Econometric Analysis of the Perception and Adaptation to Climate Change Risks Among Farmers in Congo-Brazzaville

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Research Paper 428

AFRICAN ECONOMIC RESEARCH CONSORTIUM
CONSORTIUM POUR LA RECHERCHE ÉCONOMIQUE EN AFRIQUE

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By

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AERC Research Paper 428
African Economic Research Consortium, Nairobi
March 2021

THIS RESEARCH STUDY was supported by a grant from the African Economic Research Consortium. The findings, opinions and recommendations are, however, those of the author and do not necessarily reflect the views of the Consortium, its individual members or the AERC Secretariat.

Published by: The African Economic Research Consortium
P.O. Box 62882 - City Square
Nairobi 00200, Kenya

ISBN 978-9966-61-126-0

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Abstract

This study analyzes the experience of farmers under Agri-Congo with regard to perception and adaptation to climate change. It is based on a field survey of 201 farmers, comprising 101 in Brazzaville and 100 in Pointe-Noire, the two largest cities in Congo. The statistical results show that most farmers perceive climate change (98.5% of responses) and practise adaptation (85.4% of responses). The high rates of perception and adaptation among farmers are due to their experience in farming activity, and due to their determination to maintain their farming business despite the current risks related to climate change. The problem coping index has shown that lack of experience, limited access to inputs and credit facilities are the main constraints in terms of adaptation. Crop diversification, adjustment of the farm calendar and substitution of crops within the same farm area are the strategies most developed by farmers. The study identified the determinants of perception and adaptation to climate change through the application of the Probit model. Indeed, age, level of education and number of farm employees are the main variables that increase farmers' awareness of climate change, while input donations, farming experience, property rights, engagement in a subsidiary activity and membership in an organization are the key determinants of farmers' adaptation to climate change. Finally, special attention from Agri-Congo should be directed to training, enhancement of farm inputs, fertilizer and input subsidies and issuing of land titles to strengthen the adaptive capacity of farmers.

Keywords: Perception, Adaptation, Climate change, Brazzaville, Pointe-Noire.

1. Introduction

Background and justification

Congo-Brazzaville is a country in the equatorial zone and enjoys an equatorial climate with a bimodal pattern whose dry season duration decreases from South to North. On average, the temperature oscillates around 25°C and varies only slightly during the year. However, the dry season is accompanied by a significant drop in temperature (temperature variations vary from 4° to 6°C). The air is always humid; the average rate of hygrometry (RH) is 80%. Total annual rainfall is generally more than 1,200 millimeters but its pattern, linked to the apparent rotation of the sun on either side of the equator, is the basis for the four seasons. Thus, from the North to the South of the country, the following climatic variations are observed:

- In the North of the country (Sangha, Likouala), it rains all year round, with only two seasons when the rains slow down from December to February and in July. The dense forest cover contributes to the very high humidity.

- In the Central region (Cuvette and Plateaux), there is a sub-equatorial climate, intermediate between the weather of the North and that of the South-West. The closer one gets to the equator, the shorter and longer the dry season becomes. On the plateaus, the dry season lasts for two to three months, and 1,800 to 2,000 millimeters of rainfall is experienced annually. Elsewhere, in the central basin region, for example, the dry season lasts for two months, but in June and July, between 25 and 50 millimeters of rainfall is received each month;

- In the Southwest, the climate tends to be humid tropical. Total rainfall tends to be moderate (1,200 to 1,700 millimeters). However, the monthly distribution shows a large dry season of three to four months (June to September), followed by two rainy periods (October to December, then February to May). The shorter dry season (January or February) is only marked by rain showers and less violent thunderstorms.

Congo-Brazzaville is a developing country in Central Africa. Although it enjoys a favourable climate for agriculture, it is not immune to threats of climatic change. The active agricultural population, which is estimated at 498,000 in 2009, is mainly women (70%). Currently, only 2% of arable land is being exploited (i.e. nearly 2 million hectares). Food crops occupy 75% of cultivated land: cassava, maize, groundnuts, potatoes, beans, yams, and plantains. Only sugar cane through the SARIS-Congo company is currently recording a significant increase in production. The production of paddy and other cash crops (coffee, cocoa, and palm oil) has been declining, if they have not disappeared altogether.

The agricultural sector contributed only 4.5% to GDP in 2007 and 2011. According to the Agricultural Sector Study conducted in 2011, the sector's contribution was 27% in 1960, 12% in 1980 and 10% in 1997. Between 2000 and 2005, the average annual growth of agricultural GDP was around 1%, well below the demographic growth rate (2.5%). Despite the enormous potential for crop, animal, fisheries and forestry production that the Congo has, the population is virtually totally dependent on foreign food supplies, with annual imports estimated at an average of 130 billion CFA Francs per year. Thus, food insecurity affects more than a third of the population. Agriculture, a declining sector, is already suffering from the negative impacts of climate change. National climate change observation studies conducted by UNDP in 2010 showed that the entire Congolese territory has been warming at a rate of about 0.05°C per decade during the 20th century, with a slightly greater temperature rise from January to May. This rise in temperature is consistent with global climate change and affects human development. In fact, since the 1970s, Congo-Brazzaville has been experiencing the following climate changes:

- A general increase in maximum temperatures of about 0.76°C and 0.69°C for minimum temperatures with moderate variability in space and time. However, on a seasonal scale, the most marked rise in temperature occurs in the dry season (June to September) or southern winters. Spatially, the warming is more pronounced in the savannah zones in the central and southern parts of the country. It is exacerbated in the large cities (Brazzaville and Pointe-Noire) by an additional urban effect.

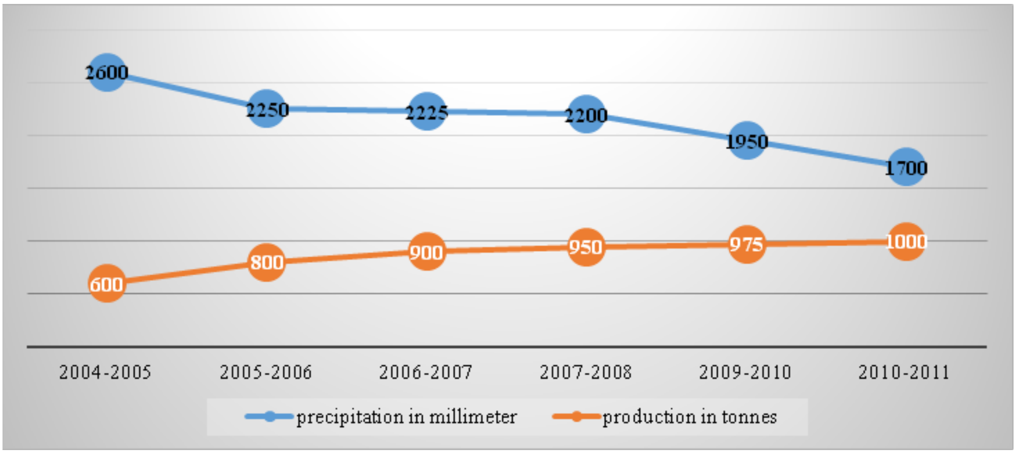
- An overall decrease in annual rainfall throughout the country with some spatial variability. This decrease was exacerbated during the 1980s, even in areas with high rainfall. This rainfall deficit is common across humid regions of Africa.

- There has been a general decline in the flow of the Oubangui-Congo rivers (+19% to -9%) and their tributaries since the 1970s. Similarly, in Southern Congo, the flow of the Kouilou-Niari is decreasing. This trend is similar to the annual rainfall pattern. The rate of evaporation has increased at the same time. Often, in the southern part of the Republic of Congo, evaporation exceeds rainfall over the entire Congo Basin.

The basic assumption of this study is that in Congo, climate is an important explanatory factor for agricultural production. This can be explained by the fact that agriculture is essentially dependant on rainfall due to the very weak irrigation system. Thus, low or excessive rainfall can hinder the growth of crops, thereby limiting productivity. In recent years, this rainfall has been unstable, leading to disruption of the agricultural calendar and a drop in the farmers' or market gardeners' productivity. Figures 1 and 2 below show the evolution of the main crops according to current rainfall. Indeed, it appears from these graphs that the country's main crops such as potatoes and groundnuts have a downward trend, except for rice due to the decrease in rainfall.

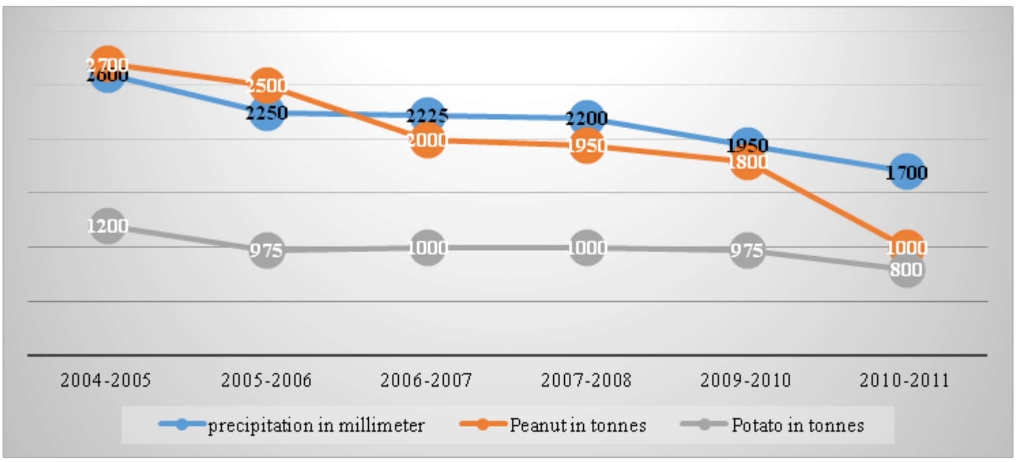
Based on this hypothetical situation, the crops grown on the various Agri-Congo farms, which are considered as the country's breadbasket, will suffer more from the effects of climate change, with a corresponding drop in yield. By studying the correlation between future climatic conditions and agricultural production in Benin, Paeth *et al.* (2008) predicted yield decreases ranging from 5% to 20%, with a higher risk of food insecurity as a result. This situation is already apparent to farmers in the country, forcing them to devise adaptation strategies to meet the challenges posed by climate change and preserve their livelihoods.

