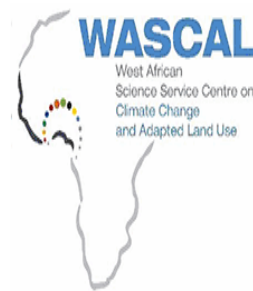


*IMPACT OF CLIMATE CHANGE ADAPTATION STRATEGIES WITHIN AGRICULTURAL COMMUNITIES IN  
CENTRAL BENIN REPUBLIC*



**GRADUATE STUDY PROGRAM IN CLIMATE CHANGE ECONOMICS (GSP-CCE)**

WEST AFRICAN SCIENCE SERVICE CENTRE ON CLIMATE CHANGE AND ADAPTED LAND USE

**CHEIKH ANTA DIOP UNIVERSITY OF DAKAR**

\*\*\*\*\*

**PhD Dissertation**

By:

**MONGBO Majorie Jennifer Kayodé**

TOPIC:

**IMPACT OF CLIMATE CHANGE ADAPTATION STRATEGIES WITHIN  
AGRICULTURAL COMMUNITIES IN CENTRAL BENIN REPUBLIC**

***Supervisor***

**Prof Mouhamadou Lamine DIAL**

College of Economics and Management  
Sciences, FASEG/UCAD

***Co- Supervisor***

**Prof Magdalene Silberberger**

Department of Philosophy, Politics and  
Economics, Witten/Herdecke

*IMPACT OF CLIMATE CHANGE ADAPTATION STRATEGIES WITHIN AGRICULTURAL COMMUNITIES IN  
CENTRAL BENIN REPUBLIC*

*UCAD and WASCAL do not intend to give any approval or disapproval of the opinions expressed in this thesis. These opinions should be considered the author's own.*

**Dedication**

I dedicate this thesis to my father, mother and my siblings,  
For all your love and support.

To my Kayrell Liliane,  
Thank you for your courage and endurance

## **Acknowledgments**

I express my sincere gratitude to the Federal Ministry of Education and Research (BMBF) and West African Science Centre on Climate Change and Adapted Land Use (WASCAL) for providing the financial support for this programme. And to the entire management of WASCAL at the headquarters, Accra.

My appreciation to Dr Ibrahim BARRY, the director of Climate Change Economics programme WASCAL/UCAD, and his staff for their logistical and administrative support. I also extend my gratitude to Prof Aly Mbaye and the late Dr Fatou Gueye Lefevre successively former directors of WASCAL/UCAD

I am grateful to my supervisors: Prof Lamine Dial for his patience, constructive comments, supports, knowledge; and Prof Magdalene Silberberger, for believing in my work, for accepting to supervise my redaction, for her great role in putting this research work up to a standard quality.

I express my most profound gratitude to Prof Boris Odilon Lokonon for his priceless guidance, comments, advices and encouragements. .

I express my thanks to Prof Alastaire Alinsato, Dr Armel Nonvide and Jores Amegnaglo for their advices and encouragements

I also thank my friends Sande Idoleke, Hamdy Bonou-Gbo, Nassirou Mouhamed, Catherine Kato-Kale, Christelle Samba, Cedric Boissy, Amour Medo-Adokon, and Moussa Ndiaye for all their assistance, encouragements and presence in a way or another during this PhD journey  
My appreciation to my fellows from WASCAL/UCAD batch 4, moments spent together, I wish you success social and a fulfilling life.

I would like to give my most profoto my family: my father Mongbo Martial Ferdinand, and mother Adjaho Marcelline for all your sacrifices; to my siblings Olaitan, Eunice and Enoch, for your endless support and love for me

## **TABLES OF CONTENTS**

Dedication .....	3
Acknowledgments .....	4
TABLES OF CONTENTS .....	5
LIST OF TABLE.....	7
LIST OF FIGURES .....	8
LIST OF APPENDICES.....	8
ACRONYMS AND ABBREVIATIONS.....	9
Abstract.....	11
INTRODUCTION.....	14
1 CHAPTER ONE: Impact of the use of improved varieties on crop yield in local communities of central Benin .....	20
1.1 Introduction.....	20
1.2 Literature review .....	22
1.2.1 Agricultural climate change adaptation and local communities .....	22
1.2.2 Methods of the impact assessment of agricultural adaptation policies on agricultural yield .....	25
1.2.3 Empirical review: impact of the adoption on climate change adaptation decision on crop yield .....	27
1.3 Materials and methods.....	30
1.3.1 Data.....	30
1.3.2 Model of the study.....	31
1.3.3 Variables of the model .....	37
1.4 Results .....	40
1.4.1 Descriptive statistics .....	40
1.4.2 Estimation of endogenous switching model of the use of Maize and Cassava’s improved varieties on crop yield.....	42
1.5 Conclusion .....	51
2 CHAPTER TWO: Impact of the crop calendar change on crop diversification in Central Benin agricultural communities .....	53
2.1 Introduction.....	53
2.2 Literature review .....	55
2.2.1 Importance of crop diversification .....	55
2.2.2 Experienced determinants of Crop diversity .....	55

*IMPACT OF CLIMATE CHANGE ADAPTATION STRATEGIES WITHIN AGRICULTURAL COMMUNITIES IN  
CENTRAL BENIN REPUBLIC*

2.3	Materials and methods.....	57
2.3.1	Data.....	57
2.3.2	Model of the study.....	58
2.3.3	Variables of the model.....	62
2.4	Results.....	64
2.4.1	Descriptive statistics.....	64
2.4.2	Estimation of endogenous switching model of cultivation calendar modification on crop diversity.....	65
2.5	Conclusion.....	71
3	CHAPTER THREE: Impact of off-farm activities as climate change adaptation strategies on monetary poverty among Maize and cassava farmer communities in central Benin.....	74
3.1	Introduction.....	74
3.2	Literature review.....	76
3.2.1	Non-farm/ off-farm activities as climate change adaptation strategies and means of poverty reduction.....	76
3.2.2	Climate change impacts and poverty.....	80
3.2.3	Determinants of poverty.....	81
3.3	Materials and methods.....	84
3.3.1	Data.....	84
3.3.2	Model of the study.....	85
3.3.3	Variables of the model.....	90
3.4	Results.....	92
3.4.1	Descriptive statistics.....	92
3.4.2	Estimation of endogenous switching model of the engagement into off-farm activities of poverty state.....	94
3.4.3	Computation of the effects of off-farm activities on monetary poverty.....	97
3.5	Conclusion.....	99
	CONCLUSION.....	100
	BIBLIOGRAPHY.....	103
	APPENDIX/ANNEX.....	112

**LIST OF TABLE**

Table 1-1 <b>Measurement of the variables</b> .....	38
Table 1-2 <b>Characteristics of the households and their farms</b> .....	41
Table 1-3 <b>Estimation of the model on the use of maize improved seeds and crop yield</b> ...	42
Table 1-4 <b>Average treatment and heterogeneity expected effects per hectare for maize crop</b> .....	<b>Error! Bookmark not defined.</b>
Table 1-5 <b>Estimation of the model on the use of cassava improved crops and the yield</b> ..	47
Table 1-6 <b>Average treatment and heterogeneity expected effects per hectare for cassava</b> .....	50
Table 2-1 <b>Measurement of the variables</b> .....	63
Table 2-2 <b>Descriptive statistics: tendency in variables of the model</b> .....	64
Table 2-3 <b>Results of the model of crop calendar modification on crop</b> .....	66
Table 2-4 <b>Average treatment and heterogeneity expected effects</b> .....	69
Table 3-1 <b>Measurement of the variables</b> .....	90
Table 3-2 <b>Tendency in the variables of the model</b> .....	92
Table 3-3 <b>Results of switch probit regression</b> .....	94
Table 3-4 <b>Effects of off-farm activities</b> .....	97

**LIST OF FIGURES**

Figure 1 **Map of the study area** ..... 113

**LIST OF APPENDICES**

Appendix 1: Presentation of the Central Benin Agro-Ecological Zone: Agro-Ecological Zone  
4..... 112

Appendix 2: Sampling ..... 114

Appendix 3: Main crops cultivated ..... 116

Appendix 4: off-farm activities observed and percentage among respondents ..... 118

## **ACRONYMS AND ABBREVIATIONS**

<b>ATDA</b>	Agence Territoriale de Développement Agricole
<b>ATH</b>	Average Transitional Heterogeneity
<b>ATT</b>	Average Treatment effect on the Treated
<b>ATU</b>	Average Treatment effect on the Untreated
<b>BH1</b>	effect of Base Heterogeneity for treated
<b>BH2</b>	effect of Base Heterogeneity for untreated
<b>CC</b>	Climate Change
<b>CFA</b>	Communauté Financière Africaine
<b>CGEM</b>	Computable General Equilibrium Model
<b>ESR</b>	Endogenous Switching Regression
<b>FAO</b>	Food and Agriculture Organisation
<b>GDP</b>	Gross Domestic Product
<b>EHCVM</b>	Harmonized Survey on Living Conditions of Households in Benin
<b>IFAD</b>	International Fund for Agricultural Development
<b>IFML</b>	Full Information Maximum Likelihood
<b>INSAE</b>	Institut National de la Statistique et de l'Analyse Économique
<b>IPCC</b>	Intergovernmental Panel on Climate Change
<b>IPCC- AR5</b>	Intergovernmental Panel on Climate Change - Fifth Assessment Report
<b>IV</b>	Instrumental Variable
<b>LDCs</b>	Least Developed Countries
<b>MAEP</b>	Ministère de l'Agriculture, de l'Elevage et de la Pêche
<b>MCVDD</b>	Ministère du Cadre de Vie et du Développement Durable
<b>MEPN</b>	Ministère de l'Environnement et de la Protection de la Nature
<b>NAP</b>	National Adaptation Plan
<b>NDC</b>	National Determined Contribution
<b>NOAA</b>	La National Oceanic and Atmospheric Administration
<b>OECD</b>	Organisation for Economic Co-operation and Development
<b>OLS</b>	Ordinary Least Square

<b>PADA</b>	Projet d'Appui à la Diversification Agricole
<b>PAG</b>	Plan d'Action Governmental
<b>PANA</b>	Programme d'Action National d'Adaptation aux Changements Climatiques
<b>PAS-PNA</b>	Projet d'Appui Scientifique aux processus de Plans Nationaux d'Adaptation
<b>PIACo</b>	Plateforme Internet sur l'Adaptation aux Changements Climatiques destinée aux Communes du Bénin
<b>PPP</b>	Purchasing Power Parity
<b>ProCAD</b>	Programme Cadre d'Appui à la Diversification agricole
<b>RNFE</b>	Rural Non-Farm Economy
<b>SDGs</b>	Sustainable Development Goals
<b>SWAC</b>	Sahel and West Africa Club
<b>UNDP</b>	United Nations Development Programme
<b>UNFCC</b>	United Nations Framework Convention on Climate Change

## **Abstract**

The harmful effects of climate change on developing countries' agriculture, particularly in the Republic of Benin, are no longer in question as they have been the subject of several studies. The analysis of the effectiveness of agricultural adaptation strategies put in place must now be further examined in order to get the best out of them. This is how the present thesis aims to analyse the socio-economic impact of Climate change agricultural coping strategies on local communities in central Benin Republic. For this, the study identifies three climate change adaptation strategies adopted at communities' level and analyses through a micro level study their outcome on the livelihood improvement of involved communities. We investigate of the use improved varieties, the crop calendar modification and the engagement in off-farm activities, on respectively crop yield, crop diversification and poverty reduction. Based on a primary cross sectional data collection from maize and cassava farmer's communities of central Benin, we use quantitative and qualitative approaches, and run endogenous switching model regressions. The results show that different factors are usually behind the decision of adaptation by the farmers. Climate variables play a determinant role in adaptation undertaking, but also, the information channels, the farm socioeconomic and unobservable factors show their importance in the farmers' adaptation decision taking. Coming to the effects of adaption strategies, it appears that, they have a globally positive impact the targeted aspects. However, the heterogeneity in socio-economic factors among the households and their farm need to be considered while shaping agricultural climate change adaptation strategies. Not all farmers' groups, and all crops respond the same way to a giving adaptation strategy.

***Key words: Agriculture, Climate change adaptation, Impact, Benin Republic***

## **Résumé**

Les effets néfastes du changement climatique sur l'agriculture des pays en développement, en particulier dans la République du Bénin, ne sont plus remis en question, faisant l'objet de plusieurs études. Il convient désormais d'analyser de l'efficacité des stratégies d'adaptation mises en place afin d'en améliorer les performances d'en tirer le meilleur parti de l'adaptation. Dans ce contexte la présente thèse vise à analyser l'impact socio-économique des stratégies agricoles d'adaptation au changement climatique sur les communautés locales du centre de la République du Bénin. À cette fin, l'étude a identifié trois stratégies d'adaptation aux changements climatiques adoptées au niveau des communautés et a analysé, par une approche microéconomique, leurs résultats sur l'amélioration des moyens de subsistance des communautés concernées. L'étude a porté sur l'impact de l'usage des variétés améliorées, de la modification du calendrier culturale et de l'engagement dans les activités hors ferme, respectivement sur le rendement agricole, la diversification des cultures et la réduction de la pauvreté. Au moyen d'une collecte de données primaires auprès des communautés de producteurs de maïs et de manioc du centre du Bénin, l'étude a utilisé des approches quantitatives et qualitatives et performé des régressions de modèles à commutation endogènes. Les résultats montrent que différents facteurs sont généralement à l'origine de la décision d'adaptation par agriculteurs. Les variables climatiques jouent un rôle déterminant dans l'entreprise de l'adaptation, mais aussi, les canaux d'information, les facteurs socioéconomiques et les facteurs non observables ont montré leur importance dans la prise de décision d'adaptation des agriculteurs. Quant aux résultats de l'adaptation, leur impact est vraisemblablement globalement positif sur les aspects ciblés. Cependant, l'hétérogénéité des facteurs socio-économiques entre les ménages agricoles et leurs exploitations doit être prise dans le processus de construction des stratégies d'adaptation dans le domaine agricole. Tous les groupes d'agriculteurs et toutes les cultures ne répondent pas pas systématiquement de la même manière à une stratégie d'adaptation.

***Mots clés : Agriculture, Adaptation aux changements climatiques, Impact, Bénin***

*IMPACT OF CLIMATE CHANGE ADAPTATION STRATEGIES WITHIN AGRICULTURAL COMMUNITIES IN  
CENTRAL BENIN REPUBLIC*

## **INTRODUCTION**

Climate change is one of the most significant events of the third millennium considering the agricultural sector (Kola Yabi & Pilabina, 2019). In developing countries, climate change and its variability adversely affect smallholder farmers (Adego et al., 2019). It presents a veritable threat to rain-fed agricultural systems causing water scarcity and decrease of yield, and hinders the achievement of the Sustainability Development Goals (SDGs), especially in the goals one and two respectively related to combating poverty and hunger (Antwi-Agyei & Nyantakyi-Friin mpong, 2021). Since agricultural sector plays an important role in sustaining growth and food security, and reducing poverty in developing countries, it appears important to promote practices that are able to as well improve agricultural productivity as to reduce environmental impact (Lokonon & Mbaye, 2018). Africa is considered as the most vulnerable region in the world considering the climate change effects. Yet, Africa produces less than 4% of the global greenhouse gas emissions (Sahel and West Africa Club (SWAC)/OECD, 2009). In fact, the agricultural production in Sub-Saharan Africa is mostly rain-fed (Danso-Abbeam et al. (2021); Bedeke et al. (2018) and Ensor et al. (2014)). The crop production in many of the countries is seriously imperilled with the yield reduced by up to 50% (IPCC- AR5, 2014). The impacts on the continent are illustrated in sectors such as agriculture and health; exacerbating poverty and sapping the socio-economic development endeavour of the continent (Ondari-Okemwa, 2006). In fact, agricultural sector is the most contributor to the subsistence of the poor in developing countries; so working in the sense of ameliorating agricultural yield and increasing the profits from the sector are needed to ensure as well food security as a number of targets specified under the SDGs (Rosegrant et al. 2006 cited in Bryan et al., 2013)..

The next decades will be more challenging for West-Africa , which is already suffering of a weak agricultural system achieving food security as well from demographic growth as from climate change (Guan et al., 2017). It is therefore indispensable for farmers to adopt strategies not only to mitigate the impact of climate change on their activities but also to manage the decline in productivity (Lokonon & Mbaye, 2018). For that purpose, in the rural parts of Africa, adaptive strategies are set by farmers in order to deal with the adverse effects of climate change (Baudoin et al. (2014) and Adego et al. (2019)). However, there is a lack of studies assessing whether or not these options profit in improving crop yield (Adego et al., 2019). In the western Africa context, few adaptation strategies have been evaluated; so, it is still enough unknown what options, the best increase resilience of crop yield in the short, medium or long term (Guan et al., 2017). The literature identifies the main adaptations strategies in Sub-saharan Africa as the use of improved crop varieties

, they generally have the property to resist to higher temperature (drought tolerant), more salinity and are quick maturing (Ensor et al. 2014). Other options include income diversification (development of off-farm activities), crop diversification, mixed crop-livestock farming systems, changes in planting calendar, the use of pesticides, the experience of technics as irrigation, soil and water conservation technics (Nhemachena et al., 2014; Okonya et al., 2013). *Adaptation refers to adjustments in ecological, social or economic systems in response to actual or expected climate stimuli and their effects or impacts. It refers to changes in processes, practices and structures to moderate potential damages or to benefit from opportunities associated with climate change*”, (IPCC-AR3, 2001). The fifth assessment report defines adaptation as *the process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects*, (IPCC- AR5, 2014)

In Benin Republic, a West African country, the economy experienced a feeble per capita GDP growth - only 1.5% on average during the period 2008–2018. The relatively higher rate about 3.8% between 2017 and 2018, was resulted from the country’s intense port activity and its agriculture sector. Indeed, apart from the informal re-export and transit trade, the country deeply relies on agriculture - (+8.5% in port activities in 2018 and a sound agricultural sector hold up by record cotton production (+17% in 2018) and the diversification of emerging export sectors like pineapple and cashew nuts) - (World Bank – Benin, 2019). However, despite the stable tendency of the economic growth over the past two decades, poverty remains prevalent with estimated headcount poverty rates at 40.1% in 2015 (World Bank – Benin, 2019). The country is vulnerable to exogenous shocks such as varying terms of trade (cotton and oil prices) and climate hazards, (World Bank – Benin, 2019). Placed 149<sup>th</sup> out of 188 countries in per capita GHG emissions<sup>1</sup>, Benin contributes only 0.03% to global emissions<sup>2</sup>. However, the country is ranked 155 out of 181 countries in the ND-GAIN index<sup>3</sup> (2017) in terms of resilience to climate change, readiness to improve mitigation and in addressing other global challenges. Benin Republic is the 19<sup>th</sup> most vulnerable country and the 45<sup>th</sup> least ready country in climate measures; showing how much the country is vulnerable and not prepared to fight climate change effects. This expresses the country’s exposure, sensibility and inability to tackle or deal with the adverse effects of climate change. The vulnerability can appear

---

<sup>1</sup> <https://en.actualitix.com/country/eth/ethiopia-co2-emissions-percapita.php> (based on 2011 data)

<sup>2</sup> WRI (20

17) <http://cait2.wri.org/> (based on 2013 data)

<sup>3</sup> GAIN index summarizes a country’s vulnerability to climate change and other global challenges in combination with readiness to improve resilience. <http://index.gain.org/country/benin>

in food or water sectors, health, infrastructures, ecosystem or even service sectors. So adaptation actions have to be thought and taken; investments in economic, environmental or social policies are to be considered (Ministry of Foreign Affairs of the Netherlands, 2018). In consideration of climate change, the main agricultural production areas of Benin Republic suffer from the slippage of seasons with late and short rains (Vodounou & Onibon Doubogan, 2016). Simulations by 2050 of the impact of the future climate on the agricultural yields in one of the country's districts have revealed that the temperature will be increasingly pushed upwards (Kate et al., 2017). The climate change reduces the productivity of certain crops such as maize or sorghum, and the reduction of these crops has a negative effect on poverty and inequality (Mouleye et al., 2019). Since agricultural incomes are strongly affected by rainfall, all other things being equal, drought reduces those incomes (Faye et al., 2021). Given that there is no food security without a productive agricultural sector, any significant negative influence of the agricultural sector has as a consequence of food insecurity, hunger and poverty (Illa, 2020).

The ratification of the Convention of the United Nations Framework on Climate Change (UNFCCC), 30 June 1994, is a political act by which the Republic of Benin committed itself - by the side of other nations in the world - to ensure its share of responsibility in greenhouse gas emissions and in the development for its population of adaptation measures in face to the effects of climate change (MEPN, 2008). Plans have thus emerged, with the aim of determining priority and urgent adaptation needs considering the resources and capacities available to social groups. There have been a series of strategic documents which ones comprise the Initial National Communication (2002), the National Determined Contribution (NDC) in 2017 or the 2016-2025 Low-Emission Climate-Resilient Development Strategy (United Nations Development Programme (UNDP), 2020). The National Adaptation Plan (NAP) was introduced in Benin in 2013 (UNDP, 2018). To be in line with that, the country has supplemented its 2016-2021 Government Action Plan (Plan d'Action Gouvernemental - PAG) by the initiation of the 'Science-based support for NAP processes in francophone Least Developed Countries (LDCs) of sub-Saharan Africa (PAS-PNA), launched in 2017. The PAS-PNA has the objective to enhance ability for science-based and results-oriented implementation of NAP processes (UNDP, 2020). Constituting, henceforth, a national priority under the National development plan 2018-2025 and the Growth Agenda for Sustainable Development 2018-2021.

The integration of climate change adaptation into the planning of Benin's development process can be summarized by naming some strategic documents written as project with some of them implemented, among them, the National Climate Change Adaptation Action Programme (PANA)

in 2008, which focuses on short-term adaptation priorities. Similarly, sectorial documents have also been developed for certain sectors. Climate change vulnerability analyses were conducted in priority sectors of agriculture, water resources and health; the other priority areas, projected to be assessed gradually. For the agriculture sector, it is question of defining new agricultural calendars adapted to a changing climate; improving the performance of Beninese agriculture, making it capable of sustainably ensuring food and nutrition sovereignty; for the sector to contribute to the economic and social development of the men and women of Benin and the achievement of the SDGs (FAO, 2018). Agricultural sector's initiatives are for example "Integrated Adaptation Programme to Address the Adverse Effects of Climate Change on Agricultural Production and Food Security in Benin", developed in 2009 and implemented from April 2011; and the "Benin National Drought Plan" by the Ministry of Living Environment and Sustainable Development (MCVDD) in 2018 ( MCVDD & Institut international du développement durable, 2019). The project « Promotion of Agriculture (ProAgri3) » established between 2017 and 2020 by the German cooperation the Ministry of Agriculture, Livestock and Fisheries (MAEP). Three hundred and sixty-two (362) cooperatives and peasant groups benefit from it to improve the production, processing and marketing of their agricultural products. The "Support to Agricultural Diversification (PADA) project" led by ProCAD was implemented from 2013 to 2017. This project operates throughout the country with small rice farmers as main beneficiaries.

It is important to notify that despite its plans, Benin Republic has not yet set concrete adaption strategies toward populations. In fact plans are still at the thought process and are being working on to settle effective measures and actions for the achievement of operative adaptation among communities in the several priority sectors. In the meantime of the materialisation of the plans, a number of farmers among the concerned populations, with the advisory assistance of extension services, or not, have implemented at their farms level some adaptation strategies. Thus, in the central region of Benin, an agricultural area par excellence. Besides cash crops such as cashew and cotton, the farmer community is really devoted to the cultivation of vital crops for the population diet, those crops are maize, cassava, cowpea, yam, peanuts, squash, soybean, etc. Those crops are critical for food security in the country, especially maize and cassava crop, for their place in the daily life of the Beninese. Real must-see, with a huge demand, not only those two crops are directly consumed, but also, they constitute the base products in several transformed food products in Benin. Then, the Central Region of Benin is a staple region when achieving and maintaining food security in Benin. Unfortunately, like the in other parts of the country, this region is facing climate change. The climate risks identified in the region are excessive heat, drought, high winds and late and severe

rains. The vulnerability diagnosis of the area, conducted in the context of the PANA on the municipality sample of Savalou reveals that small farmers would be the most vulnerable social groups (PIACo / *Impacts actuels et potentiels des changements climatiques sur la Zone cotonnière du Centre (Zone agro-écologique 5)*, 2020). The poverty headcount in the region is estimated at 47 % with a contribution to national poverty about 24% (UNDP & MEPN, 2007). The endogenous adaptation measures identified in the populations of the area, to address the adverse effects of climate change on farm activities include the adoption of improved varieties of crops that are a modified forms of the given crop in order confer it a particular property the crop, usually, doesn't have. This can range from shortening the normal crop cycle to its best resistance to drought. Another adopted strategy by the communities is the modification of their usual crop calendar with a view to adjust to the new tendency of seasons and therefore limit the decrease of yield caused by the climate change. Other farmers, rather opt for the engagement into off-farm activities, this is in order to overcome the decline in their income, implicitly caused by the harmful effects of climate change. Other strategies adopted by producers are, for example, mobility, or adoption of some improved cultivation technics promoted by extension services (PIACo, 2020).

Figuring out the climate change adaptation strategies settled by communities, the factors that affect the choice of the strategies and their effectiveness is essential to lower farmers' vulnerability (Aryal et al. (2021) and Gorst et al. (2018)). It, therefore, suits to ask:

**What is the impact of climate change adaptation strategies within agricultural communities in central Benin Republic?**

This question considers three identified agricultural adaptation strategies in central Benin. They are the adoption of improved varieties, the modification of the crop calendar and the engagement in alternative economic activities. Taking into account the achievement of the SDGs, this in the context of climate change,

- What is the effect of the use of improved varieties on crop yield in the communities?
- What is the effect of the modification of the crop calendar on crop diversification in the communities?
- What is the effect of the promotion of off-farm activities on monetary poverty reduction in the communities?

The general objective of this thesis is to estimate the effect of agricultural climate change adaptation strategies within central Benin agricultural communities.

Specifically, it is:

- To determine the effect of the use of improved varieties on crop yield in the rural communities.
- To estimate the effect of the crop calendar modification on food security in the communities.

- To appraise the effect of the engagement in off-farm activities on monetary poverty reduction in the rural communities.

The findings of the study are relevant since most of the debates on climate change in agriculture have mainly focused on the impact of climate change itself rather than on the role of climate change adaptation (Di Falco et al., 2011). An impact assessment is simultaneously based on both perspectives of an evaluation, the first being lesson-based learning and the second being accountability (OECD, 2006). An optimal prioritisation of climate change agricultural adaptation requires an evaluation of the met adaptation options or choices in order to appraise their success.

Such an assessment work would permit, from the results got, to better advise farmers in dealing with climate risks in their farm activities while increasing the positive part they can draw for climate change (Guan et al., 2017). An evaluation of the effects of climate change adaptation will allow to appreciate what works or not, what is good or not, what improves and how to even better shape the strategies in order to achieve sustainable development for Benin Republic in the context of climate change.

The dissertation is structured in three chapters. The chapter one treats the effects the use of improved varieties on crop yield in maize and cassava producer communities of central Benin Republic. The second chapter analyses the effect of crop calendar modification on crop diversification in the community. And the third chapter focus on the effects of the engagement in off-farm activities on monetary poverty reduction within the communities.

