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CONTRIBUTION TO FOOD SECURITY BY IMPROVING FARMERS' RESPONSES TO CLIMATE CHANGE IN NORTHERN AND CENTRAL AREAS OF CÔTE D'IVOIRE

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Abstract

For a long time, rural smallholder farmers have faced environmental threats; however, the speed and intensity of climate change (CC) are now outpacing the farmers' ability to cope. Effective and viable adaptation solutions are needed as farmers in developing countries have to deal with additional threats such as poverty, low level of technical innovation, etc. These constraints thus make achieving food security goals more difficult. To contribute to improving poor farmers' livelihoods and to overcome the gap in implementing adaptation strategies, understanding farmers' perceptions and their decision-making behavior related to CC adaptation in local framework conditions is essential. This thesis contributes scientifically to the process of supporting farmers' adaptation to CC in Côte d'Ivoire. The study was conducted in two regions: Toumodi in the center, characterized by two rainy seasons, and located in a transition zone between the forest and the savanna; and Korhogo in the north, a savanna region with only one rainy season. The diversity of the ecosystems, socio-demographic characteristics, and climatic characteristics in the study areas led to a holistic view of CC issues to compare and analyze adaptation strategies in different contexts. Therefore, the thesis (1) investigated farmers' threat management in general and their perception of CC, (2) identified and analyzed relevant factors of farmers' decision behavior regarding adaptation, (3) analyzed the social institutional context surrounding farmers in relation to CC adaptation, and (4) formulated realistic recommendations in the framework of extension services and local conditions to ensure appropriate implementation of our findings.

To address these objectives, qualitative and quantitative methods were used. First, focus groups provided a deep understanding of the farmers' management of threats, to assess their perception of CC and to analyze how they deal with CC; thus, sixteen focus groups were conducted with a total of 205 participants selected based on the geographic location of the villages, the type of farming activities, and the farmers' age. Then, these preliminary findings were integrated into a questionnaire for a large-scale survey (800 farmers). This subsequent step helped to quantify and test the factors influencing farmers' adaptation behavior such as socio-economic characteristics, access to information and extension services, etc. Furthermore, the strengths and weaknesses of the social networks of the agricultural institutions were assessed through personal interviews, and analysis of secondary data. Finally, from the overall previous findings, recommendations were elaborated for better adaptation capabilities at the local level.

The data collected from the focus groups were analyzed using NVivo software for qualitative data analysis. The results show that although specific threats were found in each area, the main threats are similar. The first threats felt by the farmers were related to technical farming factors (34.23%), followed by insects and diseases (16.05%) and climate (13.07%). In addition to a high perception of CC, farmers have perceived its impacts on their local environment through evidence such as the disappearance of certain farming practices, the occurrence of new insects, and the disruption of key time reference periods. The main adaptation strategies reported were the adjustment of the agricultural calendar to profit from the favorable periods for the farming season, the adoption of new short-cycle varieties, and the mixed cropping technique.

Regarding farmers' adaptation behavior, factors such as "perceived occurrence of new pests and weeds," "support from organizations," and "agro-ecological zone, food crops, livestock" were relevant in farmers' sowing and technical itinerary management strategies. Furthermore, farmers decided to adapt mainly when they made the link between CC and its negative impacts.

Considering their perception's barriers to CC adaptations and to better target policy recommendations, four farmer groups were identified: innovators (n= 75; 9.68%), who had the highest intention to adapt; early adapters (n= 368; 47.48%), who included younger, well-educated, and the most diversified farmers; late adapters (n= 186; 24%), who included older, experienced farmers; and non-adapters (n= 146; 18.84%), who were characterized by the biggest household sizes and very low intention regarding adaptation.

To develop recommendations for appropriate knowledge transfer of our findings, the social networks of actors surrounding farmers were assessed regarding adaptation to CC. The findings revealed that in Toumodi, the network structure was highly dependent on one major actor (the national extension service), while in Korhogo the networks themselves relied on a group of diverse actors including several non-governmental organizations (NGOs), international organizations, and inter-professional associations, all coordinated within the Food Security and Nutrition Group. Therefore, the networks in Korhogo appeared more resistant. The national meteorological institution was outside the networks in both study areas.

Overall, this thesis provides insights into farmers' adaptation behavior to go further in implementing strategies and supporting farmers to deal effectively with environmental threats such as climate change. Thus, the results imply that agricultural policy needs to mainstream climate change issues into development policies where actions must be performed at local levels by considering the characteristics of rural communities and the specificities of the local social networks. Furthermore, more interactions among researchers, extension agents, NGOs, and farmers must be promoted with better access to climate forecast data, involving the active participation of the national meteorological institution in the process. Finally, policies for reforesting and conserving forest should be linked to adaptation efforts.

