.010	0.282	0.278	0.003	0.287	0.276	0.011
Age of HH		49.665	50.171	49.384	0.787	49.746	49.648	0.098	50.498	49.372	1.125
Household size		4.451	4.740	4.292	0.448**	5.283	4.283	1.000***	4.676	4.372	0.304
Number of equivalent adults		3.146	3.405	3.003	0.402***	3.829	3.008	0.822***	3.347	3.076	0.271*
Cultivated land area		2.267	3.429	1.624	1.804***	3.188	2.080	1.108**	3.646	1.783	1.863***
Categorical variables	**Modalities**	**Freq**	**Non-adopters**	**Adopters**	**Test of Chi 2**	**Non-adopters**	**Adopters**	**Test of Chi 2**	**Non-adopters**	**Adopters**	**Test of Chi 2**
Education of HH	Not educated	78.90	28.05	50.85	0.005	12.93	65.98	0.436	20.49	58.41	0.000
	Educated	15.24	7.56	13.54		3.90	17.20		5.49	15.61	
Credit access	No access	98.54	34.88	63.66	1.100	16.59	81.95	0.000	25.24	73.29	3.656*
	Access	1.46	0.73	0.73		0.24	1.22		0.73	0.73	
Health service access	No access	82.32	29.63	52.68	0.254	13.17	69.15	1.875	22.32	60.00	2.560
	Access	17.68	5.98	11.71		3.66	14.02		3.66	14..02	
Flooding experience	No	97.93	34.76	63.17	0.235	16.59	81.34	0.318	25.12	72.80	2.086
	Yes	2.07	0.85	64.39		0.24	1.83		0.85	1.22	
Drought experience	No	88.78	31.10	57.68	0.960	14.63	74.15	0.554	22.68	66.10	0.613
	Yes	11.22	4.51	6.71		2.20	9.02		3.29	7.93	
Soil type	Sandy	50.85	17.07	33.78	2.079	7.32	43.54	4.463	13.66	37.20	0.451
	Silty	20.85	8.29	12.56		4.39	16.46		5.12	15.73	
	Clay	24.27	8.78	15.49		4.51	19.76		6.10	18.17	
	Glacis and other	4.02	1.46	2.56		0.61	3.41		1.10	2.93	
Disability	No	89.76	31.34	58.41	1.497	15.61	74.15	1.622	22.44	67.32	3.557*
	Yes	10.24	4.27	5.98		1.22	9.02		3.54	6.71	

Marital status of HH	Single	71.10	25.24	45.85	0.010	11.46	59.63	0.718	18.90	52.20	0.392
	Married/others	28.90	10.37	18.54		5.37	23.54		7.07	21.83	
Residential area	Urban	19.39	8.41	10.98	5.216**	4.88	14.51	9.774***	5.98	13.41	2.405
	Rural	80.61	27.20	53.41		11.95	68.66		20.00	60.61	
Soil fertility	Good	52.32	16.46	35.85	7.072**	6.95	45.37	9.645***	12.80	39.51	6.147**
	Moderate	42.44	16.83	25.61		9.15	33.29		10.98	31.46	
	Poor	5.24	2.32	2.93		0.73	4.51		2.20	3.05	
Land exploited ownership	Non-owners	16.83	3.78	13.05	12.506***	1.22	15.61	10.886***	2.93	13.90	6.359**
	Owners	83.17	31.83	51.34		15.61	67.56		23.05	60.12	

*** p<0.01, ** p<0.05, * p<0.1

Table 15: Instruments validation

	Bivariate probit			Probit		OLS
	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	CSA1	CSA2	Margins	CSA1CSA2	Margins	VI
1. improved seeds (yes)						0.005
						(0.004)
1. intercropping (yes)						-0.003
						(0.003)
Age of HH	-0.002	-0.002	-0.001	-0.002	-0.001	-0.003***
	(0.005)	(0.004)	(0.001)	(0.004)	(0.001)	(0.000)
Household size	0.163	0.095	0.047	0.164*	0.058*	-0.006**
	(0.103)	(0.096)	(0.030)	(0.092)	(0.032)	(0.003)
Number of equivalent adults	-0.316**	-0.151	-0.083**	-0.271**	-0.095**	0.008**
	(0.141)	(0.132)	(0.041)	(0.126)	(0.044)	(0.004)
Cultivated land area	-0.016*	-0.033***	-0.010***	-0.038***	-0.013***	-0.000
	(0.009)	(0.009)	(0.003)	(0.009)	(0.003)	(0.000)
1. Education of HH (educated)	-0.089	-0.030	-0.021	-0.042	-0.015	0.054***
	(0.137)	(0.123)	(0.039)	(0.117)	(0.041)	(0.003)
1. Credit access (have access)	0.145	-0.602	-0.161	-0.295	-0.108	0.087***
	(0.467)	(0.384)	(0.138)	(0.378)	(0.142)	(0.011)
1. Health service access (have access)	-0.172	0.244*	0.026	0.099	0.034	-0.059***
	(0.139)	(0.132)	(0.039)	(0.122)	(0.042)	(0.004)
1. Flooding experience	0.350	-0.297	-0.044	0.005	0.002	0.221***
	(0.442)	(0.330)	(0.114)	(0.330)	(0.116)	(0.010)