Figure 1: Rainfall and rice production



Source: Author using data from National Center for Statistics and Economic Studies (2010).

Figure 2: Rainfall, groundnut and potato production



Source: Author using data from National Center for Statistics and Economic Studies (2010).

There are three key facts that justify the consideration of this research. One, climate change poses a threat to agricultural output and food production in many African countries in general and particularly in Congo-Brazzaville. Two, because of this perceived threat by some farmers, adaptation strategies to climate change risks become necessary because of the role that agriculture plays in fostering sustainable economic growth and achieving food security. There is thus a need for in-depth studies on climate change so that it does not hinder the green revolution envisaged in Africa, including in Congo-Brazzaville. Third, there is currently no study on agriculture and climate change in Congo. This study bridges this knowledge gap. It therefore focuses on the perceptions, adaptation strategies and socio-economic determinants of climate change at the level of farmers. The opinions collected from farmers are fundamental to the development of a national strategy for adaptation to climate change at the farmers' level.

Objectives

This research aims at studying the experience of Congolese farmers in perceiving and adapting to climate change. The following specific objectives are derived from this general objective:

(i) To identify farmers' perceptions of climate change and the adaptation strategies adopted;

(ii) To identify farmers' constraints in terms of adaptation.

(iii) To analyze the determinants of perception and adaptation to climate change

(iv) To make recommendations to strengthen their capacity to perceive and adapt to climate change.

The paper is organized as follows. The second section provides the empirical and theoretical literature on the nexus between climate change and agriculture. The third section presents the methodology used. To this end, it outlines the study areas, sampling and data collection strategy and provides details on how the perception and adaptation database was developed. The fourth section is devoted to the presentation of statistical and econometric results of the survey and the subsequent analysis. The fifth section focuses on concluding remarks and recommendations.

2. Literature review

This literature review provides an overview of recent works on perception and adaptation to climate change and discusses the conceptual, empirical and theoretical framework.

Conceptual framework

Climatic risk

In agro-climatology, risk is characterized by the frequency of occurrence of a climatic or biological event that can adversely affect development. In this case, the risk may be climatic drought, cyclones, gales, temperature excesses or deficits, and attacks on crops by noxious insects. Climatic risk can be defined as the probability of insufficient rainfall leading to partial loss of harvest (Houessou, 2008). Thus, risk implies a notion of far-reaching consequences. In agriculture, Sipho (2015) define risk as the variance in producers' income due to climatic hazards. For the purposes of this study, we shall consider climatic risk, rainfall scarcity, rising temperatures and strong winds, as these are the main factors that could affect farmers' crop production within the current conditions.

According to Di Falco et al. (2011), adaptation is defined as the set of adjustments made or achieved in natural and human systems as a curative or preventive response to current or future climate stimuli, or their effects, in order to reduce damage or take advantage of them at the right time. These are changes in processes, practices and structures with a view to reducing potential damage (or taking advantage of opportunities) associated with climate change (Mansanet-Bataller, 2010). Adger et al. (2003) define adaptation as changes in procedures, practices and structures to mitigate or eliminate potential damage or take advantage of opportunities brought about by climate variability and change. According to Kurukulasuriya et al. (2006), adaptation can encompass national or regional strategies and concrete measures taken at the community or individual level.

IPCC[1] (2014) differentiates between two types of adaptation: hard and soft adaptation. Hard adaptation measures include physical infrastructure and changes to physical capital such as irrigation systems, earthworks, reservoirs and dams. Soft adaptation measures include changes in institutions, planning processes and incentives that alter the conditions under which autonomous or private adaptation investments are made.

We speak of "lack of adaptation" when measures developed to adapt to the effects of climate change can lead to unexpected outcomes, and the risks of "lack of adaptation" should not be underestimated. Lack of adaptation is defined by the IPCC as "a change in natural or human systems that increases vulnerability rather than reducing it".

Perception

Perception is the process by which we receive information and stimuli from our environment and transform it into conscious psychological acts. According to the Environment and Energy Management Agency, ADEME (2013), perception refers to the way in which farmers perceive and describe the manifestations of climate change in their activities to take the necessary adaptation measures. In other words, perception refers to the different interpretations of the evolution of climatic phenomena by farmers.

Climatic change

The IPCC (2014) considers climate change as the variation in the state of climate through changes in the mean and/or variability of its properties that persist over a long period of time, typically decades or longer. The United Nations Framework Convention on Climate Change distinguishes between "climate change" attributable to human activity altering the composition of the atmosphere and "climate variability" attributable to natural causes.

Climate change is a phenomenon characterized by a significant and sustained change in major climate or weather indicators (e.g. temperature variation, rainfall, etc). In other words, climate change in the context of this study is the set of climate changes characterized by variations in temperature, drought, rainfall and observed for more than ten years by farmers in the course of their farming activities. At the level of farmers, climate change refers to a transitory phenomenon observed by climate disruptions from one season to another and preventing them from carrying out their agricultural activities (AXA,[2] 2012).

Farming

According to Deressa *et al.* (2009), farm holding can be defined as a production unit in which the farmer marshals different natural resources (land, labour, livestock, plants, materials and buildings among others) and combines them in variable proportions to obtain crop or livestock production and thus meet their needs and interests. For this author, it is therefore a form of technical, commercial and social organization of agricultural production. According to the author, the farming activity is the whole evolutionary package consisting of the farmer, the agricultural perimeter, the farm staff, the crop, the animals and trees exploited, the technical reference implemented, the added value and the marketing strategies of the products. The concept of farming has led to the concept of enterprise. However, in the tropics, farming business operations are still traditionally run, and no one has the right to own the collective good and turn it into a source of personal wealth. In operational terms and for the purposes of this study, farming operation is made up of all cultivated land, fallow land, land leased to others and used by farmers and the workforce involved.

According to FAO (2008), a farmer is defined, for the purposes of agricultural statistics, as an economic and production unit that simultaneously meets the following three conditions:

- He carries out an agricultural activity, i.e. he regularly produces agricultural goods.
- He attains or exceeds a certain size (area, number of animals, production, etc); that is, he must play the role of an economic actor, having reached a sufficient size that, in theory, enables him to participate in a commercial (or similar) transaction process, such as sale on a market or exchange.
- He is liable to independent day-to-day management; that is, he mobilizes the production factors to carry out the work that needs to be done on the farm and operations that do not have a major impact on the general economic operation of the farm. Farmers set up by Agri-Congo and who are the subject of this study have met these criteria.

Empirical literature on perception

Sipho (2015) analyzed the perception of climate change among 600 farmers in the case of Swaziland. The results showed that 70% of the farmers perceived climate change in particular through: temperature increase; increase in the number of rainy days; decrease in the frequency and intensity of rainfall and change in temperature from one season to another. According to these authors, the age of the farmer and his level of education are the main factors that positively influence the ability of farmers to perceive climate change.

Egbe *et al.*(2014), from a sample of 120 farmers from 4 rural communities in Nigeria, show that 86% of the farmers confirmed that the climate has indeed changed in recent years. The long duration of seasons (77%), rising temperatures (75%), reduced rainfall (80%), rain scarcity (40%), dryness of rivers (10%) were the main reasons for climate change cited by farmers. These authors state that farmers' perceptions corroborate with data obtained from the Nigerian Meteorological Agency.

Loko *et al.* (2013), in a case study on the perception of climate change among 150 farmers in north-western Benin, point out that the perception of climate change among farmers is mainly reflected in temperature and rainfall. The study reports a high perception rate of 75% and an adaptation rate of 60% at the farmers' level. Concerning temperature, the authors mention that the rise in temperature and increase in the duration of sunshine are the two most reported changes with, respectively, 50.16% and 42.76% of responses. Concerning rainfall, the variability is reported at seven levels, of which three (rain delays, early rain stoppages, decrease in rainfall quantity) are the most significant and alone represent about 80.03% of the responses. Excessive rainfall is also mentioned but remains the least reported rainfall variability (4.46% of responses) according to their study.

Empirical literature on adaptation

Boko *et al.* (2007), Cline (2008) and Mansanet-Bataller (2010) point out that two types of measures are necessary to address climate change: mitigation and adaptation measures. Mitigation refers to the reduction of greenhouse gas emissions while adaptation refers to any adjustment in physical systems or human activities in response to the impacts of climate change (IPCC, 2001). Mitigation measures are difficult to implement for many developing countries. As a result, most studies measuring the economic impacts of climate change on agriculture in Africa show that these effects can be significantly reduced through adaptation (Kurukulasuriya and Mendelsohn, 2006).

Adaptation to climate change is a process that initially requires producers to recognize that the climate has changed and then identify meaningful adaptations to be implemented (Mustapha *et al.*, 2012).

For example, Yesuf *et al.* (2008) study the factors affecting the adoption of climate change adaptation strategies and the impact of climate change adaptation on food production with data from 1,000 farming households in the Nile Basin in Ethiopia. The results of their study indicate the positive role played by formal and informal institutions (access to credit markets, social linkages, farmer-to-farmer extension, and provision of information on future climate change) in climate change adaptation strategies to promote improved crop yields. They thus underline the need to provide appropriate and timely information on future climate change to farmers to raise awareness of adaptation measures. In addition, the authors show that adaptation strategies help manage the adverse effects and risks of climate change while increasing agricultural productivity in poor farming households.