## **1 CHAPTER ONE: Impact of the use of improved varieties on crop yield in local communities of central Benin**

### **1.1 Introduction**

In rural Sub-Saharan Africa communities, climate change and its variability constitute a threat for a Sustainable food production, and this is due to the rain-fed character of the agriculture (Atube et al., 2021). To respond to this, the farmers are setting a number of strategies. But there is a lack of studies assessing the effectiveness of those strategies in terms of yield improvement (Adego et al., 2019). Setting climate change adaptation strategies is indispensable for responding to climate change at local level and achieving the sustainable food production needed in face of the growing food demand (Adzawla & Alhassan, 2021). In Benin Republic, due to changes in the characteristics of rainy seasons, there is a greater menace for water availability for agriculture and an uncertainty at the producer level regarding crop calendars. Such a fact has a high impact on crop yields (Akponipke et al., 2019). In face with the consequences of climate change on the means and livelihoods of rural populations, they have developed adaptive strategies in order to still deriving most of their livelihood from their environment. Strategies include the increase in area planted, the erosion control facilities, the use of improved seed varieties, the change in seeding order, the shallows valorisation, the diversification of revenue sources..., (Akponipke et al., 2019). Among upper strategies, the use of improved seed varieties is here approached closely to understand its impact on agricultural yield. To support local producers in adapting to climate change, it is crucial to have a good understanding of the perceptions and strategies of adaptation. This would allow to design realistic strategies and policies for the sector's expansion and then food security (Atube et al., 2021).

This chapter focuses on the use of improved varieties as climate change adaptation option and estimates their impact on maize and cassava yield in central Benin agricultural communities, using a micro perspective approach. These maize and cassava crops are selected because of their strong presence in the diet of local communities. Indeed maize is at the top of staple crops in sub-Saharan Africa, a major crop for food security and in the livelihood of small scale farmers (Rajendran et al., 2017). (Rajendran et al., 2017). In the specific case of Benin, added to the maize, cassava is omnipresent in the population diet, consumed under in a variety of forms. Those two crops are highly demanded on the local market and a shock related to the both crops generally would have a large repercussion in terms of food availability for populations and lacks

of money for farmers. This is justified by the important role played by the central Benin in food supply in the country. Also, maize and cassava are two crops for which improved seeds are known to be adopted by farmers in the central region. The assessment of the impact of the use of improved varieties on crop yield in local communities could be seen as a novel one in Benin's context for the previous studies on the country have mainly focused on the impact on climate change on communities and enough less on the effectiveness of the adaptation strategies on the crop productivity. Most studies' object have essentially been related to the questions of the impact of climate change on agricultural sector, vulnerability and perceptions of farmers about climate change and their coping strategies (as example, the studies of Baudoin et al. 2014; Akponipke et al. 2019 and Sossou 2015) rather than the scale of success of the adaptation policies among communities in question.

## **1.2 Literature review**

### **1.2.1 Agricultural climate change adaptation and local communities**

Sub-Saharan African farmers smallholders are greatly affected by the adverse effects of climate change; this due to the high reliance to rainfall of the sector. The understanding of the perception of those farmers regarding the climate factor is really important to locally promote effective adaptation interventions (Bedeke et al., 2018). In fact, communities themselves generally play a role in the implementation and success of adaptation strategies. (Egeru, 2012; Subrahmanyeswari & Chander, 2013) assert that local communities are important informers about several decisions concerning environment management. Not only they have relevant lessons to give about the effective or not adaptation strategies, but also, knowledge from autochthone could be helpful for an accurate design of locally fitted strategies. Bedeke et al. (2018), from a work on maize-dependent smallholders in Ethiopia have deduced that the recognition of farmers' knowledge and experience on climate change would be beneficial in the development of context-specific and adjustable adaptation strategies that would allow to better achieve a certain resilience capacity.

In Africa, evidences show that farmers perceive climate change through the increase of heat during the days or the night and also through the changes in the precipitation frequencies, notably the decrease of rainfalls. For them, this results in the shortening of rainy seasons which start late and end earlier than before (Bedeke et al., 2018). Communities have a tight relationship with their environment, relationship which favours the emerging of valuable and efficient coping technics. Empirical evidences produce a valuable view of this with the case of Niger rural communities during the droughts of 1968–1973 and the 1984. Indeed they developed strategies as diversification outside of agricultural production, created collaborative networks, put in place a dynamic agricultural system along with livelihood and environment constraints (World Bank et al., 2003). In spite of some flaws that's local communities' adaptations strategies could present, they have the advantage to be able to be (in case of success) reproduced, ameliorated and applied in others areas (Kihila, 2018). It has been reported that the consideration of sustainable indigenous strategies is useful to improve the management of climate change effects with the purpose that the underlying limitations are overcome. In fact, those limitations to the efficiency of the strategies may, for example, come from their ineptness to the local context. So, it is important simulate their application under a number of scenarios before replicating any of them to a giving place (Kihila, 2018). This would be of the most

effective if emphasis is put on the interest of addressing institutional and informational constraints that hinder farmers from developing better farm practices (Gorst et al., 2018).

### **1.2.1.1 Experiences on adaptation policies in agricultural communities**

Sustainable agricultural practices, even though they are still considered not enough developed in developing countries, play a significant role in enhancing agricultural yield, farm household livelihood and more again, food security (Oyetunde-Usman et al., 2021). However, smallholders do not completely stay on the side-lines of adaptation initiatives. Indeed local communities in developing countries (fishermen, pastoralists and farmers) set various adaptation strategies to cope with climate change effects (Kihila, 2018). Studies conducted on Sub-saharan Africa (Adego et al. 2019; Onzima et al. 2019; Atube et al. 2021; Bedeke et al. 2018 and Oyetunde-Usman et al. 2021) have identified the use of the improved crop varieties as a major adaptation strategy adopted by numerous farmers. The utilisation of chemical fertilizer and pesticides are met as agricultural practices which application has increased with the climate change damages (Quan et al. 2019; Onzima et al. 2019 and Oyetunde-Usman et al. 2021). Traditional strategies as tree planting or the construction of water reservoirs that are run thanks to locally based water source, are deployed in Tanzania (Kihila, 2018). The same author has also identified as technics, mixed cropping and crop diversification, and then, joined by Bedeke et al. (2018) who have added to the crop diversification, the agroforestry practices and even seasonal migration that are adopted by some communities to manage the adverse effects of climate change in their living place. Onzima et al. (2019) in a paper which investigated climate change adaptation strategies on bean yield in central and northern Uganda has informed on a number of adaptation strategies adopted for bean yield, among them there is the intercropping technic, the use of fast maturing or drought-tolerant varieties, the early-planting, mixing varieties on the same plot, earthing-up to improve soil fertility, the exploitation of swan to grow crop that where not grown in such area or again the shade trees method. Crop rotation, intercropping but also the adjustment of planting date, mixed farming, and row planting, are counted among agricultural practices used to, by agricultural communities as in the case of maize production in northern Ghana (Adzawla & Alhassan, 2021). Urea and compost (Adego et al. (2019); Onzima et al. (2019)), irrigation technics (Nonvide, 2018), are widely used in some regions.

### **1.2.1.2 Overview of the agricultural sector in Benin Republic and climate change adaptation experiences**

Benin's economy is based primarily on agriculture and regional trade. Agriculture, which is the largest sector in terms of contribution to national Gross Domestic Product (36% of GDP) provides 70% of the country's jobs, and accounts for 75 to 90% of official exports. Most farms are small to medium-sized family owned. Their number was estimated at about 550,000 in 2011, with an average area of 1.7 ha. Agricultural growth is generally in the order of 3% per year, often offset by the relatively high population growth of 3%. Cotton is the main export product, accounting for 44% of official exports in 2014, followed by fruit (excluding nuts) which accounts for 19% of national exports, or the equivalent of CFA francs 43,705.80 million. Cotton production and processing have faced many challenges that have undermined their profitability and contribution to the growth of the sector in recent years. They accounted for 3.5% of national GDP between 2006 and 2011 (MAEP et al., 2019). Other agriculture-related activities accounted for 32% of national GDP in 2011, of which 47.5% for food agriculture, 18.2% for food crafts and 12.5% for livestock and hunting. According to the International Fund for Agricultural Development (IFAD), artisanal fishing provides direct employment to 50,000 fishermen and 20,000 wholesalers, mostly women, most of whom fish inland. The contribution of sub-sectors to GDP is estimated at 3%. The stagnation of fish production is due to the degradation of ecosystems, exacerbated by the widespread use of misguided techniques. Agricultural practices are mainly rain-fed and characterized by small farms, low inputs with maize, sorghum, rice, cassava, yams, other tubers and groundnuts as the main food crops and cashews, Shea and cotton as the main cash crops. The main livestock are sheep, goats, cattle, pigs and poultry. The agricultural sector is struggling to meet the food security needs of the growing population, particularly in the face of highly variable weather and climate change (MAEP et al., 2019).

Baudoin et al. (2014), in a study on Benin, identified farmer's adaptation strategies as new agricultural technics, for instance, soil conservation technics. Farmers followed by some projects can profit an easier access to a number of inputs like improved varieties seeds. As to independent farmers, they mostly adopt non-agricultural coping strategies as loans or works in in town. The country, with its Ministry of the Environment and Nature Conservation (MEPN) and the collaboration of the United Nations development Programme (UNDP), in 2008, drew up, in the framework of the United Nations Framework Convention on Climate Change

(UNFCCC), a document on the analysis of current and future adaptation options and vulnerability in Benin Republic. The resolution made in the agricultural sector is to promote appropriate agricultural production systems of climate change adaptation for food and nutrition security. More specifically, it concerns the promotion of improved cultivation techniques adapted to climate change, the promotion of counter-cultural activities and the sensitization of populations on the negative impacts of climate change on watershed resources and human activities (MEPN, 2008). Sector Vulnerability Study on Climate Change in Benin carried out on the agricultural sector as part of the National Adaptation Plans Scientific Support Project (PAS-PNA) highlights the perceptions and adaptation strategies put in place by producers themselves, in order to better support producers. The working report, elaborated in 2019 mentions that communities, faced with the consequences of climate change on the means and livelihoods of rural populations, they have developed strategies to continue to derive most of their livelihood from their environment. These strategies include the erosion control, use of short-cycle varieties, change in seeding order and diversification of income sources (AKPONIKPE et al. 2019).

### **1.2.2 Methods of the impact assessment of agricultural adaptation policies on agricultural yield**

The economic approach is the one essentially used in the studies on the impact of agricultural climate change adaptation strategies on crop productivity (Di Falco et al. 2011; Quan et al. 2019; Adegbo et al. 2019; Onzima et al. 2019; Nonvide 2018; Oyetunde-Usman et al. 2021; Asfaw et al. 2013; Gorst et al. 2018; Khanal et al. 2018 and Bedeke et al. 2018). Studies investigating the impact of the adoption of adaptation strategies among smallholder farmers on crop yield generally go towards the logic of the endogeneity of adaptation decision (existence of factors that influence implementation of adaptation strategies at the household level) (Adegbo et al. 2019; Onzima et al. 2019; Nonvide 2018; Oyetunde-Usman et al. 2021; Asfaw et al. 2013; Gorst et al. 2018 and Khanal et al. 2018). Giving the assumed endogeneity of the adaptation decision, many studies on the impact of adaptation on crop yield use the instrumental variable method to correct the endogeneity (Di Falco et al. 2011; Quan et al. 2019; Onzima et al. 2019; Oyetunde-Usman et al. 2021; Asfaw et al. 2013; Adegbo et al. 2019; Khanal et al. 2018 and Nonvide 2018). If there is practically a consensus about the endogenous character of the adaptation decision, the way to tackle the endogeneity can vary from a study to another. A number of studies handle the subject by estimating a simultaneous equations model with

endogenous switching regression. They employ a simultaneous equations model to check the differential effects of adaptation on adapters and non-adapters. The endogenous switching mechanism allows to account for selectivity bias as heterogeneity in the adaptation decision and to account for unobservable characteristics of farmers and their farm, Di Falco et al. (2011); Quan et al. (2019) from rural china; Khanal et al. (2018) from rice farmers in Nepal; Nonvide (2018) on rice yield in Malanville, northern Benin. In a study on maize and Teff staple crops from northwest Ethiopia Adego et al. (2019) added to the endogenous switching regression method a time-series climate data analysis in order to determine the response of crop yield to climate variability.

Onzima et al. (2019) in the case of Uganda have opted for the approach of control function (CFA) to correct the endogeneity in adaptation decision. The approach is known for its ability to check and control for an eventual endogeneity of an explanatory variable in an outcome equation (Smith & Blundell 1986; Imbens & Wooldridge 2008; Lewbel et al. 2012 cited in Onzima et al., 2019). The CFA assumes that in the first stage, the endogenous (explanatory) variable can be expressed as a function of all exogenous variables entering the outcome equation added to the variables chosen as instruments. The residuals from the first stage estimation are extracted and then added as regressor into the reduced outcome's equation which is here the yield function. The method produces an unbiased and consistent parameter of the impact of climate change adaptation strategies on yield provided that at least one variable in the selection model affect exclusively the adaptation decision and not at all the yield equation (Ogutu et al. 2014 cited in Onzima et al. 2019).

Considering the unobservable characteristics (as farmers' skill or motivation) that may affect the decision to adapt, they are difficult to be modelled; but omitting them would lead to an overestimated impact of adaptation (Gorst, Groom, and Dehlavi 2015). In fact, the adaptation decision may come from more skilled or more motivated farmers. If the propensity score matching (PSM) approach is also used in the literature (Caliendo and Kopeinig 2008, cited in Adego et al. 2019), it requires only observable characteristics that may affect the outcome, supposing that there no selection bias related to the treatment. Failing to control for unobservable characteristics but only the observable ones is a shortcoming of the (PSM) approach in the context of a study on the impact of adaptation decision on the productivity studies (Adego et al., 2019). Giving that fact, another method found in the literature, is use of the propensity score matching which is followed by the running of an endogenous switching regressions to account for the possibility that farmers self-select into adaptation. The method is

employed by Gorst et al. (2018) in a study from Pakistan on the productive benefits for farmers who implemented on-farm adaptation strategies for two wheat and rice crops.

In fact, a convenient model to solve the issue related to non-observable factors is the Endogenous Switching Regression (ESR) model, for it accounts for unobservable elements that influence both the adaptation decision and the crop yield (Asfaw et al. 2013; Adego et al. 2019; Di Falco et al., 2011). As a valid instrument variable (IV) needs to affect the adaptation decision without itself involving any change in the yield outcome, in other words, the IV is correlated with the adaptation decision but not with the error term in the yield equation (Asfaw et al. 2013). The choice of the IVs, hence, follows the logic of the researcher, using here an economic or statistical reasoning (Onzima et al., 2019).

Other studies (Oyetunde-Usman et al. 20021; Onzima et al. 2019 and Asfaw et al. 2013 in a study on food security from Malawi) at a micro scale have used instrumental variable techniques in a two-stage econometric model, the methods of data analysis are based on the Multivariate probit to model simultaneous and interdependent adoption decisions and the Ordered probit models to model the intensity of adaptation. The reasoning here is that the farmers follow the logic of maximising their utility and therefore choose the bundle of technics that allow them to reach that objective. The ordered probit is used in measuring the intensity of the adaptation (which is assimilated to the number of strategies at farm level). As to the bivariate probit model, it is used to have a view on factors susceptible to influence the choice of each of the strategies (Onzima et al., 2019).

### **1.2.3 Empirical review: impact of the adoption on climate change adaptation decision on crop yield**

The empirical evidences on the impact of agricultural climate change adaptation policies on crop productivity present a mixed conclusion. However, several authors (Adego et al., 2019; Adzawla & Alhassan, 2021; Asfaw et al., 2013; Beye, 2021; Di Falco et al., 2011; Khanal et al., 2018; Nonvide, 2018), through their works, agree on the fact that the strategies impact positively the crop yield. Some studies comparing farmers who have adapted with farmers who had not adapted have concluded that both adapters and non-adapters would benefit from the adaptation. It is the case of Khanal et al. (2018), who assessed on 422 rice farmers from Nepal the impact of adaptation on rice productivity, with for results a significant increase in the yield as well for adapters as for non-adapters in the counterfactual case. These conclusion joins the works on Ethiopia of Di Falco et al. (2011) and Adego et al. (2019) who have, furthermore,

revealed that the households that did not adapt would gain the most from adaptation. Adegbo et al. (2019) have also raised the existence of the heterogeneity between the two groups (the treated who are the adapters and the non-treated who are the non-adapters). The use of control variables has permitted to handle the heterogeneity and the results has, for instance, showed that the age of the farmer adapter is negatively related the maize productivity while the inverse is observed for the farmer who has not adapted. Also, the marital status (here, being non-married), the soil erosion or infertility are likely to reduce the productivity for adapters when it they have the opposite effect for the non-adapters Adegbo et al. (2019). Such results attest of the importance of taking into account the heterogeneity of the groups while assessing the impact of agricultural climate change adaptation decisions. Example of instrument variables use in case studies (Adegbo et al. 2019; Di Falco et al. 2011 and Gorst et al. 2018)) are variables on climate information, access to extension services, access to credit or distance to market.

The analyse of the effects of climate adaptation strategies on 619 maize farmers in Northern Ghana (Adzawla & Alhassan, 2021) has concluded that among other factors that positively impacted the output, only crop rotation and row planting have significantly improved efficiency of maize farmers, suggesting that the two strategies are essential to reach sustainable food production in that place. Other factors that contribute to productivity improvement among adapters are the use of improved seeds varieties (Adegbo et al. 2019; Adzawla & Alhassan 2021), the contact with development agents, the use of urea, compost and the onset of rainfall (Adegbo et al., 2019). The level of education, the access to credit, the income from off-farm activities, and the access to media have a positive impact on the food productivity increase (Nonvide, 2018). The farm size, the labor, and the use of chemicals also plays a non-negligible role in crop productivity (Adzawla & Alhassan 202) and Nonvide 2018). Onzima et al. (2019), assessing the impact of adaptation to climate change on bean productivity focusing on two categories of strategy (improved seeds and weather-smart practices) from central and northern Uganda have showed that more the number of adaptation strategies used is higher, stronger are their effects on the outcome, so the author preconize the simultaneous use of two strategies for a better result. This joined Asfaw et al. (2013), who, from a study on adaptation and food security, has suggested that giving the positive and statistically significant impact of a number of strategies, there is a need of positive synergy between them and food security.

If most of the literature presents the adaptation strategies with a really optimistic and positive eye, it fit to specify that not all case studies have reached to clear results. Indeed some opposite

results been found in some studies (Quan et al. 2019; Gorst et al. 2018). The paper of (Quan et al., 2019) has measured the impact of climate change adaptation strategies on wheat yield, based on 314 wheat farmers in rural China. The result reveal that farmers' adaptation to climate change is maladaptive with a negative influence on the wheat productivity. The study, therefore requires the attention of policy makers on the policies, in order to prevent maladaptive strategies and promote efficient measure, this in order to help smallholders to really deal with the climate change risks on their activities and the improvement of their livelihood. Gorst et al. (2018) abound in a quite same direction with their work from Pakistan which investigated the adaptation productive gain for rice and wheat farmers who decided to adapt to climate change. The results show positive and significant gains for rice farmers who adapted but gains for the wheat farmers who adapted was not significant and the study has suggested the existence of transaction costs of adaptation.

### **1.3 Materials and methods**

#### **1.3.1 Data**

Cross-sectional data were obtained with a primary data collection in the Collines department region of central Benin, that region is part of the development pole 4 of the Territorial Agency for Agricultural Development (ATDA). But just before the survey's conduction, a documentary research had been done and preliminary information collected from ATDA of each commune. The ATDA is the national structure responsible for the facilitation and integration of national agricultural policies for producers. The surveyed area is conducive to agriculture and hosts «agricultural colonizers». It is watered by the river Ouémé and its tributaries (the Zou and the Okpara)<sup>4</sup>. The region covers six communes (see *Appendix 1* and *Figure 1*). Households having among their main crops cassava and/or maize are identified in a first stage, adapters or not. Using the Schwartz formula, the sample size was computed (see sampling in *Appendix 2*), farmers population size information were drawn from the book of villages and districts of the Collines region in Benin (MPD & INSAE, 2016). On the advisory of the Territorial Agency for Agricultural Development (ATDA) specialists in the region, specific villages are sampled within communes on the basis of a reasoned sampling that took into consideration the most relevant villages in growing maize and cassava crops. Finally a total of 420 farm households are randomly surveyed, proportionally spread over 24 villages at the rate of 4 villages by communes.

The data collection includes both qualitative and quantitative data. The collection is done through the administration of individual questionnaires to the heads of sampled agricultural households and through focus group discussions. The data collected concern the demographic and socio-economic characteristics, adaptation practice and yield of the sampled actors and their households. The survey is done among agricultural households and carries information about crop practices: type of cultures and their order of importance (measured by the cultivated surface area), varieties, rotations, irrigation practice, fertilizations..., and information about elder, recent or any of their approaches to adaptation practices. Details asked about the inputs used, the production costs, the yield and the crops market prices. Also, information are carried about off-season activities and farmers' perception their vulnerability, the changes in the climate during the last two decades, its manifestations and consequences on their livelihood. Another category of data that is Climatic secondary data were also used, this in order to capture

---

<sup>4</sup> <https://www.changementsclimatiques.bj/actualites/zones-agro-ecologiques-de-la-republique-du-benin.html>

how important could be for the farmer the climate features observed in its area in terms of changes, consequences on outcomes, and changes in behaviour made by him on the basis of climate change. Those data come from the Daily Global Historical Climatology Network version of 3.29 found with the United States National Oceanic and Atmospheric Administration (NOAA) Climatic Data Center (Menne, Durre, Korzeniewski, et al., 2012; Menne, Durre, Vose, et al., 2012). The climate data consider the last then year rainfall and temperature daily values during the last ten years prior to the study (2012-2021). For more relevance, the climate data were summarized in average annual temperature for each of the seasons observed by year in the Region (two rainy seasons and two dry seasons), and in total average annual rainfall over the last ten years, and also by season. The operation is individually made of each of the 24 villages of the sample, households belonging to a same village have the same climate features. Statistics tests, and estimation of the model are finally performed with STATA software.

### **1.3.2 Model of the study**

For a study which objective is to analyse the impact of an agricultural adaptation strategy on agricultural yield, a crop simulation model with Ordinary Least Square (OLS) method would be adequate, but the decision of adaptation by a farmer may not be exogenous and depend on some observable or non-observable factors (Adego et al., 2019; Di Falco et al., 2011; Onzima et al., 2019)). A suitable technic here is therefore to use an instrumental variable (IV) regression technic in order to consider the factors which influence the adaptation decision. The IV technics assumes a joint normal error distribution and allows to account for the endogeneity (Di Falco et al., 2011). The present theoretical development of the model is inspired of the work of Di Falco, Veronesi, and Yesuf (2011) which studies, with a Micro-perspective from Ethiopia, the impact of Adaptation to climate change on food security. The idea is to separate unobserved heterogeneity effects from the casual effects of adaptation policies on the agricultural yields. For this, a prior step is therefore to identify the factors which determine the farmers' decision to adopt adaptation strategies or not. At the second step, simultaneous equations model with endogenous switching by full information maximum likelihood estimation is hence estimated to take into account the endogeneity of the decision of adaptation and so, avoid misleading policy implications. To have an identified model, some instrument variables are selected, they are here about the government extension, farmer-to-farmer extension, information from radio

and neighbourhood. Finally, a counterfactual analysis is done on both the group that adapted and those who did not (Di Falco et al., 2011).

The effect of climate change adaptation strategies on agricultural yield can be modelled in a scheme of a two-stage equations settings. As the adaptation decision may not be taken randomly (not exogenous) but rather, influenced by many factors, it is here important to account for the heterogeneity in the group. Therefore, an Ordinary Least Square (OLS) method does not fit in this case, reason why instrument variables are defined to control factors that influence the adaptation choice but not the agricultural yield. Also, as in any impact evaluation study, unobservable characteristics should be handled to avoid bias. In this context, unobservable characteristics of the farm may impact both the adaptation decision and the agricultural yield. In a first stage, a selection model on the decision of adaptation to climate change is used in order to figure out the determinants of adaptation among farmers. In the second stage, yield equation is expressed taking into account the endogeneity of the adaptation decision.

➤ *Modelling of the decision of the use of improved crop as Climate change adaptation strategy*

Pretending that the adaptation is assigned randomly, its impact on agricultural yield could be simply analysed by comparing the outcome for adapters and non-adapters. But the fact is that farmers adapters may have different features from the non-adapters and then, the method of simple comparison would be biased (Adego et al., 2019). A prior step is thus to identify factors influencing the adaptation decision among farmers. In fact many elements (in instance government projects, the climate factors, and learning from the experience of peers who adapted, local awareness...) may make a farmer decide to implement adaptation techniques or not to do it. The logic behind the selection model on climate change adaptation is that the farm household decides to implement climate change adaptation if it gets net benefits from this (Di Falco et al., 2011).

Let  $A^*$  be a variable that captures the expected benefits from the adaptation choice compared to non-adaptation, for there is adaptation if and only if positive benefits can be derived from it. In fact, if adaptation does not generate benefits, farmers have no interest in adopting adaptation techniques

For a farmer household  $i$ , it comes

$$(1) \quad A_i^* = Z_i \alpha + \eta_i \quad \text{With} \quad A_i = \begin{cases} 1 & \text{if } A_i^* > 0 \\ 0 & \text{otherwise} \end{cases}$$

Z is the (n x m) matrix of explanatory variables

$\alpha$  is the (1,...,m) vector of model parameters to be estimated,

$\eta$  is an  $n \times 1$  vector of error terms.  $\eta$  follows a normal distribution with mean equal to zero

Z represents the factors affecting the expected benefits of the adaptation decision. These variables are the farm's soil biophysical characteristics, current climate features and climate events in the past, implementation of project, sensitisation, and other sources of information...). The socio-economic characteristics of the farm household (the characteristics of the head, the assets of the family, the off-farm activities of the head,), access to credit and market which is here measured by the proximity of the agricultural plot farm land to a practicable road, can play a non-negligible role in the adaptation decision. The variable access to credit is here considered because a farm household that has access to credit is more likely to have a facility (availability of means) to undertake actions in order to cope with the adverse effects of climate change on its farm. As to the variable access to market, its choice is motivated by the fact that more the farm is close to a practicable road, more it would have facilities in the crop transportation or an easier access to opportunities or technologies. Climate information are about rainfalls over the last three years.

Among the variables of the matrix Z, some are chosen as instrument variables (variables that affect the adaptation implementation by the farmer but not the final output which is the agricultural yield). The selection of the instrument variables has followed the recent existing literature (Di Falco et al. 2011; Asfaw et al. 2013; Onzima et al. 2019). The selection instruments are here the variables related to the information sources as implementation of project, extension services, sensitisation, and other sources of information, access to market and climate information are also considered. A falsification test is also performed to validate the variable instruments as non-correlated with the productivity (Adego et al., 2019; Di Falco et al. 2011)

➤ ***Modelling of the effect of adaptation on agricultural yield***

The decision of adoption or not to climate change adaptation strategies by farmers may be based on the individual choice of farmers. In fact, the decision may be affected by differences as well in observable characteristics as in unobservable characteristics within the farmers (Di Falco et al., 2011). Those unobservable characteristics are likely to influence both the adaptation

decision and the agricultural yield. To account for this, an Endogenous Switching Regression (ESR) model on agricultural yield is adopted. The estimation of a simultaneous equations model of climate change adaptation and agricultural yield with endogenous switching by full information maximum likelihood (FIML) is done.