1. Drought experience	-0.116	0.008	-0.016	-0.042	-0.015	0.125***
	(0.169)	(0.154)	(0.049)	(0.148)	(0.052)	(0.004)
1. Disability (apt)	0.214	-0.254	-0.041	-0.168	-0.060	0.004
	(0.192)	(0.157)	(0.053)	(0.152)	(0.055)	(0.005)
1. Marital status of HH (Married)	-0.183	0.001	-0.028	-0.108	-0.038	0.002
	(0.132)	(0.119)	(0.038)	(0.113)	(0.040)	(0.003)
1. Residential area (Rural)	0.313**	0.182	0.094**	0.245**	0.088**	0.006*
	(0.134)	(0.125)	(0.041)	(0.120)	(0.044)	(0.004)
Soil type (ref: Sandy)						
1. Silty	-0.294**	0.059	-0.030	-0.179	-0.063	0.043***
	(0.139)	(0.127)	(0.040)	(0.120)	(0.043)	(0.004)
2. Clay	-0.238*	0.041	-0.025	-0.092	-0.032	0.075***
	(0.135)	(0.121)	(0.038)	(0.115)	(0.040)	(0.003)
3. Glacis and other	-0.133	0.088	0.003	-0.031	-0.011	0.119***
	(0.291)	(0.248)	(0.078)	(0.238)	(0.083)	(0.007)
Soil fertility						
1. Moderate	-0.351***	-0.074	-0.072**	-0.237**	-0.084**	0.037***
	(0.113)	(0.101)	(0.032)	(0.096)	(0.034)	(0.003)
2. Poor	0.031	-0.519**	-0.148*	-0.356*	-0.128	0.060***
	(0.272)	(0.213)	(0.075)	(0.212)	(0.079)	(0.006)
1. Land ownership (owners)	-0.616***	-0.318**	-0.152***	-0.461***	-0.152***	-0.005
	(0.176)	(0.140)	(0.039)	(0.132)	(0.040)	(0.004)
Constant	2.059***	1.061***		1.107***		0.345***
	(0.344)	(0.294)		(0.280)		(0.009)
athrho		0.311***				
		(0.075)				

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Note: CSA1: Use of improved seeds, CSA2: Intercropping, VI_0: Vulnerability index for non-adopters, VI_1: Vulnerability index for adopters

Table 16: CSA impacts on households headed by women's vulnerability

	Improved varieties and intercropping			Improved varieties			Intercropping		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
VARIABLES	CSA1CSA2	VI_0	VI_1	CSA1	VI_0	VI_1	CSA2	VI_0	VI_1
Age of HH	-0.002	-0.003***	-0.003***	-0.002	-0.003***	-0.003***	-0.003	-0.003***	-0.003***
	(0.004)	(0.000)	(0.000)	(0.005)	(0.000)	(0.000)	(0.004)	(0.000)	(0.000)
Household size	0.191**	-0.013**	-0.004	0.154	-0.012*	-0.004	0.109	-0.009	-0.005*
	(0.092)	(0.005)	(0.003)	(0.103)	(0.007)	(0.003)	(0.097)	(0.006)	(0.003)