Résumé

Les petits agriculteurs ruraux ont depuis toujours fait face aux problèmes environnementaux. Cependant, la vitesse et l'intensité du changement climatique (CC) ont outrepassé leur habilité à lutter contre ce phénomène global. Trouver des solutions d'adaptation viables et efficaces s'avère être une nécessité pour les agriculteurs des pays en développement qui sont, en plus, confrontés à d'autres difficultés comme la pauvreté, le faible niveau d'innovation technologique, etc. Ces nombreuses contraintes rendent d'autant plus difficile l'atteinte des objectifs de sécurité alimentaire. Par conséquent, pour contribuer à améliorer le bien-être des agriculteurs pauvres et combler ce vide par la mise en place de stratégies d'adaptation, il est essentiel de comprendre la perception des agriculteurs et leur comportement de décision en matière d'adaptation au CC dans un contexte local. Cette thèse représente une contribution scientifique dans le processus de soutien aux agriculteurs pour s'adapter au CC en Côte d'Ivoire. Elle a été conduite dans deux régions: Toumodi qui est situé au centre du pays dans une zone de transition forêt-savane à deux saisons de pluies et la région savanicole de Korhogo au Nord possédant une seule saison pluvieuse. La diversité de l'écosystème, des caractéristiques socio démographiques et climatiques observée dans la zone d'étude a permis d'avoir une vue holistique des problèmes liés au CC afin de faire des comparaisons et d'analyser des stratégies d'adaptation dans des contextes différents. Ainsi, la thèse a permis (1) d'examiner les problèmes rencontrés en général par les agriculteurs dans la gestion de leur champ et d'évaluer leur perception du CC, (2) d'identifier et d'analyser les facteurs pertinents de leur comportement de décision d'adaptation au CC, (3) d'analyser l'environnement institutionnel social autour des agriculteurs en lien avec l'adaptation au CC, et (4) de formuler des recommandations réalistes dans un cadre de vulgarisation locale pour assurer une mise en application adéquate des résultats de notre recherche.

Pour répondre aux objectifs ci-dessus, aussi bien des méthodes qualitative que quantitative ont été utilisées. Premièrement, les discussions de groupe ont permis d'avoir une compréhension singulière de la gestion des problèmes rencontrés par les agriculteurs, d'évaluer leur perception du CC et de savoir comment ils en font face. Ainsi, 16 discussions de groupe ont été conduites avec un total de 205 participants sélectionnés sur la base de la situation géographique du village, du type d'activités agricoles et de l'âge de l'agriculteur. Ensuite, les résultats préliminaires obtenus grâce à l'issue de cette première étape ont été intégrés dans un questionnaire pour une enquête à une échelle plus large (800 agriculteurs) ; ce qui a permis de quantifier et de tester les facteurs influençant le comportement de décision d'adaptation des agriculteurs tels que des facteurs socio-économiques, l'accès à l'information et aux services de vulgarisation, etc. Conjointement, les forces et faiblesses des réseaux sociaux constitués par les institutions agricoles ont été évaluées à l'aide d'interviews personnelles et d'analyse de données secondaires. Finalement, des recommandations pour une meilleure

adaptation au niveau local ont été élaborées par la mise en commun de l'ensemble des résultats précédemment obtenus.

Les données des discussions de groupe ont été analysées à l'aide de NVivo, un logiciel de traitement de données qualitatives. Les résultats montrent que, malgré des spécificités observées entre chaque zone d'étude, les problèmes majeurs étaient liés aux facteurs techniques agricoles (34,23%), suivis par les insectes et maladies (16,05%) et le climat (13,07%). En plus, d'une forte perception du CC, les agriculteurs ont perçu ses impacts sur leur environnement local à travers des signes comme la disparition de certaines pratiques agricoles, l'émergence de nouveaux insectes ravageurs et la perturbation de certaines périodes de référence clé. Par ailleurs, les principales stratégies rapportées étaient l'ajustement du calendrier agricole pour tirer le meilleur profit des périodes favorables des saisons agricoles, l'adoption de nouvelles variétés à cycle court et la technique d'association de cultures.

Concernant le comportement de décision des agriculteurs, des facteurs tels que "perception de l'émergence de nouvelles pestes et mauvaises herbes", "soutien d'organisations" et "zone agro-écologique, cultures vivrières, élevage" étaient pertinents sur l'adoption de stratégies à travers la gestion des semis et des itinéraires techniques. Par ailleurs, la décision de s'adapter survenait principalement lorsque les agriculteurs faisaient le lien entre le CC et ses impacts négatifs.

En considérant par la suite la perception des barrières au CC en vue de mieux cibler les recommandations de politiques, 4 groupes d'agriculteurs ont été identifiés et analysés : les innovateurs (n= 75; 9,68%) qui possèdent la plus forte intention d'adaptation; les adaptateurs précoces (n= 368; 47,48%) qui comprennent les plus jeune agriculteurs, les mieux scolarisés et les plus diversifiés en terme de cultures ; les adaptateurs tardifs (n= 186; 24%) où l'on retrouve les plus âgés ayant le plus d'expérience ; et les non-adaptateurs (n= 146; 18,84%) qui sont caractérisés par les tailles de ménages plus larges et la plus faible intention d'adaptation.