The farmers face two regimes, the first being to adapt and the second not to adapt. The agricultural yield model can be specified for each regime as follow.

- 1<sup>st</sup> regime: regime of adapters

$$(2a) \quad y_{1i} = X_{1i}\beta_1 + \varepsilon_{1i} \quad \text{if } A_i = 1$$

- 2<sup>nd</sup> regime: regime of non-adapters

$$(2b) \quad y_{2i} = X_{2i}\beta_2 + \varepsilon_{2i} \quad \text{if } A_i = 0$$

$y_i$  represents the agricultural yield per hectare

$X_i$  is the vector related to all other variables including inputs (e.g., seeds, fertilizers, manure, and labour) and the farm physical and physiological characteristics. The farm household and its head socio-economic characteristics, and the climatic factors are also part of  $X$ . The estimated impact of the use of improved variety on agricultural yield is the parameter  $\beta_i$

The error terms of both the selection equation (1) and the production equations (2a) and (2b) are assumed to follow a trivariate normal distribution, with zero mean and covariance matrix

$$Cov(\eta, \varepsilon_1, \varepsilon_2) = \begin{bmatrix} \sigma_\eta^2 & \sigma_{\eta 1} & \sigma_{\eta 2} \\ \sigma_{1\eta} & \sigma_1^2 & . \\ \sigma_{2\eta} & . & \sigma_2^2 \end{bmatrix}$$

$\sigma_\eta^2$ ,  $\sigma_1^2$  and  $\sigma_2^2$  represent respectively the variance of the error term in the selection equation (1) and the production equations (2a) and (2b).  $\sigma_\eta^2$  is assumed equal to 1 as the coefficients are estimable only up to a scale factor (Maddala 1983, p. 223 cited in Di Falco et al., 2011).  $\sigma_{1\eta}$  and  $\sigma_{2\eta}$  are the covariance of the error term in (1) with each error term in (2a) and (2b). The covariance between  $\varepsilon_{1i}$  of (2a) and  $\varepsilon_{2i}$  of (2b), is not defined since the two

situations are not observed simultaneously. Because of omitted variables and unobservable factors in the selection equation (1), its error term  $\eta_i$  is correlated to those of the productivity equations  $\varepsilon_{1i}$  and  $\varepsilon_{2i}$ . So, the expected values of  $\varepsilon_{1i}$  and  $\varepsilon_{2i}$  conditional on the sample selection are different from zero:

$$\begin{aligned} E[\varepsilon_{1i} | A_i = 1] &= \sigma_{1\eta} \frac{\varphi(Z_i \alpha)}{\phi(Z_i \alpha)} & \text{and} & & E[\varepsilon_{2i} | A_i = 0] &= -\sigma_{2\eta} \frac{\varphi(Z_i \alpha)}{1 - \phi(Z_i \alpha)} \\ E[\varepsilon_{1i} | A_i = 1] &= \sigma_{1\eta} \lambda_{1i} & & & E[\varepsilon_{2i} | A_i = 0] &= \sigma_{2\eta} \lambda_{2i} \end{aligned}$$

Where  $\varphi(\cdot)$  represents the standard normal probability density function,  $\phi(\cdot)$  the standard normal cumulative density function, and  $\lambda_{1i} = \frac{\varphi(Z_i \alpha)}{\phi(Z_i \alpha)}$ , and  $\lambda_{2i} = -\frac{\varphi(Z_i \alpha)}{1 - \phi(Z_i \alpha)}$

The finding of the significance of the estimated covariance between the error term of the selection equation and those of the production equations ( $\hat{\sigma}_{1\eta}$  and  $\hat{\sigma}_{2\eta}$ ) would mean that there is indeed a correlation between the decision to adapt and the agricultural yield (Di Falco et al., 2011). There is then the rejection of the null hypothesis of sample selectivity bias, which puts an accent on the importance of the Endogenous Switching Regression (ESR) model (Adego et al., 2019). The model in this case is a “switching regression model with endogenous switching” (Maddala and Nelson 1975). One method, proposed by Lee and Trost (1978) cited in Di Falco et al. (2011) is the full information maximum likelihood estimation. In fact, the full information maximum likelihood estimate gives an efficient ESR output while simultaneously estimating both the selection equation and the production equation. This is advantageous comparing to the two-step estimator which is revealed inefficient for deriving standard errors (Lokshin & Sajaia, 2004).

$$(3) \quad \ln L = \sum_{i=1}^N A_i \left[ \ln \varphi\left(\frac{\varepsilon_{1i}}{\sigma_1}\right) - \ln \sigma_1 + \ln \phi(\theta_{1i}) \right] + (1 - A_i) \left[ \ln \varphi\left(\frac{\varepsilon_{2i}}{\sigma_2}\right) - \ln \sigma_2 + \ln (1 - \phi(\theta_{2i})) \right]$$

where  $\theta_{ji} = \frac{(Z_i \alpha + \rho_j \varepsilon_{ji} / \sigma_j)}{\sqrt{1 - \rho_j^2}}$ ,  $j = 1, 2$ , and  $\rho_j$  being the correlation coefficient between the

error term  $\eta_i$  of the selection equation (1) and the error terms  $\varepsilon_{ij}$  of equations (2a) and (2b), respectively.

### **Adaptation, non-adaptation and counterfactual effects expectations**

The conditional yield expectation respectively among adapters (4a) and non-adapters (4b) are presented:

$$(4a) \quad E(y_{1i} | A_i = 1) = X_{1i}\beta_1 + \sigma_{1\eta}\lambda_{1i}$$

$$(4b) \quad E(y_{2i} | A_i = 0) = X_{2i}\beta_2 + \sigma_{2\eta}\lambda_{2i}$$

For the counterfactual situations, we have: the adapters in the case they had not adapted (4c) and the non-adapters if they had adapted (4d)

$$(4c) \quad E(y_{1i} | A_i = 0) = X_{1i}\beta_1 + \sigma_{1\eta}\lambda_{2i}$$

$$(4d) \quad E(y_{2i} | A_i = 1) = X_{1i}\beta_2 + \sigma_{2\eta}\lambda_{1i}$$

We compute the difference between the adapters' actual agricultural yield (4a) and the agricultural yield they would have had if they had not adapted (4c). It gives the impact of climate change adaptation on the agricultural yield of the farm households that actually adapted to climate (ATT). By the same, the difference between the agricultural yield the non-adapters would have got if they had decided to adapt (4d) and their actual agricultural yield (4b) is computed. It expresses the average impact that the decision to adapt to climate change would have had on the non-adapters' agricultural yield (ATU)

### **Effects of the treatment**

- The effect of climate change adaptation on the agricultural yield of the farm households that actually adapted to climate (adapters or treated). It is the average treatment effect for the treated (ATT).

$$(5) \quad \begin{aligned} ATT &= E(y_{1i} | A_i = 1) - E(y_{2i} | A_i = 1) \\ &= X_{1i}(\beta_1 - \beta_2) + (\sigma_{1\eta} - \sigma_{2\eta})\lambda_{1i} \end{aligned}$$

- The effect that the decision to adapt to climate change would have had on the non-adapters' (untreated) agricultural yield. It is the average treatment effect for the untreated (ATU).

$$(6) \quad \begin{aligned} ATU &= E(y_{1i} | A_i = 0) - E(y_{2i} | A_i = 0) \\ &= X_{2i}(\beta_1 - \beta_2) + (\sigma_{1\eta} - \sigma_{2\eta})\lambda_{2i} \end{aligned}$$

### **Heterogeneity effects**

The Heterogeneity effects are computed by comparing between the two groups, which group would gain more if the two group have decided to adopt adaptation (BH<sub>1</sub>) and which group would gain less if the both have decided not to adapt (BH<sub>2</sub>). In fact, the heterogeneity is made of the some unobservable differences that may exist between the two groups of farm households (eg: the skills, the motivation) and so may have involved differences in the outcomes of the two groups whether they conjointly decided to adopt adaptation or not to adopt.

Carter and Milon (2005) defined (BH1) as “the effect of base heterogeneity” for the group of farm households that decided to adapt which is the difference between (a) and (d). And similarly (BH2) as “the effect of base heterogeneity” which is the difference between (c) and (b), (Di Falco et al. 2011)

$$(7) \quad \begin{aligned} BH_1 &= E(y_{1i} | A_i = 1) - E(y_{1i} | A_i = 0) \\ &= (X_{1i} - X_{2i})\beta_{1i} + \sigma_{1\eta}(\lambda_{1i} - \lambda_{2i}) \end{aligned}$$

$$(8) \quad \begin{aligned} BH_2 &= E(y_{2i} | A_i = 1) - E(y_{2i} | A_i = 0) \\ &= (X_{1i} - X_{2i})\beta_{2i} + \sigma_{2\eta}(\lambda_{1i} - \lambda_{2i}) \end{aligned}$$

To finish, the difference in effect between the two groups is computed to see the group the most impacted by the adoption of adaptation, this is called the transitional heterogeneity (ATH).

$$(9) \quad ATH = ATT - ATU$$

### **1.3.3 Variables of the model**

The choice of the variables of the model has been made on the based on the literature about adaptation strategies impact on agricultural communities (Onzima et al., 2019), (Adego et al., 2019), (Quan et al., 2019), (Khanal et al., 2018). And a validation test is performed on the instruments (Di Falco et al., 2011).

**Table 1-1 Measurement of the variables**

<b>Variables</b>	<b>Measurement</b>	<b>Expected sign</b>
<b><i>Dependent variables</i></b>		
Use of improved crop	1 if yes , 0 otherwise	+
Crop yield per hectare	continuous	
<b><i>Explanatory variables</i></b>		
<b><i>Climatic factors</i></b>		
Longer and sorter rainy seasons total précipitations during the last 10 years		
Longer and sorter drought seasons total précipitations during the last 10 years		
Average temperature during the 10 last years		
<b><i>Soil characteristics</i></b>		
Soil fertility	1 if yes , 0 otherwise	+
Erosion experience	1 if yes , 0 otherwise	-
<b><i>Assets of the farm</i></b>		
Farm size	continuous	+/-
Land ownership	1 if yes , 0 otherwise	+
<b><i>Inputs</i></b>		
Household Labor	continuous	+
Inorganic fertilizers	1 if yes , 0 otherwise	+
Organic fertilizers	1 if yes , 0 otherwise	+
<b><i>Social characteristics of the farm household</i></b>		
Age of the head	continuous	+/-
Literacy of the head	continuous	+
Sex of the head	1 if male , 0 otherwise	+/-
Marital status of the head	1 if married, 0 otherwise	+/-
Household size	continuous	+
Off-farm activity source of income	1 if yes , 0 otherwise	+/-
Access to credit	1 if yes , 0 otherwise	+
Access to market (existence of practicable road from farm to market)	1 if yes , 0 otherwise	+
Flood experience	1 if yes , 0 otherwise	-
Drought experience	1 if yes , 0 otherwise	-
Experience in agriculture (number of years)	continuous	+
<b><i>Farm income</i></b>		
Income from the crops ( year - 1)	continuous	+
Income from off-farm activities ( year - 1)	continuous	+/-

*IMPACT OF CLIMATE CHANGE ADAPTATION STRATEGIES WITHIN AGRICULTURAL COMMUNITIES IN  
CENTRAL BENIN REPUBLIC*

<i>Information sources</i>		
Government extension	1 if yes , 0 otherwise	
Radio information,	1 if yes , 0 otherwise	
Neighborhood information	1 if yes , 0 otherwise	
Own climate observation	1 if yes , 0 otherwise	
Cooperaive membership	1 if yes , 0 otherwise	

The endogenous variable is the use of improved crops respectively maize and cassava crops. The adaptation decision is determined by a set of control variables related climate variables and to the farm assets that are its size, the property rights of farmer, the use of fertilizer, flood, drought, and erosion experiences the access to credit or to market. All those factors are susceptible to influence decision of the farmer to experience or not new varieties crops depending on whether he/she is satisfied by his/her current condition or not. The control variables group takes into consideration the farm household and its head such as the age, sex, level of instruction, experience in agriculture and farm and non-farm income from the household. The binary variables are measured by asking the respondent yes or no questions, those questions being applied to the last three years prior to the survey. In the cases of continuous variables, answers are reported after a step-by-step interview procedure, in order to have reliability and precision in the answers. After the validation test, the instruments retained are the information source variables. The information source are the canals used by the respondent to get information about possible adaptation options that he can explore in his activity. Those information could come from extension services (Government extension), from radio, from a framer to another or from the farmer cooperative the respondent belongs to. Some farmers rather rely on their own experience about how the climate features have progressed during the years and make decision on that basis. The outcome variable, here the yield could not be influenced by only adaptation but also by all those same control variables.

## **1.4 Results**

### **1.4.1 Descriptive statistics**

The table 1-2 shows the trends in the variables of the model for the maize producer group on the one hand and cassava producers on the other hand. Both Crops: Among maize farmers, the adapters are less experienced in agriculture when with cassava producers, the most experienced are the adapters. But for both crops. Adapters are younger, they have in average a higher instruction level compared to non-adapters, and more than 90% of respondents are male and married, however there is more married people among adapters than non-adapters. And adapters have the biggest households and they involve more of their family members in the farm works compared to the second group. A curious fact is that non-adapters, for both crops are among those who the most, have property right on the land their use. More than 90% of the farmers declare their land fertile. Adapters for the two crops experienced more flood and land erosion than non-adapters. If maize farmers are the most opened to the use of inorganic fertilizer, we can see that in average, adapters more users than non-adapters. And they are also of those who apart from their own farm activities, have the most undertaken to join other activities as an adaptation strategy. They are also mainly involved in cooperatives and then benefit more from access to credit, information from extension services while farmers who are not member of cooperatives rely mostly on information from radio and neighbourhood. In both maize and cassava cases, adapters yield more than non-adapters.

**Table 1-2 Characteristics of the households and their farms**

Variables	Maize producers						Cassava producers					
	Total sample		Adapters		Non-adapters		Total sample		Adapters		Non-adapters	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Age of the head	43.827	11.726	43.258	11.541	44.771	12.004	43.146	11.593	42.506	11.275	43.650	11.841
Literacy of the head	0.285	0.452	0.304	0.461	0.255	0.437	0.267	0.443	0.275	0.448	0.261	0.440
Sex of the head	0.957	0.203	0.965	0.183	0.943	0.233	0.964	0.186	0.962	0.191	0.966	0.183
Marital status	0.93	0.255	0.958	0.202	0.885	0.320	0.926	0.263	0.931	0.254	0.921	0.270
Household size	8.897	5.006	9.512	5.233	7.879	4.437	8.835	4.927	9.831	5.260	8.049	4.508
Household Labour	2.755	2.898	3.123	3.176	2.146	2.247	2.645	2.726	3.031	3.097	2.340	2.356
Experience in agriculture	19.513	11.126	19.435	10.880	19.643	11.555	19.433	11.053	19.706	10.883	19.217	11.207
Land ownership	0.849	0.359	0.804	0.398	0.924	0.267	0.851	0.356	0.812	0.392	0.882	0.324
Soil fertility	0.921	0.27	0.912	0.285	0.936	0.245	0.942	0.234	0.925	0.264	0.956	0.206
Erosion experience	0.158	0.365	0.215	0.412	0.064	0.245	0.182	0.386	0.281	0.451	0.103	0.305
Drought experience	0.954	0.209	0.946	0.226	0.968	0.176	0.956	0.206	0.963	0.191	0.951	0.217
Flood experience	0.472	0.5	0.462	0.499	0.490	0.502	0.46	0.499	0.431	0.497	0.483	0.501
Inorganic fertilizers	0.47	0.5	0.612	0.488	0.236	0.426	0.039	0.193	0.063	0.243	0.020	0.139
Off-farm activity	0.312	0.464	0.315	0.466	0.306	0.462	0.317	0.466	0.331	0.472	0.305	0.462
Cooperative membership	0.492	0.5	0.538	0.499	0.414	0.494	0.479	0.5	0.475	0.501	0.483	0.501
Access to credit	0.384	0.487	0.454	0.499	0.268	0.444	0.38	0.486	0.425	0.496	0.345	0.476
Agricultural yield per hectare	1.48	1.405	1.620	1.658	1.250	0.781	29.836	11.957	29.969	13.654	29.731	10.461
Government extension	0.302	0.46	0.296	0.457	0.312	0.465	0.298	0.458	0.169	0.376	0.399	0.491
Radio information,	0.168	0.374	0.142	0.350	0.210	0.409	0.182	0.386	0.088	0.283	0.256	0.438
Neighbourhood information	0.221	0.415	0.108	0.311	0.408	0.493	0.229	0.421	0.044	0.205	0.374	0.485
Own climate observation	0.293	0.455	0.365	0.482	0.172	0.379	0.292	0.455	0.456	0.500	0.163	0.370
Sample size	417	-	157	-	260	-	363	-	160	-	203	-

Source: Excel, from primary data

#### **1.4.2 Estimation of endogenous switching model of the use of Maize and Cassava's improved varieties on crop yield**

This section presents the results of the estimations, this separately for maize (table 1-3) and cassava (table 1-5) crops. In the first column, are presented the results of OLS regression of the adaption on the crop yield. This is make in view comparing the OLS with the ESR regression. The second three columns are the results of the ESR model. The results of the selection equation (that treats of the endogeneity of the adaptation decision). The third and fourth column respectively report the estimated coefficients for the crop yield for farmers who adapted and those who did not. The ESR model uses the full information maximum likelihood. The OLS estimation shows an average positive and significant effects of maize and cassava improved varieties on crop yield. The ESR model allows us to have a close look on the determinants of adaption but also to make a comparative analyse between adapters and non-adapters. Rhos in ESR regressions are not significant which may express that the adaptation decision is not endogenous While OLS a priori that the two groups of producers have the same structure of yield function, the ESR here shows that the coefficients and their significance of same variables are different from a group to another s and then allows to compute counterfactuals for each group of farmers. And to see which group of farmers would gain the most from that adaptation.

From the table 1-4, the determinants of the decision of use of maize improved seeds are the climate factors, the experience of erosion, the use of inorganic fertiliser, income from cassava, neighbourhood experience and access to market. In fact, the evolution of the average total rainfall during the last ten years is a factor that reduces the probability of adoption of improved maize seeds at the farmer level, More there it rain, less the farmers would feel the need to invest in the use of improved maize seeds, those seeds being in general drought tolerant seeds. The frequency of soil erosion is also a fact that positively impact the probability of adoption of improved maize seed. A farmer who experienced erosion in his farm, experienced yield decrease due to the soil impoverishment caused by the erosion. Then he may want to support his activity by introducing more strong variety of crop to limit damage. Considering the use of fertilizers this variable significantly impacts de decision of adaptation. In fact, farmers who use inorganic fertilizers are really opened to the use of improved varieties in their farms.

*IMPACT OF CLIMATE CHANGE ADAPTATION STRATEGIES WITHIN AGRICULTURAL COMMUNITIES IN  
CENTRAL BENIN REPUBLIC*

**Table 1-3 Estimation of the model on the use of maize improved seeds and crop yield**

Dependent variables	OLS	Determinants of the use of maize improved seeds	Households who used improved seed (Adaptation=1)  Quantity produced per hectare	Households who did not (Adaptation=0)  Quantity produced per hectare
<i>Climatic factors</i>				
Rainy season total rainfall during the last 10 years	0.875*** (0.330)	-2.556*** (0.791)	1.042** (0.522)	1.186*** (0.367)
<i>Soil characteristics</i>				
Soil Fertility	0.107 (0.111)	0.091 (0.303)	0.073 (0.166)	0.035 (0.194)
Erosion	-0.044 (0.084)	0.418* (0.232)	-0.102 (0.098)	-0.272 (0.287)
<i>Assets of the farm</i>				
Farm size	0.003 (0.041)	0.027 (0.102)	-0.018 (0.049)	0.023 (0.063)
Land ownership	0.058 (0.087)	-0.366 (0.262)	0.159 (0.103)	-0.286 (0.265)
<i>Inputs</i>				
Household Labor	0.032 (0.046)	0.154 (0.117)	-0.023 (0.052)	0.037 (0.068)
Inorganic fertilizers	0.221*** (0.065)	0.912*** (0.159)	0.056 (0.106)	0.310*** (0.105)
<i>Social characteristics of the farm household</i>				
Age of the head	0.005 (0.154)	-0.529 (0.410)	0.126 (0.173)	0.035 (0.359)
Literacy of the head	-0.106 (0.069)	-0.016 (0.173)	-0.029 (0.076)	-0.224** (0.101)
Sex of the head	0.247 (0.154)	0.044 (0.343)	0.210 (0.173)	0.220 (0.223)
Marital status	0.058 (0.131)	0.150 (0.326)	-0.033 (0.118)	0.092 (0.232)
Household size	-0.010 (0.061)	0.125 (0.159)	0.089 (0.077)	-0.131 (0.097)
Off-farm activity source of income	-0.008 (0.065)	0.147 (0.162)	0.097 (0.082)	-0.250** (0.101)
Access to market thanks to cooperative	-0.040 (0.086)	0.137 (0.241)	-0.102 (0.089)	-0.118 (0.175)
Flood experience	0.159*** (0.059)	-0.048 (0.147)	0.274*** (0.080)	0.060 (0.094)
Drought experience	-0.105	-0.027	-0.036	-0.211

**IMPACT OF CLIMATE CHANGE ADAPTATION STRATEGIES WITHIN AGRICULTURAL COMMUNITIES IN  
CENTRAL BENIN REPUBLIC**

	(0.144)	(0.426)	(0.156)	(0.283)
Experience in agriculture (number of years)	-0.026	0.263	-0.030	-0.080
	(0.061)	(0.181)	(0.078)	(0.124)
<b>Farm income</b>				
Income from maize (year - 1)	0.000***	0.000	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)
Off-farm Income (year - 1)	0.000	0.000	0.000	0.000**
	(0.000)	(0.000)	(0.000)	(0.000)
Income from cassava (year - 1)	0.019***	-0.037***	0.027***	0.013
	(0.005)	(0.014)	(0.008)	(0.009)
Income from other crops (year - 1)	-0.000*	0.000	-0.000*	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)
<b>Instruments</b>				
Government extension		0.001		
		(0.174)		
Radio information,		0.222		
		(0.243)		
Neighbourhood information		-0.756***		
		(0.209)		
Climate Own observations		0.274		
		(0.199)		
Access to credit		0.227		
		(0.144)		
Access to market by praticable road		0.324**		
		(0.156)		
Use of Maize improved seeds	0.175**			
	(0.069)			
constant	-8.424***	23.508***	-10.186**	-10.387***
	(2.985)	(7.132)	(4.671)	(3.196)
$\sigma_i$			-0.546***	-0.630***
			(0.144)	(0.167)
$\rho_i$			-0.555	-0.073
			(0.418)	(0.141)

Note: \*Significant at the 10% level; \*\*Significant at the 5% level; \*\*\*Significant at the 1% level.

(.) Robust standard errors

$\sigma_i$ , square-root of the variance of the error terms in the respective outcome equations;

$\rho_j$ , the correlation coefficient between the error term of the selection equation and the respective error terms of the outcome equations.

We can also notice that among information sources, neighbourhood information is determinant in the probability of adoption of improved maize seed, this could be interpreted as producers give a lot of credit to their companions and also they draw a lot from the experiences of neighbouring producers. And we have seen with the descriptive statistics that the group of non-

adapters are of those who rely on neighbourhood information sources explaining the negative sign of the coefficient. When the producer has an accessible road from his farm to the market, he is motivated in investing in his agriculture. The increase of income from cassava (year - 1) affects negatively the decision of maize improved seed adaptation. Farmers would tend to devote themselves to crops with more returns for them, what was the case of cassava for some producers.

Now considering the endogenous switching regression, the rainy season average rainfall during last ten years has a positive impact on the maize yield in both groups of farmers; giving the already known positive relation between rainfall and yields, especially in developing countries. The effect of incomes from maize at year-1 is positive and highly significant for the two groups of producers, showing how much farmers can be motivated to invest in a crop growing when they get increasing income from the crops. For farmers who did not adopt maize improved seeds, the use of inorganic fertilizers is a very significant factors in the probability of increase of the yield. In contrast, the engagement into off-farm activities source of income has a negative impact on the probability to increase maize yield this could be comprehensive in the sense that producers can become more involved in activities, that they feel, are more profitable for them, to the point where they can somehow reduce their implication into to farm activity. In the group of adapters, respective incomes from maize and cassava at year-1 have a significant impact on the maize yield. In fact, when farmers' income increase, they use that increase as investment in the next crop year, this money can buy for example, fertilizer or pesticides... on the other hand, one can see a negative relationship between maize yield and income from other crops, this could be explained that farmers may increase their attention to other crops than maize if ever the latters provided more profits to them, this could imply a decrease of their maize yield as its happened a decrease of the time or money accorded to maize cultivation. In non-adapters 'group both incomes provided by off-farm activities in the year-1 and by maize production in the year-1 have as positive impact on the probability of increase of the maize yield. The first fact would mean that producers generally do not completely abandon the cultivation of maize even when they have other activities nearby, activities that would also contribute to the financing of maize production. The second observation shows that the more the producers gain in the production of the maize, the more they invest in it and that implies an increase of the yield.

The table 1-6 presents the average treatment effects the actual and counterfactual cases. (a) and (c) represent respectively the expected maize yield in Tonnes by hectare.

**Table 1-4 Average treatment and heterogeneity expected effects per hectare for maize crop**

	Decision		
	Adaptation	Non- adaptation	Treatment Effects
Households who used maize improved seed (yield in Kilogramme)	(a) 259 (0.310)	(c) 105 (0.472)	ATT = 154*** (0.350)
Households who did not use maize improved seed (yield in Kilogramme)	(d) 688 (0.283)	(b) 44 (0.346)	ATU = 644*** (0.357)
Heterogeneity Effects	BH1 = -429*** (0.303)	BH2 = 61*** (0.434)	ATH = - 490 (0.036)

For the farmers who adopted the use of improved maize seeds, the yield is about 259 kg and would have been of 105 kg if they had not adapted. So, the adaptation seems beneficial for that group of farmers. The cases (d) and (b) which respectively represent the expected yield for non-adapters in actual and counterfactual cases for non-adapters. The average effect is about 44 kg by hectare and would have been of 724 kg if they had decided to adapt. The difference in outcome for non-adapters is of 680 which implies that farmers who did not adapt would have gained a lot from adaptation.

The adaption has an overall positive impact on farmers. However, effect of the treatment is higher with non-adapters, the average heterogeneity effect is negative (ATH= -490). That difference draws the attention on the differences, observable or not, that may exist among the two groups. The descriptive statistics have, for instance, revealed that the adapters have an easier access to credit compared to non-adapters that obviously could be for them a hindrance for getting into adaptation. Another point is that non-adapters seem of the more experienced in terms of years in agriculture. That, group maybe of the type old school and then, is much less opened to novelties such as, the use of fertilizers or the use of improved seeds. They are also less found in farmers' cooperative, and they judge their soil in average more fertile compared to adapters. All of those factors may play to their disadvantage while they have the most important potential to success adaptation.