Apata T. (2011) also present an analysis of the effects of global warming on Nigerian agriculture and estimate the determinants of adaptation to climate change using a multinomial model and a stochastic simulation model. The results indicate that hunger-related deaths could double if cereal production does not keep up with population growth in an unfavourable climatic environment. However, the authors note that adaptation measures have a significant impact on agricultural productivity. The study finds, as Hassan and Nhemachena (2008) found in a dozen African countries, that lack of effective access to climate information, farmer empowerment and experience, and access to education are key determinants of adaptation and mitigation strategies.

Furthermore, Di Falco *et al.* (2011) study the impact of climate change adaptation on agricultural productivity based on a survey of 1,000 farms in Ethiopia. The authors find that adaptation to climate change has a significant impact on agricultural yields and farmers' net incomes. According to the authors, extension services (formal and farmer-to-farmer), and access to credit and information on future climate change are the main determinants of adaptation.

Asfaw et al. (2013; 2015) assess the factors governing farmers' decisions to adopt adaptation or mitigation strategies and the impact of the adoption of these strategies on agricultural productivity using data collected from a nationally representative sample of 7,842 households in Malawi. The authors use a multivariate Probit model to model strategy adoption decisions, and the instrumental variable method to estimate the impact of adaptive strategies. The results of their studies suggest that favourable rainfall positively affects the decision to adopt strategies such as improved seeds in the short term, while unfavourable rainfall encourages farmers to adopt strategies such as tree planting, use of organic fertilizers, and soil and water conservation measures. In addition, the authors show that secure land tenure increases the likelihood that farmers will adopt strategies that will capture the benefits of their long-term investments and reduce the demand for inputs in the short term. Access to extension services, social capital and collective action also have a positive impact on decisions to adopt strategies, suggesting to the authors the importance of information and networks.

Sessinou (2016), using the household and agriculture survey database collected by the National Institute of Statistics of Niger from a sub-sample of 2,490 households that are small farmers deriving their income mainly from agricultural and other non-agricultural activities, showed that the vast majority (84%) have adopted one or more strategies to cope with perceived climate change (temperature, rainfall). Among them, 54% of households have adopted at least one strategy, 17% one and only one and 37% more than one strategy.

Hassan and Nhemachena (2008) analyzed the determinants of climate adaptation measures for agriculture in Africa. They used a multinomial choice model adapted to data from a cross-sectional study of more than 8,000 farms in 11 African countries. The results indicate that specialized cultivation (monoculture) is the practice most vulnerable to climate change in Africa. The authors emphasize that government policies and investment strategies must support education, markets, credit and information on climate change adaptation, including institutional and technological methods, particularly for poor farmers in dry lands of Africa.

Empirical literature on perception and adaptation to climate change in Africa is summarized in Table 1.

Table 1: Summary of empirical studies on perception and adaptation to climate change

Sources	Objectives	Sample	Methods	Outcomes
Ishaya and Abaje (2008)	Examine how indigenous farmers in Jema'a, Nigeria, perceive climate change and their strategies for adaptation to climate change	200 farming households	Analysis of Variance (ANOVA) and Chi-Square	• Indigenous people are aware that the climate has changed over the years. • The threat of climate change is affecting health, food supply, loss of biodiversity and firewood availability. • Lack of improved seeds, access to water for irrigation, current knowledge of modern adaptation strategies, capital, awareness and knowledge of climate change scenarios are factors that hinder the adoption of modern climate change techniques.
Deressa *et al.* (2009)	Identify the main methods used by farmers to adapt to climate change in the Nile Basin in Ethiopia, the factors that affect their choice of method, and barriers to adaptation	1,000 farmers	Multinomial Logit (MNL)	• The level of education, gender, age and wealth of the household head; access to extension and credit; climate information; social capital; agro-ecological parameters and weather, all positively influence farmers' choices.
Bryan *et al.* (2009)	Examine farmers' perceptions of climate change, the extent of adaptation, barriers to adaptation, and factors influencing adaptation choices in Ethiopia and South Africa	1,800 farming households	Probit model	• Adaptation at the farm level involves more than the adoption of new agricultural technologies. • Results suggest that strategies should also be adapted to meet the particular needs and constraints of different countries and farmer groups.

continued next page

Table 1 Continued

Sources	Objectives	Sample	Methods	Outcomes
Hassan and Nhemachena (2008)	Assess the perception and understanding of farmers in the Niger Delta on the role of national governments in the governance of climate change Examine the perception of grassroots communities and the challenges to climatic change adaptation	400 households	Simple descriptive statistics, figures, tables	• The main obstacles to climate change adaptation for farmers in the Niger Delta are: lack of information, low levels of awareness, inconsistent extension services, inadequate government attention to climatic issues, and lack of access to available information, ineffective indigenous methods, no subsidies for farming equipment, limited knowledge of adaptation measures, weak institutional capacity, and lack of government policy on climate change. • Farmers have a low level of knowledge of government policies/ programmes on climate change. • Farmers have a poor perception of the effectiveness of policies/ programmes and low awareness of the existence and impact of climate change committees in the National Assembly.
Deressa *et al.* (2011)	Analyze the climate change adaptation process in two stages, which initially requires farmers' perceptions before responding to adaptation strategies	1,000 mixed crops and livestock breeders	A Heckman Probit model A multinomial logit (MNL) model	• Household size, farming experience, wealth, access to credit, access to water, land rights, farming activities and access to extension services are the main factors that improve farmers' adaptive capacity. • Lack of access to credit is the main factor inhibiting adaptation to climate change. • Farmers perceive that overall seasonal rainfall and the number of "heavy rains" during the rainy season have decreased over the last 30 years. • Rural households respond to drought by changing their farming practices.
West *et al.* (2008)	Analyze local perceptions and regional climate trends in the central plateau of Burkina Faso	120 people	Ethnographic interviews, focus groups, active observation	

Source: Author

Theoretical literature

At the theoretical level, in assessing farmers' adaptive capacity to change, one must not only assess their ability to adapt, but also their actual desire to do so (Piya, 2013). Producers' adaptive capacity depends, among other things, on their perception of change, their personal characteristics, their attitude to change, their vision of their enterprise, the economic context of the sector and the social and professional framework (Sérès, 2010). The personal characteristics (human capital) of producers influence their ability to react and adapt to a more or less predictable situation, such as a change in input prices, the current climate or anticipated climate change and the end of quota systems. Thus, a farmer with good training, good skills, including management skills, varied experience and an "offensive" attitude will have a better chance of implementing appropriate adaptation measures in a timely manner (Lemmen *et al.*, 2004; Tarleton and Ramsey, 2008; Sérès, 2010; Darnhofer *et al.*, 2010).

Perception Analysis model is well suited to climate change in that producers do not adapt directly to the change in question, but according to the way in which they have conceived of it; that is perceived it. Indeed, climate change is only a stimulus whose observable response is adaptation. At the system level, adaptation refers to changes observed in response to forces or disruptions such as climate change, rising input prices, etc (Smithers and Smit, 1997). Since the perception of climate change is the translation of the observed stimulus, the adaptation decision of producers would be a reasoned process linked to their perception.

From this literature review, we can draw two major lessons. The first lesson is that most of the work shows that farmers in several African countries have a good perception of climate change and, to a lesser extent, practice adaptation strategies. The second lesson is that many studies examine perception and adaptation separately. These studies do not consider the theoretical literature on this issue, which would require that adaptation be studied simultaneously with perception.

From these theoretical considerations, the basic hypothesis emerges that producers' adaptation to stimuli such as climate change is only coherent with respect to their conception and, therefore, their perception. In this study, we explore adaptation if perceived.

3. Methodology

Presentation of areas of study

This study was conducted in Brazzaville and Pointe-Noire, the two main cities of Congo-Brazzaville, and more specifically targeted farmers established by the Agri-Congo agricultural company. The choice of these two cities was based mainly on the fact that climate forecasts in recent years indicate that they are the most vulnerable cities in the country regarding climate change.

Agri-Congo is a public company created in 1986 with the aim of developing and promoting urban and rural agriculture in Congo-Brazzaville. It is an institution that assures the support of market garden producers so that they become efficient and autonomous. This company tries to improve the supply to consumption center and to create jobs for young people in agriculture. The aim of this institution is also to set up farmers in agricultural land purchased or reserved by the State. These established farmers can benefit from supervision, training, support and advice thanks to the company's expertise. Farm premises become the property of the farmers following a long period of practice or experience in farming. A distinction is therefore made between those who own the land and those who do not. According to data from the latest 2013 census to monitor the number of operators, there are 550 farm operators established by Agri-Congo throughout the country. Agri-Congo operates in four departments of Congo, each with one or more production sites (Table 2):

1. Kouilou in the south of the country (Chimbambouka site at Pointe-Noire);
2. Niari in the south-west (Ngouzoungou site in Dolisie);
3. The Cuvette in the centre (Obouya and Makoua site); and
4. Le Pool in the south-east (Kombé sites, sites on the right bank of the Djoué and Igné site in Brazzaville).

This study covered two exploitation sites, namely the site on the right bank of the Djoué River in Brazzaville and that of Chimbambouka in Pointe-Noire. Table 2 gives an overview of the agricultural production sites available to Agri-Congo.