Dans le but d'élaborer des recommandations appropriées pour un transfert de connaissance convenable de nos résultats, les réseaux sociaux d'acteurs autour des agriculteurs ont été évalués. Les résultats révèlent qu'à Toumodi, la structure des réseaux était fortement tributaire d'un acteur majeur qui est l'agence nationale de vulgarisation agricole; alors qu'à Korhogo, les réseaux se structurent autour d'un groupe de divers acteurs comprenant des Organisations Non-Gouvernementales (ONG), des organisations internationales, des associations interprofessionnelles, tous coordonnés au sein du "Groupe Sécurité Alimentaire et Nutrition". Par conséquent, les réseaux à Korhogo apparaissent plus résistants que ceux à Toumodi. Il est important de noter que l'institut national de météorologie s'avère être hors des réseaux dans les deux zones d'études.

Dans l'ensemble, cette thèse fourni un aperçu intéressant du comportement d'adaptation des agriculteurs, permettant d'aller plus loin dans la mise en place de stratégies et de soutien pour

faire face aux problèmes environnementaux émergeants comme le CC. De ce fait, les résultats de cette thèse suggèrent que les politiques agricoles doivent intégrer désormais l'enjeu du CC dans les politiques de développement où les actions doivent se réaliser au niveau local; ces politiques devront prendre en compte les caractéristiques des communautés rurales et les spécificités des réseaux sociaux locaux. Par ailleurs, une plus forte intégration des chercheurs, des agents de vulgarisation, des ONG et des agriculteurs doit être encouragée avec un meilleur accès aux données de prévisions climatiques; ce qui sous-entend une participation active de l'institut nationale de la météorologie dans le processus. Finalement, des politiques de reboisement et de conservation des forêts encore existantes pourraient accompagner les efforts d'adaptation.

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1. Introduction

1.1 Challenge of climate change for developing African countries

According to the Intergovernmental Panel on Climate Change (IPCC) (2007), after an increase of 0.74°C during the last century, the average global surface temperature is projected to rise from 1.1°C to 6.4°C by the last decade of the 21st century. Africa is one of the most vulnerable continents to climate change (CC) because of multiple stresses and low adaptive capacity[1] (IPCC 2007; Brooks 2006). Agricultural production and access to food are predicted to be severely compromised by climate variability and change. Additionally, CC has emerged as a major threat to sustainable growth and development in Africa, with the potential to undermine, and even undo, the progress made in improving the socioeconomic well-being that the continent has been experiencing over the past several years (Hope 2009). Africa's vulnerability arises from a combination of physical and social processes and represents the interface between exposure to climatic threats interacting with other non-climatic problems and the capacity of the systems to cope with those threats (Nyong 2005). More than 95% of Africa's agriculture is rain-fed. By 2050, overall crop yields in Africa may decline by 10–20% due to warming and drying (Thornton et al. 2009). Projected reductions in yield in some countries could be as much as 50% by 2020, and crop net revenues could fall by as much as 90% by 2100, with small-scale farmers the most affected. This will adversely affect food security on the continent (Boko et al. 2007).

1.2 Climate change in Côte d'Ivoire

Similar to most developing countries in Africa, Côte d'Ivoire has experienced an increase in climatic variability with a 25% to 28% reduction in rainfall and an increase in temperature since the late 1960s that have affected food crops and livestock (Brou et al. 2005). A general decrease in annual rainfall with a late beginning and an early end to the rainy seasons, irregular rain, rise in temperatures, floods, and coastal erosion have been observed. The dry season has

[1] Adaptive capacity is the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences (IPCC, 2007).

become increasingly long in the north as well as in the central part of the country, which has aggravated the existing water shortage problems (Brou et al. 2005; Dje 2008).

Projected changes in annual precipitation under four down-scaled general circulation models (GCMs) in the A1B scenario[2] have been reported by Ahossane et al. (2013). The CNRM-CM3 model showed a 50–100 mm increase in precipitation in the north and on the coast; ECHAM 5 showed a similar increase in the southwest. CSIRO Mark 3 showed a 200 to 100 mm decrease in precipitation in the north, whereas MIROC 3.2 showed an up to 400 mm decrease in the southwest and a 200 to 100 mm decrease in the southeast (Ahossane et al. 2013)[3]. In addition, the models for the average daily maximum temperature change for the warmest month of the year based on the A1B scenario showed an increase in temperature up to 2.5°C by 2050 (Ahossane et al. 2013).

The projections (assuming an unchanged 2000 climate) of the impacts of CC on rain-fed rice and rain-fed maize by 2050 present different patterns. The CSIRO, ECHAM 5, and MIROC 3.2 GCMs show a yield loss of 5–25% from the baseline for rice in the central and northeast regions of the country. In contrast, the CNRM-CM3 shows a yield gain of 5–25% from the baseline in many parts of the country, with a small portion of the country showing losses of between 5% and 25%. All models present a relatively more pessimistic scenario for maize compared to rice in Côte d'Ivoire (Ahossane et al. 2013).