**Table 1-5 Estimation of the model on the use of cassava improved crops and the yield**

Dependent variables	OLS	Determinants of the use of Cassava improved plants	Households who used improved plants (Adaptation=1)	Households who did not (Adaptation=0)
			Quantity produced per hectare	Quantity produced per hectare
longer rainy seasons total rainfall during the last 10 years	0.004*** (0.001)	-0.000** (0.000)	0.010*** (0.003)	0.005** (0.002)
shorter rainy seasons total rainfall during the last 10 years	-0.044*** (0.008)	0.004*** (0.001)	-0.075*** (0.014)	-0.052*** (0.020)
longer drought seasons total rainfall during the last 10 years	0.020*** (0.007)	0.001 (0.001)	0.042*** (0.012)	0.005 (0.016)
Fertility	4.892* (2.604)	0.081 (0.330)	6.370* (3.395)	3.178 (3.281)
Absence of erosion	-2.532 (1.709)	-0.223 (0.213)	-1.743 (2.742)	1.415 (3.233)
Farm size	1.024** (0.403)	0.027 (0.057)	1.087** (0.532)	0.443 (0.481)
Land ownership	-3.572** (1.801)	-0.161 (0.229)	-2.186 (2.375)	-2.668 (2.367)
Household Labor	1.378 (1.018)	0.182 (0.119)	0.163 (1.431)	1.509 (1.162)
Inorganic fertilizers	-3.683 (3.201)	0.172 (0.385)	-6.653** (3.163)	-0.199 (3.878)
Organic fertilizers	-0.009 (5.165)	0.352 (0.787)	-4.127 (4.778)	-3.873 (6.501)
Age of the head	0.163* (0.085)	-0.005 (0.014)	0.052 (0.142)	0.241 (0.212)
Literacy of the head	0.765 (1.476)	-0.076 (0.180)	1.242 (2.453)	0.764 (1.888)
Sex of the head	2.200 (3.351)	-0.521 (0.361)	4.597 (3.176)	1.805 (4.145)
Marital status	-5.893** (2.427)	0.075 (0.301)	-4.168 (4.024)	-6.413 (4.875)
Household size	-0.252 (0.164)	-0.002 (0.021)	-0.057 (0.197)	-0.380* (0.212)
Off-farm activity source of income	-0.642 (1.326)	0.008 (0.155)	0.731 (2.168)	-0.616 (1.589)
Access to credit	0.556 (1.307)	0.047 (0.177)	-0.778 (1.911)	1.270 (1.472)
Access to market thanks to cooperative	-0.740 (1.865)	0.101 (0.244)	-0.374 (2.972)	-2.251 (3.018)

*IMPACT OF CLIMATE CHANGE ADAPTATION STRATEGIES WITHIN AGRICULTURAL COMMUNITIES IN  
CENTRAL BENIN REPUBLIC*

Access to market by praticable road	-1.463 (1.297)	0.104 (0.174)	-5.379** (2.223)	0.732 (1.521)
Flood experience	1.058 (1.228)	-0.105 (0.180)	1.999 (1.872)	0.330 (1.549)
Drought experience	-8.216*** (2.968)	0.608 (0.443)	-1.591 (6.619)	-11.063 (6.820)
Experience in agriculture (number of years)	-0.135 (0.088)	0.007 (0.014)	-0.077 (0.139)	-0.208 (0.212)
Income from maize (year - 1)	-0.067 (0.207)	-0.038 (0.026)	-0.065 (0.340)	0.375 (0.294)
Off-farm Income (year - 1)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	-0.000 (0.000)
Income from cassava (year - 1)	0.000** (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
Income from other cultures ( year - 1)	0.000 (0.000)	-0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
Other sources of income	0.000*** (0.000)	0.000 (0.000)	0.000*** (0.000)	0.000 (0.000)
Government extension		-0.002 (0.267)		
Radio information,		-0.461** (0.193)		
Radio information,		-0.050 (0.169)		
Neighborhood information		-1.004** (0.409)		
Climate information		-0.052 (0.238)		
cooperative membership		-0.430** (0.198)		
used improved plants	2.974** (1.360)			
constant	57.576*** (13.152)	-3.963** (1.698)	47.819** (21.956)	67.347*** (19.355)
$\sigma_i$			2.439*** (0.048)	2.343*** (0.180)
$\rho_i$			-0.360 (0.316)	-1.068 (0.928)

Note: \*Significant at the 10% level; \*\*Significant at the 5% level; \*\*\*Significant at the 1% level.

(.) Robust standard errors

$\sigma_i$ , square-root of the variance of the error terms in the respective outcome equations;

$\rho_j$ , the correlation coefficient between the error term of the selection equation and the respective error terms of the outcome equations.

The table 1-5 presents the results of the OLS and the ESR model on the use of cassava improved plants. From the OLS (1<sup>st</sup> column), the determinants of the crop yield, beyond the adaptation are total rainfall observed s along the last 10 years. While the longer rainy season's rainfalls effects are negative on the adaptation decision, the shorter rainy season's effect is negative.

What is comprehensible since cassava is a plant that just needs a given amount of water for its cycle and any additional water would lead to damages. Much humidity and coolness can spoil cassava crops. By the same, does not need much water; a too dry drought season could be source of damages for the crops, reason why, the drought season's rainfall has a positive effect on the yield. The ESR model displays, in the second column the determinants of the use of Cassava improved plants. The rainy season's rainfalls have a negative effect on the probability of decision of adaptation. Since it rains rightfully during the right season, the farmer does not complain, he may complain only when the rain would be more than expected at a given time, this justifies the positive sign toward adaptation observed for the shorter rainy season. Other determinants of adaptation are the information variables being radio information, neighbourhood information and cooperative membership. That fact was already reflected in descriptive statistics where the non-adapters are those who rely the most on those specific information sources. The third column 1-5 of the table displays the results related to the farmers who use the improved seeds of cassava. Besides the climate variables that effects are once again highly significant, the soil fertility, the farm size and the income from other crops have positive effect on the yield. If the soil fertility effect is evident, the positive effect observed for the two other factors may come from the commitment of the farmer in growing cassava, only a devoted farmer would dedicate an increasingly large surface for cassava farming and could use income provided by other sources to invest in cassava crop. The use of inorganic fertilizer does not play a favourable role in cassava yield in the group of adapters. It could be that the adapters feel to get into adaptation due to their judged poor performance in terms of yield; performance that could also, in a certain way, partially find its explanation in their use of inorganic fertilizer; especially when the descriptive statistics show that adapters are more fertilizer users than non-adapters. Non-adapters' yield is, in turn, is affected by the climate factors and the household size; the latter's effect being negative

The table 1-6 presents the average treatment effects the actual and counterfactual cases. (a) and (c) represent respectively the expected cassava yield in Tonnes by hectare. For the farmers who as adopted, the cassava yield is actually about 29.96 tons and would have been of 15.22 tons if they had not adapted. Their yield almost doubled, comparing to the non-adapters' group that would also so be positively impacted by the adaptation but to a lesser extent. (ATT>ATU)

**Table 1-6 Average treatment and heterogeneity expected effects per hectare for cassava**

	Decision		Treatment Effects
	Adaptation	Not adaptation	
Households who use cassava improved plant	(a) 29.957 (7.908)	(c) 15.221 (5.914)	ATT = 14.736*** (0.781)
Households who do not use	(d) 40.536*** (7.060)	(b) 30.083 (5.052)	ATU = 10.453*** (0.609)
Heterogeneity Effects	BH1 = -10.579*** (0.787)	BH2 = -14,862*** (0.576)	ATH = 4.283*** (0.643)

An observed fact is that, even without adaption, the non-adapters are already performing the double of the yield performed by adapters in their counterfactual case. So for adapters, adaptation may have come from desperation caused by more erosion experience implying an impoverishment of the soil, which had led to the use of inorganic fertilizer by many of them; the use of inorganic fertilizer seemingly not being a solution. Only adaptation has helped adapters to almost reach the yield level of non-adapters. And non-adapters might not adapt because of their satisfaction compared to the second group, given their yield, they might not need (according to them) adaptation, nonetheless they would still perform better with adaptation. This rises and interdependency, nay an endogeneity question between adaptation and yield in cassava crop.

## **1.5 Conclusion**

The findings of this study show that climate change adaptation is necessary for cassava and maize producers in Central Benin. The use of maize and cassava improved plant has an overall positive and significant effect on the yield for both crops. Unfortunately, in the group maize farmer, results showed that farmers who, the most needed adaptation did not undertake it. Indeed, different factors are to be taken into account in the adaptation decision among these are the climate observables during the last past years, the farm assets, the socio-demographic features of the household and its income. The access to credit, or to market by an existing constructed road from farm to market are element that motivate the adaptation decision. Some farmers do not undertake adaptation because of the cost of adaptation. The adaptation is also influenced by the exposure of the farmer to information sources. Adapters are generally in farmers cooperatives and rely in information provided by extension services while non-adapters are more exposed to farmer to farmer information sources. In contrary with maize crop, adaptation with cassava has been performed with farmers who needed adaptation the most. This express that adaption the contours of the adaptation may not be the same from a crop to another.

If the adaptation decision can have an effect on the crop yield, the cassava crop shows in this chapter that the yield also may have an impact on the decision of adaptation. Farmers make decision based on a set of factors related to the climate, their farm assets, their financial resources, but actually also on the basis of his yield, compared to what he judges reasonable, with respect to all the other factors. It finally appears comprehensible that the crop yield would be one of the decisive observables on which the producer himself relies before undertaking adaptation. Then it would be important, in the context of the actions implemented by policy makers, to categorize crops with their specificities, their markets, the features of farmers engaged in those crops farming in order to assist farmers by delivering a customized support depending on the crop. This chapter also concludes on the role that income from certain other crops can play in improving the yield of given crops; thus testifying the certain complementarity between crops. It is therefore essential not to completely abandon crops in favour of others because even the most important crops could benefit more from extension thanks to the association of other crops. Besides, income provided by other sources of income different from agriculture are also really valuable in terms of investment in farm activities by the farmer. Hence, encouraging Off-farm activities could really contribute to the development of farm activities, especially among smallholder farmers.

In rain-fed agricultural systems, developing adaptation strategies within agricultural communities is required to improve yields in a context of climate adverse impacts on agriculture. Yield improvement is necessary for food availability which is a condition in food security achievement. However, food has to be available not only in quantity but also in quality. The utilisation dimension is as well important in food security, and its fulfilment includes an adequate diet. A prerequisite to satisfy the food utilisation aspect is the disposal of a variety, a range of food products. It is not just a question of transforming a given product into a diversity of other derived products, but above all, of diversity in the commodities consumed, sources of different nutrient inputs. Different products that can not only complement each other but also be substitutes for each other; hence the importance of diversified agriculture. Climate change adaptation strategies in agriculture has therefore to address all aspects of food security. The next chapter looks at the impact of agricultural climate change adaptation strategies on agricultural diversification in Central Benin

## **2 CHAPTER TWO: Impact of the crop calendar change on crop diversification in Central Benin agricultural communities**

### **2.1 Introduction**

A number of farm households in developing countries rely, for their livelihoods, upon the variety and continuous production of food and other products supplied by their own farms. In these systems, it is important to maintain the agro-biodiversity and food security, for the safety of people's livelihood (Abebe, 2013). Crop diversification is one of the most practical ways to reduce income uncertainty for farmers, mainly poor smallholder farmers (Feliciano, 2019). Crop diversification is a key agricultural policy for economic growth and particularly for the development of rural areas. It plays a fundamental role in terms of livelihood improvement among low-income smallholders, especially in the developing countries. (Abdalla et al., 2013). Cropping patterns need to be diversified to insure not only suitable supply but also economic access to a wider variety of foods for small-scale farming households (Rajendran et al., 2017). Indeed, crop diversification has come out as even the most important approach to sustainable agriculture development. (Barman et al., 2022). Crop diversification can be defined as the enlargement of the number of crops cultivated by a farmer (horizontal diversification) or from another perspective, defined as the introduction of various other ensuing activities related to a given crop (vertical diversification). Thus, diversification at the farm level will involve growing multiple crops to achieve self-sufficiency, but this may be a completely different approach at national level (Adjimoti et al., 2017).

In Benin Republic, the agricultural sector is characterised by small-scale farmers, and a population predominated by people widely relying on agricultural products to make lives. The advent of climate change, added to factors such as low access to inputs, soil degradation, lack of infrastructure and technology has increased the vulnerability of smallholders by the lowering of the productions and incomes. With the country's main crops, maize, cassava, millet, sorghum, rice, yam, cowpea, cotton and cashew, the last two being cash crops, subsistence farming, at the household scale is often not very diversified (Adjimoti et al., 2017). In spite of the relevant function of crop diversification, farmers may not automatically diversify, as expected, crops they grow because of various factors actually affecting the possibility of crop diversification practice. A set of factors can lead the agricultural household to diversify or not crops and this may vary between countries or regions. Aspects influencing crop diversification are commonly risk management needs, income sources diversification, the performances of

labour and credit markets, the demand on the market, reforms in government policies, and the most recent factor, but not least as climate change (Gajigo, 2013).

A number of papers have focused on the role of crop diversity on sustainable agriculture, food security or many other well-being indicators ( Barman et al., 2022; Adjimoti & Kwadzo, 2018; Rajendran et al., 2017; Abdalla et al., 2013; Benin et al., 2004)... but very few studies have addressed the question of the determinants of food diversity ((Abdalla et al., 2013; Benin et al., 2004)). Promoting crop diversification could be profitable as well for farmers as for biodiversity conservation. However, evidences on the facts that influence the decision to plant varying crops are required, especially in the context of Benin Republic where the question is still little studied. Addressing the drivers underneath crop diversification has yet come to be necessary in order to figure out the elements on which policies can act to promote agricultural diversification for an effective fight against food insecurity, a sustainable agriculture, and a sustainable development. Thus, this chapter attends, in the context of climate change, to analyse the impact on horizontal crop diversification (cultivation on diverse crops) of the agricultural calendar modification as a climate change adaptation strategy within central Benin region maize and cassava communities.

## **2.2 Literature review**

### **2.2.1 Importance of crop diversification**

Several studies on the purpose of food diversification on food security or the living conditions of smallholder farmers reports its positive effects. Indeed, it is above all, an essential income, production and market risk management tool (Kemboi et al., 2020). For Barman et al., (2022) crop diversification has a great capacity in reaching nutritional and food security goals, improving income for farmers and agricultural sustainability; this by conserving resource base, lessening ecological or environmental threats and boosting the land productivity. Maru et al., (2022) go along with this, especially in the context of developing countries, countries known as agriculture-dependants countries that crop diversification leads to poverty reduction, farm income raising, and employment creation. It ensures the care of the biodiversity, the soil, and the water resources while sustaining agriculture. Rajendran et al., (2017) also have concluded after a study on some districts of Tanzania that crop diversification has to be encouraged among maize smallholder farmers because it economically helps the household to have access to food diversity. The role of crop diversification on food security is constantly addressed, it is thus that Adjimoti & Kwadzo, (2018), in a study of the effect of crop diversification in the Collins region in Benin, reached the result of the positive impact of crop diversification on the food security status of households studied, it allows them to diversify their diet for their dietary is mainly based on their own production. Crop diversification therefore relieve the barrier of the lack in financial resources or in physical access to afford a diversity of food. The same observations on the benefits provided by crop diversity has been experienced in East Asia where Li et al., (2021), in the case of south China, showed that crop diversity improves the farmers livelihood.

In view of the above, it is therefore essential for Benin to promote crop diversification with a view to improving the living conditions of small-scale farmers while combating food insecurity and preserving biodiversity and soil quality. But in doing so, it is necessary to identify the factors which in one way or another have an effect on the development of crop diversification by producers.

### **2.2.2 Experienced determinants of Crop diversity**

Studies focusing on the drivers of crop diversification have revealed many factors susceptible to influence to undertaking of crop diversification. That is how using a multiple stepwise linear

regression model Maru et al., (2022) have showed that crop diversification option is positively driven by the farm size, the income of the household, the altitudinal gradient of the farm's location, the existence of suited road infrastructures and market features. These findings correspond to the ones of Li et al., (2021) in East Asia region where the land size and the proximity to the city have boosted the crop diversification attitude of the farmers. The effect of the farm size often appears in the evidences, this was the case with Abebe, (2013). An interesting conclusion was reached by Cutforth et al., (2001) , showing that the slope of the landscape this, added to predisposition or not of the farmer toward rotations may also have an influence the crop diversification. Abdalla et al., (2013), besides the effect of the level of income of the farm household, showed the effect of socioeconomic characteristics of the household such as the household size and the gender of the head which respectively have positive and negative influence on the crop diversification. Other socioeconomic characteristics of the household such as the age of the head, his education level, the income per capita of the household, the physical features of the farm, the cattle ownership, the labour stock of the household are also significantly involved in crop diversification undertaking by farmers (Benin et al., 2004; Dembele et al., 2018). Moreover, the cropping system, the kind of the cultivated crops, the consistency of the credit allocated to the farmer and irrigation perspectives are to be accounted among influencers of crop diversification (Benin et al., 2004). Gajigo, (2013) summarized all this through his study and stated that numerous factors might lead to crop diversification by a farmers, and this also, according to places, countries or regions. However, recurrent drivers comprise credit and labour markets mechanisms, the will of the farmer to diversify cropping risks or income sources, the aim to fulfil the market parameters in terms of demand on the market, of reforms in government policies; and the lately the question of climate change, in face of which the farmer is looking for adaptation mechanism.

## **2.3 Materials and methods**

### **2.3.1 Data**

To perform analyses, cross-sectional primary data were collected from communities of maize and cassava producers in the Collins region of Central Benin, a Region is made of six (6) communes (see *Appendix 1* and *Figure1*). With the assistance of the Territorial Agency for Agricultural Development (ATDA) that covers the Region, four (4) villages were sampled in each of the 6 communes, being a total of 24 villages sampled. Villages were selected depending on their relevance in the study area in the domain of maize and cassava farming. The sample size is computed using the SCHWARTZ formula (see *Appendix 2*), on the basis of information source on farmers populations provided by the book of villages and districts of the Collines region in Benin (MPD & INSAE, 2016). Sample size within communes and villages are respectively affected proportionally to the farm population in each area. Finally, households are randomly surveyed in each village. A total of 420 farm households were interviewed with structured interviews, semi-structured interviews, and focus group.

The data collection provided information on the socio-economic characteristics of the households (size of the household, number of production units in the household, the household labor, incomes...), its head (sex, age, instruction level) and the farm assets (farm size, the grown crops, the production system, the cultivation technics drought or flood experience, yield, access to finance and market perspectives, use of inputs...). Farmers were asked about their perception of climate change, its manifestations during the last ten years and their eventual adaptation strategies set by them to limit the adverse effects. The challenges they face in their

Climate data also are used for the analysis, in order to see the importance of climate variables in the decision making of farmers but also their possible effect on the outcome of the analysis. The data are provided by the Daily Global Historical Climatology Network version of 3.29 found with the United States National Oceanic and Atmospheric Administration (NOAA) Climatic Data Center (Menne, Durre, Korzeniewski, et al., 2012; Menne, Durre, Vose, et al., 2012). In the six communes of the Region, Daily temperature and rainfall data were considered over the period 2012 to 2021, meaning the last ten years before the socioeconomic data collection. The climate data provide village individual information for each of the 24 sampled villages. By village, the ten-year annual average was calculated for temperature by splitting each of the four annual seasons observed in the study area. Similarly, the average annual total

rainfalls has been computed by village for each season over the last ten years. The averages computed per village are assigned to individuals belonging to the same villages. (In villages the points are close enough for us to consider any difference from one point to another). Using STATA software, statistics tests, and estimation of the model are performed.

### **2.3.2 Model of the study**

The effect of the cultural calendar modification on crop diversity can be modelled in two steps equations regressions. In fact, many factors intervene in the adaption decision taking which is therefore not exogenous (Di Falco et al., 2011). To account for the endogeneity of the adaptation decision, instrumental variables method is used. Instruments are variables that have an impact on the variable related to the adaptation, without having any impact on the outcome variable which is here the crop diversity. The instruments' purpose is to control the bias actually generated by unobserved heterogeneity. The required model in this case is the endogenous switching model, which is run using the full-information Maximum Likelihood method (FIML) to simultaneously fit binary (adaptation or not ) and continuous (crop diversity ) parts of the model. In fact, a model with only one equation estimated using the two steps least square or the maximum likelihood estimation method would not be efficient, and would require a number of adjustments before deriving satisfying error terms (Lokshin & Sajaia, 2004).

➤ *Modelling of the cultural calendar modification as Climate change adaptation strategy*

The decision of adaptation may not be assigned randomly. In fact, adapters could have different characteristics compared to non-adapters, and then, just comparing of the outcome of the two groups would be biased (Di Falco et al., 2011). First, factors susceptible to influence de decision of the modification of cultural calendar by the farmer are to be identified, based on the existing literature.

Let  $B^*$  be a variable representing the benefits for a farmer expects to derive from adaptation. The farmer will opt for adaptation only if that benefit is positive.

$$(10) \quad B_i^* = Y_i \delta + \mu_i \quad \text{With} \quad B_i = \begin{cases} 1 & \text{if } B_i^* > 0 \\ 0 & \text{otherwise} \end{cases}$$

$Y$  is the (n x m) matrix of explanatory variables

$\delta$  is the (1,...,m) vector of model parameters to be estimated,

$\mu$  is an  $n \times 1$  vector of error terms.  $\eta$  follows a normal distribution with mean equal to zero

Z is made of all the variable (instruments and control variables) that affect the expected benefits from the adaptation decision. The instruments are the information variables such as Government extension, Climate information, access to market, the use improved crop varieties... The control variables are any other variables that can also influence the adaptation decision; among them, the sex of the farmer, the experience in agriculture, the access to finance, the cooperative membership, rainfall and rainfalls experienced other the last three years ...

➤ **Modelling of the effect of on cultural calendar modification on crop diversity**

1<sup>st</sup> regime: farm households modify the cultural calendar as an adaptation to climate change strategy

$$(11a) \quad y_{1i} = X_{1i}\alpha_1 + v_{1i} \quad \text{if } B_i = 1$$

2<sup>nd</sup> regime: farm households that did not change the cultural calendar

$$(11b) \quad y_{2i} = X_{2i}\alpha_2 + v_{2i} \quad \text{if } B_i = 0$$

$y_i$  represents the number of crops cultivated per household

$X_i$  is a vector of variables related to the socio-economic characteristics of the household and the cultivation conditions (farmers' cooperation membership, access to market, access to finance...).

$\alpha_i$  is the estimated parameter of the impact of the cultural calendar change on the crop diversification.

The error terms of the selection and outcome equations are assumed to follow a trivariate normal distribution, with zero mean and covariance matrix  $\Omega$ , i.e.,  $(\mu_i, v_{1i}, v_{2i})' \sim N(\mathbf{0}, \Omega)$

$$\Omega = \begin{bmatrix} \sigma_\mu^2 & \sigma_{\mu 1} & \sigma_{\mu 2} \\ \sigma_{1\mu} & \sigma_1^2 & . \\ \sigma_{2\mu} & . & \sigma_2^2 \end{bmatrix} \quad \text{with } \sigma_\mu, \sigma_1^2 \text{ and } \sigma_2^2 \text{ the variance of the error term in the selection}$$

equation (10) and the crop diversification equations (11a) and (11b). The coefficients are estimable only up to a scale factor (Lokshin & Sajaia, 2011), and it is then assumed that  $\sigma_\mu^2$  is equal to 1.  $\sigma_{i\mu}$  is the covariance of the error term in the selection equation with each error term in (11a) and (11b). The error terms in (11a) and (11b) are not observed at the same time as the

two events do not occur simultaneously, so the covariance between the error terms of the two equations is not defined.

The expected values of the error terms in the outcome equations conditional to the selection equation are different from zero, this due to the potentially omitted variables and unobservable factors not reflected in the selection equation:

$$E[v_{1i} | B_i = 1] = \sigma_{1\mu} \frac{\phi(Y_i \delta)}{\phi(Y_i \delta)} \quad \text{and} \quad E[v_{2i} | B_i = 0] = -\sigma_{2\mu} \frac{\phi(Y_i \delta)}{1 - \phi(Y_i \delta)}$$

$$E[v_{1i} | B_i = 1] = \sigma_{1\mu} \lambda_{1i} \quad \quad \quad E[v_{2i} | B_i = 0] = \sigma_{2\mu} \lambda_{2i}$$

$\varphi(\cdot)$  is the standard normal probability density function, and  $\phi(\cdot)$  the standard normal cumulative density function, and  $\lambda_{1i} = \frac{\phi(Y_i \delta)}{\phi(Y_i \delta)}$ , and  $\lambda_{2i} = -\frac{\phi(Y_i \delta)}{1 - \phi(Y_i \delta)}$

The significance of covariance between the error term of the selection equation and those of the poverty equations ( $\hat{\sigma}_{1\eta}$  and  $\hat{\sigma}_{2\eta}$ ) would mean an existing correlation between the off-farm job equation and the poverty equations, rejecting the null hypothesis of sample selectivity and therefore suggesting an Endogenous Switching Regression (ESR) model proposed by Lee and Trost (1978) (Adegbo et al., 2019). Compared to the two-step estimator which fails in extracting the standard error terms, the ESR model has the advantage to estimates simultaneously the coefficients of the selection and the output equations, this using the full information maximum likelihood method (Lokshin & Sajaia, 2004).

The log-likelihood function for the output equations' system is the following.

$$(12) \quad \ln L = \sum_{i=1}^N B_i \left[ \ln \varphi \left( \frac{v_{1i}}{\sigma_1} \right) - \ln \sigma_1 + \ln \phi(\theta_{1i}) \right] + (1 - B_i) \left[ \ln \varphi \left( \frac{v_{2i}}{\sigma_2} \right) - \ln \sigma_2 + \ln(1 - \phi(\theta_{2i})) \right]$$

where  $\theta_{ji} = \frac{(Y_i \delta + \rho_j v_{ji} / \sigma_j)}{\sqrt{1 - \rho_j^2}}$ ,  $j = 1, 2$ , and  $\rho_j$  the correlation coefficient between the error

term  $\mu_i$  of the selection equation (1) and the error terms  $v_{ij}$  of equations (2a) and (2b), respectively.