Number of equivalent adults	-0.303**	0.019***	0.005	-0.307**	0.017*	0.005	-0.167	0.013	0.007
	(0.125)	(0.007)	(0.005)	(0.141)	(0.009)	(0.004)	(0.133)	(0.009)	(0.004)
Cultivated land area	-0.032***	0.001	-0.001	-0.015*	0.001	-0.000	-0.028***	0.001	-0.001
	(0.009)	(0.000)	(0.000)	(0.009)	(0.001)	(0.000)	(0.009)	(0.001)	(0.000)
1. Education of HH (educated)	-0.069	0.048***	0.057***	-0.098	0.040***	0.057***	-0.063	0.049***	0.056***
	(0.115)	(0.007)	(0.004)	(0.137)	(0.009)	(0.004)	(0.121)	(0.008)	(0.004)
1. Credit access (have access)	-0.204	0.103***	0.080***	0.134	0.086***	0.087***	-0.486	0.116***	0.081***
	(0.369)	(0.019)	(0.016)	(0.460)	(0.030)	(0.012)	(0.368)	(0.021)	(0.016)
1. Health service access (have access)	0.092	-0.053***	-0.063***	-0.171	-0.062***	-0.059***	0.212	-0.062***	-0.061***
	(0.120)	(0.007)	(0.004)	(0.139)	(0.009)	(0.004)	(0.130)	(0.009)	(0.004)
1. Flooding experience	-0.067	0.126***	0.127***	-0.114	0.116***	0.126***	-0.003	0.129***	0.125***
	(0.145)	(0.008)	(0.005)	(0.170)	(0.011)	(0.005)	(0.152)	(0.009)	(0.005)
1. Drought experience	-0.105	0.230***	0.209***	0.327	0.192***	0.220***	-0.375	0.238***	0.212***
	(0.322)	(0.018)	(0.012)	(0.437)	(0.035)	(0.010)	(0.317)	(0.019)	(0.013)
1. Disability (apt)	-0.116	0.021**	-0.000	0.238	0.027*	0.003	-0.197	0.024**	0.001
	(0.150)	(0.008)	(0.006)	(0.194)	(0.014)	(0.005)	(0.155)	(0.010)	(0.006)
1. Marital status of HH (Married)	-0.143	0.015**	-0.003	-0.184	0.010	0.001	-0.049	0.009	-0.001
	(0.113)	(0.006)	(0.004)	(0.132)	(0.009)	(0.004)	(0.118)	(0.008)	(0.004)
1. Residential area (Rural)	0.217*	0.001	0.003	0.315**	0.021**	0.002	0.187	-0.001	0.005
	(0.119)	(0.006)	(0.005)	(0.135)	(0.009)	(0.004)	(0.123)	(0.008)	(0.004)
Soil type (ref: Sandy)									
1. Silty	-0.178	0.052***	0.042***	-0.273*	0.042***	0.044***	0.039	0.042***	0.043***
	(0.119)	(0.007)	(0.004)	(0.141)	(0.010)	(0.004)	(0.126)	(0.008)	(0.004)
2. Clay	-0.097	0.076***	0.076***	-0.228*	0.080***	0.075***	0.008	0.062***	0.079***
	(0.114)	(0.006)	(0.004)	(0.135)	(0.010)	(0.004)	(0.120)	(0.008)	(0.004)
3. Glacis and other	-0.105	0.117***	0.118***	-0.125	0.109***	0.122***	0.004	0.118***	0.117***
	(0.236)	(0.013)	(0.009)	(0.291)	(0.019)	(0.007)	(0.244)	(0.016)	(0.008)
Soil fertility									
1. Moderate	-0.225**	0.040***	0.038***	-0.349***	0.034***	0.037***	-0.033	0.038***	0.037***
	(0.095)	(0.006)	(0.004)	(0.113)	(0.009)	(0.003)	(0.101)	(0.007)	(0.003)
2. Poor	-0.307	0.072***	0.065***	-0.012	0.061***	0.061***	-0.457**	0.084***	0.065***
	(0.209)	(0.011)	(0.008)	(0.268)	(0.018)	(0.007)	(0.209)	(0.013)	(0.008)
1. Land ownership (owners)	-0.381***			-0.673***			-0.356***		
	(0.118)			(0.177)			(0.114)		
Constant	1.050***	0.297***	0.345***	2.101***	0.363***	0.347***	1.099***	0.294***	0.341***
	(0.272)	(0.017)	(0.010)	(0.346)	(0.040)	(0.008)	(0.285)	(0.020)	(0.010)
σ_A			-3.297***			-3.293***			-3.281***
			(0.033)			(0.029)			(0.031)
σ_N		-2.990***			-3.172***			-2.880***	

		(0.090)			(0.154)			(0.095)	
ρ_A			-0.091			-0.143			-0.082
			(0.269)			(0.194)			(0.349)
ρ_N		-1.121***			0.468			-1.433***	
		(0.211)			(0.448)			(0.204)	
LR test of Indep.			4.22**			1.4			11.07***
Observations	820	820	820	820	820	820	820	820	820

Standard errors in parentheses; *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Note: CSA1: Use of improved seeds, CSA2: Intercropping, VI_0: Vulnerability index for non-adopters, VI_1: Vulnerability index for adopters

Table 17: Average treatment effect of climate-smart agriculture (CSA) adoption on vulnerability of sample households

	Vulnerability index					
CSA packages	Adopters (actual)	If they do not adopt	ATT	Non-adopters	If they would adopt	ATU
CSA1CSA2	0.275	0.289	-0.014***	0.286	0.362	0.076***
CSA1	0.278	0.295	-0.017***	0.282	0.305	0.023***
CSA2	0.276	0.289	-0.013***	0.287	0.381	0.094***

Standard errors in parentheses; *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Note: CSA1: Use of improved seeds, CSA2: Intercropping

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3.4.2. Impact of CSA on households' vulnerability to climate risk