1.3 Motivation of the research

In Côte d'Ivoire, research related to CC issues and crops is lacking; no scientific knowledge is available to aid in proposing viable adaptation strategies to CC. Our study will fill in this knowledge gap and will help Côte d'Ivoire implement effective and acceptable CC adaptation measures. Any effective contribution to improving food security in the context of CC must be

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[2] The A1B scenario is a greenhouse gas emissions scenario that assumes fast economic growth, a population that peaks midcentury, and the development of new and efficient technologies, along with a balanced use of energy sources.

[3] CNRM-CM3 is National Meteorological Research Center–Climate Model 3. ECHAM 5 is a fifth-generation climate model developed at the Max Planck Institute for Meteorology in Hamburg. CSIRO is a climate model developed at the Australia Commonwealth Scientific and Industrial Research Organization. MIROC is the Model for Interdisciplinary Research on Climate, developed at the University of Tokyo Center for Climate System Research.

based upon a clear understanding of the context in which decisions about adaptation are made. Often, the best adaptation options involve innovative modifications of known good practices rather than completely new solutions (FAO 2008). For adaptation policies to be successful, it is also important to investigate individual perceptions of CC, especially if farmers and other stakeholders perceive it as a negative impact. Only if people perceive CC as a threat will they be ready to respond appropriately. Farmers may perceive a different set of climatic changes or perhaps no changes at all. It is arguably more meaningful to examine the adaptations made according to the perception of CC (Maddison 2007). Adaptation to CC involves a two-stage process: first, perceiving change in climatic conditions and, second, deciding whether to adapt by taking a particular measure (Temesgen et al. 2008). Therefore, studying farmers' perceptions of CC, their adaptation behavior, and the institutional context surrounding farmers is essential. People are better able to adopt new ideas when they can be seen in the context of existing practices (Boko et al. 2007). Understanding the relationship between farmers' perceptions and responses to CC within the social context is crucial for future agricultural policies in Côte d'Ivoire regarding the negative effects of CC. Many climate policies and measures have not given priority to farmers' perceptions and to the participatory approach, which partly explains the policies' inadequacy.

1.4 Overview

The thesis is divided into three main parts involving nine chapters. The first chapter consists of the general introduction, followed by the second chapter on background literature related to CC as a threat to food security for smallholders. Studies on CC adaptation and institutional support are also presented. The research questions and the research design are in Chapters 3 and 4, respectively.

The second part of the thesis consists of four self-contained articles. The first article in Chapter 5 investigates farm management decisions and responses to climate variability and change. A qualitative analysis provides a better understanding of threat management in general with a focus on climate-related threats, and farmers' perception of CC. How farmers deal with CC is also analyzed. Since the results reveal a high perception of CC by farmers, in the second article (Chapter 6), farmers' decision behavior regarding adaptation to CC regarding subjective, socio-demographic, institutional, and physical variables is investigated using focus group discussions and large-scale surveys. The data are analyzed using a Categorical Principal Component Analyses (CATPCA), reliability analyses, and binary logistic regression models to determine relevant influences on farmers' adaptation behaviors. In the third article (Chapter 7), farmers are identified and characterized based on various barriers to CC adaptations in order to elaborate targeted policy recommendations and appropriate knowledge transfer. As appropriate adoption of adaptation strategies is coupled with strong institutional support at the local level, the fourth article (Chapter 8) applies a social network analysis with agriculture actors to facilitate future implementation of adaptation strategies. Thus, an empirical diagnosis of strengths and weaknesses in the social networks in the study areas is conducted to evaluate the ability of stakeholder networks to support farmers’ capacity for CC adaptation.

The last part of the thesis (Chapter 9) summarizes the results of the previous chapters and elaborates implications for policymakers. The chapter closes with a discussion of the research approach and suggestions for further research based on the findings.

2. Background literature

2.1 Climate change and food security

2.1.1 Climate change and food security in the African context

Food security exists when all people at all times have physical or economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life (FAO 2008). In Africa, low levels of food security and economic development conspire with high levels of climate risk (FAO 2012). Warmer temperatures affect crops and crop production, and changes in rainfall patterns are as important. CC also influences the availability of water for human consumption and for food production (Walter 2007). CC represents an immediate and unprecedented threat to the food security of hundreds of millions of people who depend on small-scale agriculture for their livelihoods. In many African countries and regions, food security is likely to be severely compromised by CC and climate variability (Boko et al. 2007). By the 2080s, CC is estimated to place an additional 80–120 million people at risk of hunger, and 70–80% of these will be in Africa (Parry et al. 2004). Although CC seems marginal compared to the pressing issues of poverty alleviation, hunger, health, and economic development in Africa, it is becoming increasingly clear that the realization of the Millennium Development Goals can be seriously hampered by CC (Nyong 2005).

2.1.2 Key challenges related to climate change and regarding the survival of smallholders in sub-Saharan Africa

CC will significantly impact agriculture by increasing water demand, limiting crop productivity, and reducing water availability in areas where irrigation is most needed or has comparative advantage (FAO 2012). CC may also bring new pests, diseases, and weeds. Indeed, it is clear that some pests will be able to invade new areas and become increasingly problematic for maintaining biodiversity, the functioning of ecosystems, and the profitability of crop production (Ingram et al. 2008). Temperatures above the ranges tolerated by crops will definitely affect the physiology of plants, including staple crops, resulting in decreased productivity that will affect food production.