**Conditional expectations: Adaptation, non-adaptation and counterfactual effects expectations**

The conditional crop diversity expectations respectively among cultural calendar changers and non-changers are:

The expected crop diversity with adapters conditional to their factual adaption

$$(13a) \quad E(y_{1i} | B_i = 1) = X_{1i}\alpha_1 + \sigma_{1\mu}\lambda_{1i}$$

The expected crop diversity with non-adapters conditional to their factual non-adaption

$$(13b) \quad E(y_{2i} | B_i = 0) = X_{2i}\alpha_2 + \sigma_{2\mu}\lambda_{2i}$$

The expected crop diversity with adapter's conditional if they had not adapted

$$(13c) \quad E(y_{1i} | B_i = 0) = X_{1i}\alpha_1 + \sigma_{1\mu}\lambda_{2i}$$

The expected crop diversity with non-adapters if had adapted

$$(13d) \quad E(y_{2i} | B_i = 1) = X_{1i}\alpha_2 + \sigma_{2\mu}\lambda_{1i}$$

**Treatment effects**

- The expected average effect of cultural calendar change on the crop diversity of households adapters. It is given by the average of the difference between (4a) and (4c).

$$(14) \quad ATT = E(y_{1i} | B_i = 1) - E(y_{2i} | B_i = 1) \\ = X_{1i}(\alpha_1 - \alpha_2) + (\sigma_{1\mu} - \sigma_{2\mu})\lambda_{1i}$$

- Analogously, the expected average effect of cultural calendar change on the crop diversity of household non-adapters (ATU) is expressed by the difference between (4d) and (4b).

$$(15) \quad ATU = E(y_{1i} | B_i = 0) - E(y_{2i} | B_i = 0) \\ = X_{2i}(\alpha_1 - \alpha_2) + (\sigma_{1\mu} - \sigma_{2\mu})\lambda_{2i}$$

**Heterogeneity effects**

The computation of the heterogeneity effects allows to see which of the two groups of household would gain the most from the engagement or not into off-farm activities as adaptation strategy.

$$(16) \quad \begin{aligned} BH_1 &= E(y_{1i} | B_i = 1) - E(y_{1i} | B_i = 0) \\ &= (X_{1i} - X_{2i})\alpha_{1i} + \sigma_{1\mu}(\lambda_{1i} - \lambda_{2i}) \end{aligned}$$

$$(17) \quad \begin{aligned} BH_2 &= E(y_{2i} | B_i = 1) - E(y_{2i} | B_i = 0) \\ &= (X_{1i} - X_{2i})\alpha_{2i} + \sigma_{2\mu}(\lambda_{1i} - \lambda_{2i}) \end{aligned}$$

To finish, the transitional heterogeneity (ATH) is computed to check which of the two groups (adapters and non-adapters) is impacted or would be impacted the most by that adaptation strategy.

$$(18) \quad ATH = ATT - ATU$$

### **2.3.3 Variables of the model**

The variables of the model are identified based on the existing literature on the subject (Abdalla et al., 2013; Adjimoti & Kwadzo, 2018; Benin et al., 2004). To validate a variable as an instrument or not, a validation test is performed (Di Falco et al., 2011). The outcome variable is crop diversification, measured by the number of crop by farm household. The endogenous variable is a binary variable on the modification of the crop calendar during the last three years. The calendar modification decision taking is determined by a number of control variables and instruments. Control variables are main temperature and rainfall evolution during the last ten years, the soil fertility, drought or flood experience, the household's head characteristics as the level of instruction, the sex, the marital status, the land ownership, the access to credit, and the experience in agriculture. The cost of the production and the practice of any off-farm activities are also considered. For the instruments, information sources that could be from government extension services, from the farmer's neighbourhood and from his own experience on climate variables. The access to market is a variable susceptible of influencing the decision to grow a given crop by the farmer. Other variables, apart from the adaptation, that may affect the crop diversification are the same control variables upper announced.

**Table 2-1 Measurement of the variables**

<b>Variables</b>	<b>Measurement</b>	<b>Expected sign</b>
<i><b>Dependent variables</b></i>		
Modification of the agricultural calendar	1 if yes , 0 otherwise	+
Crop diversification		
<i><b>Explanatory variables</b></i>		
<i><b>Climatic factors</b></i>		
Main rainy season précipitations during the last 10 years		
Main drought season précipitations during the last 10 years		
Main drought season temprature during the last 10 years		
<i><b>Characteristics of the farm and household</b></i>		
Soil fertility	1 if yes , 0 otherwise	+
Land ownership	1 if yes , 0 otherwise	+
Sex of the head	1 if male , 0 otherwise	+/-
Instruction level of the head	Ordinal 1 to 4	+
Marital status of the head	1 if married, 0 otherwise	+/-
Off-farm activity source of income	1 if yes , 0 otherwise	+/-
Cooperative membership	1 if yes , 0 otherwise	+
Cost of production year-1	continuous	-
Access to credit	1 if yes , 0 otherwise	+
Experience in agriculture (number of years)	continuous	+
Flood experience	1 if yes , 0 otherwise	-
Drought experience	1 if yes , 0 otherwise	-
<i><b>Instruments</b></i>		
Government extension	1 if yes , 0 otherwise	+
Neighbourhood information	1 if yes , 0 otherwise	+
Climate information	1 if yes , 0 otherwise	+
Access to market by praticable road	1 if yes , 0 otherwise	+

## 2.4 Results

### 2.4.1 Descriptive statistics

**Table 2-2 Descriptive statistics: tendency in variables of the model**

Variables	Sample		Adapters		Non-adapters	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Soil fertility	0.930	0.255	0.919	0.273	0.937	0.243
Land ownership	0.848	0.359	0.801	0.4	0.878	0.328
Sex of the head	0.952	0.214	0.956	0.205	0.949	0.221
Instruction level of the head	0.289	0.454	0.329	0.471	0.264	0.442
Marital status of the head	0.925	0.263	0.944	0.230	0.913	0.282
Off-farm activity source of income	0.318	0.466	0.304	0.462	0.327	0.470
Cooperative membership	0.487	0.5	0.422	0.495	0.528	0.500
Cost of production year-1	412060.8	513784.1	413677.3	529022.7	411036.2	504940.8
Access to credit	0.388	0.488	0.447	0.499	0.350	0.478
Experience in agriculture (number of years)	19.414	11.047	18.969	11.007	19.697	11.085
Flood experience	0.470	0.5	0.360	0.482	0.539	0.500
Drought experience	0.949	0.219	0.944	0.230	0.953	0.213
Government extension	0.311	0.463	0.224	0.418	0.366	0.483
Neighborhood information	0.227	0.419	0.093	0.292	0.311	0.464
Own experience on climate features	0.275	0.447	0.590	0.493	0.075	0.264
Access to market by practicable road	0.554	0.497	0.497	0.502	0.591	0.493
Use of maize improved seed	0.663	0.473	0.780	0.416	0.589	0.493
Use of Cassava improved variety	0.466	0.499	0.635	0.483	0.361	0.481
Number of cultivated crops	4.792	1.413	4.803	1.483	4.775	1.298
Sample size	415		161		254	

Source: Excel, from primary data

The table 2-2 presents frequencies of the variables of the model within the group of adapters and the one of the non-adapters. The two groups of producers appear to be sufficiently homogeneous when considering the social characteristics of heads of household and their households. However, some differences are observed on both sides of the groups. Adapters are on average more instructed than non-adapters: however; more than half of non-adapters are members of cooperatives whereas among adapters, barely half of it. Yet, the group of adapters has not, in terms of proportions, experienced as much flooding as non-adapters and the fact that they are less found in agricultural cooperatives may justify that they have less access to information provided by government extension agents. However; in the group of adapters; many producers report more reliance on their observations in the weather and changes in

climate manifestations especially through seasons; temperature and rainfall. For adapters, their decision to change their cultural calendar comes essentially from their analysis of manifestations in recent years of climate in the area. Non- adapters, on the other hand, do not seem at all to rely on or really use their observations on climate change to make their adaptation decisions. Although non- adapters appear to be somewhat more advantaged than since their road from farms to markets are in general accessible. And farmers from that group t are slightly less likely than the adapters to adopt improved varieties of maize and cassava.

#### **2.4.2 Estimation of endogenous switching model of cultivation calendar modification on crop diversity**

The results of the endogenous switching regression are presented in the table 2-3. The endogenous switching model estimates the parameters by the full information maximum likelihood method. Are respectively reported the OLS estimation of the crop diversification, and the ESR regression results with the adaptation decision as an endogenous variable. The OLS results say that the change of crop calendar does not have any effect on the number of crop grown by the farmer. With the ESR results in turn, we see that rhos are not significant, however the control variables do not automatically have same coefficients or same significance from adapters to non-adapters. The ESR is still therefore relevant in that sense that each group of farmers could be analysed separately and group own specificities revealed.

**Table 2-3 Results of the model of crop diversification**

Dependent variables	OLS	Determinants of crop calendar changes	Households changing cultivation calendar (Adaptation=1)	Households who did not (Adaptation=0)
			Number of crops produced	Number of crops produced
Main rainy season rainfalls during the last 10 years	0.001*** (0.000)	0.001*** (0.000)	0.001*** (0.000)	0.001*** (0.000)
Main drought season rainfalls during the last 10 years	6.768*** (1.435)	4.503*** (1.723)	8.162*** (2.076)	5.681** (2.214)
Main drought season temprature during the last 10 years	-0.001 (0.001)	0.004*** (0.001)	0.001 (0.001)	-0.003** (0.001)
<i>Characteristics of the farm and household</i>				
Soil fertility	-0.121 (0.258)	0.262 (0.347)	-0.486* (0.263)	0.247 (0.234)
Land ownership	0.300 (0.193)	-0.232 (0.230)	0.436** (0.219)	0.384 (0.264)
Sex of the head	-1.181*** (0.335)	-0.543 (0.379)	-0.694 (0.686)	-1.426*** (0.451)
Age of the head	0.003 (0.006)	-0.003 (0.007)	0.003 (0.008)	0.004 (0.009)
Instruction level of the head	-0.262* (0.148)	0.060 (0.161)	-0.293 (0.181)	-0.231 (0.209)
Marital status of the head	0.759*** (0.272)	0.605* (0.310)	0.792 (0.508)	0.518 (0.406)
Off-farm activity source of income	-0.364** (0.143)	-0.163 (0.163)	-0.035 (0.186)	-0.547*** (0.178)
Cooperative membership	0.383*** (0.137)	-0.365** (0.171)	0.640*** (0.203)	0.303* (0.182)
Cost of production year-1	0.000* (0.000)	-0.000 (0.000)	-0.000 (0.000)	0.000* (0.000)
<i>Instruments</i>				
Government extension		0.268 (0.168)		
Neighborhood information		-0.749*** (0.203)		
Own climate observations		2.021***		

*IMPACT OF CLIMATE CHANGE ADAPTATION STRATEGIES WITHIN AGRICULTURAL COMMUNITIES IN  
CENTRAL BENIN REPUBLIC*

			(0.275)	
Access to market by praticable road			-0.542***	
			(0.164)	
Crop calendar change	0.004			
	(0.135)			
Constant	-195.459***	-139.454***	-236.772***	-161.622**
	(42.568)	(51.363)	(61.273)	(65.529)
$\sigma_i$			0.129**	0.339***
			(0.056)	(0.063)
$\rho_i$			-0.032	-0.626
			(0.131)	(0.392)

Note: \*Significant at the 10% level; \*\*Significant at the 5% level; \*\*\*Significant at the 1% level.

(.) Robust standard errors

$\sigma_i$ , square-root of the variance of the error terms in the respective outcome equations;

$\rho_j$ , the correlation coefficient between the error term of the selection equation and the respective error terms of the outcome equations.

The results of the selection equation show that the factors behind the decision of the farmer to opt for a modification of the cultural calendar as an adaptation strategy to climate change are among other the climate patterns observed in the area during the last ten years, these are total rainfalls, and the main temperature observed for each season. Producers pay attention to the observed changes in climate variables and make decisions about adaptation based on their experiences with those climate variables. The fact that all the three climate variables observed during the last ten years have a positive effect on the crop calendar changing may appear intriguing especially in the rainfall which abundance leads calendar change by the farmer. Indeed, climate change manifestations very often observed in the study area are late rains, pockets of drought in the middle of rainy season, too much abundant rains that instead of feeding the seasonal crops destroy them, causing erosion and flooding. Thus, when producers experience rainfalls that exceeds the appropriate level, this can led them to modify their crop calendar in future times to protect themselves from the risks of crop destruction.

The belonging to a cooperative of farmers has a negative influence on the decision to modify crop calendar as a climate change adaptation strategy. The explanation may be that in cooperatives, vulgarisation services namely the ATDA services, promote the use of improved seeds for maize and soybeans in instance and some sustainable land management methods. Farmers involved in these coping strategies in cooperative's framework may not really feel the need of changing their crop calendar. The information from farmer to farmer, the access to

market and the use of maize improved seed are also determinants of the modification of the cultural calendar.

From the results, one of the variables that impact crop diversification among the group of adapters is total rainfalls during the main rainy season, which here has a significant and positive effect on the number of crops grown. Indeed, agriculture is rain-fed in Benin Republic and most of the crops are grown during the main rainy season; the years of lack of rain are years of scarcity for many crops. Land ownership and cooperative membership are also aspects with good influence on crop diversification. Land owners cultivate broader lands compared to farmers who have to rent lands. Moreover, farmers feel free in their practices and in the choice of the crop grown when they own some rights on the cultivated land, otherwise, they feel limited in how they manage the land, this because of actual restrictions given by the landowners. Cooperatives are exchange frameworks for producers where experiences are shared and crops or land management practices with satisfying outcomes are interchanged.

In the case of the group of non-adapters, total rainfalls during the rainy season appear significant for the same reasons enounced upwards in the case of adapters. Adding to this, the fact for a farmer to have another activity different from agriculture has a negative effect on his crop diversification, this could be comprehensible since once engaged into off-farm activities, the farmer has to devote less time for his farm, which implies the reduction extend of the cultivated land, the incapacity to grown as many crops as he could do otherwise and time constraint to keep the farm. What is more, the variable sex may be a factor that does not totally favour crop diversification with the males of the group of non-adapters; the fact is that males produce less diversified crops than females. In the region most of women heads of household, are dabble in everything in terms of activity. They take everything that comes to them and could make them earn some resources. Women, generally in Benin rural areas, are engaged into many activities, there are generally not exclusive farmers, carrying out, in addition, other activities for instance in sectors of trade, food transformation, or being labour force in other farm. And women are very sensitive to the issues of subsistence of their families. They have this natural tendency to diversify crops despite that they are generally part of the group of smaller farmers. Regardless of the size of the farm, it is often important for a woman to grow several plants with the priority of meeting the food needs of her household, even before generating income (their farming is, first, a subsistence farming); without forgetting that crop diversification is also for them a strategy to diversify farming-related risks. For men, they are more inclined to

specialization or devotion to cultures which, they expect, for the current agricultural season, will yield more surplus-value. This could justify the reduced performance of men in terms of crop diversification. In both cases of adapters and non-adapters, the instruction level as curiously a negative effect on the way producers diversify main crops they grow, this finds its explanation in the fact that the most instructed producers generally tend to specialise in specific crops, dedicating a good part of their energy and resources to these crops in order to draw the most of their profits, in many cases, other crops are set aside, these crops not being cultivated by that farmer, or then grown in tiny quantities just for the needs of the household itself.

**Table 2-4 Average treatment and heterogeneity expected effects**

	Decision		Treatment Effects
	Adaptation	Not adaptation	
Households who changed their crop calendar	(a) 4.775 (0.617)	(c) 3.953 (0.764)	ATT = 0.821*** (0.077)
Households who did not	(d) 4.889 (0.609)	(b) 4.866 (0.679)	ATU = 0.084 (0.057)
Heterogeneity Effects	BH1 = -0.114* (0.062)	BH2 = '-0.852*** (0.719)	ATH = 0.738*** (0.066)

The table 10 displays the computed treatment and average effects of the modification of cultural calendar on crop diversification. (a) and (c) respectively represent the expected crop diversification in the group of adapters the case they adopt and the case they do not adopt. The results show that the adapters produce more diverse crops than if they had not changed their crop calendar. Calendar changers, in average, grow five (5) different crops versus four (4) crops in their counterfactual case. That adaptation option is therefore significantly beneficial for them with an average of one other crop more. Considering now the group of non-adapters in cells (d) and (b), the calendar modification would have just a very slight positive effect on their crop diversification (4.889 crops versus 4.866 crops). That difference between to two groups of farmers is potentially due to observable and unobservable factors which differentiate them. One of those differences is that initially; non-adapters was already, without adaptation, producing more crops than adapters (b). And if adapters perform as observed, this is thanks to their adaptation, otherwise, their performance, would have been more less (c). If the crop calendar

change is potentially beneficial for both the two groups, the group of adapters is from far the one that, the most, draws advantages from adaptation. Adapters appears as the main beneficiaries of the adaptation; the transitional heterogeneity (ATH) is positive and equal to 0.738. If the two groups seem to share the same characteristics These communities, toward the modification of crop calendar as CC adaption strategy have showed the importance of customized strategies given the individuals needs of farmers.

## **2.5 Conclusion**

Diversify crops is essential, particularly for smallholder farmers, who depend mostly on their own production, first for their diet and second, to make a living. Different parameters come into play when it is about crop diversification. From climate variables to socioeconomic factors, the effect on crop diversification can be of different order and senses. This chapter studied the effects of crop calendar change as a climate change adaptation strategy on crop diversification on the maize and cassava producers of the central region of Benin Republic. Accounting for the endogeneity of the adaptation decision, the results display several elements affecting the decision to make a change in the crop calendar as a coping strategy to climate change. The climate variables that are the average temperature and total rainfalls for each season, especially the main rainy season play a non-avoidable role in both the decision of adaptation and the outcome of the adaptation which here is the crop diversification. This as once more showed how much is the role of climate factors in the adaptation. The access to market, the land ownership, the cooperative membership and the information variables are other elements that comes into play when the farmer decides whether he will adapt to climate change or not. And the factors intervening in crop diversification's achievement, apart from elements cited upwards are the engagement into off-farm activities, the sex, and the soil fertility. If adapters and non-adapters have together the climate factors that impact the number of crop they grow, it is still they have other factors that differentiate them in their crop diversification. This is reflected by the overall effect of crop calendar modification of crop diversification. If the effect is globally positive for both groups, first, the group of adapters is still the one that the most benefits from that adaptation strategy option; and second the group of non-adapters initially is already producing more crop than what adapters would have performed without adaptation. This meaning that the groups, apart from the fact to adapt or not, are different in other features that fit to be understood for a better understanding of their behaviour towards the adaption.

Based on the findings of this chapter, and giving the importance of crop diversification in food security and income improvement for smallholders, it fits to promote crop diversification. Policy interventions should assist farmers in market accessibility process by helping them in finding outlets for their products and by constructing roads for conveying products to the markets. There is also, the need of facilitation in term of access to inputs, notably improved seeds for the different crops, plant health products and even machinery for farmers. Indeed, collected information showed that the decision to adapt and diversify crops is sometimes not

taken because of lack of financial means by many producers who stress the cost involved and their inability to commit themselves to it; added to this, the risk of loss they don't feel safe of. A strategy would be to set up a system of subsidies targeting especially the most disadvantaged farmers. Extension services has a great function to provide, which is to further train farmers on methods of sustainable land management, sustainable farming techniques, and novelties in terms of strategies in face of climate change. Extension services have therefore to be reinforced for they remain the main source of information for farmers. Another approach of boosting crop diversification in the region would be to focus on socioeconomic factors such as the access to credit by farmers, the land attribution system of the region, the level of income of the household, the engagement into off-farm activities the instruction level and the gender considerations; since the results have showed that those variables have an effect of crop diversification. It would be interesting to set up a system of assistance and advice for producers wishing to diversify their income sources by engaging in off-farm activities. In this way, producers will be able to better plan their time between the various activities, choose the right moment in the year for each activity in order to get the greatest benefit from off-farm activities without putting their agricultural activities at a disadvantage. For the access to credit, it is a preponderant factors here, non-negligible for a flourishing farming system, especially for smallholders, as in this study. Agricultural policies must go a long way towards facilitating access to credit because many producers are nevertheless open to the introduction of new techniques, to experiment in new things, even more nowadays where the climate has quite changed. Finally, further studies on observable and non-observable heterogeneity among adapters and non-adapters are needed to understand the unobservable which lead to the difference in outcome observed between the two groups. This is important and could allow to elaborate tailored policies based on the characteristics and needs of each group of farmer.

Make food available in quantity and diversity passes respectively through crop yield improvement and crop diversification. However, another not negligible aspect of food security is the food access, food accessibility focusing on financial resources (income and expenditure) needed by individuals to afford required food. Besides, food access achievement, financial resources are requisite for livelihood improvement, and poverty eradication, which, like food security, is one of the Sustainable Development Goals. It is thus equally sensible to check how climate change agricultural adaptation affects monetary poverty reduction especially among most vulnerable communities as farm smallholder's communities. The third chapter focuses on the effect of climate change adaptation strategies on monetary poverty reduction within the agrarian communities of central the Benin.

### **3 CHAPTER THREE: Impact of off-farm activities as climate change adaptation strategies on monetary poverty among Maize and cassava farmer communities in central Benin**

#### **3.1 Introduction**

One of the main goals of governments and international organisations is a world free of poverty. This will pass through getting poor people out of the poverty while preventing others from falling into it (Noufé, 2020). In developing countries, livelihoods of poor people are sensitive to climate change, because, most of them rely on activities such as farming, pastoralism, fishing and forest use. The climate dependency of those activities and the resource-based livelihoods of the communities make more difficult the attempts to adapt to climate change (Ensor et al., 2014). In sub-Saharan African region, changes in climate constitute an enclave to agricultural production as it is here about a completely rainfall over-relying agriculture (Oppong-Kyeremeh & Bannor, 2018); climate change therefore comes to jeopardize efforts in the improvement of living conditions of population and then, the reduction of poverty (Amare & Waibel, 2014). According to the World Bank, Benin had a poverty rate of 45.9% in 2020. In the country, poverty is more prevalent in rural areas than in urban areas. In fact, Benin has an incidence of 44.2% in rural areas versus 34.4% in urban areas and a depth of poverty of 12.5% in rural areas versus 8.6% in urban areas (INSAE, 2019). These results show that rural areas are significantly more vulnerable to poverty. Indeed, the incidence of rural poverty in the country remains high as the majority of the population depends on agriculture as a means of subsistence (Nonvide, 2019).

Studies on developing countries have shown that a number of producers increasingly turn to income diversification (with off-farm activities) to face threat posed to their livelihood by the decline in crop productivity (fact which implies poverty and food insecurity) due to adverse agro-climatic conditions. Income generated by off-farm activities could serve to provide farm households assets of make a living (Rantšo, 2016). So, the expansion of rural non-farm economy may be a way for a number of rural people in developing countries to emerge from poverty problems (Ensor et al., 2014) and it is essential to understand the relation between the climate change and non-farm employment in the context of sub-Saharan Africa countries as many climate change adaptation plans for farmers are being implementing. Even if non-farm activities among agricultural communities in Sub-Saharan Africa have been object of considerations, it is still not enough discussed as an option for adaptation (Danso-Abbeam et al., 2021). Why could rural non-farm activities be so important for climate change adaptation? Because negative effects of climate

change increases the vulnerability of poor and near-poor people, whose activities and livelihood are highly climate dependent.

In the developing world, the number of people working in the agricultural sector, at the existing level of technology, is higher than required. The situation is favoured by the shortfalls in systems of land tenure and the power relation between people with as consequence the worsening of the situation of poor people (Ensor et al., 2014). Diversification of revenues sources could therefore be, for rural people, a means not only to escape to the dependence to resources but also provide additional means to improve their livelihood. Notwithstanding the increasing interest given to climate change adaptation strategies elaboration, especially in the most vulnerable countries, the question of the non-farm employment as an adaptation option for agricultural communities, especially smallholders, has not been rightly touched on (Oppong-Kyeremeh & Bannor, 2018). The present chapter considers the adoption of off-farm activities as a climate change adaptation strategies among central Benin agrarian communities and assesses its contribution in terms of poverty reduction within the communities. This study defines poverty as the deterioration of living conditions of an individual or a household, which generated by a lack of financial means. Using the income based-approach, poverty is here measured by the disposable income, whether from farm activities, wage labour, trade, self-employment, transfers received. The absolute poverty line is here used. Is considered household, any entity living in the same dwelling, sharing every day the family meals and participating in the daily life of the household.

## **3.2 Literature review**

### **3.2.1 Non-farm/ off-farm activities as climate change adaptation strategies and means of poverty reduction**

Non-farm activities are sorted into different sectors: primary, secondary and tertiary. The primary sector is made of commerce, manufacture, and the public services; the secondary sector comprises wood, food, textile, metal products, tobacco, construction and renovation while tertiary includes education, personal services, public administration, land transport, small-scale retail trade, medical services, hotels and restaurants (Fisher et al., 1997). Non-farm activities are activities different from primary activities like primary agriculture or forestry or fisheries. Yet, the category includes trade and processing activities related to agriculture independently of the location, scope or technology used. (Gordon et al., 2001; Davis & Bezemer, 2004). In turn, is generally considered off-farm activity an activity engaged into by a farm household but out of its own farm. Off-farm activities for a farm household is defined as agricultural works in someone else's farmland (Ellis, 1998). In the context of the present study, off-farm activities designs as well non-agricultural (non-farm) activities as para-agricultural activities undertaken by the farmer either it is a wage work, a work in someone else's farmland or a self-employment. In this study, off-farm activities simply describes activities engaged into by the farm households out of its own farm activities. The off-farm activity is supposed to provides income to supplement income from the household agricultural production especially in the case of climate shocks on agricultural production. An off-farm activity can be a seasonal or a permanent activity; it can be as well a non-farm activity as a farm related activity (work in someone else farm, transformation of agricultural products, handcraft...).

The existing literature has essentially documented the role of rural non-farm economy (RNFE) rather than the role of a "Rural off-farm economy". RNFE referring to economic activities undertaken by rural residents that provide income from sources different from agricultural (Haggblade et al., 2010; Lanjouw, 2001; Wiggins & Hazell, 2010). It is a bunch in livelihood activities counting employment or self-employment, trading whether in formal or informal sectors production and encompasses manufacturing, mining, construction, transport, agro-processing, tourism, etc. The significance of RNFE dwells in the fact that it could constitute new or additional income to rural households; and therefore, is helpful in livelihood improvement for rural people (Wiggins & Hazell, 2010). Non-earned income sources and social payments help in poverty reduction at the household level, they impact the work-leisure

decisions and favour investments (Davis & Bezemer, 2004). RNFE plays an important role in job creation, livelihood improvement, income raising, new skills gaining, and also developing other services (Berdegué & Escobar, 2000).

The negative effects of climate variability can be exacerbated by a lack of insurance and credit markets, which touch the performance of the households in terms of adaptation or responses to climate shocks (Amare & Waibel, 2014). Agricultural households rely on non-agricultural wage and self-employment as adaptation strategies in face of shocks caused by rainfall variability. Amare & Waibel (2014) have described relationship between rainfall variability and both non-agricultural wage and non-farm self-employment as concave; however poorer households are less able benefit from high returns of the labour market to manage shocks because of a lack of start-up assets. The risk characterising the agricultural production may lead to the fluctuation of single-source income, fact which can be lessened by diversifying the portfolio of activities (Reardon, 1998). Farmers can resort to non-farm labour to reduce the total variance of their income or to raise the total returns to labour. More, the seasonal character of the agricultural labour may be another reason of devoting time to non-farm activities (Davis & Bezemer, 2004). In rural areas, the diversity and size of non-farm activities are directly related to the average age and the size of the population, so it could be difficult to create job when the rural population is focused on growing the agricultural sector, nonetheless it is essential to draw the attention of non-farm activities which may be an alternative to increasing employment, reducing poverty and migration, and creating new job opportunities for the local labour force. And this could be more again relevant in the context of underdeveloped or least developed countries (Artemyan, 2015). Yet their study has specified that that the labour market may be less effective as a means for adapting to severe rainfall variability, economic and demographic shocks.