Table 2: Population of established farmers by Agri-Congo

Localities	Date established	Workforce	Farmers Interviewed	Activities carried out
Brazzaville (Kombé)	1989	63	0	Vegetable growing
Brazzaville (right bank of the Djoué)	1996	260	101	Vegetable growing and livestock
Igné (PK 45)	1993	13	0	Mixed crop farming and livestock
Dolisie	1994 and 2001	94	0	Vegetable growing and livestock
Pointe-Noire	1999 and 2004	120	100	Vegetable growing and livestock
Total		550		

Source: Agri-Congo (2013).

Sampling and data collection

The observation units were the farmers represented by the farm manager. A field survey was conducted among 201 randomly selected farm operators identified from a summary census of farm operators conducted by Agri-Congo in 2013, including 101 in Brazzaville out of 263 operators and 100 in Pointe Noire out of 120 operators (Table 2). The study sample covered 52.48% of the total agricultural population of Agri-Congo in Brazzaville and Pointe-Noire.

Thus, for this study, the questionnaire contains about 30 questions. These are grouped into 5 modules, namely:

Module 1: collects information on the socio-economic characteristics of the farmer. The aim is to obtain basic information (gender, age, surface area, number of agricultural assets, property rights, etc).

Module 2: collects general information on agricultural activity. The aim of the questions in this module is to identify the main crops grown on the farm sites and to question the reasons for the choice of these crops.

Module 3: concerns the perception of climate change. The objective is to ask farmers if they perceive the climate change of recent years and to identify the factors showing this climate change, and possible explanations. The aim is also to assess their experiences and trends in agricultural yields before and after perception of climate change.

Module 4: focuses on adaptation to climate change. The objective is to identify the different strategies used by these operators to adapt to climate change.

Finally,

Module 5: looks at the constraints faced by the farmers. It aims at identifying the needs of farmers in terms of adaptation and in terms of capacity building regarding climate change perception.

Data on the average annual change in temperature and rainfall and specific to the study areas were collected from meteorological services to compare them with the perception of farmers. These data were collected over a period of 24 years (1990-2014) and produced by the National Civil Aviation Agency (ANAC) by direct reading of observation logs (CO) and the monthly climate table (TCM). Temperatures are expressed in degrees celcius; rainfall is measured in millimeters by means of a rain gauge with a 4 square decimeter (dm^2) reception area placed at 150 cm above the ground.

The questionnaires were entered on SPSS and the data processing was done on Excel and Stata software. Questionnaire testing was carried out prior to the actual fieldwork. This activity allowed us to assess the level of understanding of the questions by the farmers in order to improve and adapt them to their level of understanding and to collect the right information. The test took place at the Agri-Congo site on the right bank of the Djoué River in Brazzaville one week before the investigations. Interviews with the leaders of the union of farmers' groups were also conducted to assess the adaptation efforts at the level of the associations.

Collection and processing of data on perception

To avoid a possible case of incorrect perception, a series of three open-ended questions addressed to each sampled farmer was used to define the variable "perception of climate change". In chronological order, the questions were as follows:

1) in recent years, have you perceived a change (or changes) in one or more climate factors?

2) What factor(s) did you perceive as having changed?

3) What change (or changes) did you observe with respect to this (or these) factor(s)?

Based on this set of questions, a producer was considered to have perceived climate change if and only if :

1) he perceived at least one change in at least one climate factor over the past few years;

2) he was able to identify the factor(s) whose change(s) he perceived; and

3) he was able to describe the change(s) he perceived.

In doing so, the variable "perception of climate change" was later treated as a dichotomous dummy variable taking the value of 1 if the producer perceived climate change and 0 if not.

Collecting and processing adaptation data

To avoid a possible case of erroneous adaptation, a series of two questions was asked to each sampled farmer to define the variable "adaptation to climate change". The first question was: "In recent years, have you adjusted one or more of your farming practices in order to adapt your production system to climate change?" Then, the strategies developed in the framework of adaptation to climate change were listed through the question: "What adaptation strategy (ies) do you use?".

To facilitate the description of the results, the strategies listed have been grouped into four categories according to their nature. These are:

1) crop diversification strategies;

2) adjustment of cropping practices and the agricultural calendar (especially planting dates);

3) land use and management strategies;

4) changes in crops on the same site; and

5) other adaptations not included in the previous groups (traditional prayers and rituals, credit and migration).

In considering the two adaptation issues, a producer was considered to be adapting to climate change if and only if:

1) he has adjusted his farming practices to adapt his production system to the previous change(s) he would have mentioned; and

2) he has adopted at least one of the five groups of adaptation strategies.

Finally, the variable "adaptation to climate change" was later treated as a dichotomous dummy variable taking the value of 1 if the producer is adapting and 0 if not.

Theoretical model

The determinants that influence farmers' perceptions to climate change have been analyzed by several authors using binary logic regression (Oyekale and Oladele, 2012; Maddison, 2007; Acquah, 2011; Gbetibouo, 2009) according to the following model:

$$y_i = x_i \beta + \varepsilon_i \quad (1)$$

Where y_i is the latent variable indicating whether or not the producer perceives climate change, x_i is the set of explanatory variables indicating the factors that influence the perception to climate change, and ε_i is the standard error. The dependent variable is a dummy variable equal to 1 if the producer perceives climate change and 0 if not (Oyekale and Oladele, 2012).

Binary logical regression was also used according to Nabikolo *et al.* (2012) to determine the factors that influence the decision of agricultural producers to develop adaptation strategies. In this case, y_i represents in equation (1) a dichotomous dependent variable (the variable takes the value 1 if the producer adopts an adaptation strategy in response to perceived climate change and the value 0 if not) and x_i is the set of explanatory variables.

Other models on the factors influencing the choice of agricultural producers to use a specific climate change adaptation method are based on the use of the multinomial logit or multivariate Probit model (Tazeze *et al.*, 2012; Rashid Hassan and Nhemachena, 2008; Asfaw *et al.*, 2015). In this type of model, the dependent variable is multinomial with as many categories as the number of climate change adaptation methods identified in the study area. The model specification in this case, in reduced form, is as follows:

$$Y_i = f\,(X_1, X_2,\ldots, X_n) \quad (2)$$

Where y_i, a polychotomous dependent variable, is the adaptation method chosen by the producer and X_1 to X_n are the explanatory variables. On the basis of the information collected on the adaptation strategies developed by producers in the study area, the dependent variable (y_i) is often coded 1 for "no adaptation", 2 for "use of varietal diversity", 3 for "good farming practices (mulching and tutoring)", 4 for "drainage", 5 for "land change" and 6 for "multiple adaptation strategies". Explanatory variables most often include: level of education, age, gender, years of experience in agricultural production, farm size, labour used, and membership in a farmer or producer association.

Model specification

The regression model in this study is based on the recent works of Yegbemey *et al.* (2014), who studied adaptation in relation to perception and whose general form is as follows:

$$A_i = f(Z_i) \quad (3)$$

Where A_i and Z_i, respectively, represent the adaptation decision of producer i and a set of demographic and socio-economic characteristics of the same producer I, by considering the hypothesis of the perception-adaptation link, the simplest way to integrate the perception of producers (P) in the previous model is to express it in the form below:

$$A_i = f\,(Z_i,\ P_i) \quad (4)$$

However, still in the context of the theoretical framework, perception itself appears as an endogenous variable (a function of a number of characteristics specific to the individual). Therefore, equation estimation (4) shows endogeneity biases. Under these conditions, the specification of two separate models, an adaptation model (equation (5) and a perception model (equation (6) appears as an alternative that would limit the estimation bias; that is:

$$A_i = f\,(Z_i) \quad (5)$$

$$P_i = f\,(Y_i) \quad (6)$$

Where Y_i represents a set of socio-demographic and socio-economic characteristics of the same producer i, which could be the same as or different from Z_i. This new formulation, although it eliminates to some extent the perception-related endogeneity bias, does not take into account the initial hypothesis that producers' adaptation to stimuli such as climate change is only conceivable with regard to their conception of the said change. According to Maddison (2007), echoed by Gbetibouo (2009), perception is a prerequisite for adaptation. In other words, one must perceive before adapting. The problem is therefore no longer a matter of endogeneity, but rather one of selection; adaptation if it is perceived.

Accordingly, as proposed by Maddison (2007) and Gbetibouo (2009), a selection model such as Heckman's Probit model makes it possible to better explore producers' adaptation decisions in relation to their perception. In doing so, the general model becomes:

$$A_i = f(Z_i) \text{ if and only if } P_i = f(Y_i) > 0 \tag{7}$$

The form as defined is based on two sub-models: the output model or adaptation model whose dependent variable is adaptation (A) and the selection model whose dependent variable is perception (P). Considering j demographic and socio-economic characteristics linked to producer i and capable of determining his adaptation decision (characteristics noted z_{ij}) on the one hand, then j′ demographic and socio-economic characteristics linked to the same producer i and capable of determining his perception (characteristics noted $y_{ij'}$) on the other hand, the resulting econometric model is:

$$A_i = \alpha_0 + \sum j \alpha_j z_{ij} + u_i \tag{8}$$

If and only if,

$$P_i = \beta_0 + \sum j' \beta_j' y_{ij}' + v > 0 \tag{9}$$

In this model, a_i is the adaptation decision (1 = adapts; 0 = does not adapt) of producer i and p_i his perception which is defined here as a dichotomous dummy variable (1 = perceives; 0 = does not perceive); α and β are the parameters to be estimated. Finally, u and v are the error terms.

Then, Heckman's Probit model will be used to estimate the parameters (α and β) if and only if the selection is strong. If almost all operators perceive climate change (low selection), the adaptation (8) and perception (9) equations will be estimated separately. Table 3 below presents the different variables introduced in the two models.