Many people in the developing world depend directly on agriculture as their primary source of food, and negative impacts of CC on crop productivity will affect crop production and thus overall food supply at the local level (Ingram et al. 2008). Agriculture represents the single largest economic activity on the continent. In sub-Saharan Africa, agriculture contributes to at least 40% of exports, 34% of the gross domestic product (GDP), and more than 50% in some countries, up to 30% of foreign exchange earnings, and 64–80% of employment (Hope 2008). Although it is estimated that, by the 2080s, the proportion of arid and semi-arid land in Africa is likely to increase by 5-8% (Boko et al. 2007), the projected losses in cereal production add up to about 33% by 2060 (Nyong 2005). Moreover, accessibility to water resources will be a key to the future sustainability of many existing livelihood systems, especially those of small-scale farming households (FAO 2008). Some analyses suggest that the population at risk of increased water stress in Africa is projected to be 75–250 million by the 2020s and 350–600 million by the 2050s (Boko et al. 2007).

2.2 Decision-making process and climate change: Coping strategies/adaptation

Coping capacity is the ability of actors to draw on available skills, resources, and experiences as an immediate response to manage adverse stressor shocks brought about by climate variability (ISDR 2009). Adaptive capacity in turn is the ability to prepare in advance for stresses and changes and to adjust, respond, and adapt to the effects caused by the stress associated with future CC (including the impact on climate variability) (Engle 2011; Smit and Pilifosova 2001). For Birkmann et al. (2009), coping includes strategies and actions undertaken within existing institutional settings, whereas adaptive capacity is associated with longer-term strategic actions that may require institutional change. Adaptation and coping strategies are not always planned. Coping is largely an autonomous and "ad-hoc" activity (Brooks et al. 2009) that increases the risk of maladaptation. Thus, there are various definitions of coping capacity and adaptive capacity, and there is no consensus on what trade-offs might be needed to adapt to long-term CC. The evidence suggests that coping and adaptive capacity, although different, are connected (Berman et al. 2012).

Adaptation is defined as an adjustment of ecological, social, or economic systems in response to observed or expected changes in climatic stimuli and their effects and impacts in order to alleviate the adverse impacts of change or take advantage of new opportunities. Adaptation can involve building adaptive capacity thus increasing the ability of individuals, groups, or organizations to adapt to changes, and implementing adaptation decisions, i.e., transforming that capacity into action (IPCC, 2001). Rural communities in the developing world are at risk of CC, and adaptation is a necessity (Boko et al. 2007; Smit and Wandel 2006; Parry, 2009).

Indeed, it was argued that the negative effects of CC could be reduced if effective adaptation strategies are implemented (Kurukulasuriya and Rosenthal 2003; Poonyth et al. 2002; Mendelsohn et al. 1994; Rosenzweig and Parry 1994). For example, varieties with a short vegetation cycle and the timing for an effective season have been reported as effective measures adopted by farmers in Africa (Yabi and Afouda 2007). Breeding plants for tolerance to drought, heat stress, salinity, and flooding will become increasingly important (FAO 2008). Moreover, cropping systems moved from locations where the climate has become unsuitable to locations that have become more favorable have also been observed (Ingram et al. 2008).

Regarding Côte d'Ivoire, Brou et al. (2005) reveal that the farmers in the northern part of the country have modified the distribution of cultures in response to water shortages. Crops that are sensitive to water shortage, such as rain-fed rice, are increasingly being cultivated in hollows with access to rivers. Cultures with long cycles such as tubers (yam and cassava) have gradually disappeared from the agricultural activity in the area because they are increasingly unsuited to the new agricultural calendar. Thus, for a long time African farmers have developed several adaptation options to cope with climate variability, but these adaptations may not be sufficient for future climate changes (Boko et al. 2007). The severity and pace of CC are presenting new, unprecedented challenges (FAO 2012).

2.3 Institutional context: Key stakeholders for supporting smallholders' adaptation to climate change

Individual adaptation actions are not autonomous: They are constrained by institutional processes such as regulatory structures, property rights, and social norms associated with rules in use (Adger et al. 2005). Institutions all affect how an individual, a household, or a community is able to respond in the short term to climatic and other stressors (Young 2002; Brondizio et al. 2009). Institutions are often interlinked, and understanding how institutions structure power, rights, and entitlements at multiple levels of governance is essential to understand the adaptive capacity of a community or society (Berman et al. 2012). Institutions are also likely to be important for fostering adaptive capacity (Adger and Vincent 2005; Brooks et al. 2005; Leach et al. 2010). Thus, Gaillard (2010) suggests that institutions are centrally involved in transforming current coping capacity into longer-term adaptive capacity. The institutional context includes not only specific institutions but also their inter-links. Although a substantial amount of research has examined the capacity of institutions themselves to adapt, there is much less research on how they influence adaptive capacity of individuals or communities

(Anderies et al. 2004). Local institutions that maintain and enhance adaptive capacity must be identified to ensure they continue to play this important role in the future (Berman et al. 2012).