Danso-Abbeam et al. (2021) have assessed the effect of the involvement of farmers in non-farm economic activities on their investments in agricultural climate adaptation. They have found farmers seek for income diversification as adaptation strategy in situation of climate change risks and incomes derived from other activities are used to buy, for instance, drought-tolerant improved seeds, fertilizer, and irrigation systems, as well as to participate in other climate-change mitigation measures. The finding are the same with mall-scale rice producers in the Volta Region are into off-farm jobs as a means of survival against climate change (Oppong-Kyeremeh & Bannor, 2018). Farmers participate in non-farm activities to make a living, finance subsistence agriculture and purchase the basic needs for their families. In Lesotho, such

activities have proved their relevance in rural development (Amare & Waibel, 2014). In the framework of a study on the significance of rural non-farm activity in the development of Tavush, Republic of Armenia, a number of respondents asked have told on how much the income got from non-farm activities is crucial for their household budget (Artemyan, 2015). Rantšo (2016) also has abounded in the same direction in the case of Lesotho where rural non-farm activities contribute positively to rural development, then the author highly encouraged the country's government assistance in improving the available non-farm activities or order to reduce poverty, unemployment and food insecurity. In fact, rural non-farm jobs increase smallholder farmers' adaptive capacities and that participants would have used less adaptation techniques if they had not participated in non-farm work. Efforts should then go in the sense of providing more employment opportunities for farmers, during the off-cropping time (Danso-Abbeam et al., 2021). For this Oppong-Kyeremeh & Bannor (2018) have suggested farmers' training in taking available off-farm job opportunities to moderate the adverse impacts of climate change on their livelihood.

The engagement or not of a farmer's household into non-farm/off-farm activities can be influenced by a set of factors. Studying factors which determine the participation or not to non-farm activities, Artemyan, (2015) have noted elements such as the age, gender, education, location, comparative advantage, etc. The level of education and type of production system have a positive effect on the off-farm job participation while the age, the average and the productivity of the land have shown a negative effect on it (Oppong-Kyeremeh & Bannor, 2018). It has also been noticed that a number of farmers producing under a rain fed system were essentially those into off-farm jobs because of uncertainty in weather conditions in comparison with those under irrigation system (Oppong-Kyeremeh & Bannor, 2018). Given the significant potential role of such activities in agricultural communities, have suggested that government should direct policies intended to improve factors that have an impact on increasing engagement in non-farm activities (Artemyan, 2015)..

➤ **Importance of income diversification among farm households**

The literature on the subject reports that rural non-farm activities contribute to economic growth, rural employment, poverty reduction. Agricultural household income diversification, by associating other activities to the farm activities, whether on or off the farms, allow households to raise their income level and to improve the viability of the farms (Berjan et al., 2013; Ensor et al., 2014; Gordon et al., 2001; Lanjouwa, 2001). The most is a family engaged in non-farm activities at full-time, part-time or seasonal time, the higher is its income (Walker & Ryan, 1990). A part from the significant economic role that plays the rural income diversification, it is also important in employing the labour surplus in rural communities even if seasonally and then reducing unemployment and migration questions (Artemyan, 2015). However, in small agricultural communities, it has been found that smallholder household members generally work on their farm don't have labour surplus to dedicate to non-farm works; but in larger agricultural communities as in China, it has been showed the non-negligible role of non-farm activities in income increasing, rural poverty reduction and work surplus absorption (Lewis, 1954). The observation has been the same in the case of Côte d'Ivoire, where the promotion of non-farm activities like beekeeping and snail breeding in the central west region has enabled cocoa farmer households to cope with eventual agricultural shocks (Iritié & Djaléga, 2016). The surplus of the number of rural poor giving the agriculture capacity and the inability of cities to offer suitable livelihoods conditions for rural migrants, remind the potentially significant role of rural non-farm activities in reducing poverty (Gordon et al., 2001). In fact non-farm activity may be relevant in the absorption of agricultural labour surplus, diversifying risks for farm-based households, and expanding income sources toward higher return activities (Ensor et al., 2014; Gordon et al., 2001).

Two types of effects are identified in the engagement in non-farm activities: short-term effects and long term effects. The short term effect on how the household deal with difficult times such as harvest shortfall or drought periods by using income from other activities to buy food and ensure the daily life. In the long term, several empirical evidences conclude to a positive on food security and also the reduction of income inequality especially when the income from activities that particularly favour the poor. However, results might be inconclusive if the richer is the one deriving greater benefit from non-farm activities than the poor, this fact is recurrent in the African context where the richer is the one deriving greater benefit from non-farm activities than the poor, involving entry barriers and segmentation of markets (Gordon et al., 2001; Lanjouwa, 2001).

It seems evident that income diversification contributes a lot to livelihood improvement of rural communities, however its success is also conditioned by the existence of a healthy and diversified rural economy. Such a climate provides as well off-farm work opportunities as services. To make this possible, rural projects and programmes have to be reframed or redesigned in such a way to integrate (especially for the poor / the farm and non-farm households) development policies since there is other ways out of agriculture to improve rural livelihood and allay rural poverty (Berjan et al., 2013; Gordon et al., 2001). Berjan et al. (2013) have suggested in the case of a study on Bosnia that the country requires, for a full exploiting of its economic diversification potential, an improvement of the rural governance, an enhancement of human capital of rural communities, a reinforcement of rural social, physical and financial capital without forgetting a favourable and enabling legal and legislative climate to promote farm activity diversification. In rural areas, non-farm activities are much linked with agricultural systems and the rural economy is likely to be viewed from an agricultural angle like farming is what matters and other activities are just residual activities. Foregoing discussion on the subject argue that this is wrong and that as well existing and, potential non-farm activities are to be considered as due especially in poverty reduction and adaptation to shocks perspectives (Ensor et al., 2014).

### **3.2.2 Climate change impacts and poverty**

Climate change and poverty have distinctly been objects of economic literature. Considered as complex problems, both are often accosted distinctly and no worthy attention has been drawn on the link between them. Though, it is crucial to appreciate the link between the two in order to set effective policy responses to climate change (Hertel & Rosch, 2010). As well as climate change is, from the past decades, at the core of most debates, poverty question has also received a particular attention mainly during the formulation of the Millennium Development Goal. Climate change can have a potential earning effect on poverty reduction via the market response to the climate change. Studies have merely focused on the negative effect of climate change on food availability and prices but seen from the angle of the producer, one can realize that higher food prices could involve higher incomes for producers, a then lead to a poverty reduction. This could be observed in regions less affected by the climate adverse effects, where poverty is mainly about agricultural populations and where a potential climate vagaries could boost the demand for unskilled labour for instance to replant fields. Additional complication arises due to the prevalence of non-priced goods in the consumption and income clusters of poor

households. The adverse effects of climate on publicly accessible forests and wildlife resources could have a significant negative impact on the poor who depend on them for fuelwood, food and other consumer products. In short, the consequences of climate change on poverty are much more nuanced than has been suggested in most discussions to date (Hertel & Rosch, 2010).

### **3.3.3 Determinants of poverty**

An analyse of the determinants of sustainable and transitional poverty in the Comoros has concluded that the level of poverty is the result of the way of mobilisation and return of multiple physical assets (material and human), which is controlled as well by markets, institutions and norm and values, and the probability to poverty increases with the size of the household (Lachaud, 2005). In the case of female-headed rural households in Benin Republic, results have shown that less educated heads' household are more exposed to poverty risks, when the age of the head or the household size have little effect on the probability to poverty, education plays therefore as fundamental role in rural poverty state (Attanasso, 2004).

Avom and Carmignani (2008), in a study covering 83 countries over the world have concluded that fighting against poverty in agricultural sector, and achieving a pro-poor development will pass through promotion of a financial system development, the control of inflation, the boost of agricultural productivity, the promotion of education, the development of energy infrastructure and the lessening of public expenditure for consumption. Delarue et al. (2009), and Cervantes-Godoy & Dewbre (2010) go in the same sense concerning the important role of the agricultural productivity. Delarue et al. (2009), using a Computable General Equilibrium Model (CGEM) have shown that reducing poverty among agricultural household in Mali would be largely effective, especially for the poorest if there is an increase of the agricultural productivity as the farmers consume a large part of their production. In turn, the analysis of Cervantes-Godoy & Dewbre (2010) was focused on twenty-five developing countries, where using panel data, they reach the conclusion that there is a strong correlation between the rate of increase in agricultural productivity and the rate at which poverty decreases. More the total factor productivity grows, more the poverty declines.

An analyse of the effects of the technical efficiency of agricultural households on their poverty status in Burkina Faso by a multidimensional approach of poverty has revealed that poverty, in the country is concentrated in rural areas affecting farm households much more. Their poverty state is affected by their technical efficiency. Considering cereal and groundnut croppers, the study has shown the positive effect of the technical efficiency on poverty reduction. Based on

such results, one can conclude that rural poverty reduction is not only about production increase but also the development of initiatives to improve the performance of crops (Noufé, 2020).

➤ **Approaches of poverty and measurements**

Clarifying the concepts of poverty and low income is essential from a policy perspective. The term is used by a number of institutions to differentiate, from other communities, communities which need particular attention and resources (Deonandan, 2019). Many definitions of poverty have been provided and its conception have varied over time and schools involving different assessments of the poor. Poverty is an annual income level beneath which an individual or a family is set (Krugman & Wells, 2016). For the utilitarian schools, the monetary aspect is very important in defining poverty while for other schools, poverty is a lack of means evaluated in terms ownership of essential goods (Noufé, 2020). Ravallion (1994) asserts that poverty means being unable to support the minimum needs that are judged reasonable by the norms within a giving society. So, one talks about poverty when a person does not have sufficient resources, especially material resources to satisfy his/her minimum needs, comprising social participation (Goulden et al., 2014). Poverty is related to inequalities but cannot be reduced to only in income inequalities (Sen, 1997). Poverty is a situation in which inequalities alienate some people from the social mainstream to the point where the deprivation they suffer pushes them below what are considered basic standards (United Nations, 2018).

Poverty is dynamic. In fact, resources as well as needs, generally have an inclination to rising and falling, and then, also the aptitude of people to get them. People can enter into and leave poverty over time, which can be momentary, recurring or persistent over longer periods of time and some people and groups are far more vulnerable than others (Goulden et al., 2014). Poverty can be analysed from several angles; in fact there is a *relative poverty* and an *absolute poverty*. The notion of *relative poverty* refers to a measure of poverty which defines it as being below a threshold computed from within the population of interest. The relatively poor is the person who has less wealth than other members of society. The threshold for the comparison can be, for example, set at the 60% of the population's median income, then, any person below that value is considered poor. This approach has the advantage to contextualize the poverty within a specific community but has the default of not accounting for actual levels of wealth and always designates a priori some members of the community as poor. As to the *absolute poverty*, it refers to a level of poverty related to the minimal condition required to afford a basic standard of living. An individual unable to achieve that minimal standard is considered facing deprivation and therefore poverty. The absolute poverty computation is done by defining a set

of necessities that constitutes the grocery basket (Deonandan, 2019). Within a society, the cost of minimum standard of living is function of the scope to which goods and services are furnished by the state or the market, of the social standards and of the general level of price of goods. This justifies the economic context, time and space-variant character of the poverty conception (Goulden et al., 2014) .

Poverty is seen as strictly economic state by ones, a condition of political vulnerability by some, and mainly as a measure of social class by others. If all of these conceptions are right, there are still not sufficient. Even if the vision of the poverty concept is, in a certain way, sufficiently clear in minds, its integration into a set of measurable indicators is still difficult, this leads to the emergence of several competing measures, each measure focus more on an aspect than another (Deonandan, 2019). The main approaches to poverty are the monetary approach, the non-monetary approaches and the multi-dimensional approach. The monetary approach is a neoclassical approach that defines poverty as the insufficiency of needed resources to ensure adequate consumption. It denotes an aspect of the standard of living (Ravallion, 1994). The non-monetary approaches allow to focus on other specific approaches of deprivation. The non-Monetary poverty approaches comprise basic needs approaches, capability approaches and multidimensional poverty (Townsend, 1979).

In practice, the measure of poverty is computed in terms of income or consumption poverty (United Nations, 2018). The monetary approach to poverty relies either on income or on consumption translated into monetary value as a measure of well-being, this comes to solve problem related to the alternative nature of utilities and the unfeasibility of their direct measurement (Noufé, 2020). A poverty line has to be defined, with two options: absolute needs which include the cost of a minimum food basket plus a ration for non-food basic needs; and relative needs based on the social standards that dominate a given society at a given time (United Nations, 2018). The poverty line set by the World Bank and widely used to measure absolute poverty is the Purchasing Power Parity (PPP) \$ 1.90/day (in 2011 prices) lines for extreme poverty, however, countries could choose to consider a different value to better fit to their realities (United Nations, 2018). Based on the Harmonized Survey on Living Conditions of Households in Benin (EHCVM 2019), the annual global poverty line is estimated at 246,542 FCFA income per capita of the household, which threshold is used here (Institut National de la Statistique et de l'Analyse Économique (INSAE), 2022). As well for practical as conceptual reasons, the unit of observation that would be considered in income or consumption data collection is the household. In fact, it comes non-practical and costly to get detailed data from

each member of the household or to assign economic flow to a single member within the household. Although the fact that the levels of income or consumption are measured at the household level, poverty data have to be reported at the individual level for poverty is experienced by individuals (United Nations, 2018).

### **3.3 Materials and methods**

#### **3.3.1 Data**

To analyse the effect of off-farm activities as climate change adaption strategy among maize and cassava farmers in Central Benin. Primary cross-sectional data collection had been performed in the study area (see *Appendix 1* and *Figure 1*). The data collection covered the Collines Region of central Benin, that region accounts 6 communes and belong to the of the development pole 4 of the Territorial Agency for Agricultural Development (ATDA). The sample size was constituted with the Schwartz formula, thanks to the support of the book of villages and districts of Collines Region in Benin (MPD & INSAE, 2016), that provided needed information of the different crops' farmers population size in the region . Once the 420 farm households sample size defined (see sampling in *Appendix 2*), we rely on the recommendations of the ATDA specialists in the Region to sample appropriate villages in each of the six communes, this contingent upon their weight in terms of cassava and maize growing. Afterwards, the sample is proportionally distributed within the 24 villages where households are finally randomly selected for the survey.

Through structured interviews, semi-structured interviews, and focus group, the data collected provided both qualitative and quantitative information on the last three years (period of 2019-2021) related to the farm household, its head and its farm. Only the last three years are considered with a view to the accuracy of the data collected. If questions go farer in the past, it could be harder for a farmer to remind with accuracy details about his /her production. Apart from socio-demographic features of the farmer and his/her household such as age, sex, instruction level, marital status, household size, number of inactive members, the existence or not of an off-farm activities, the farmer was also asked for each last three years to provide specific information. The respondents furnished information for the farm size; and for each culture, the yield, the income, the cost of labour, fertilizer and any expenses by year, the income from any other income source for each year and also the income from other production units of

the household). Information about cultivation practices and their source of information regarding climate change, the access to credit or market, a cooperative membership, the perception of the farmer on climate change... were also given. Respondents are farm households, with their head engaged or not in another income-generating activity as a climate change adaptation.

Climate data on the last ten years about temperature and rainfall are also exploited in order to understand weather farmers relies on change their observed to make decision towards climate change adaptation strategies and also observe the effects that climate variables could have on the targeted outcome. The data are provided by the Daily Global Historical Climatology Network version of 3.29 found with the United States National Oceanic and Atmospheric Administration (NOAA) Climatic Data Center (Menne, Durre, Korzeniewski, et al., 2012; Menne, Durre, Vose, et al., 2012). The climate data account for the last ten years prior to the analyse (2012-2021). They are daily data on each sampled village and we respectively computed the average annual temperature and the average annual total rainfall for each of the 24 villages, considering separately each of the 4 seasons observed per year in the region. On the operation done, values are affected to the individuals according to their village. STATA software is used for the analyses.

### **3.3.2 Model of the study**

The treatment variable of this study is the participation of the farm household in off-farm activities source of income over last year before the survey. It is a binary variable which takes the value of 1 if the head of the farm household has participated and the value 0 if not. The outcome variable is the poverty state which is a binary variable too: 1 for households below the poverty threshold defined and 0 for those beyond the threshold. An approach to assess the effect of the off-farm activities participation on the poverty would be to run a linear regression of the variable related to off-farm activities participation, on the variable of poverty, with a set of control variables. However, such a approach might induce a bias since the decision by the farmer to engage into off-farm activities as a climate change adaptation is possibly endogenous. The the decision of adaptation may have been taken based on an expected benefit from it. Also the group of participant could have different features from the group of non-participants; features that could be observable or not and could affect as well the adaptation decision as the poverty state of the households (Hausman, 1978). Therefore, using an Ordinary Least Square (OLS) method in this

case may imply biased parameters. To work around the issue, instrument variables are identified, with them, some control variables to account for the endogeneity of the off-farm activity engagement (Lokshin & Sajaia, 2011). The model used is the Endogenous Switching Probit (ESP). The ESP estimates the casual effect of the interest variable (here the off-farm activities engagement of households) on the outcome binary variable (Poverty). The ESP regression, is an appropriate model to fix endogeneity issues in regressions with a binary outcome. It has the advantage to account for self-selection, endogeneity issues and unobservable characteristics while estimating the parameters. Also, compared to the propensity score matching method, the ESP constructs counterfactuals on the basis of returns to characteristics of the two groups (Lokshin & Sajaia, 2011).

### **3.3.1.1 Model of the engagement into off-farm activities**

The ability to engage into the different types of activities, as well farm activities as non-farm activities is driven by the assets available to the farmer ( the bunch of different types of capital human, financial, social, physical or natural for each individual or household ) (Ensor et al., 2014). Another driver of the decision to engage into off-farm activities could be the perception of the farmer of the effect of climate change on his production. Indeed, the farmers who undertake such activities are the ones who perceive changes in rainfall patterns, changes which negatively affect their agricultural activity. Then, undertaking off-farm jobs comes as risk-reducing strategy to cope with the climate change (Oppong-Kyeremeh & Bannor, 2018). Additional factors identified as influencing off-farm activity participation are the level of education, the type of the production system (rain fed or irrigation system), the age, the land size, the productivity (Oppong-Kyeremeh & Bannor, 2018).

Let  $T^*$  be a variable that captures the expected benefits from the engagement into off-farm activities compared to non-engagement into off-farm activities; indeed, the farmer would undertake an off-farm activity only if he/her can get some advantages from it.

$$(2.1) \quad T_i^* = Y_i \delta + \mu_i \quad \text{With} \quad T_i = \begin{cases} 1 & \text{if } T_i^* > 0 \\ 0 & \text{if } T_i^* < 0 \end{cases}$$

$Y$  is the  $(n \times m)$  matrix of variables which explain the decision of adaptation or not

$\delta$  is the  $(1, \dots, m)$  vector of model parameters to be estimated,

$\mu$  is an  $n \times 1$  vector of error terms.  $\mu$  follows a normal distribution with mean equal to zero

$Y$  represents the factors which determine the expected benefits of off-farm activities. Based on the existing literature, these variables are the level of education, the type of the production system (rain fed or irrigation system), the age, the land size, the farm's soil biophysical characteristics, the property right, the productivity, the climate perception, the access to credit and market.

### 3.3.1.2 The computation of the household poverty level

- **Compute the level of disposable Income per capita for each household for each of the last three years and compute the average income per capita for the last three years.** The annual disposable income for a household is computed by summing up its income from agricultural production minus the charge involved by the production, and the income provided by all other revenue source whether para-agricultural or non-agricultural, labour wage, transfers, permanent or seasonal income.... For a given household, all the units of production that are part of the household are considered. The value of annual income is then divided into the number of person in the household to get the income per capita of the household.
- **Compute the variable poverty** which expresses the poverty state (poor or not) for each household during the last three years. The line used is the national poverty line which is estimated to 246,542 FCFA per person by year.

### 3.3.1.3 Estimation of the impact of off-farm activities on the monetary poverty:

#### Switch-Probit regression

The outcome equation (poverty) is switched into two. Each group (participants group and non-participants group) with its regression in order to capture the potential effects of the unobservable factors among individuals. The ESP implements a Maximum likelihood method to estimate parameters of binary choice models with endogenous regressors. It estimates simultaneously the selection equation and the binary outcome equation. The error terms are assumed to follow the normal distribution.

1<sup>st</sup> regime: farm households engaged into off-farm activities as adaptation strategy

$$(2.2) \quad p_{1i} = X_{1i}\alpha_1 + \nu_{1i} \quad \text{if } T_i = 1$$

2<sup>nd</sup> regime: farm households not engaged into off-farm activities

$$(2.3) \quad p_{2i} = X_{2i}\alpha_2 + \nu_{2i} \quad \text{if } T_i = 0$$

$p_i$  represents the poverty condition (poor or not)

$X_i$  is a vector of variables related to the characteristics of the household and the cultivation conditions (belonging to a farmer's cooperation, access to market, access to finance...).

$\alpha_i$  is the estimated parameter of the impact of off-farm activities on Poverty state of the farm household.

The error terms of three equations are assumed to follow a trivariate normal distribution, with zero mean and covariance matrix  $\Omega$ , i.e.,  $(\mu_i, v_{1i}, v_{2i})' \sim N(\mathbf{0}, \Omega)$

$$\Omega = \begin{bmatrix} \sigma_\mu^2 & \sigma_{\mu 1} & \sigma_{\mu 2} \\ \sigma_{1\mu} & \sigma_1^2 & \cdot \\ \sigma_{2\mu} & \cdot & \sigma_2^2 \end{bmatrix} \text{ with } \sigma_\mu, \sigma_1^2 \text{ and } \sigma_2^2 \text{ the variance of the error term in the selection}$$

equation (2.1) and the production equations (2.2) and (2.3).  $\sigma_\eta^2$  is assumed equal to 1 as the coefficients are estimable only up to a scale factor (Lokshin & Sajaia, 2011)

$\sigma_{i\mu}$  is the covariance of the error term in the selection equation with each error term in ( ) and ( ). In the same, the covariance between  $v_{1i}$  of ( ) and  $v_{2i}$  of ( ), is not defined since the two situations are not observed simultaneously. We assume that  $\sigma_{12} = 1$  ( $\delta$  is estimable only up to a scalar factor)

$\mu_i$ , is correlated to  $v_{1i}$  and  $v_{2i}$  due to the omitted variables and unobservable factors that are not accounted in the selection equation. So, the expected values of  $v_{1i}$  and  $v_{2i}$  conditional on the sample selection are different from zero.

The log-likelihood function for the simultaneous system of equations [( )-( )] is given by (Lokshin & Sajaia, 2011):

$$\begin{aligned} \ln(L(X_i, Y_i, \alpha, \delta, \sigma)) = & \sum_{T_i \neq 0, P_i \neq 0} \omega_i \ln \{ \Phi_2(X_{1i}\alpha_1, Y_i\delta, \sigma_{\mu 2}) \} \\ & + \sum_{T_i \neq 0, P_i = 0} \omega_i \ln \{ \Phi_2(-X_{1i}\alpha_1, Y_i\delta, -\sigma_{\mu 2}) \} \\ & + \sum_{T_i = 0, P_i \neq 0} \omega_i \ln \{ \Phi_2(X_{0i}\alpha_0, -Y_i\delta, -\sigma_{\mu 1}) \} \end{aligned}$$

$$+ \sum_{T_i=0, P_i \neq 0} \omega_i \ln \left\{ \Phi_2(-X_{0i}\alpha_0, -Y_i\delta, \sigma_{\mu 1}) \right\}$$

$\Phi_2$  represents the cumulative function of a bivariate normal distribution  $\omega_i$  is a chosen weight affected to the observation  $i$ . The maximum likelihood estimates the  $\text{atanh}(\sigma)$ :

$$\text{atanh } \sigma_j = \frac{1}{2} \ln \left( \frac{1 + \sigma_j}{1 - \sigma_j} \right) \quad j=0,1$$

The parameters of the model estimated, the following statistics are derived (Heckman et al., 2001). The switch probit command allow to compute the average and marginal effects of the treatment on the treated and the untreated (Lokshin & Sajaia, 2011).

### Treatment effects

$F$  designs the cumulative function of the univariate normal distribution.

- The expected effect of the treatment on the treated individuals with observed characteristics  $x$ :

$$\begin{aligned} TT(x) &= \Pr(P_1 = 1 | T = 1) - \Pr(P_0 = 1 | T = 0) \\ &= \frac{\Phi_2(X_1\alpha_1, y\delta, \sigma_{\mu 2}) - \Phi_2(X_0\alpha_0, y\delta, \sigma_{\mu 1})}{F(y\delta)} \end{aligned}$$

- The expected effect of the treatment on the untreated individuals with observed characteristics  $x$  (TU):

$$\begin{aligned} TU(x) &= \Pr(P_1 = 1 | T = 0) - \Pr(P_0 = 1 | T = 0) \\ &= \frac{\Phi_2(X_1\alpha_1, -y\delta, -\sigma_{\mu 2}) - \Phi_2(X_0\alpha_0, -y\delta, -\sigma_{\mu 1})}{F(-y\delta)} \end{aligned}$$

- The expected effect of the treatment on a randomly selected individual from the population with observed characteristics  $x$  (TE):

$$TE(x) = \Pr(T = 1) - \Pr(T = 0) = F(X_1\alpha_1) - F(X_0\alpha_0)$$

- The effect of the treatment on a randomly selected individual from the population with observed characteristics  $x$  and unobserved characteristics  $\mu$ : (MTE):

$$MTE(x, \bar{\mu}) = \Pr(T = 1 / X = x, \mu = \bar{\mu}) - \Pr(T = 0 / X = x, \mu = \bar{\mu})$$

$$= F\left(\frac{X_1\alpha_1 + \sigma_{\mu 2}\bar{\mu}}{\sqrt{1 - \sigma^2_{\mu 2}}}\right) - F\left(\frac{X_0\alpha_0 + \sigma_{\mu 1}\bar{\mu}}{\sqrt{1 - \sigma^2_{\mu 1}}}\right)$$

The respective average treatments ATT, ATU, and ATE, respectively corresponding to the treated, untreated, and randomly selected individuals from the population are obtained by averaging the treatment effects computed for each subgroup

The statistical significance of  $\sigma_{1,\mu}$  and  $\sigma_{2,\mu}$  would mean that there is a correlation between the decision of engagement into off-farm activities and the poverty condition of the farm household. Hence, the evidence of the endogenous switching regression and the rejection of the null hypothesis that absence of sample selectivity bias (Maddala & Nelson (1975) cited in Endrisis et al. (2021)).