Multicollinearity tests were conducted to ascertain whether independent variables in the adaptation model to be estimated provide redundant information on the response variables. We tested for multicollinearity using the variance inflation factor, $VIF_j = 1 / (1-R^2_j)$, where R^2_j is the coefficient for determining the model that includes the independent variables except the j^th variable. Annex Table 2 shows the VIF for all variables that are less than 10, indicating that there is no multicollinearity problem.

To assess farmers' constraints in adapting to climate change, we used the Problem Coping Index (PCI) with levels of constraint ranging from 0 to 3 with 3 being the highest constraint. This index is calculated using the following formula:

$$PCI = P_n \times 0 + P_l \times 1 + P_m \times 2 + P_h \times 3 \quad (10)$$

With:

PCI = Problem coping index;

Pn = Number of operators who do not consider constraints to be a problem;

Pl = Number of operators who consider constraints to be low;

Pm = Number of operators who consider constraints to be moderate;

Ph = Number of operators who consider constraints to a high degree.

Table 3: Variables introduced in regression models.

Variables	Definitions	Modalities	Expected sign
Adaptation Model (output model)			
Property rights	The farmer holds a land title issued by Agri-Congo	No = 0; Yes= 1	+
Membership to an Organization	The farmer is a member of a producers' group or organization	No = 0; Yes= 1	+
Cultivated area in ha	Extent of land or size of farming activity	---	+/-
Access to credit	The farmer has applied for and received credit in the last three years	No = 0; Yes= 1	+
Subsidiary activity	Carrying out a non-agricultural activity	No = 0; Yes= 1	+
Level of education	Education level of the farm manager	1= primary; 2= secondary; 3= higher	+ +
Age per year	Age of the farmer measured in years	---	+
Age ^{2}	Age squared of the farmer measured in years	---	+
Input donations	The farmer has received input donations from support institutions over the last three years.	No = 0; Yes= 1	
Experience in agriculture	Number of years in farming business		

contnued next page

Table 3 Continued

Variables	Definitions	Modalities	Expected sign
Perception Model (selection model)			
Experience in agriculture	Number of years in farming business	---	+
Property rights	The farmer holds a title deed issued by Agri-Congo	No = 0; Yes= 1	+
Contact with extension services	The farmer has benefited from the advice and information provided by Agri-Congo's extension officers	No = 0; Yes= 1	+
Number of farm workers	Number of people employed by the farmer	---	+
Level of education	Education lever of the farm manager	1= primary; 2= secondary; 3= higher	+ +
Age ^{2}	Age squared of the farmer measured in years	---	+

Source: Author

Since the methodological approach used to carry out this study has been specified, it is incumbent upon us to present the results obtained. This is then the purpose of the subsequent section.

4. Presentation and analysis of the results obtained

This part includes presentation and descriptive analysis, and presentation and econometric analysis.

Descriptive analysis of results

This analysis is based on the results from a field survey involving 201 farmers, including 101 in Brazzaville and 100 in Pointe-Noire. The following tables present the results obtained.

Characteristics of farmers

The survey results presented in Table 4 show that 49.75% of the sample are men and 50.25% are women. More than half of the farmers have secondary education level. All farmers reported that agriculture is their main source of income. However, in addition to agriculture, 46.23% of the samples have a secondary activity. Trade, pig and cattle breeding, handicrafts and informal businesses are the most common secondary activities carried out by farmers. Access to credit is low among farmers (27.78%). The main reasons for this low access are: low purchasing power, restrictive conditions required by financial institutions, and fear of incurring debts.

Regarding membership to an organization, 91.04% of respondents belong to an organization. These producers are not all members of the same organization. Farmers in Brazzaville are members of the Union of Livestock Breeders and Farmers' Groups, while those in Pointe-Noire are members of the Market Gardeners' Union. This membership is an asset for the latter because they can benefit from mentoring and training. The services provided by these organizations are limited only to the learning of agricultural or market gardening techniques (87%). Very few farmers have received training on climate change from these organizations (only 5%) and information on climate change (10%).

Inheritance is the main mode of accessing land; thus 65.82% of the farmers surveyed own property rights, mainly through inheritance. There are practically no land tenure problems in the Agri-Congo farm sites, according to 60% of the farmers surveyed. Contact with extension services is low (39.30%). Farmers testify that the extension services provided by Agri-Congo agents are not regular, which means that there is little contact with them. Access to inputs is difficult, which is one of the challenges facing agricultural activities; 86.57% of respondents said that this is one of the difficulties of farming business, and only 19.40% of farmers have already received input donations from institutions such as Agri-Congo or the Departmental Directorate of Agriculture and Livestock.

Family manpower is the one most commonly used by farmers to reduce production costs. The number of farm workers employed in the sites is on average two (2) persons. The average area cultivated by farmers is 0.859 hectares. This shows that they are small farmers. However, they have a great deal of experience because most of them began their farming activities in the 1990s. The average age of the farmers is 36 years.

Table 4: Socio-economic characteristics of farmers

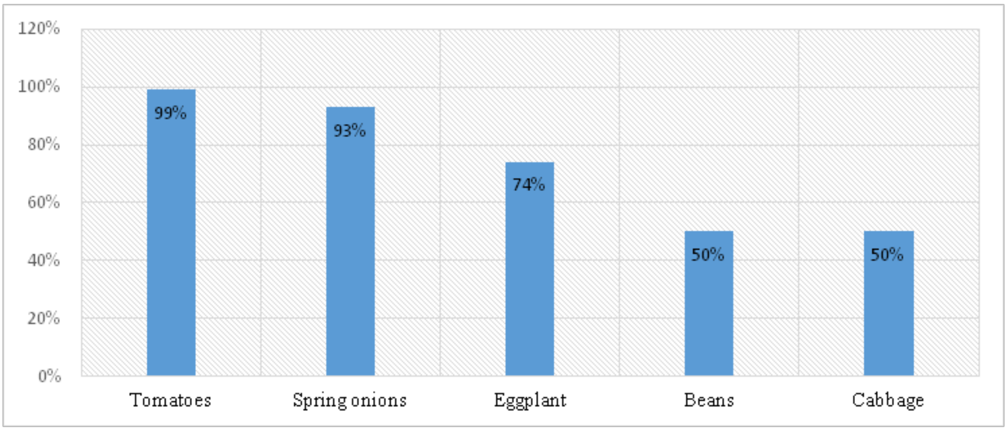
Qualitative variables	Absolute values	Percentage (%)
Masculine	100	49.75
Feminine	101	50.25
Secondary level education	104	51.74
Agriculture as main activity	201	100
Engaged in subsidiary activity	92	46.23
Access to credit	55	27.78
Membership to an organization	183	91.04
Holding property rights	129	65.82
Contact with extension services	79	39.30
Input donations	39	19.40
High cost of inputs	174	86.57
Quantitative variables	Average	Standard deviation
Number of farm workers	2	0.96
Average age in years	36	3.1
Experience in agriculture (years)	10,24	7.29
Cultivated surface area in m2	859	280.67

Source: Survey (2015)

Description of main crops

The survey identified five (5) main crops most grown by Agri-Congo farmers. At the time of the survey, these were tomato, spring onion, eggplant, beans and cabbage. Figure 3 shows the percentages of each crop. Three reasons were given for the choice of these crops: mastery of cultivation techniques in relation to training received or experience (45% of responses); the dry season (40%); and ease of selling in the market (15% of responses).

Figure 3: Presentation of the main crops



Source: Survey (2015)

Farmers' perception of climate change

Perception was analyzed through three questions that farmers would have to answer chronologically to get around the misperception. The first question was to ask the farmers if they themselves perceived climate change over the past 10 years. In case the farmer answered "yes" to the second question, the farmer should be able to cite the climatic factors that he perceived to have changed. The third question would require the operator to explain the change they observed in the climate factor they found to have changed. Valid answers to these three questions assume that the farmer has perceived climate change; otherwise the farmer has not perceived climate change.

In response to these questions, the survey reveals that almost all farmers (198 farmers), i.e. 98.5%, perceived climate change in recent years in a general way, as they validly answered these questions based on their experience in the exercise of agricultural activity. Only three (3) farmers were unable to give valid answers to these questions and therefore could not be aware of climate change. The perception rate is very high and shows that climate change is a reality in the eyes of these farmers (Table 5).

Table 5: Perception of climate change through selection

Rate of perception	Number of respondents	Percentage
Those who perceived climate change	198	98.50%
Those who didn't perceive climate change	3	1.50%
Total	201	100.00%

Source: Survey (2015)

Regarding descriptions of climate change, the survey showed that climate change is mainly explained by rain, temperature, wind and drought. Table 6 shows the results obtained on the climatic factors that have changed over the last years.

Table 6: Climate factors that have changed

Perception rate of climate factors	Number of respondents	Percentage
Perception through rain	123	62%
Perception through temperature	127	64%
Perception through other factors	59	30%

Source: Survey (2015)

The description of climatic factors that have changed is shown in Table 7, where we note that, in terms of rainfall factor, farmers mention more cases of rainfall decrease (77%) and cases of rainfall abundance (62%), but rainfall decrease is more cited by farmers as compared to rainfall abundance. We conclude that, according to farmers, there has been a decrease in rainfall in recent years. As far as the temperature factor is concerned, the survey shows that climate change can be explained by increase in temperature (71% of responses) but especially by the change in time interval where it is getting hotter and hotter even during the dry season. Concerning the other factors, farmers mainly report strong winds.