Although households and communities have historically adapted to climate variability through many different strategies, their capacity to adapt depends significantly on how institutions regulate and structure their interactions (Agrawal et al. 2009). Local institutions play a crucial role in influencing the adaptive capacity of communities ex ante, and the adaptation choices made by community members ex post (Agrawal et al. 2009). Therefore, to strengthen the adaptive capacity of the rural poor, governments and other external actors need to strengthen and take advantage of existing strategies that many households and social groups use collectively or individually (Agrawal and Perrin 2008). Examining the environmental risks that rural populations have historically faced, their cultural responses to these risks, and the institutional configurations that facilitate individual and collective adaptation strategies is therefore a fruitful area of inquiry and policy analysis for generating effective coordination with external interventions (Agrawal and Perrin 2008).

If adaptation is local, attention to local institutions is critically important when designing adaptation projects and policies (Agrawal and Perrin 2008). Without greater attention to local institutions, their role in different types of adaptation, and the ways in which local and external institutions can be articulated in the context of adaptation, it is unlikely that adaptation interventions and investments will achieve much success (Agrawal and Perrin 2008). This is why this study also integrates the analysis of the local institutional contexts (Chapter 8), in order to elaborate sound recommendations (Chapter 9).

3. Research questions

3.1 Goal

The overall goal of this thesis is to contribute to improving food security in rural areas by improving farmers' responses to CC. Thus, a better understanding of farmers' behavior in the local context regarding CC is especially important to identify effective and acceptable adaptation strategies. This will help in formulating recommendations to ensure the transfer of the most appropriate strategies in the framework of extension services in the local context. The specific objectives are as follows:

- To understand and analyze farmers' threat management in general on their farms and assess their perceptions of CC.
- To identify and analyze the relevant factors (access to extension services, education, socio-economic factors, etc.) for the decision behavior in farmers' decision-making process regarding adaptation to CC.
- To analyze the local institutional context by identifying the knowledge and intention of environmental institutions, extension services, NGOs, and the Ministry of Agriculture regarding CC and food security. The institutional context is taken into account as farmers are not independent from this context, and it will help to assess the institutional adaptive capacity of the agricultural sector.
- To elaborate feasible and acceptable solutions to better adapt to CC and formulate recommendations for each stakeholder group in the framework of extension services in the local context.

3.2 Research questions

More specifically, this thesis focuses on the following research questions:

- What are the relevant threats in farm management with a particular focus on climate-related threats?
- How do farmers perceive CC?
- How do they deal with climate uncertainties in general and more specifically with CC issues?
- Which factors are relevant for the decision behavior of farmers regarding adaptation?
- How can farmers be characterized in relation to adaptation barriers?

- What are the institutional conditions surrounding farmers at the local and national levels? Are the networks well established? Are there strengths and weaknesses in the networks in the two study regions?

4. Research design

4.1 Conceptual framework of research activities

The research activities are divided into four main parts addressing the specific objectives.

Part 1: Farmers’ threat management and their perceptions of climate change

The first part focuses on the interrelationship between a farmer’s individual level and CC. Farmers have a personal decision field regarding their farm-related decisions that is limited by threats and extended by opportunities. Indeed, farmers are facing a broad number of threats including climatic risk. Their management decision in this context is influenced by intra-personal conditions and exogenous factors. A better understanding of farmers’ capacity to deal with all threats encountered is needed to frame and ensure feasible CC solutions within the farmers' field of adaptation possibilities. Thus, through focus groups, we will understand and analyze farmers’ threat management, assess their perception of CC, and analyze how they deal with CC in general. The results will be integrated into the questionnaire that will be elaborated in the second part.

Part 2: Decision behavior in the farmers’ decision-making process, and climate change

The relevant factors expected to influence farmers' decision behavior in their participation in adaptation strategies have to be assessed and analyzed. Factors such as socio-economic conditions, access to information and extension services, education, etc., were identified in Part 1. Then, a survey was conducted to analyze the knowledge of farmers’ behavior regarding CC as it is determinant to ensure implementation of adaptation measures.

Part 3: Institutional context and climate change

In this part, we analyze the local and national contexts as different socio-economic and climatic conditions require different adaptation measures. Our focus is the local institutional context. By identifying environmental institutions’ knowledge and intentions, extension services, NGOs, and ministries of agriculture to respond to CC, we can assess the adaptive capacity of Côte d’Ivoire regarding CC. Identifying the institutional conditions surrounding farmers at the local and national levels helps recommend realistic CC adaptation solutions and contributes to improving food security. The analysis of the institutional context uses a social network analysis with data from personal interviews, and secondary data. This analysis helps to understand decision-making processes, and interdependencies within a community, e.g., which institutions, organizations, and individuals are important and how they are interrelated.

Indeed, different stakeholders have to agree about the need for adaptation, the seriousness of climate risks, and the potential negative consequences of CC, otherwise implementation of such measures will fail (Patt and Schröter 2008); sometimes, farmers completely disagree with professionals or scientists' opinions on the climate issue (Medina et al. 2007).