As shown in **Table 17**, on average, adopters of improved seeds and intercropping systems (CSA1CSA2) have a 4.84% (-0.014) decline in vulnerability index, whereas their counterparts showed a 21% (0.076) rise in vulnerability index, and the difference is also statistically significant. On average, adopters of improved seeds (CSA1) indicated a 5.76% (-0.017) fall in the vulnerability index, whereas their counterparts revealed a 7.54% (0.023) rise in the vulnerability index. In addition to this, it is shown that adopters of intercropping (CSA2) have a 4.50% (-0.013) decrease in vulnerability index, whereas their counterparts showed a 24.74% (0.094) increase in vulnerability index, and the difference is also statistically significant. We can understand that CSA adopters, on average, have a lower vulnerability index, and they would have a higher vulnerability index if they did not adopt. We can infer that the adoption of CSA packages has a positive and significant impact on reducing rural women's vulnerability to climate risk in Côte d'Ivoire. The results of this study further suggest that, as indicated by Ali et al. (2023), CSA adoption enables farm households headed by women to cope and bounce back from an exogenous shock, while non-adoption results in a loss of agricultural production during the shock and being unable to recover from it. Overall, the result implies that CSA adoption is very important to achieve Sustainable Development Goal 13, which aims to battle climate change by reducing households' vulnerability to climate change hazards. The result agrees with the findings of Oo et al. (2018), Assefa & Gebrehiwot (2023), Mujere (2016), and Nchanji et al. (2022). The mentioned studies support the idea that adopting Climate-Smart Agriculture (CSA) is crucial for achieving Sustainable Development Goal 13. They highlight the importance of reducing households' vulnerability to climate change hazards. While each study may have its unique findings and methodologies, their consensus underscores the significant role of CSA in battling climate change.

3.5. Conclusion and policy implications

Climate change exacerbates existing gender inequalities in poorer countries by increasing the vulnerability of women in agricultural households. Adoption of climate-smart agriculture (CSA) practices is necessary to build women's resilience to climate risk. The objective of this paper are, hence, to estimate an index of vulnerability using principal component analysis (PCA), identify factors that determine vulnerability, and examine whether the adoption of CSA practices impacts women's vulnerability in Côte d'Ivoire. The study therefore used Côte d'Ivoire's Harmonized Survey on Living Conditions of Households in 2018 and further assessed which package performs better in reducing women’s vulnerability to climate risk. The endogenous switching approach is used, and the results show that age positively affects the probability of adopting improved seeds and intercropping. In contrast, increasing the number of equivalent adults in the household and exploited land area decreases women's likelihood of adopting improved seeds and intercropping. Moreover, floods, drought, and being married compared to being single increase women’s vulnerability to climate risk. However, the age of households headed by women, household size, and health access statistically reduce women’s vulnerability to climate risk. We can infer that the adoption of CSA packages has a positive and significant impact on reducing rural women’s vulnerability to climate change in Côte d’Ivoire.

Households adopting diverse CSA package combinations are less vulnerable than non-adopters, according to the estimated ATEs. As a result of this study, CSA packages and packages adopted in synergy are critical for women to build resilience and reduce vulnerability, contributing to the achievement of Sustainable Development Goal 13. CSA packages adopted in synergy may be critical for women because they provide a more diverse range of food and resources, allowing women to have greater control over their nutritional intake and economic stability. Additionally, the combination of different CSA packages can offer a holistic approach to addressing multiple aspects of vulnerability, such as climate change adaptation, income generation, and empowerment, which are essential for achieving Sustainable Development Goal 13. Implementing policy measures that increase farm households headed by women's adaptive capacity is critical. Some specific policy measures that can increase the adaptive capacity of farm households headed by women include providing access to climate-smart agricultural practices and technologies, offering financial and technical support for diversification of income sources, promoting gender-responsive extension services, and ensuring equal access to land and resources. These measures can empower women to effectively respond to climate change, enhance their resilience, and contribute to the achievement of Sustainable Development Goal 13

GENERAL CONCLUSION AND POLICY IMPLICATIONS

The dissertation provides a comprehensive analysis of the interplay between Climate-Smart Agriculture (CSA), vulnerability to climate risks, and food security in Côte d'Ivoire, with a particular emphasis on gender disparities. Across the various chapters, the study underscores the importance of CSA in mitigating climate risks and improving food security while also revealing significant barriers to adoption and disparities in the benefits accrued across different demographic groups. The research offers new insights into the effectiveness of CSA practices from the perspective of smallholder farmers and highlights the need for tailored interventions that address both structural and socio-economic constraints.

The first chapter explores smallholder farmers' perceptions of climate change and the factors influencing CSA adoption in the Hambol region. The results indicate that while farmers are largely aware of climate change and its adverse effects, their adoption of CSA practices remains limited. A total of 35 CSA practices were inventoried in the region, yet the majority were underutilized, with 25 practices being adopted by fewer than 20% of farmers surveyed. Farmers' perceptions of climate variability, including changes in temperature, precipitation patterns, and meteorological conditions, align with long-term climate data. However, despite recognizing the benefits of CSA in terms of productivity and resilience, a significant proportion of farmers remain skeptical about the extent of these benefits. This low adoption rate can be attributed to multiple barriers, including limited access to meteorological information, inadequate knowledge of CSA practices, financial constraints, water scarcity, and limited availability of improved seeds. Moreover, socio-demographic factors such as education level, gender, marital status, and location play critical roles in determining CSA adoption. The findings suggest that targeted training programs and enhanced advisory services could improve the understanding of CSA benefits and encourage broader adoption, thereby strengthening the resilience of rural farming communities.