Table 7: Observed changes in each climate factor

Climatic factors	Number of respondents	Percentage
1) Rain factor		
Decreased rainfall	152	77%
Abundant rainfall	123	62%
Frequent flooding	71	36%
Shortening the rains duration	26	13%
2) Temperature factor		
Temperature increase	141	71%
Decrease in temperature	59	30%
Changing the time interval	158	80%
3) Other factors		
Extinction of species	25	12,50%
Strong winds	50	25%
Drought	20	10%

Source: Survey (2015)

In summary, according to the perception of farmers, climate change translates into:

- A decrease in annual rainfall.
- A sequence or repetition of a few dry to very dry years. Farmers note the sequence of the last four years with very little rainfall in Brazzaville and Pointe-Noire.

- Changes in climatic calendars: the start dates of the rains are delayed compared to normal times. Depending on the case, this may be a simple shift (with a later end to the rains) or a shortening of the rainy season.

- The gradual transition from two to one rainy season by disappearance/mitigation of the short dry season.

- An increase in temperatures at certain times of the year.

Table 8: Manifestations of climate change by farmers

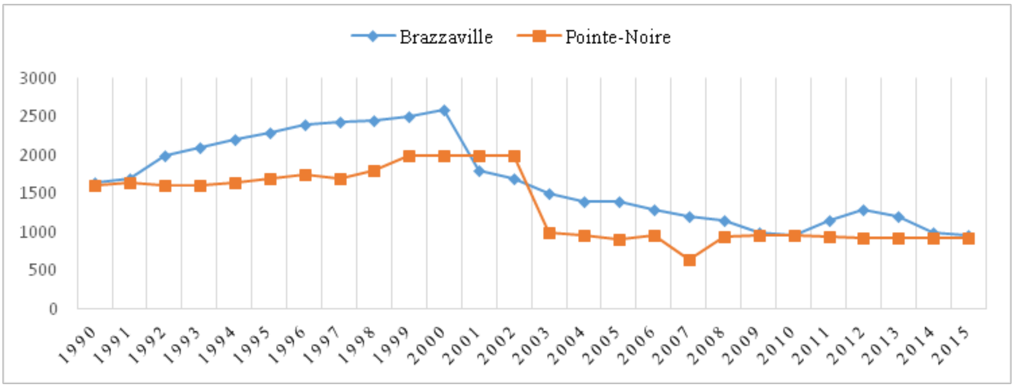
Observed changes in rainfall		Manifestations
Late start and/ or poor rainfall distribution	GSP	The major rainy season no longer starts in April as it used to. Early planting of eggplants and cassava, for example, is no longer possible in March.
	PSP	The short rainy season no longer begins towards the end of the bean-cult ceremonies in the last decade of August. It starts late in early October and the rains are poorly distributed.
Shorter rainy seasons Duration of seasons	GSP	Only 13% of farmers noted a shortening of the length of the long rainy season due to its early break-up and late start. The early break in the season disrupts the flowering and maturing of cabbages. This very often results in loss of the entire crop for many farmers.
	PSP	The late onset of the short rainy season is more pronounced than the early breaks recorded.
Decrease in the number of rainy days	GSP	According to 77% of farm managers, the number of rainy days in the main rainy season is decreasing. The rains are concentrated over very short periods, especially in May, with the highest rainfall in June.
	PSP	The late start coupled with the cessation of rains towards the end of the season leads to a decrease in the number of rainy days during the short rainy season according to all the farm managers surveyed.
Floods	GSP	64% of farmers reported incidents of flooding during the major rainy seasons.
	PSP	According to some farmers, the late onset of rains during this season is leading to flooding, which is leading to crop losses which were not previously the case.
Observed temperature change		
71% of farmers reported an increase in temperature in recent years, mainly due to delayed rains. They indicated that it is getting warmer and warmer at all times of the year, with an increase in the number of sunny days over the last few years. Even during the rainy season, with light sunshine, the heat is unbearable. This increase in temperature has a negative impact on crops.		

Source: Survey (2015)
NB: GPS= major rainy seasons; PSP = shorter rainy season.

Comparison of weather data with farmers' perceptions

Data collected from the National Civil Aviation Agency (ANAC) show the evolution of the average rainfall from 1990 to 2014. Indeed, on Figure 4, we can deduce three main different time periods concerning the rainfall amounts. Firstly, in these cities, an increase in rainfall between the 1990-2000 decades, followed by a slight decrease in rainfall from the 2000-2004 periods, especially in Brazzaville. Finally, from 2005 to the present day, there has been a gradual decrease in rainfall. According to Figure 4, rainfall amounts have been on a decline in recent years. This analysis confirms farmers' perceptions, as most farmers surveyed (77%) perceived climate change through decrease in rainfall in recent years (Table 7).

Figure 4: Evolution of the average annual rainfall in millimeter (mm)



Source: Author following the compilation of National Civil Aviation Agency (ANAC) and Agency for the safety of air navigation in Africa and Madagascar (ASECNA) data.

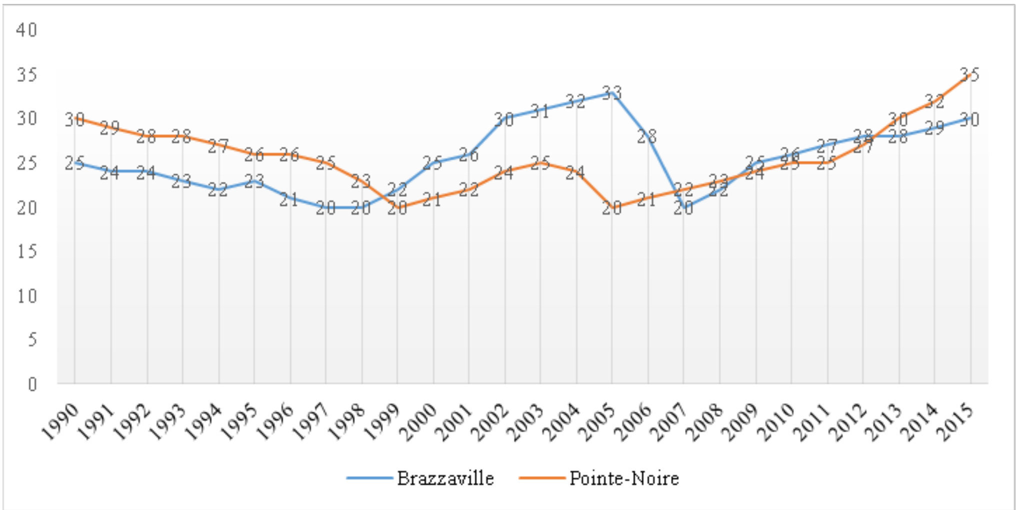
By analyzing the evolution of the average annual temperature in Figure 5 below, it is noted that in the years 1990-2000, average temperatures were not too high and oscillated around 20°C to 30°C. It is precisely from the years 2000-2006 that the cases of rising and falling temperatures began to be recorded. From 2007 to the present day, the average annual increase in temperature has increased. The same observation was made by the farmers interviewed (71% of the responses in Table 7).

In comparing meteorological data and farmers' perceptions, we can state that climate change is mainly explained by the inverse evolution between temperature and rainfall; that is, while temperatures and the number of sunny days increase, rainfall tends to decrease or become scarce. This could not be observed 20 years ago. In Figure 6, we present the seasonal aspect of the evolution of rainfall to better identify these climatic variations.

In Congo, the main rainy season occurs in the period March-April. In this period, it rains heavily and floods are frequent. However, from Figure 6, the period March-April now records a decrease in rainfall over the whole period while the period February-March records an increase in rainfall. There is, therefore, a change in the rainy season period. This means that the heavy rains no longer occur in March-April as usual but rather in February-March. This is what farmers call “the poor distribution of rains”. The period June-July-August, which used to be characterized by scarcity of rains or by the major dry season records a slight increase in rainfall until September when the number of rainy days during the major rainy season is decreasing, while the number of rainy days during the main dry season is slightly increasing.

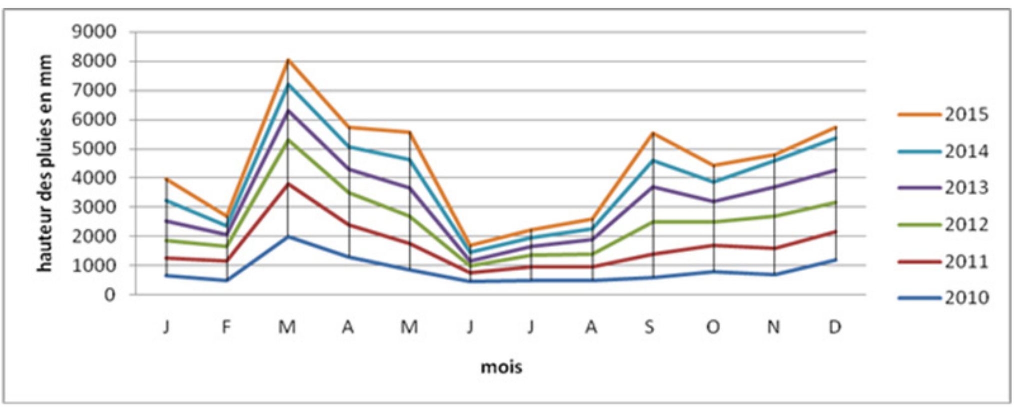
All this analysis points to possible climate change and confirm farmers’ perceptions.

Figure 5: Evolution of the average annual temperature in degree celcius (°C)



Source: Author following the compilation of National Civil Aviation Agency (ANAC) and Agency for the safety of air navigation in Africa and Madagascar (ASECNA) data.