Part 4: Recommendations and adequate strategies for ensuring successful transfer

By joining the results from the previous parts, we draw recommendations for each stakeholder group in the framework of extension and local conditions. We also elaborate adequate knowledge transfer strategies about CC to facilitate implementing measures.

4.2 Methods

Methods for collecting data include participatory tools such as focus groups, qualitative interviews, and surveys. The qualitative information from focus groups and interviews help to formulate the relevant questions for the questionnaire. After the first overview of the data and their interrelations, the indicators for variables are identified and collected through surveys. Literature research, document analysis, and expert interviews during the initial stage of the research are useful for defining the system boundaries; and then, focus groups help to assess farmers' perceptions of CC, the threats in their farm management, and how farmers deal with CC. Similarly, personal interviews are used to identify the institutional conditions surrounding farmers at the local and national levels. Farmers, agents of extension services, NGOs, and Ministry of Agriculture employees are interviewed. Furthermore, for sampling reasons, farmers are selected related to the type of crops in different villages with different agro-ecological and climatic conditions.

4.3 Presentation of the study areas

Côte d'Ivoire, a Western African country, is 322,465 km^2. It is bordered by Liberia in the southwest, Guinea in the northwest, Mali and Burkina Faso in the north, and Ghana in the east. The southern part of the country borders the Atlantic Ocean. Côte d'Ivoire is characterized in general by a warm and humid climate, which is overall transitional from equatorial to tropical. The research was carried out in two regions, namely, the Toumodi area in the center and the Korhogo area in the northern part of the country. Toumodi is located in a forest-savanna transition zone with two rainy seasons. The area includes a mosaic of environments, composed of mesophile forest (or semi-deciduous) and Guinean savanna (MEDD 2011). The average annual rainfall is 1000–1200 mm, and the temperature ranges between 14°C and 39°C

(MPARH 2003; Tié et al. 2010). It has 60% to 70% relative humidity. The soil is characterized by sandy-humus and clayey horizons (Birgit and Bruzon 2006).

Korhogo, a savanna region, is characterized by a single rainy season and annual rainfall of about 1100 to 1600 mm. The temperature ranges between 10°C and 42°C (MPARH 2003), with relative humidity of 40% to 50% (Birgit and Bruzon 2006; Tié et al. 2010; MEDD 2011). The area is characterized by the intermittent presence of a cool and dry wind called “harmattan,” which occurs between December and February (UFR-STRM 2009). Generally, the soil in Korhogo is ferruginous with low humus content and average fertility (Zagbaï et al. 2006).

As in most areas of the country, agricultural fields are mainly rain-fed with crops such as maize, rice, groundnut, cotton, and yam (Birgit and Bruzon 2006; Tié et al. 2010). Moreover, perennial crops (mango, shea trees) and livestock are also important sources of income (Birgit and Bruzon 2006). The two regions have different socio-demographic characteristics with 65-80% of the population relying on subsistence agriculture (CountrySTAT 2012).

5. Farm management decision and response to climate variability and change in Côte d'Ivoire[4]

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ABSTRACT

This paper investigates threats to farm management in the northern and central region of Côte d'Ivoire, with a particular focus on climate-related threats. To this end, farmers' perception and adaptation strategies for climate change have been analyzed. The data were collected from 205 respondents by means of the focus groups method, and they were evaluated using a framework analysis. The main reported threats related to the implementation of farming activities are the high cost of inputs and the lack of technical support, which are followed by diseases, insects, and climate variations (scarcity of rains, strong winds, and high temperature). We find that most farmers have a strong perception of changes in climatic conditions. Their perceived impacts on the local environment through evidences like the disappearance of certain farming practices, occurrence of new insects, and the disruption of key time reference periods. Farmers mainly attempt to adapt by adjusting their agricultural calendar, adopting new short-season varieties, and using mixed cropping. We find that the most influential factors for farmers' adaptation behavior is lack of contact with extension services and the scarcity of rainfall. Our suggestions for future agricultural policies for better adaptation to climate change are to take into account farmers' perception, to provide suitable climate forecast, and to improve local technical support.

KEYWORDS

Adaptation strategies, Agriculture, Climate change, Côte d'Ivoire, Perception, Smallholder farmers

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5.1 Introduction

Climate change (CC) according to the Intergovernmental Panel on Climate Change (IPCC), refers to any change in climate over time, whether due to natural variability or as a result of human activity. Climate variability refers to variations in the mean state and other statistical measures (such as standard deviations and statistics of extremes) of the climate on all temporal and spatial scales beyond that of individual weather events (IPCC 2007). Unless formal distinctions between CC and climate variability are drawn, CC itself becomes a difficult concept to define, because all natural "change" is merely a reflection of variability on some appropriate time scale (Washington et al. 2006). CC and climate variability are not conveniently separated processes, but are instead closely coupled in the complicated evolution of the climate system.