Chapter two investigates the gendered impact of CSA adoption on household food security using an extended ordered probit model to correct for selection bias and endogeneity. The analysis finds that CSA adoption significantly enhances food security, though the effects differ by gender and region. Female-headed households benefit more from improved seeds, with a 33.9% increase in food security probability, whereas intercropping is more effective for male-headed households, increasing their food security probability by 47.3%. The combined adoption of CSA practices improves food security across all groups, with varying effects based on gender and regional conditions. The study further highlights that structural barriers such as land tenure insecurity and limited access to credit disproportionately affect female farmers, thereby constraining their ability to benefit fully from CSA adoption. Moreover, exposure to climate shocks exacerbates food insecurity, underscoring the need for complementary adaptation measures alongside CSA adoption. The findings call for region-specific CSA strategies that prioritize drought-resistant crops and soil fertility improvements, as well as gender-responsive policies that enhance women's access to land, credit, and extension services. Additionally, infrastructure investments and the promotion of climate adaptation measures such as irrigation and early warning systems are essential for enhancing resilience and ensuring the sustainability of CSA interventions.

The third chapter examines the impact of women's adoption of CSA practices on household vulnerability to climate risks. Using principal component analysis (PCA) to construct a vulnerability index and an endogenous switching approach to assess CSA adoption effects, the study finds that CSA adoption significantly reduces women's vulnerability. However, various socio-economic factors influence adoption rates, with age positively affecting the likelihood of adopting improved seeds and intercropping, while larger household size and greater land area reduce adoption probabilities. Climate shocks such as floods and droughts further exacerbate vulnerability, with married women being more vulnerable than single women. The findings indicate that adopting diverse CSA packages in synergy yields the greatest benefits in terms of resilience-building and vulnerability reduction. By improving food security, income stability, and adaptive capacity, CSA adoption contributes to achieving Sustainable Development Goal 13 (climate action). Policy measures aimed at increasing women's adaptive capacity, such as expanding access to climate-smart technologies, providing financial and technical support for diversification, promoting gender-responsive extension services, and ensuring equal access to land and resources, are critical for enhancing resilience in rural farming communities.

The policy implications of this research are profound. First, ensuring broader CSA adoption requires the removal of key barriers, particularly those related to financial constraints, land tenure insecurity, and information gaps. Providing targeted financial support, such as microfinance schemes and subsidies for CSA inputs, could encourage adoption among resource-constrained farmers. Second, gender-responsive policies are crucial for bridging disparities in CSA benefits. Women face significant structural barriers that limit their participation in CSA adoption, including restricted land ownership rights, limited credit access, and inadequate extension services. Policies that promote women's land rights, develop credit facilities tailored to female farmers, and enhance their access to agricultural advisory services are essential for achieving gender-equitable outcomes. Third, CSA interventions must be tailored to regional contexts. The study finds that the effectiveness of CSA practices varies by location due to differences in climatic conditions, soil fertility, and market access. As such, region-specific policies that prioritize suitable CSA strategies, such as drought-resistant crops in arid regions and soil fertility enhancements in degraded areas, should be implemented. Additionally, investments in rural infrastructure, including irrigation systems, storage facilities, and transportation networks, are necessary to strengthen market linkages and reduce post-harvest losses.

Despite its significant contributions, this research has several limitations. One key limitation is its reliance on cross-sectional data, which restricts the ability to capture long-term adoption patterns and dynamic changes in food security and vulnerability. A longitudinal approach would provide deeper insights into the sustained impacts of CSA adoption over time. Additionally, while the study employs robust econometric techniques to account for selection bias and endogeneity, it does not fully capture the social dynamics and interactions that influence CSA adoption. Social networks, cooperative membership, and community-based learning play vital roles in technology diffusion and should be considered in future research. Another limitation is the lack of detailed analysis of the role of agricultural markets, including price fluctuations, input supply chains, and access to markets, which are critical determinants of CSA adoption and food security outcomes.

Future research should explore these limitations by adopting agent-based modeling to examine the dynamic interactions between farm households, market agents, and agricultural cooperatives. Agent-based models can provide a more nuanced understanding of how social relationships, economic incentives, and external shocks influence CSA adoption and food security. Additionally, investigating the willingness of households to adopt CSA practices could offer valuable insights for designing incentive-based policies that accelerate adoption rates. Expanding the scope of research to include the role of climate information services, digital technologies, and mobile-based agricultural advisory platforms in CSA adoption could further enhance policy recommendations. Moreover, future studies should assess the long-term impacts of CSA interventions using panel data to track adoption trajectories and resilience outcomes over time.

In conclusion, this dissertation highlights the transformative potential of CSA in reducing food insecurity and building resilience to climate risks in Côte d'Ivoire. However, the findings underscore the need for targeted interventions that address gender disparities, financial constraints, and climate-related challenges. Holistic approaches that combine CSA promotion with institutional and socio-economic support mechanisms are essential for creating a more resilient and food-secure agricultural sector. By integrating region-specific CSA strategies, gender-responsive policies, and infrastructure investments, policymakers can ensure that CSA adoption translates into meaningful and sustainable improvements in rural livelihoods. Future research should continue to refine these strategies, incorporating dynamic modeling approaches and longitudinal analyses to provide deeper insights into the evolving impacts of CSA adoption. Ultimately, achieving widespread and effective CSA adoption requires coordinated efforts from governments, development organizations, and private sector stakeholders to create enabling environments that empower farmers, enhance adaptive capacity, and foster sustainable agricultural development in the face of climate change.