Figure 6: Evolution of the average monthly rainfall per month in mm

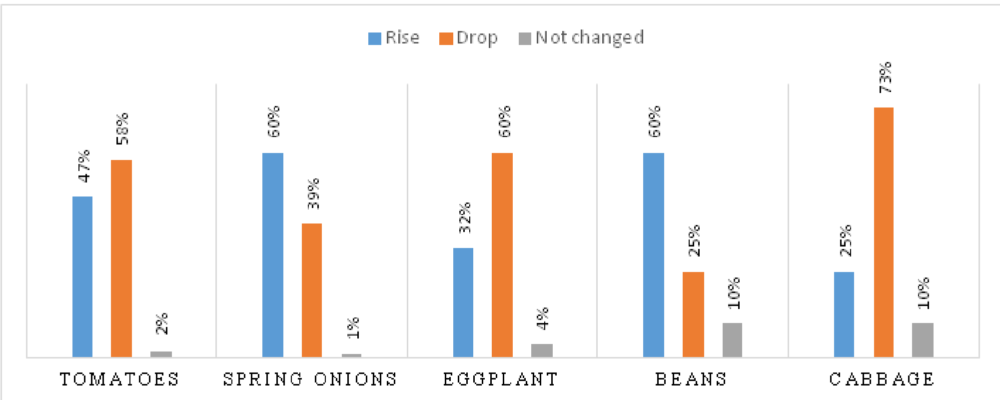


Source: Author following the compilation of National Civil Aviation Agency (ANAC) and Agency for the safety of air navigation in Africa and Madagascar (ASECNA) data.
NB: Hauteur des pluies en mm = rain height in millimeter and mois = months.

Trends in major crops after climate change perception

The results of the survey show that climate change has affected the production activities of farmers (99.50% of responses). As shown in Figure 7, while climate change has negatively affected some crops such as tomatoes, cabbages and eggplants, whose harvests are on a downward trend, it has had a positive impact on others such as beans and chives. We can see that these crops have an upward trend. Nevertheless, according to the farmers interviewed, 163 or 81.50% of responses stated that climate change represents a concern for their agricultural productivity. Poor harvests (70.25%), a drop in income (26.58%) and the risk of changing business (3.16%) are the main sources of this concern.

Figure 7: Response rate on agricultural yields



Source: Survey (2015)

Adaptation to climate change

Adaptation to climate change accounts for all the adjustments made by farmers to adapt their production systems.

In fact, the results of the survey show that, out of the 198 farmers who perceived climate change, 169 farmers practiced adaptation; that is, a total of 85.35% of responses. Some producers who did not develop any adaptation strategy and others who practiced adaptation mentioned, among others, the lack of information on adaptation strategies, the lack of initiatives on adaptation measures within the farmers' union, and the financial constraints for its implementation as the main barriers to adaptation. These results are in line with the observations made by Deressa et al. (2009).

Out of the five (5) groups of adaptation strategies listed, farmers who practiced adaptation used crop diversification (92%), adjusting the agricultural calendar (85%), and changing crops on the same site followed by land use strategy (40%). It should be noted that farmers make combinations of adaptation strategies. Table 9 below illustrates the adaptation strategies developed by farmers.

Table 9: Strategies for adaptation to climate change

Strategy Clusters	Response rate (%)	
	Yes	No
Diversification of crops	92	8
Adjustment of the farming calendar	85	15
Change of crops in the farm	60	40
Land use	40	60
Other strategies	16	84
N=169		

Source: Survey (2015)

Indeed, according to farmers, the main objective of crop diversification is to increase their resilience in the event of a hazard on one of their productions. This is the strategy mostly used by farmers in the face of climate change. It is also the farming method favoured by these farmers since their establishment.

Adjustment or modification of the agricultural calendar is used by farmers to match the crop cycle with the current configuration of the seasons. In Brazzaville, for example, farmers bring forward the date for sowing beans from the second rainy season.

Changing crops within the same site is based on the choice of speculation. Some farmers act on the abandonment or introduction, reduction or extension of certain speculations depending on the nature of the climate. Slow and continuous growing of crops such as okra and maize are thus replaced by fast growing crops such as tomato and cabbage in the dry season to limit the risk of zero harvest, reported the farmers interviewed.

The land use strategy consists of maintaining soil fertility: manure utilization, promotion of composting, use of Nitrogen, Phosphorus, and Potassium (NPK) fertilizer, which enriches manure, bat droppings, urea, super phosphate, and super ammonia. Thus, mechanization (harnessed cultivation) allows for faster crop planting, thus adapting to a late start to the season. It also allows for an increase in cultivated areas, which can compensate for the low yields observed.

Other adaptations relate to certain rituals or prayers that farmers perform before planting their crops. However, this technique seems to be rarely used by the farmers contacted.

It should be noted that 62 farmers, or 36.69%, practiced adaptation compared to imitating the experience of the neighbour. The cost of adaptation is not an obstacle to adaptation for most farmers (55% of responses) because they already have some essential equipment such as greenhouses, water and motorcycle pumps made available to them by Agri-Congo.

According to the results in Table 10, farmers use crop diversification strategy more in the case of rising temperatures than other strategies. The strategy of adjusting the agricultural calendar is more practiced in cases of reduced or irregular rainfall. This means that rising temperatures encourage farmers to adopt crop diversification strategy rather than the farming calendar adjustment strategy, whereas unfavourable rainfall favours the farming calendar adjustment strategy.

Table 10: Adaptation strategies based on current climatic trends

Nature of climate	Adaptation strategies	Pointe-Noire (n=71)	Brazzaville (n=98)
		% of responses	
Rise in temperatures	Crop diversification	90	96
	Adjustment of farming calendar	65	67
	Change of crops in the farm	35	48
	Land uses	15	25
	Other strategies	2	0
Decrease in rainfall	Crop diversification	69	70
	Adjustment of farming calendar	82	72
	Change of crops in the farm	40	50
	Land use	10	20
	Other strategies	8	0

Source: Survey (2015)

Farmers' adaptation constraints to climate change

The results in Table 11 illustrate the different adaptation constraints faced by Agri-Congo farmers. Indeed, the assessment of constraints based on the Problem Coping Index (PCI) shows that lack of experience with adaptation techniques, difficulties in accessing credit and agricultural inputs, and lack of adequate agricultural equipment are the main obstacles mentioned by farmers.

Table 11: Adaptation constraints (n=198)

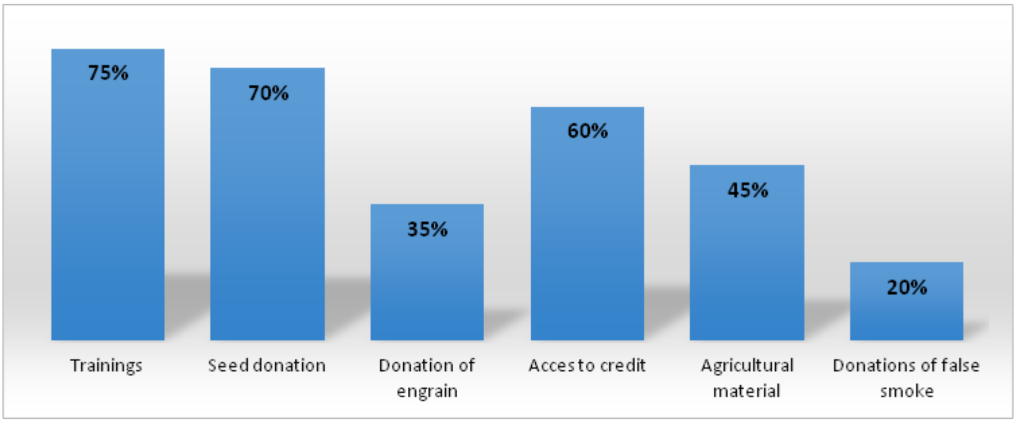
	Degree of constraints				PCI	Ranking
Constraints	High	Average	Low	No issues with PCI		
Lack of experience	100	48	39	11	435	1
Difficulties in accessing farm inputs	60	58	78	2	374	2
Lack of farm equipment	40	50	99	9	319	3
Lack of farm credit	25	35	41	97	186	4
Difficulties in accessing water	0	0	52	146	52	5
Unfertile soils	0	1	25	172	27	6
High adaptation cost	0	0	11	187	11	7

Source: Survey (2015)

Farmers' expectations on adaptation

The adaptation techniques developed by farmers with the support of some NGOs, Agri-Congo or the government have had fairly positive results, but this has not succeeded in reducing farmers' vulnerability to climate change. The farmers surveyed are aware of this, and believe that to achieve this, they need to have access to fertilizer, easy access to credit and continuous training, since science is evolving and so is technology. They also need more efficient and better agricultural equipment so that they can put into practice some of the adaptation methods they have learned. Yield improvement also requires the use of improved seeds in case of crop failure. All these expectations are represented in Figure 8 below.

Figure 8: Adaptation expectations



Source: Survey (2015)

Analysis of econometric results

Based on the statistical results presented in Table 5, there is a very low selection because almost all farmers have perceived climate change. There is no selection problem at all in this case (Bryan et al., 2009). Consequently, since the two-step estimation of the Heckman model is no longer necessary, the two models were estimated separately and their results are presented in the tables below.

Regression results

Table 12: Determinants of perception to climate change

Variables	Perception
Age per year	0.011*** (0.004)
Level of education	0.384** (0.208)
Number of farm employees	0.188** (0.838)
Experience in farming	0.4073 (0.385)
Contact with extension services	0.3867 (0.325)
Property rights	0.213 (0.4529)
Constant	0.0439 (7.265)
Observations	198

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 13: Determinants of adaptation to climate change

Variables	Adaptation
Input donations	0.587** (0.295)
Access to credit	0.0704 (0.282)
Property rights	0.671*** (0.234)
Membership to an organization	0.553* (0.321)
Experience in farming	0.0263** (0.0124)
Cultivated surface area in m2	-0.000130 (0.000307)
Level of education	0.107 (0.161)
Subsidiary activity	0.877*** (0.263)
Age per year	-0.0693 (0.0670)
Age^2	0.000844 (0.000745)
Constant	0.0489 (1.623)
Observations	198

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Discussion of econometric results on perception

The estimation results presented in Table 12 show that only three out of 201 farmers did not perceive climate change. Out of the six (6) variables retained in the perception model, three (3) variables are significant and positively correlated with the perception of climate change at the 1% and 5% thresholds. These are respectively the following variables: age, education level and the number of agricultural workers.