### 3.3.3 Variables of the model

(un petit paragraphe sur le choix des variables)

**Table 3-1 Measurement of the variables**

Variables	Measurement	Expected sign on poverty
<i>Dependent variables</i>		
Off-farm activity source of income	1 if yes , 0 otherwise	
Probbility to poverty	1 if poor , 0 otherwise	
<i>Explanatory variables</i>		
<i>Climate variables</i>		
Longer rainy seasons total précipitations during the last 10 years	continuous	
Shorter rainy seasons total précipitations during the last 10 years	continuous	
Average temperature during the 10 last years	continuous	
<i>Social characteristics of the farm household</i>		
Age	continuous	+

*IMPACT OF CLIMATE CHANGE ADAPTATION STRATEGIES WITHIN AGRICULTURAL COMMUNITIES IN  
CENTRAL BENIN REPUBLIC*

Literacy	continuous	+
	1 if male , 0	
Sex	otherwise	+/-
Marital status		
Proportion of household inactive members	continuous	+
Number of off-farm activities	continuous	-
Flood experience	1 if yes , 0 otherwise	-
Access to credit	1 if yes , 0 otherwise	-
Experience in agriculture	continuous	-
Animal Traction	1 if yes , 0 otherwise	-
Access to market (road passability)	1 if yes , 0 otherwise	-
 <b><i>Farm income</i></b>		
Head's agricultural incom in year_1	continuous	-
Head's non-agricultural incom in year_1	continuous	-
 <b><i>Instruments</i></b>		
Government extension		
neighborhood information		
Own Climate experience		
Cooperative		
Farm income year-1		
Non-farm income year-1		

---

### 3.4 Results

#### 3.4.1 Descriptive statistics

**Table 3-2 Tendency in the variables of the model**

Variables	Total sample		Off-farm activity engagers		Off-farm activity non-engagers	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Longer rainy seasons total précipitations during the last 10 years	5855.596	672.545	5755.118	640.430	5902.462	683.066
Shorter rainy seasons total précipitations during the last 10 years	925.942	90.507	927.902	88.174	925.027	91.714
Average temperature during the 10 last years	28.770	0.102	28.783	0.102	28.764	0.103
Age	43.680	11.621	41.803	10.649	44.555	11.965
Literacy	0.289	0.454	0.356	0.481	0.258	0.438
Sex	0.952	0.214	0.917	0.277	0.968	0.176
Marital status	0.925	0.263	0.894	0.309	0.940	0.238
Proportion of household inactive members	0.726	0.176	0.712	0.161	0.733	0.182
Number of off-farm activities	0.361	0.593	1.136	0.475	0	0
Flood experience	0.470	0.500	0.500	0.502	0.456	0.499
Access to credit	0.388	0.488	0.394	0.490	0.385	0.487
Experience in agriculture	19.414	11.047	17.174	9.905	20.459	11.408
Animal Traction	0.007	0.085	0.023	0.150	0	0
Access to market (road passability)	0.554	0.498	0.508	0.502	0.576	0.495
Government extension	0.311	0.463	0.235	0.426	0.346	0.477
neighborhood information	0.227	0.419	0.212	0.410	0.233	0.424
Own Climate experience	0.275	0.447	0.288	0.454	0.269	0.444
Farmers Cooperative	0.246	0.431	0.311	0.465	0.216	0.412
Farm income year-1	1529873	2310921	1228747	1730472	1670328	2527208
Non-farm income year-1	225785	445301	285068	327082	198134	488878
Poverty state	0.675	0.469	0.689	0.465	0.668	0.472
Sample size	415	-	132	-	283	-

The table 3-2 reports the descriptive statistics of the variables of the model. The average values of the climate variables during the last ten years shows that even if the two groups of farmers experience the climate change almost the same way, the group of those who undertake off-farm activities engagers seems a bit more disadvantaged with the climate than the other group. The engagers are younger, more literate and have less inactive members in their household. They are less experienced in agriculture and have slightly more access to credit compared to the other group, certainly because they are more found in farmers cooperatives. However, the group of non-adapters have more access to market, less experienced flood in their farm and earn more income from agriculture compared to the other group. The non-farm income of the engagers is in average higher than the one of the non-engagers, the latter could also have non-farm income from other source even if they did not engage in other activity as a strategy of climate change adaptation. Engagers are engaged in average in more than one off-farm activity and are in average less poor than the other group. The *Appendix 4* show an overview of off-farm activities observed in the sample and percentage among respondents.

### 3.4.2 Estimation of endogenous switching model of the engagement into off-farm activities of poverty state

**Table 3-3 Results of switch probit regression**

<b>Dependent variables</b>	<b>Probit Regression</b>	<b>Determinants of the engagement into off-farm activities</b>	<b>Households having off- farm activity (T=1)</b>	<b>Households without off- farm activity (T=0)</b>
<i>Climate variables</i>				
Longer rainy seasons total précipitations during the last 10 years	-0.001*** (0.000)		-0.001*** (0.000)	-0.000* (0.000)
Shorter rainy seasons total précipitations during the last 10 years	-0.003*** (0.001)		-0.000 (0.001)	-0.004*** (0.001)
Average temperature during the 10 last years	-2.938** (1.487)		-3.940*** (1.184)	-1.879 (1.602)
<i>Social characteristics of the farm household</i>				
Age	-0.013 (0.009)	0.002 (0.010)	-0.001 (0.012)	-0.026** (0.011)
Literacy	-0.255 (0.155)	0.066 (0.165)	0.178 (0.211)	-0.306* (0.180)
Sex	-0.130 (0.367)	0.010 (0.358)	-0.597 (0.448)	-0.009 (0.422)
Marital status	-0.192 (0.307)	-0.516* (0.307)	-0.254 (0.398)	-0.145 (0.340)
Proportion of household inactive members	1.929*** (0.450)	-0.180 (0.442)	1.511*** (0.514)	1.642*** (0.503)
Number of off-farm activities	-0.170 (0.269)		-0.152 (0.191)	
Flood experience	0.366*** (0.141)	0.334** (0.150)	0.496*** (0.174)	0.211 (0.155)
Access to credit	-0.399*** (0.143)	-0.135 (0.154)	-0.524*** (0.170)	-0.274* (0.162)
Experience in agriculture	0.007 (0.010)	-0.018* (0.011)	-0.006 (0.013)	0.014 (0.012)
Animal Traction	-0.091 (0.767)	7.697 (1327493.704)	0.775 (0.782)	
Access to market (road passability)	0.204 (0.144)	-0.031 (0.155)	0.193 (0.176)	-0.107 (0.162)
<i>Instruments</i>				
Government extension		-0.349** (0.172)		
neighborhood information		0.017 (0.148)		
Own Climate experience		0.003		

*IMPACT OF CLIMATE CHANGE ADAPTATION STRATEGIES WITHIN AGRICULTURAL COMMUNITIES IN  
CENTRAL BENIN REPUBLIC*

			(0.154)	
Cooperative			0.275*	
			(0.156)	
Farm income year-1			0.099**	
			(0.040)	
Non-farm income year-1			0.136***	
			(0.014)	
Adaptation (Engagement into Off-Farm activities)	0.275			
	(0.339)			
<b>Constant</b>				
	91.012**	-2.196***	117.559***	60.701
	(44.192)	(0.741)	(35.438)	(47.664)
$\rho_i$			12.953	1.455
			(397.833)	(0.894)

Note: \*Significant at the 10% level; \*\*Significant at the 5% level; \*\*\*Significant at the 1% level.

(.) Robust standard errors

$\sigma_i$ , square-root of the variance of the error terms in the respective outcome equations;

$\rho_j$ , the correlation coefficient between the error term of the selection equation and the respective error terms of the outcome equations.

The first column of the table 3-3, show the results of the Probit regression of off-farm activities as climate change adaptation strategy on poverty. With the Probit, the engagement into off-farm activity does not have a significant effect on the poverty variable of households. The determinants of poverty state of households are the climate variables, the number of inactive members of the household, flood experience in the farm and the access to credit. The results show that favourable climate conditions does not push farmers to engage in other activity, they don't really feel the need. And more there is inactive members in a household, more that household tends to be poorer, it is the same for the households that have experienced flood in their farm. Contrary, the access to credit has a positive effect on poverty reduction of the household.

The three last columns show the results of the endogenous switching regression. Factors affecting in a significant way the decision of the engagement into off-farm activities as climate change adaptation option among farm households are the marital status, the experience of flood, the number of years in agriculture and the instruments variables that are the relying on information provided by extension services, the belonging to farmers' cooperatives and the respective incomes from farm and non-farm sources. The bad experience of flooding in their farm leads the farmers to get into such adaptation option. The positive relationship between the farmers 'different incomes and off-farm activities shows that a lack of financial resources could

sometimes be an hindrance for a farmer who would like to undertake another activity apart from agriculture, especially when that activity needs a capital.

Analysing the factors that influence the outcome variable, the poverty variable of the households, it appears that within both groups, the variable that significantly and positively affects their monetary poverty is the proportion of inactive members in the household which is a dependency ratio and the occurrence of flood on the farm during the last three years, that finding is an evidence since more there is inactive members in a household, more the income by head of that household is reduced. In the group of engagers, the poverty state is also positively affected by the occurrence of flood in the farm. The occurrence of flood on the farm during the last three years weakens the living conditions of the household for it implies the destruction of crops, this leads the producer to heavy losses, thus worsening the financial situation of the household. The variables that negatively affect poverty variable in the two groups are climate variables and the access to credit, when it rains conveniently with favourable temperatures in dry seasons, the farm incomes improves and then the living conditions of the farmers. The access to credit is once again proving its importance, it helps not only to improve the farm assets and cultivation technics but also undertake other activities sources of income for them, especially with the occurrence of climate adverse effects on the farming. Finance facilities could therefore be an important instruments, helping farm households getting out of poverty. In the group of non-engagers, other factors that negatively affect the poverty variable are socio-economic variables that are the age of the head of the household and his/her instruction level.

### 3.4.3 Computation of the effects of off-farm activities on monetary poverty

**Table 0-1 Effects of off-farm activities**

<b>Effects</b>	<b>Mean</b>	<b>Standard error</b>
<b>Treatment effect on the treated (TT)</b>	-0.240	0.237
<b>Treatment effect on the untreated (TU)</b>	-0.406	0.201
<b>Treatment effect (TE)</b>	-0.352	0.163
<b>Marginal treatment effect MTE</b>	-0.736	0.173

The table presents the average treatment effects (TT), (TU) and (TE) representing respectively the expected poverty state among households that have associated off-farm activities to their agriculture, households that did not and the average effect of the adaptation on an individual taken randomly. The treatment effect on poverty among adapters is in average of -0.24 while of -0.41 among non-adapters if they had adapted the same strategy. The off-farm activities engagement as adaptation strategy seemingly has a generally positive effect on both groups. And people who did not adopt the same strategy are still the one who would profit the most from it. It would be important here to understand the reasons why they unfortunately did not engage into off-farm activities. Since the Probit regression and the selection equation does not reveal such factors, this could be explained the by existence of some non-observable characteristics specific to each group. Possibly, adapters have some non-observable characteristics that favour their engagement in other activities. The group of adapters, could have been, from the beginning the group who actually needed the most to associate non-farm activities to their agricultural activity in order to overcome adverse effects of climate change on their farm activities. Because we see that even with the positive effect of adaptation on their income, they still do not reach yet the average income level of non-adapters.

For those who did not engage, apart from the financial question that constitute a huge hindrance for some farmers, it would fit to investigate what other facts could have discouraged or disadvantaged them from undertaking off-farm activities. Even if the descriptive statistics have showed that they are in average less poor than engagers, their situation is still not satisfying with respect to the financial living standard, for this study to conclude that they did not engage

because they did not need it. The hypothesis are: because they feel satisfied of their farm; they are quite enough busy to associate other activity to what they are already doing; they do not have the financial means to undertake other activity and find a loan would be for them like a vicious circle from which they cannot escape; another activity would require them to invest more time to the detriment of their agricultural activity whereas that other activity would not bring them as much as agriculture anyway. The average effect of the treatment TE for the whole sample is of -0.352 (more than what is observed for adapters only). That implies that it would be very meaningful for poverty reduction, to support non-adapters in a way they could, them too, associate other activity to their farming.

### **3.5 Conclusion**

This chapter analyses the impact of the engagement into off-farm activities as climate change adaptation strategy on the monetary poverty state among maize and cassava farmers in the central region of Benin Republic. The results suggest that the decision of adaptation is driven by the household income, flood experience, number of years experienced in agriculture and cooperative membership. The number of production units in the household (dependency ratio) is a factor that reduces the probability of off-farm activity as more production units implies more income sources for the household. Several factors influence the monetary poverty situation of the sampled households. The climate variables are significant in that. Other elements that would deepen the monetary poverty are the dependency ratio of the household and the flood experience, the latter is exclusively for the group of adapters. Many factors favour a better financial condition for surveyed households, those factors are the access to credit (both groups), the age and the instruction level.

The treatment (engagement into off-farm activities) has a profit to both groups of adapters and non-adapters, with a higher effect on non-adapters. The study concludes to the existence of some non-observable other determinants of the adaptation different from variables revealed by the equation on the determinants from adaptation. This attests the importance of the consideration of specific and non-observable characteristics of each group of individuals to better guide farmers' decisions in adaptation. In most cases, very poor and disadvantaged households are unable to undertake off-farm activities due as well to a lack of financial means as to a lack of minimum skills needed to start a business. Thus, they in low-income non-farm micro-activities that are generally insufficient to lift them out of poverty (Artemyan, 2015). Understanding the features of the population could promote the implementation of personalized policies, taking into account important parameters for each specific group of individuals and thus allowing a better achievement of the target indicator. A further study perspective would be to investigate which of non-agricultural or para-agricultural activities could be the most recommended in terms of accessibility and benefits for producers who want to engage in secondary activities as an adaptation to the adverse effects of climate change on agriculture. While this study has focused on monetary poverty, it is also important not to forget the multi-dimensional dimension of poverty, as research always has to consider the edges of poverty as far as possible. Since poverty is a concept, its monetary and non-monetary aspects such as food quality; health or education aspects are equally important for improving the level of well-being of agricultural households and for the development of the country.

## **CONCLUSION**

Climate change is a worldwide threat with variable effects depending on the regions. Benin Republic is not spared by the manifestations of the climate change and its adverse effects on the agricultural sector, especially with the decrease in yield, the threat of famine and the deterioration in the livelihood of smallholder producers. Coping measures in communities are function of their degree of exposure and vulnerability but also of their capacities in terms of economical assets, financial situation and social environment (Ajilogba & Walker, 2021). In a context where efforts to achieve SDGs are shared, especially in developing countries; the consideration of climate change adaptation measures in the agricultural sector; would greatly help in reaching the objectives related poverty and hunger. This thesis examined the impact of climate change adaptation strategies put in place by communities of maize and cassava producers in the central Benin region. It was discussed to see the impact of the adoption of improved varieties, the involvement in non-agricultural activities and the modification of the crop calendar respectively on agricultural yield, the reduction of monetary poverty and agricultural diversification. The study focusing on these crops in particular because of their place in the diet of nationals and their weight in local agriculture. With cross-sectional primary data collected, the approach used accounted for the probable endogenous character of the adaptation decision. Numerous are farmers who perceive the decreasing rainfall, the extreme heat, the bad distribution of rain in time and space, the shortening the duration of the rainy season, the early cessation of rains..., as manifestations of climate change, endangering some crops, which with the time, would risk disappearing from the region.

We found that a farmer's decision to engage in a given climate change adaptation strategy is motivated by a number of factors that may be observable or not. These factors include changes during the recent years in climatic variables, the way the information about adaptation comes to the farmers, the socio-economic characteristics of the household and its farm and also by some non-observable variables or situations. Changes in climate features observed by farmers over the last ten years, relatively quantified by average total rainfall by season and the average temperature by season, have a general impact on the behaviour of producers relative to their decision and their choices in terms of adaptation. As regards the socio-economic characteristics of the household and the farm, they are mainly the literacy level, the sex, the marital status, the land ownership, the farmer cooperative membership, the soil fertility, the access to credit, the household income, and the access to market...The farmers did not respond the same way for

each of the adaptation strategies. If climate factors and the information factors play a certain role of the adaptation decisions, a socio-economic factors may intervene for a given adaptation option but not for another one. Then, climate change adaptation in agriculture generally speaking, has its drivers and now, adaptation options, taken separately have also their own drivers and this is one of the most important results from this study. The adaptation strategies considered in this study have, from a global perspective, a positive and significant effect on the communities studied. But the effects do not have exactly the same extent from a group of farmer to another. In the cases of the use of maize improved seed and the engagement into off-farm activities, the results suggested that adaptation would have been extremely beneficial for producers who did not adapt; but unfortunately those groups did not adapt. This confirms the presence of heterogeneity factors between the two groups and the endogeneity of the adaptation decision. If information sources, cooperative membership, climate experienced, access to credit or to market, farm and non-farm incomes variables certainly allow to understand who the adaptation decision is made, there is a part of the determinants that are still not really discerned. They are the non-observable factors. However, the use of the endogenous switching regression models in this thesis has permit to eliminate bias that those unobservable factors could induce in the analysis. Since those factors could not be directly identified. Adaption has therefore to be shaped for specific needs for farmers, taking into account diversity and heterogeneity among farmers and also specificities of some group of farmers among a whole community.

The enquiry among the communities has showed that if some farmers are not yet really opened to novelties in their farming practices, other farmers do no engage into adaptation because of lack of financial resources. Also, adaptation has not; in some cases; led to the expected extend for the outcome, because in practice, it is not performed as due. It does not suffice to perform adaptation, but to perform it in a good way. For the case of maize improved seeds adapters for instance, the field work has revealed that instead of buying at each season new improved seeds to plant, some farmers just use de maize crops from the last harvest provided by improved seed of the previous season. Yet, the improved seeds, because they have been modified in order to provide a certain property, they have to be renewed, what is not systematically the case. One thing is the intention of adaptation and another is the affordability of adaptation or the existence of necessary means to set up the intended adaptation option. If the advantages of adaptation are object of consensus, the resources for achieving a certain level of climate change adaptation for a low income country like Benin Republic is a non-negligible question.

An evidence of this study is that, in the study area, the agriculture is exclusively rain-fed. The development of irrigation systems for producers, at an affordable price, would be a great relief for them and for the entire population. The introduction of further technology in the practice of agriculture would be a step forward for Benin's agriculture, which, in many respects, needs it. Social-type resolutions, in the agricultural system, targeting female heads of households in the community and the most disadvantaged producers are needed for more equity and for more inclusive outcomes. The exercise of this thesis are to be renewed because not all type of adaptation fit to every farmers. Adaption have to be customized depending on the study area, the needs of each farm, and the features of each farmer... A prior step to adaptation strategies implementation is to conduct studies based on the needs and the characteristics of the area of interest, the culture, the mind-set, the assets, and the probable hindrances. The use of cross-sectional data in this study may constitute a limit, as a follow-up of farmers in the time (panel data) time it could have been pertinent in order to draw even more consistent and evident conclusions in terms of drivers of adaptation options and the outcome derived from such options, and even the time-horizon of the options' effect. Then, it sounds interesting with future studies, using to panel data, to focus on understanding farmers' behaviours towards climate change adaptation and to better handle their differences, especially in unobservable factors are from now on required. This in a view to better perform agricultural climate adaptation in the region.

## BIBLIOGRAPHY

- Abdalla, S., Leonhäuser, I., Bauer, S., & Elamin, E. (2013). Factors influencing crop diversity in dry land sector of Sudan. *Sky J Agric Res.*, 2, 88-97.
- Abebe, T. (2013). *Determinants of crop diversity and composition in Enset-coffee agroforestry homegardens of Southern Ethiopia*. <https://kobra.uni-kassel.de/handle/123456789/2013030542580>
- Adego, T., Simane, B., & Woldie, G. A. (2019). The impact of adaptation practices on crop productivity in northwest Ethiopia : An endogenous switching estimation. *Development Studies Research*, 6(1), 129-141. <https://doi.org/10.1080/21665095.2019.1678186>
- Adjimoti, G. O., & Kwadzo, G. T.-M. (2018). Crop diversification and household food security status : Evidence from rural Benin. *Agriculture & Food Security*, 7(1), 82. <https://doi.org/10.1186/s40066-018-0233-x>
- Adjimoti, G. O., Kwadzo, G. T.-M., Sarpong, D. B., & Onumah, E. E. (2017). Input Policies and Crop Diversification : Evidence from the Collines Region in Benin. *African Development Review*, 29(3), 512-523. <https://doi.org/10.1111/1467-8268.12286>
- Adzawla, W., & Alhassan, H. (2021). Effects of climate adaptation on technical efficiency of maize production in Northern Ghana. *Agricultural and Food Economics*, 9(1), 14. <https://doi.org/10.1186/s40100-021-00183-7>
- Amare, M., & Waibel, H. (2014). *Climate Variability, Shocks and Non-farm Employment : Evidence from Rural Households in Northeast Thailand*. 24.
- Artemyan, M. (2015). *SIGNIFICANCE OF RURAL NON-FARM ACTIVITY IN DEVELOPMENT The Case of Tavush, Republic of Armenia*. 50.
- Aryal, J. P., Sapkota, T. B., Rahut, D. B., Marenja, P., & Stirling, C. M. (2021). Climate risks and adaptation strategies of farmers in East Africa and South Asia. *Scientific Reports*, 11(1), 10489. <https://doi.org/10.1038/s41598-021-89391-1>
- Asfaw, S., McCarty, N., Lipper, L., Arslan, A., & Cattaneo, A. (2013). *144- Adaptation to Climate Change and Food Security : Micro-evidence from Malawi*. 29.
- Attanasso, M.-O. (2004). Analyse des déterminants de la pauvreté monétaire des femmes chefs de ménage au Bénin. *Mondes en développement*, 128(4), 41. <https://doi.org/10.3917/med.128.0041>

- Atube, F., Malinga, G. M., Nyeko, M., Okello, D. M., Alarakol, S. P., & Okello-Uma, I. (2021). Determinants of smallholder farmers' adaptation strategies to the effects of climate change : Evidence from northern Uganda. *Agriculture & Food Security, 10*(1), 6. <https://doi.org/10.1186/s40066-020-00279-1>
- Avom, D., & Carmignani, F. (2008). Pauvreté, croissance et redistribution. *Revue française d'économie, 23*(1), 89-116. <https://doi.org/10.3406/rfeco.2008.1661>
- Barman, A., Saha, P., Patel, S., & Bera, A. (2022). Crop Diversification an Effective Strategy for Sustainable Agriculture Development. In *Sustainable Crop Production—Recent Advances*. IntechOpen. <https://doi.org/10.5772/intechopen.102635>
- Bedeke, S., Vanhove, W., Wordofa, M., Natarajan, K., & Van Damme, P. (2018). Perception of and response to climate change by maize-dependent smallholders. *Climate Research, 75*(3), 261-275. <https://doi.org/10.3354/cr01524>
- Benin, S., Smale, M., Pender, J., Gebremedhin, B., & Ehui, S. (2004). The economic determinants of cereal crop diversity on farms in the Ethiopian highlands. *Agricultural Economics, 31*(2), 197-208. <https://doi.org/10.1016/j.agecon.2004.09.007>
- Berdegú, J. A., & Escobar, G. (2000). *Rural diversity, agricultural innovation policies and poverty reduction*. [http://www.laolink.org/Literature/agrenpaper\\_122.pdf](http://www.laolink.org/Literature/agrenpaper_122.pdf)
- Berjan, S., Simić, J., & el Bilali, H. (2013). *Off-Farm and Non-Farm Activities Development in Rural South-Eastern Bosnia*. 7.
- Beye, A. (2021). Améliorer la productivité rizicole sous changement climatique au Sénégal : Quelles stratégies d'adaptation ? *Économie rurale, 377*, 125-141. <https://doi.org/10.4000/economierurale.9228>
- Bryan, E., Ringler, C., Okoba, B., Koo, J., Herrero, M., & Silvestri, S. (2013). Can agriculture support climate change adaptation, greenhouse gas mitigation and rural livelihoods? Insights from Kenya. *Climatic Change, 118*(2), 151-165. <https://doi.org/10.1007/s10584-012-0640-0>
- Cervantes-Godoy, D., & Dewbre, J. (2010). Economic Importance of Agriculture for Poverty Reduction. *OECD, Directorate for Food, Agriculture and Fisheries, OECD Food, Agriculture and Fisheries Working Papers*.
- Cutforth, L. B., Francis, C. A., Lynne, G. D., Mortensen, D. A., & Eskridge, K. M. (2001). Factors affecting farmers' crop diversity decisions : An integrated approach. *American Journal of Alternative Agriculture, 16*(4), 168-176.

- Danso-Abbeam, G., Ojo, T. O., Baiyegunhi, L. J. S., & Ogundeji, A. A. (2021). Climate change adaptation strategies by smallholder farmers in Nigeria : Does non-farm employment play any role? *Heliyon*, 7(6), e07162.  
<https://doi.org/10.1016/j.heliyon.2021.e07162>
- Davis, J. R., & Bezemer, D. J. J. (2004). The Development of the Rural Non-farm Economy in Developing Countries and Transition Economies : Key Emerging and Conceptual Issues. *SSRN Electronic Journal*. <https://doi.org/10.2139/ssrn.693061>
- Delarue, J., Mesple-Somps, S., Naudet, J.-D., & Robilliard, A.-S. (2009). *Le paradoxe de Sikasso : Coton et pauvreté au Mali*.
- Dembele, B., Bett, H. K., Kariuki, I., le bars, M., & Ouko, K. (2018). *Factors influencing crop diversification strategies among smallholder farmers in cotton production zone in Mal*.
- Deonandan, R. (2019). Defining Poverty : A Summary of Competing Models. *Journal of Social and Political Sciences*, 2(1). <https://doi.org/10.31014/aor.1991.02.01.44>
- Di Falco, S., Veronesi, M., & Yesuf, M. (2011). Does Adaptation to Climate Change Provide Food Security? A Micro-Perspective from Ethiopia. *American Journal of Agricultural Economics*, 93(3), 825-842.
- Egeru, A. (2012). Role of Indigenous Knowledge in Climate Change Adaptation : A case study of the Teso Sub-Region, Eastern Uganda. *Indian Journal of Traditional Knowledge*, 11, 217-224.
- Ellis, F. (1998). Household strategies and rural livelihood diversification. *The Journal of Development Studies*, 35(1), 1-38. <https://doi.org/10.1080/00220389808422553>
- Ensor, J., Berger, R., & Huq, S. (Éds.). (2014). *Community-based Adaptation to Climate Change : Emerging lessons*. Practical Action Publishing.  
<https://doi.org/10.3362/9781780447902>
- FAO. (2018). *FAO.org* : <http://www.fao.org/faolex/results/details/en/c/LEX-FAOC188175/>
- Faye, N. F., Gérard, F., Sall, M., Affholder, F., & Roudier, P. (2021). *Pauvreté et inégalités en milieu rural dans le centre du Sénégal : État des lieux, causes et conséquences*.
- Feliciano, D. (2019). A review on the contribution of crop diversification to Sustainable Development Goal 1 “No poverty” in different world regions. *Sustainable Development*, 27. <https://doi.org/10.1002/sd.1923>
- Fisher, T., Mahajan, V., & Singha, A. (1997). *The forgotten sector : Non-farm employment and enterprises in rural India*. Intermediate Technology Publications Ltd.