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APPENDIX

WASCAL GRP: Climate Change Economics, University Cheikh Anta Diop Dakar

Enquête sur l'évaluation genre de la perception, de l'adoption et de l'efficience des pratiques d'agriculture climato-intelligente en Côte d'Ivoire

Ce questionnaire développé rentre dans le cadre de notre travail de recherche dont le thème est : l'évaluation genre de la perception, de l'adoption et de l'efficience des pratiques d'agriculture climato-intelligente en Côte d'Ivoire.

Le présent questionnaire nous permettra :

- D'analyser les facteurs explicatifs des différences genre de perception et d'adoption des pratiques d'agriculture climato-intelligente en Côte d'Ivoire
- Capter selon le genre, l'efficience subjective de ces pratiques
- Et enfin, analyser le rôle des caractéristiques des ménages sur l'efficience des pratiques d'agriculture climato-intelligente en Côte d'Ivoire

Merci de bien vouloir prendre part à cet exercice de collecte de données en répondant à ces quelques questions relatives au changement climatique et à la connaissance, la pratique et l'impact des pratiques d'agriculture climato-intelligente.

Partie 0 : Identification

00 : Localisation géographique	1. Latitude 2. Longitude	03 : localité
01 : Département	-------------	
02 : sous-préfecture	-------------	
Date de l'enquête	../../2023	Heure :

Partie A : Caractéristiques démographiques

A1 : Combien de personnes (vous y compris) vivent dans votre foyer ?	/------/
A2 : Combien d'enfants (de moins de 18 ans) vivent dans votre foyer ?	/------/

A3 : Parmi ces enfants, combien ont moins de 5 ans ?	/------/		
A4 : Etes-vous le chef du ménage ?	**1.** Oui 2. Non		
A5 : Si Non qui est le chef de votre ménage ?	----------------------------		
A6 : Sexe du chef ?	1. Masculin 2. Féminin		
A7 : Age du chef ?	/------/		
A8 : Quelle est la situation matrimoniale du chef de ménage ?	1. Célibataire 2. Marié(e) monogame 3. Marié(e) polygame 4. Union libre 5. Veuf(ve) 6. Divorcé(e) 7. Séparé(e)		
A8 : Quel niveau d'étude identifie le mieux le chef ?	1. Aucun niveau 2. CP1 3. CP2 4. CE1 5. CE2	6. CM1 7. CM2 8. 6ème 9. 5ème 10. 4ème 11. 3ème	12. Seconde 13. Première 14. Terminale 15. Universitaire 16. Professionnelle 17. Alphabétisation
A9 : Quelle est sa situation professionnelle actuelle du chef de ménage ?	1. A votre compte 2. Salarié(e) (à temps plein, à temps partiel ou en congé temporaire) 3. Retraité(e) 4. Homme/femme au foyer	5. En recherche d'emploi/sans emploi 6. Etudiant(e) 7. Dans l'impossibilité de travailler, par exemple en invalidité 8. Autre, veuillez préciser	
A10 : Dans quelle branche d'activité le chef du ménage a-t-il travaillé ou travaille-t-il principalement ?	1. Sans emploi 2. Agriculture, Elevage, Pêche… 3. Mines, carrières 4. Industries, électricité, eau	5. Construction 6. Commerce 7. Transport 8. Restauration, hôtel 9. Arts et spectacles 10. Services 11. NSP	

B. Perception du changement climatique et chocs

B1 : Au cours des 20 dernières années, avez-vous remarqué un changement dans les conditions météorologiques	1. Oui 2. Non |__|				
B2 : Quels changements avez-vous observés ?	………………… /				
B3 : Avez-vous entendu parler du changement climatique ?	1. Oui 2. Non				
B4 : Si oui, d'où l'avez-vous entendu ?	1. Télévision 2. Radio 3. Dans notre coopérative/réunion 4. Par un ami				
B5: Y a-t-il eu un changement dans le régime des précipitations au cours des 20 dernières années ?	1. Oui 2. Non 3. Je ne sais pas				
B6 : Si oui, la période de précipitations a-t-elle	1. Augmentée 2. Diminuée 3. Je ne sais pas				
B7 : Quelles sont les causes des changements observés dans les précipitations ?	1. Très élevé	2. Elevé	3. Moins élevé	4. Moins faible	5. Très faible
B7Q1 : Abattage d'arbres/Déforestation					
B7Q2 : Brûler					
B7Q3 : Moins de plantations d'arbres					
B7Q4 : Augmentation de la population					
B8 : La durée des périodes de sécheresse pendant la saison des pluies a-t-elle augmenté ?	1. Augmenté 2. Diminué 3. Je ne sais pas				
B9 : Y a-t-il eu un changement de température au cours des 20 dernières années ?	1. Oui 2. Non 3. Je ne sais pas				
B10 : La température des 20 dernières années est-elle :	1. En augmentation ? 2. En baisse ? 3. Je ne sais pas ?				