The results obtained on the age variable show that the perception capacity to climate change among farmers increases with age. This means that the older we get, the more the perception capacity increases. Older age makes it easier to make comparisons on climate change between past and present years to see climate change. Older producers who have some experience with planting dates and seasonal control are more likely to understand changes in agricultural production systems. As a result, they are among the 'farmer leaders' and are often targeted by Agri-Congo extension workers to pass on their knowledge of climate change to younger farmers.

The level of education of farmer increases the likelihood of perceiving climate change. Indeed, several studies have shown that producers who have received formal education have a better perception of climate change and apply innovations well (Arun and Yéo, 2019). Majority of Agri-Congo farmers have secondary level of education, which enables them to better understand and appreciate the risks associated with the current climate change. This explains the positive correlation observed between education level and perception of climate change in this study. Contrary to the results obtained for the case of Benin by Yegbemey et al. (2014), according to which climate change is a rather physical phenomenon that is imposed on producers and that one does not need a high level of education to perceive, this study shows that the level of education is a determining factor in the perception of climate change by farmers in Congo.

The variable number of farm workers on a farm positively influences farmers' perceptions of climate change. This can be justified by the fact that the perception of climate change can be ignored by one but captured by the other. Those who work with a large workforce are more likely to grasp the possible risks of climate change compared to farmers who do not have any farm assets because of the neighbourhood effect.

The non-significant positive results are obtained in the perception model with the variables: experience in agriculture, contact with extension services and property rights; whereas several studies have shown that these variables positively and significantly influence perception of climate change (Maddison, 2007; Gnangle et al., 2012; Yegbemey et al., 2013; Piya et al., 2013). Sessinou (2016) in Niger has shown, for example, that contact with the extension services enables farmers to have reliable and real information on climate change, which increases the perception capacity of the farmer. In the case of Agri-Congo farmers, the insignificance of the variables can be explained by the fact that experience in agriculture is not enough and that only a limited number of farmers have had contact with Agri-Congo extension agents. Efforts should therefore be made at this level.

Discussion of econometric results on adaptation

The adaptation equation is positively and significantly influenced by the following variables: input donation, experience in agriculture, property rights, secondary activity and membership in an organization at the 10%, 1% and 5% thresholds, respectively.

Input donation variable significantly increases the probability of adaptation in the case of Agri-Congo farmers. Indeed, the input subsidies received by farmers from supporting NGOs, Agri-Congo and other institutions enable them to strengthen their capacity to adapt to climate change. Having benefited from the inputs, they can easily adapt their farming practices to the changing climate.

Experience in agricultural activity in our model is positively correlated with adaptation. Experience therefore allows farmers to adjust their farming practices more quickly before witnessing the consequences of climate change. In several studies, it has been shown that the number of years spent in agricultural activity allows the producer to have some control over the entire production process and the factors that influence the different stages of this process. The results obtained confirmed those of Maddison (2007) and Gbetibouo (2009), who concluded that experience in agriculture is a potential determinant of the level of adaptation to climate change rather than the level of the producer's perception of it.

According to the results obtained, the more property rights a farmer has, the more likely he is to adapt to climate change to sustain his agricultural activity. Ownership of property rights is an indicator of land tenure security and a determining factor in the exercise of agricultural activity. This shows that farmers who hold land titles issued by Agri-Congo are better able to withstand climate change and practice adaptation than those who do not. This is in line with the findings of Yegbemey et al. (2013) that secure property rights promote producer investment and also facilitate adaptation to climate change. The fact that Agri-Congo establishes farmers by granting them land is an asset for sustainability and thus for the motivation to adapt.

Carrying out of a secondary activity is positively and significantly correlated with the decision to adapt to climate change. The more the farmer engages in a non-agricultural activity, the more his adaptive capacity increases. A non-agricultural activity is considered an adaptation strategy because it constitutes another source of income for farmers. Thus, income from secondary or off-farm activity can be used to increase the level of investment in inputs such as labour, fertilizers and pesticides, and new varieties. Producers who already have a secondary activity would be more likely to adapt to climate change.

The results show that belonging to an organization is positively and significantly correlated with adaptation. This means that farmers who are members of a farmers' organization are more likely to respond to climate change than others. Membership in an organization facilitates access to information and adaptive practices or techniques and allows the sharing of climate risks. The role of Agri-Congo's extension workers is to inform farmers, often grouped in associations, about everything related to agricultural activity. In this case, producers are made aware of the current climate variability and the present and future consequences on agricultural production chains and on the immediate environment of mankind. In addition to these sources of learning, there are also the relationships between farmers that serve as channels for sharing experiences and that can lead to joint adaptation initiatives, hence the positive correlation observed.

Finally, access to credit is positively correlated with the producer's adaptation to climate change but is not significant. Whenever a producer has access to credit, he can easily develop adaptation strategies, particularly those requiring additional investments (increase in fertilizer levels), purchase of new short-cycle varieties, etc). The cultivated area is not significant and has a negative coefficient. This can be explained by the fact that the field survey revealed that Agri-Congo farmers, for the most part, work on small areas, whereas the larger the area, the more adaptive means are possible, especially in terms of crop diversification.

5. Conclusion and recommendations

The study on perception and adaptation to climate change that we carried out on the farmers established by Agri-Congo revealed that almost all the farmers have a good perception of climate change of recent years and are developing adaptation strategies. The rate of perception of climate change is 98.50% and the rate of adaptation to climate change is 85.35%. The high rates of perception and adaptation recorded among farmers are attributable to their experience in agricultural activity and to their determination to preserve their farming activities despite the current risks related to climate change.

The study also shows that climate change is a source of concern for farmers, as three out of five major crops at the time of the survey have been on a downward trend in recent years, accounting for 60% of the crops. These crops are: tomatoes, cabbages and eggplants. For most farmers, climate change is mainly explained by decrease in rainfall, disruptions in the duration of the seasons and the increase in temperature. Comparisons with meteorological data confirmed farmers' perceptions and led to the conclusion that climate change is an undeniable reality in Congo-Brazzaville.

The study identified several adaptation strategies, but the most common ones practiced by farmers are: crop diversification, adjustment of the agricultural calendar and crop substitution within the same farm site. The Problem Coping Index (PCI) calculated showed that lack of experience, limited access to inputs and agricultural credit are the main constraints to adaptation. To this end, training in adaptation techniques, support in the form of donations of inputs and fertilizers, facilitation of access to credit and improvements in agricultural equipment were the main expectations cited by farmers from Agri-Congo and its partners to enhance their adaptive capacity.

Finally, the study pinpointed the determinants of perception and adaptation to climate change through the application of the Probit model. In the case of our study, age, education level and the number of farm workers are the main variables that increase farmers' perception of climate change, while input donations, experience in agriculture, property rights, engaging in a secondary activity and membership in an organization are the determining factors influencing farmers' adaptation to climate change.

To strengthen farmers' experiences in perceiving and adapting to climate change, the study makes the following recommendations:

- Agri-Congo should encourage farmers to join producer organizations to receive appropriate advisory services and training to strengthen their capacity to perceive and adapt to climate change through a mechanism of close collaboration;

- The Ministry of Agriculture in partnership with Agri-Congo should set up a capacity building program for farmers in the field of perception and adaptation to climate change through targeted training;

- The Ministry of Agriculture should provide input grants and especially equip farmers with the agricultural equipment they need to help them scale up their technical efforts to adapt to climate change; and

- The Ministry of Agriculture should reflect on the creation of a future agricultural bank through a public-private partnership to facilitate farmers' access to bank credit.

Notes

1. The Intergovernmental panel on climate change.

2. AXA is a French organization for agricultural insurance.

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Annexes

Annex Table 1: Results of the normality test of the adaptation model

The normality test is used to determine whether the residuals of a regression follow a normal distribution. It states:

H0: the residuals follow a normal distribution.

H1: the residuals do not follow a normal distribution.

Ktest residu als

Skewness/Kurtosis tests for Normality

	------- Joint ------				
Variable	Obs	Pr(Skewness)	Pr(Kurtosis)	adj chi2(2)	Prob >chi2
Residuals	198	0.967	0.602	0.49	0.7100

Source: Author from Stata 11

The probability of the test is 0.71 > 0.05, we accept the H0 hypothesis of normality of the residues. Thus, U and V follow a normal distribution.

Annex Table 2: Results of the multicollinearity test of the variables included in the adaptation model

Variables	VIF	1/VIF
droitsdepr~t	3.00	0.333333
Don intra~n	2.64	0.378787
appartenan~n	1.18	0.892857
activitsec	1.09	0.980392
superficie~e	1.21	0.826446
accsauxcrd~s	1.06	0.943396
age2	2.02	0.495049
exprienced~e	1.78	0.561797
Mean VIF	1.74	

Source: Author from Stata 11

The variance-inflation factor (VIF) test and its inverse (1/VIF) test are used to detect the multicolineraity of the explanatory variables. Indeed, 1/FIV must be greater than 0.1 for us to conclude that there are no multicollinearity problems. We can see from the above table that the 1/FIV ratio is greater than 0.1 for all the coefficients. We can conclude that we do not have a multicolineraity problem.

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