- [https://scholar.google.com/scholar\\_lookup?title=The+forgotten+sector%3A+non-farm+employment+and+enterprises+in+rural+India&author=Fisher%2C+T.&publication\\_year=1997](https://scholar.google.com/scholar_lookup?title=The+forgotten+sector%3A+non-farm+employment+and+enterprises+in+rural+India&author=Fisher%2C+T.&publication_year=1997)
- Gajigo, O. (2013). Credit Constraints and Agricultural Risk for Non- Farm Enterprises. *African Development Review*, 25(4), 648-662. <https://doi.org/10.1111/1467-8268.12059>
- Gordon, A., Craig, C., Natural Resources Institute (Great Britain), Great Britain, & Department for International Development. (2001). *Rural non-farm activities and poverty alleviation in Sub-Saharan Africa*. Natural Resources Institute, University of Greenwich.
- Gorst, A., Dehlavi, A., & Groom, B. (2018). Crop productivity and adaptation to climate change in Pakistan. *Environment and Development Economics*, 23(6), 679-701. <https://doi.org/10.1017/S1355770X18000232>
- Goulden, C., D'Arcy, C., & Joseph Rowntree Foundation. (2014). *A definition of poverty*.
- Guan, K., Sultan, B., Biasutti, M., Baron, C., & Lobell, D. B. (2017). Assessing climate adaptation options and uncertainties for cereal systems in West Africa. *Agricultural and Forest Meteorology*, 232, 291-305. <https://doi.org/10.1016/j.agrformet.2016.07.021>
- Haggblade, S., Hazell, P., & Reardon, T. (2010). The Rural Non-farm Economy : Prospects for Growth and Poverty Reduction. *World Development*, 38(10), 1429-1441.
- Hausman, J. A. (1978). Specification Tests in Econometrics. *Econometrica*, 46(6), 1251-1271. <https://doi.org/10.2307/1913827>
- Heckman, J., Tobias, J. L., & Vytlačil, E. (2001). Four Parameters of Interest in the Evaluation of Social Programs. *Southern Economic Journal*, 68(2), 211-223. <https://doi.org/10.2307/1061591>
- Hertel, T. W., & Rosch, S. D. (2010). Climate Change, Agriculture, and Poverty. *Applied Economic Perspectives and Policy*, 32(3), 355-385. <https://doi.org/10.1093/aep/32.3.355>
- Illa, E. I. (2020). CHANGEMENT CLIMATIQUE ET SECURITE ALIMENTAIRE DES MENAGES RURAUX AU NIGER. *Annale des Sciences Economiques et de Gestion*, 20(1), Art. 1. <https://www.annaesumng.org/index.php/seg/article/view/637>

- Institut National de la Statistique et de l'Analyse Économique (INSAE). (2022). *Enquête Harmonisée sur le Conditions de Vie des Ménages 2018-2019* [Data set]. World Bank, Development Data Group. <https://doi.org/10.48529/RN3K-Z374>
- IPCC- AR5. (2014). *IPCC, 2014 : Summary for policymakers. In : Climate Change 2014 : Impacts, Adaptation, and Vulnerability. The Fifth Assessment Report.* 34.
- IPCC-AR3 (Éd.). (2001). *Climate change 2001 : Impacts, adaptation, and vulnerability: contribution of Working Group II to the third assessment report of the Intergovernmental Panel on Climate Change.* Cambridge University Press.
- Iritié, B. G. J. J., & Djaléga, F. S. (2016). Diversification of income sources for cocoa farm households : A case study of the Central West of Côte d'Ivoire. *African J. of Economic and Sustainable Development*, 5(3), 230.  
<https://doi.org/10.1504/AJESD.2016.077412>
- Kate, S., Teka, O., Chabi, R. B., Djikpo, R., Ogouwalé, E., Tenté, B. A. H., & Sinsin, B. (2017). Simulation du climat futur et des rendements agricoles en region Soudano-Sahelienne en Republique du Benin. *African Crop Science Journal*, 25(4), 405.  
<https://doi.org/10.4314/acsj.v25i4.2>
- Kemboi, E., Muendo, K., & Kiprotich, C. (2020). Crop diversification analysis amongst smallholder farmers in Kenya(empirical evidence from Kamariny ward, Elgeyo Marakwet County). *Cogent Food & Agriculture*, 6(1), 1834669.  
<https://doi.org/10.1080/23311932.2020.1834669>
- Khanal, U., Wilson, C., Hoang, V.-N., & Lee, B. (2018). Farmers' Adaptation to Climate Change, Its Determinants and Impacts on Rice Yield in Nepal. *Ecological Economics*, 144, 139-147. <https://doi.org/10.1016/j.ecolecon.2017.08.006>
- Kihila, J. M. (2018). Indigenous coping and adaptation strategies to climate change of local communities in Tanzania : A review. *Climate and Development*, 10(5), 406-416.  
<https://doi.org/10.1080/17565529.2017.1318739>
- Krugman, P., & Wells, R. (2016). *Microéconomie* (3è éd). De Boeck.
- Lachaud, J.-P. (2005). Modélisation des déterminants de la pauvreté durable et transitoire, et capital social aux Comores. *Documents de Travail*, Art. 108.  
<https://ideas.repec.org/p/mon/ceddtr/108.html>
- Lanjouwa, P. (2001). *The rural non-farm sector : Issues and evidence from developing countries.* 24.

- Lewis, W. A. (1954). Economic Development with Unlimited Supplies of Labour. *The Manchester School*, 22(2), 139-191. <https://doi.org/10.1111/j.1467-9957.1954.tb00021.x>
- Li, C., Chen, X., Jiang, A., Lee, M.-B., Mammides, C., & Goodale, E. (2021). Socioeconomic Determinants of Crop Diversity and Its Effect on Farmer Income in Guangxi, Southern China. *Agriculture*, 11(4), Art. 4. <https://doi.org/10.3390/agriculture11040336>
- Lokonon, B. O. K., & Mbaye, A. A. (2018). Climate change and adoption of sustainable land management practices in the Niger basin of Benin. *Natural Resources Forum*, 42(1), 42-53. <https://doi.org/10.1111/1477-8947.12142>
- Lokshin, M., & Sajaia, Z. (2004). Maximum Likelihood Estimation of Endogenous Switching Regression Models. *The Stata Journal: Promoting Communications on Statistics and Stata*, 4(3), 282-289. <https://doi.org/10.1177/1536867X0400400306>
- Lokshin, M., & Sajaia, Z. (2011). Impact of Interventions on Discrete Outcomes : Maximum Likelihood Estimation of the Binary Choice Models with Binary Endogenous Regressors. *The Stata Journal: Promoting Communications on Statistics and Stata*, 11(3), 368-385. <https://doi.org/10.1177/1536867X1101100303>
- MAEP, M. de l'Agriculture, de l'Élevage et de la Pêche, MENC, M. de l'Économie N. et de la C., ITU, I. T. U., & FAO, F. and A. O. (2019). *Stratégie nationale pour l'e-Agriculture au Bénin 2020-2024*.
- Maru, B., Maryo, M., & Kassa, G. (2022). Socioeconomic determinants of crop diversity in Bule Hora Woreda, Southern Ethiopia. *Heliyon*, 8(5), e09489. <https://doi.org/10.1016/j.heliyon.2022.e09489>
- Menne, M. J., Durre, I., Korzeniewski, B., McNeill, S., Thomas, K., Yin, X., Anthony, S., Ray, R., Vose, R. S., Gleason, B. E., & Houston, T. G. (2012). *Global Historical Climatology Network—Daily (GHCN-Daily), Version 3* [Data set]. NOAA National Centers for Environmental Information. <https://doi.org/10.7289/V5D21VHZ>
- Menne, M. J., Durre, I., Vose, R. S., Gleason, B. E., & Houston, T. G. (2012). An Overview of the Global Historical Climatology Network-Daily Database. *Journal of Atmospheric and Oceanic Technology*, 29(7), 897-910. <https://doi.org/10.1175/JTECH-D-11-00103.1>
- MEPN, M. de l'Environnement et de la P. de la N. (2008). *Programme d'Action National d'Adaptation aux changements climatiques du Bénin (PANA-Bénin)*.

- Ministère du Cadre de Vie et du Développement Durable, (MCVDD), & Institut international du développement durable, (IISD). (2019, novembre). *Pour un processus de Plan National d'Adaptation (PNA) qui réponde aux questions de genre au Bénin*. <https://napglobalnetwork.org/wp-content/uploads/2019/12/napgn-fr-2019-pour-un-processus-de-plan-national-dadaptation-qui-reponde-aux-question-de-genre-au-benin.pdf>
- Ministry of Foreign Affairs of the Netherlands. (2018). *Climate Change Profile Benin.pdf*. [www.government.nl/foreign-policy-evaluations](http://www.government.nl/foreign-policy-evaluations)
- Mouleye, I. S., Diaw, A., & Hamadou Daouda, Y. (2019). Effets du changement climatique sur la pauvreté et les inégalités en Afrique subsaharienne. *Revue d'économie du développement*, 27(3), 5-32. <https://doi.org/10.3917/edd.333.0005>
- MPD, M. du P. et du D., & INSAE, I. N. de la S. et et l'Analyse E. (2016). *Cahier des villages et quartiers de ville des Collines.pdf*. [https://instad.bj/images/docs/insae-statistiques/enquetes-recensements/RGPH/1.RGPH\\_4/resultats%20finaux/Cahiers%20villages/Cahier%20des%20villages%20et%20quartiers%20de%20ville%20des%20Collines.pdf](https://instad.bj/images/docs/insae-statistiques/enquetes-recensements/RGPH/1.RGPH_4/resultats%20finaux/Cahiers%20villages/Cahier%20des%20villages%20et%20quartiers%20de%20ville%20des%20Collines.pdf)
- Nhemachena, C., Hassan, R., & Chakwizira, J. (2014). Analysis of determinants of farm-level adaptation measures to climate change in Southern Africa. *Journal of Development and Agricultural Economics*, 6(5), 232-241. <https://doi.org/10.5897/JDAE12.0441>
- Nonvide, G. M. A. (2018). A re-examination of the impact of irrigation on rice production in Benin : An application of the endogenous switching model. *Kasetsart Journal of Social Sciences*, S2452315117303909. <https://doi.org/10.1016/j.kjss.2017.12.020>
- Noufé, T. (2020). Agricultural productivity and poverty of agricultural households in Burkina Faso. *African J. of Economic and Sustainable Development (AJESD)*, 7(4), 20. <https://doi.org/10.1504/AJESD.2020.106819>
- Okonya, J., Syndikus, K., & Kroschel, J. (2013). Farmers' Perception of and Coping Strategies to Climate Change : Evidence From Six Agro-Ecological Zones of Uganda. *Journal of Agricultural Science*, 5(8), Art. 8. <https://doi.org/10.5539/jas.v5n8p252>
- Ondari-Okemwa, E. (2006). Knowledge Management in a Research Organisation : International Livestock Research Institute (ILRI). *Libri*, 56(1). <https://doi.org/10.1515/LIBR.2006.63>
- Onzima, B., Katungi, E., & Bonabana-Wabbi, J. (2019). *The effect of climate change adaptation strategies on bean yield in central and northern Uganda*. 14(4), 13.

- Oppong-Kyeremeh, H., & Bannor, R. K. (2018). *Off-Farm Job as Climate Change Adaptation Strategy for Small Scale Rice Producers in the Volta Region of Ghana*. 8.
- Oyetunde-Usman, Z., Olagunju, K. O., & Ogunpaimo, O. R. (2021). Determinants of adoption of multiple sustainable agricultural practices among smallholder farmers in Nigeria. *International Soil and Water Conservation Research*, 9(2), 241-248. <https://doi.org/10.1016/j.iswcr.2020.10.007>
- PIACo | *Impacts actuels et potentiels des changements climatiques sur la Zone cotonnière du Centre (Zone agro-écologique 5)*. (2020). <http://www.piacobenin.org/fr/impacts-actuels-et-potentiels-des-changements-climatiques-sur-la-zone-cotonniere-du-centre-zone-agro-ecologique-5/>
- Quan, S., Li, Y., Song, J., Zhang, T., & Wang, M. (2019). Adaptation to Climate Change and its Impacts on Wheat Yield : Perspective of Farmers in Henan of China. *Sustainability*, 11(7), 1928. <https://doi.org/10.3390/su11071928>
- Rajendran, S., Afari-Sefa, V., Shee, A., Bocher, T., Bekunda, M., dominick, I., & Lukumay, P. J. (2017). Does crop diversity contribute to dietary diversity? Evidence from integration of vegetables into maize-based farming systems. *Agriculture & Food Security*, 6(1), 50. <https://doi.org/10.1186/s40066-017-0127-3>
- Rantšo, T. A. (2016). The role of the non-farm sector in rural development in Lesotho. *The Journal of Modern African Studies*, 54(2), 317-338. <https://doi.org/10.1017/S0022278X16000197>
- Ravallion, M. (1994). *Poverty Comparisons*. Taylor & Francis. <https://doi.org/10.4324/9781315015095>
- Reardon, T. (1998). *RURAL NON-FARM INCOME IN DEVELOPING COUNTRIES*.
- Sen, A. K. (1997). From Income Inequality to Economic Inequality. *Southern Economic Journal*, 64(2), 384-401. <https://doi.org/10.1002/j.2325-8012.1997.tb00063.x>
- Sossou, C. H. (2015). *LE FINANCEMENT DE L'AGRICULTURE AU BÉNIN : STRATÉGIES DE GESTION ET D'ADAPTATION DES EXPLOITATIONS AGRICOLES*. 199.
- Subrahmanyeswari, B., & Chander, M. (2013). *Integrating indigenous knowledge of farmers for sustainable organic farming : An assessment in Uttarakhand state of India*. 12(2), 6.
- Townsend, P. (1979). *Poverty in the United Kingdom : A Survey of Household Resources and Standards of Living* (First Edition). Penguin.

UNDP, U. N. D. P., & MEPN, M. de l'Environnement et de la P. de la N. (2007).

*PANA\_BENIN.*

United Nations. (2018). *Guide on Poverty Measurement*. UN.

<https://doi.org/10.18356/b6557c18-en>

United Nations Development Programme (UNDP). (2018).

*Naps\_in\_focus\_lessons\_from\_benin.pdf.*

United Nations Development Programme (UNDP). (2020). *Supporting Benin to advance their*

*NAP Process*. <https://www.adaptation-undp.org/projects/benin-nap-process>

Vodounou, J. B. K., & Onibon Doubogan, Y. (2016). Agriculture paysanne et stratégies

d'adaptation au changement climatique au Nord-Bénin. *Cybergeo: European Journal of Geography*. <https://doi.org/10.4000/cybergeo.27836>

Walker, T., & Ryan, J. (1990, mai 1). *Village and household economies in India's semi-arid tropics*. Baltimore, Md. U. S. A. : Johns.

[https://www.semanticscholar.org/paper/Village-and-household-economies-in-](https://www.semanticscholar.org/paper/Village-and-household-economies-in-India%27%27s-Md.-U.-Walker-Ryan/cf85980cfdc3f2e025c7cd710fd96ce910b2484c)

[India%27%27s-Md.-U.-Walker-Ryan/cf85980cfdc3f2e025c7cd710fd96ce910b2484c](https://www.semanticscholar.org/paper/Village-and-household-economies-in-India%27%27s-Md.-U.-Walker-Ryan/cf85980cfdc3f2e025c7cd710fd96ce910b2484c)

Wiggins, S., & Hazell, P. (2010). *Access to rural non-farm employment and enterprise*

*development Prepared*. [https://www.semanticscholar.org/paper/Access-to-rural-non-farm-employment-and-enterprise-Wiggins-](https://www.semanticscholar.org/paper/Access-to-rural-non-farm-employment-and-enterprise-Wiggins-Hazell/8364f6ddf0802fc5cae24d69ff57726c11f51f7f)

[Hazell/8364f6ddf0802fc5cae24d69ff57726c11f51f7f](https://www.semanticscholar.org/paper/Access-to-rural-non-farm-employment-and-enterprise-Wiggins-Hazell/8364f6ddf0802fc5cae24d69ff57726c11f51f7f)

World Bank, ADB, AfDB, BMZ, DFID, DGIS, EC, GTZ, BMZ, OECD, UNDP, & UNEP.

(2003). *Poverty and Climate Change Reducing the Vulnerability of the Poor through Adaptation*.

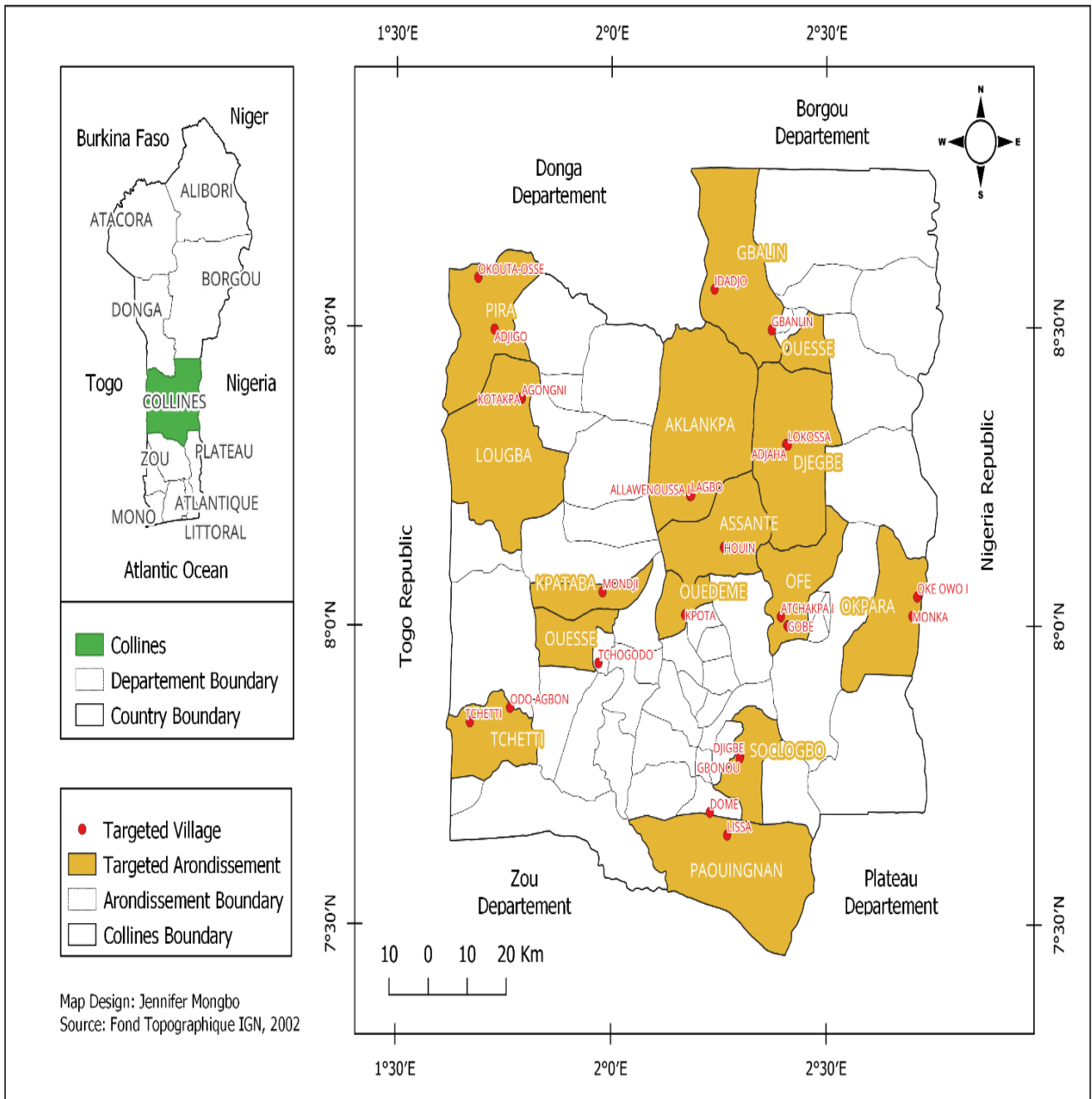
## **APPENDIX/ANNEX**

### **Appendix 1: Presentation of the Central Benin Agro-Ecological Zone: Agro-Ecological Zone 4**

This agro-ecological zone comprises the municipalities of Bassila, Parakou, Tchaourou, Ouessè, Bantè, Savè, Savalou, Glazoué, Kétou, Djidja, Dassa and Aplahoué (see *Appendix 1*). Spread over an area of 31722 km<sup>2</sup>, we observe a climate of the Sudanese-Guinean type with 2 rainy seasons, with a trend towards the Sudanese type Sahelian with a single rainy season in the northern sector of the zone; rainfall from 600 to 1400 mm spread over 80 to 110 days. Several soil types are found, including tropical ferruginous soils, leached soils with varying degrees of concretion, sandy soils, sandy-clay soils, and black and hydromorphic soils in valleys. The vegetation is composed of forests classified as threatened by man, state plantations of teaks and cashew trees, shrubby savanna, forest galleries; there is an advanced degradation of vegetation due to bush fires and population pressure. The main rivers that flow through the area are the Ouémé, Zou and Okpara rivers. The dominant ethnic groups in the area are Adja, Anni, Bariba, Fon, Holli, Idatcha, Kotocoli, Lokpa, Mahi, Nago, Peuhl, Yoruba, with an estimated rural population of 79.3% of the total population (UNDP & MEPN, 2007).

The cultivation techniques observed are mainly mobile slash-and-burn agriculture, fallow and ploughing with burial of grasses. The crops grown are cotton, yam, cassava, maize, peanut, oil palm, rice, sugar cane, and tobacco and market garden crops. Other economic activities include cassava processing, livestock, hunting and trade. Concerning the major climatic risks, the cotton zone of central Benin is on Precambrian material of the old granito-Central Benin and hence the scarcity of water resources is a particular risk associated with this area and climate change may increase. Other major climate risks identified by populations in the context of vulnerability studies conducted by the National Adaptation Action Programme are, in descending order: excessive heat, high winds and late and violent rains, drought (PIACo | Current and potential impacts of climate change on the Central Cotton Zone (Agro-ecological Zone 5), 2020).

Figure 1 Map of the study area



Source : (UNDP & MEPN, 2007)

## **Appendix 2: Sampling**

The sample size can be defined by the SCHWARTZ formula:

$$N = \frac{[t^2 \times p \times (1-p)]}{m^2}$$

N = Initial sample size in the six communes

t = Confidence Level (standard 95% confidence level will be 1.96)

p = Proportion of the population of interest in the total population (the population of interest is households that have grown maize and/or cassava in the past three years)

m = Margin of error set at 5%

### **- Distribution of the sample size by municipality**

Once the sample size is obtained, we proceed to the distribution between the different municipalities (in the case of two or more). This total population, also called theoretical population, will be distributed in proportion to the geographical weight of each village.

$$N1 = \frac{\text{Number of households in the commune}}{\text{Total number of households of the communes}} * N$$

This same distribution approach will be replicated at the village level. Indeed, the sample size within a municipality will be prorated according to the number of households in that village. Here is the formula:

$$N2 = \frac{\text{Number of households in the village}}{\text{Number of households in the communes}} * N1$$

Referring to the “Book of villages and city districts Of the department of Collines”, documents elaborated during the RGPH-4, 2013 by the National Institute of Statistics and Economic analysis (INSAE-Benin):

*IMPACT OF CLIMATE CHANGE ADAPTATION STRATEGIES WITHIN AGRICULTURAL COMMUNITIES IN  
CENTRAL BENIN REPUBLIC*

<b>t</b>	1,96	
<b>p</b>	0,4584	
<b>m</b>	0,05	
<b>N</b>	381,500752	
<b>the N1s</b>		
Bantè	70	70
Glazoué	58	58
Dassa-Zoume	65	65
Savalou	53	53
Savè	52	52
Ouèssè	86	86

- Household's choice

The final draw of the sample consists of the choices of households by the simple random sampling method or by the table of random numbers.

### **Appendix 3: Main crops cultivated**

<b>Crops</b>	<b>Producer 's frequency in %</b>
Maize	95.66
Soya	76.63
Cassava	74.94
Cashew nuts	39.76
Yam	32.53
Cowpea	30.60
Rice	23.61
Cotton	22.41
Vegetable products	8.67
Squash	4.34
local lentils	1.93

Source: Excel, from primary data

The table presents the main crop cultivated in the study area. The crop on top of the production is Maize, with more than 95% of producing farmers. This, once again testifies how much maize is important in the community diet, with a huge demand. Maize crop is followed by Soya, near to 77% of the farmers grow soya. In fact, soybean cultivation has surprisingly taken the lead over cassava. In full expansion in the region, data collection reports that this crop is currently being promoted by the agricultural structures of the State. Also, producers attest that its yield is very satisfactory and that it is also subject to a good price on the market.

Cassava comes in third position with 75% of the producers, while the proportion of cassava producers remains relatively high, cassava production is nevertheless experiencing a sharp decline due to the ups and downs that producers endure year after year in its production. Cassava, a staple crop in Benin agriculture, is one of the crops with the greatest added value for producers. It is the raw material in the manufacture of many staple foods for populations, such as gari, tapioca, kpaki, agbeli, fofou and many more. It is also sometimes used in bread making. Thus, cassava is essential and any damage to its sector will have adverse and unavoidable effects on food security in the country. Unfortunately, cassava cultivation is suffering a lot from the effects of climate change, characterized by late rains, unexpected interruption of rains and pockets of drought. These phenomena result in the interruption of

vegetative cycles including that of cassava. This pushes producers to increasingly abandon it or to grow it only for the internal needs of their household. More and more heavy losses are recorded each year and cassava is continually subject to inflation, a situation decried on all sides because it has become practically inaccessible to the mass. To all this is added the producer-breeder conflict that exasperates the situation. Indeed, cassava producers in the region are victims of the destruction of their farm by the cattle herds of Peuhl farmers, a situation that further discourages farmers, pushing many of them to abandon the cultivation of cassava from year to year. After the first three top cultures, come respectively cashew nuts (39.76%), yam (32.53%) and black-eyed pea (30.60%). Cashew, like cotton, is a cash crop for the Beninese economy. If there are not many more producers in the cashew sector, it is in fact due to the question of land ownership. Since cashew is not an annual crop but rather a long-term crop, cashew plantations are only owned by landowners. Other main crops are rice, cotton, vegetables, squash and local lentils called *doyiwé*. In the group of secondary crops we can find pea nuts, the other beans, sweet potato, taro.

**Appendix 4: off-farm activities observed and percentage among respondents**

<b>Name of oof-farm activity</b>	<b>Frequence in %</b>
Timber exploitation	7.24
Breeder	9.05
Trader	33.48
Fisherman	1.81
Officer	3.17
Taxi	8.60
Food processor	2.26
Farm worker	3.17
Other worker	1.81
Coiffure/couture	3.62
Mecanic/electrician	4.52
Bricklayer/Carpenter	5.43
Other diverse artisan	4.52
Tradipractitioner	2.26
Restauration	0.90
Gardien	0.90
Nurse's aide	0.45
Pastor	0.5
Entrepreneur	0.45
Other	5.88

In the sample surveyed, 218 individuals, or 52.53% of people, report having in addition to their agricultural activities, another activity to make ends meet. Table 2.2 shows the different non-agricultural or para-agricultural activities carried out by these heads of agricultural households with the aim of diversifying incomes. The dominant activity is trade (33.48%), followed respectively by breeding (9.05%), taxi conducting (8.60%) and timber exploitation (7.24%). We can see that two of those activities (breeding and timber exploitation) belong to the primary sector which still has a sector that is highly sensitive to the climate change. The question is whether these activities are most appropriate if the aim of the head of household is to choose them as a climate change adaptation option. We also note in the sample that many individuals have for secondary activity manual trades such as crafts, hairdressing, sewing, mechanics, electricity, masonry, carpentry with a cumulative percentage of 18.10%.