B11 : Quelles sont les causes des changements observés dans la température ?	1. Très élevé	2. Elevé	3. Moins élevé	4. Moins faible	5. Très faible
B11Q1 : Buissons ardent					
B11Q2 : Abattage d'arbres/Déforestation					
B11Q3 : Utilisation d'un trop grand nombre de voitures					
B11Q4 : Augmentation de la population					
B12 : Y a-t-il eu un changement dans la durée/longueur de la principale période de végétation au cours des 20 dernières années ?	1. Oui 2. Non 3. Je ne sais pas				
B13 : La durée/longueur de la petite saison de végétation a-t-elle changé au cours des 20 dernières années ?	1. Oui 2. Non 3. Je ne sais pas				
B14 : Avez-vous constaté un changement dans le rendement des céréales ou des produits au cours des 20 dernières années ?	1. Oui 2. Non 3. Je ne sais pas				
B15 : Quel est le changement de rendement ?	Augmentation du rendement des cultures Diminution du rendement des cultures Je ne sais pas				
B16 : S'il y a une baisse de rendement, quelle pourrait en être la raison ?	1. Moins de précipitations 2. Température élevée 3. Faible fertilité du sol 4. Invasion des insectes 5. Je ne sais pas				

C. Les stratégies d'adaptation

C1 : Quels ajustements avez-vous faits ou ferez-vous pour réduire l'impact des changements climatiques sur votre exploitation ou sur le rendement de vos cultures et animal ou sur vos moyens de subsistance ?

1. Oui
2. Non

Pratique Agricole	**Pratique d'élevage**	**Utilisation des terres et intensification**	**Pertes liées à la récolte et à la transformation**
1. Semences améliorées	15. Amélioration des systèmes d'élevage (sélection des races et gestion des périodes de reproduction ou d'insémination)	24. Technique de lutte contre le ruissellement	31. Stockage solaire dans la chaîne du froid
2. Culture intercalaire	16. Intensification de la production de fourrage	25. Irrigation par inondation	32. Mécanisation de certaines cultures
3. Rotation des cultures	17. Développement du recours à la transformation des aliments pour animaux	26. Irrigation au goutte-à-goutte ou par aspersion	33. Amélioration du stockage et de l'emballage
4. Utilisation des procédés d'analyse de sol	18. Optimisation de la composition des aliments pour animaux et passer à des régimes	27. Irrigation à énergie solaire	34. Utiliser les déchets végétaux
5. Réduire l'application excessive d'engrais azotés	19. Intégration des systèmes d'élevage et de culture	28. Mécanisation de l'agriculture	
6. Développer l'utilisation d'amendements du sol (fumier, compost, résidus de culture, chaux, biochar et inoculations diverses)	20. Amélioration de la surveillance de la santé animale et la prévention des maladies	29. Protection de forêts	
7. Changement des cultures	21. Amélioration du calendrier des ventes de bétail	30. Agroforesterie	
8. Développer l'utilisation de nouvelles pratiques de lutte contre les ravageurs	22. Optimisation du taux de charge (têtes de bétail par hectare) en		
9. Incorporation des résidus de culture dans le sol paddy	23. Développement du pâturage tournant et la restauration des pâturages		

10. Fertilisation profonde à l'urée)			
11. Développement des procédés de stockage et de gestion d'eau			
12. Utiliser la technologie du semis direct à sec			
13. Irrigation			
14. Passage de la culture à l'élevage			

C2: Quels ajustements Ferez-vous pour réduire s d'avantage l'impact des changements climatiques sur votre exploitation ou sur le rendement de vos cultures et animal ou sur vos moyens de subsistance ?

Pratique Agricole	**Pratique d'élevage**	**Utilisation des terres et intensification**	**Pertes liées à la récolte et à la transformation**
15. Semences améliorées	24. Amélioration des systèmes d'élevage (sélection des races et gestion des périodes de reproduction ou d'insémination)	31. Technique de lutte contre le ruissellement	35. Stockage solaire dans la chaîne du froid
16. Culture intercalaire	25. Intensification de la production de fourrage	32. Irrigation par inondation	36. Mécanisation de certaines cultures
17. Rotation des cultures	26. Développement du recours à la transformation des aliments pour animaux	33. Irrigation au goutte-à-goutte ou par aspersion	37. Amélioration du stockage et de l'emballage
18. Utilisation des procédés d'analyse de sol	27. Optimisation de la composition des aliments pour animaux et passer à des régimes	34. Irrigation à énergie solaire	38. Utiliser les déchets végétaux

19. Réduire l'application excessive d'engrais azotés	28. Intégration des systèmes d'élevage et de culture	35. Mécanisation de l'agriculture	
20. Développer l'utilisation d'amendements du sol (fumier, compost, résidus de culture, chaux, biochar et inoculations diverses)	29. Amélioration de la surveillance de la santé animale et la prévention des maladies	36. Protection de forêts	
21. Changement des cultures	30. Amélioration du calendrier des ventes de bétail	37. Agroforesterie	
22. Développer l'utilisation de nouvelles pratiques de lutte contre les ravageurs	31. Optimisation du taux de charge (têtes de bétail par hectare) en		
23. Incorporation des résidus de culture dans le sol paddy	32. Développement du pâturage tournant et la restauration des pâturages		
24. Fertilisation profonde à l'urée)			
25. Développement des procédés de stockage et de gestion d'eau			
26. Utiliser la technologie du semis direct à sec			
27. Irrigation			
28. Passage de la culture à l'élevage			

C3 : Quels est selon vous l'impact des stratégies que vous pratiquez :

1. Très élevé 2. Elevé 3. Moins élevé 4. Moins faible 5. Très faible

Stratégies	Atténuation/diminution des émissions des gaz à effet de serre	Adaptation	Sécurité Alimentaire/gain de productivité
1.			
2.			
3.			

C4: Quels sont les obstacles/difficultés possibles pour s'adapter au changement climatique ou aux changements météorologiques à long terme ?	1. Manque de fonds ou de facilités de crédits/Pauvreté 2. Faute de technologie 3. Augmentation de la population 4. Manque d'accès à l'eau 5. Manque d'accès au marché 6. Manque de semences appropriées 7. Manque de connaissances sur les stratégies 8. Manque d'information sur les prévisions météorologiques 9. Autres (à préciser)
C5 : Par stratégie agricole utilisée, indiquez-nous :	

Stratégies	Surface agricole		Produit principal cultivé	Coût	Production	
	Unité	Estimation			Unité	Estimation
1						
2						
3						

D. Sécurité alimentaire

D1 : Au cours des 7 derniers jours, le ménage a-t-il eu des difficultés à subvenir aux besoins alimentaires de ses membres ?	|__|__|
D2 : Au cours des 7 derniers jours, combien de jours le ménage a-t-il eu à:	
D2Q1 : compter sur des aliments moins appréciés et/ou moins couteux ?	|__|__|
D2Q2 : réduire les quantités consommées chaque fois ?	|__|__|
D2Q3 : réduire le nombre de repas par jour ?	|__|__|
D2Q4 : réduire les quantités consommées par les adultes au profit des enfants ?	|__|__|

D2Q5 : emprunter des vivres ou compter sur l'aide de parents ou d'amis ?	|__|__|
D3 : Combien de repas, y compris le petit-déjeuner, ont été pris par jour dans le ménage au cours des 7 derniers jours ?	
D3Q1 : Enfants (6-59 mois)	|__|__|
D3Q2 : 5 à 17 ans	|__|__|
D3Q3 : 18 ans ou plus	|__|__|
D4 : Au cours des 12 derniers mois, avez-vous fait face à une situation où vous n'aviez pas suffisamment de nourriture pour tout le ménage ?	1. Oui 2. Non
D5 : Dans quel mois avez-vous rencontré ce problème au cours des 12 derniers mois ?	
D5Q1 : Mois durant lequel le ménage n'a pas eu suffisamment à manger	|__|__|
D5Q2 : Mois durant lequel le ménage a eu suffisamment à manger	|__|__|
D6 : Quelles étaient les causes de cette situation ?	1. Faibles récoltes du fait de la sécheresse 2. Faibles récoltes du fait de l'attaque des insectes 3. Faibles récoltes du fait du faible accès aux terres cultivables 4. Faibles récoltes du fait du manque des intrants 5. Faibles récoltes du fait de la pauvreté des sols 6. Cherté des produits sur le marché 7. Accès difficile aux marchés du fait des coûts de transport élevé 8. Faibles ressources financières 9. Peu de produits alimentaires au marché 10. Conflit (tribal, foncier,…) 11. Inondations 12. Autre (à préciser)
D7 : Votre ménage s'adapte-t-il à la pénurie alimentaire par un des moyens suivants ?	1. Oui 2. Non
D7Q1 : Réduire le nombre de repas pris dans la journée	|__|
D7Q2 : Limiter la taille des portions au moment du repas	|__|
D7Q3 : Compter sur des aliments moins appréciés et/ou moins coûteux	|__|

D7Q4 : Changer la préparation des aliments	|__|
D7Q5 : Emprunter de l'argent, de la nourriture ou compter sur l'aide d'un ami ou parent	|__|
D7Q6 : Reporter l'achat de thé/café ou d'autre article ménager ?	|__|
D7Q7 : Reporter le paiement de frais liés à l'éducation (frais de scolarité, livres, etc.) ?	|__|
D7Q8 : Reporter le paiement de frais de loyers, d'électricité, d'eau, etc ?	|__|
D7Q9 : Vendre des animaux du ménage (bétail ou volaille, etc.?)	|__|
D7Q10 : Vendre des biens mobiliers ou matériels du ménage, terrains, maisons, pagnes, bijoux, etc.?	|__|

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