In West Africa, the impact of CC is expected to be very severe because it directly causes damage to domestic welfare, which depends mostly on the primary sector of the economy (Mendelsohn et al. 2000). During the last decades, CC has been very evident and has resulted in a southward shift of the climate zones, e.g., spread of the Sahara Desert into the Sahelian zone (Wittig et al. 2007). A decline in annual rainfall has been observed since the end of the 1960s, with a decrease of 20–40% noted between the periods 1931–1960 and 1968–1990 (Nicholson 2000; Chappell and Agnew 2004). As a prevision, it is foreseen that the crop yields will be adversely affected and the frequency of extreme weather events will increase (Collier et al. 2008). The projected reductions in yield could rise up to 50% by 2020, and net crop revenues could fall down to 90% by 2100, with small-scale farmers being the most affected (Boko et al. 2007).

Adaptation is defined as the "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (IPCC 2007). Although CC is a difficult phenomenon to detect according to some authors (Blennow and Persson 2009; Elke 2010), farmers in Sub-Saharan Africa are well aware of CC (Benedicta et al. 2010). In particular, subsistence farmers are far more likely to notice changes in climate than other farmers because of their experience in farming (de Wit 2006). The fact that farmers are very good at detecting CC is a basic precondition for adaptation (Maddison 2006). Despite this fact, many African farmers have done almost nothing in response to CC (Ringler 2010). To overcome this gap in implementing adaptation strategies, it is essential to understand farmers' behavior in their decision-making with regard to climate risks, in order to establish efficient and acceptable adaptation strategies for CC.

Like most developing countries in Western Africa, Côte d'Ivoire is vulnerable to CC, specifically in the sectors of agriculture, coastal resources, water resources, and forestry (MEEF 2000; Ochou 2011). This vulnerability is exacerbated by widespread poverty, environmental degradation, natural resource mismanagement, and dependence on rain-fed agriculture (Dixon et al. 2003). The temperatures increased approximately by 1°C between 1960 and 2000 (Kouakou et al. 2012), and annual rainfall decreased by an average of 0.5% per year between 1965 and 1980 and by 4.6% per year in the 1980s (MET 1994; Birgit and Bruzon 2006). The impacts of CC are gradual in the South of the country, but are already significant in the North (Gadegbeku 2009).

Based on this background, we aim to investigate how farmers in two regions of Côte d'Ivoire—Toumodi in the central part and Korhogo in the North—have perceived as well as reacted to these changes. More specifically, this paper intends to (i) identify farmers' decisions regarding farm management in general and more specifically regarding actions for adapting to CC; (ii) assess their perception of CC; and (iii) identify influencing factors for their adaptation behavior. This first study of its type in Côte d'Ivoire will provide useful insight into farmers' decision-making processes regarding adaptation to CC.

5.2 Study Areas

The climate in Côte d'Ivoire is generally warm and humid and is overall transitional from equatorial to tropical (Figure 5.1). Toumodi is located in the forest-savanna transition zone of central Côte d'Ivoire and has two rainy seasons; the average annual rainfall is 1000–1200 mm and the temperature ranges between 14°C and 39°C (MPARH 2003; Tié et al. 2010). The soil is characterized by sandy-humus and clayey horizons (Birgit and Bruzon 2006). The climate in Korhogo (North) is Sudano-Guinean with a single rainy season and annual rainfall between 1100 and 1600 mm. The temperature ranges between 10°C and 42°C (MPARH 2003). Generally, the soil in Korhogo is ferruginous with low humus content and average fertility (Zagbaï et al. 2006). The central and northern areas are different with regard to both their vegetation and socio-cultural characteristics. Therefore, the results of the study could help understand the importance of these socio-cultural factors in farmers' decision-making behavior regarding adaptation to CC.

Figure 5.1: Study areas.

5.3 Methodology

This study used a qualitative research method because the purpose is to develop an in-depth understanding of farmers' perception of and their adaptation behavior regarding adaptation to CC. The collected qualitative data allow us to identify in an exhaustive manner all factors influencing farmers' behavior.

5.3.1 Focus groups

Focus group is a method for collecting data through group interaction on a topic determined by the researcher (Morgan 1997). This method has been developed and applied since the 1990s (for more details see Krueger 1994; Templeton 1994; Morgan and Krueger 1998). One of the key advantages of focus groups is its flexibility and ability to reveal rich and sensitive information. One of the limitations of focus groups is that it can result in an undesirable bias: first, the moderator could exert too big an influence on the group; second, the phenomenon of dominance may occur (some participants may strongly influence the discussion). To avoid these biases, we developed precise guidelines and trained the moderator on how to deal with group interactions and dominant participants.

We have chosen this approach because it is ideal for exploring the complexity surrounding farmer's adaptation behavior regarding climate variability and change, and can generate large amounts of data in a relatively short time span; moreover, the findings may be used as preliminary data for quantitative procedures (Rabiee 2004).

The questions discussed were tailored around guidelines related to the following four topics: (i) Farmers' farm management and opportunities, including farmers' aims regarding farm management, the relevant threats, and implemented actions; (ii) Farmers' perception of CC through atmospheric characteristics, farming practices, and local environment; (iii) The way farmers deal with climate uncertainties, especially the sources and types of information they receive; (iv) Factors influencing farmers' behavior related to adaptation to CC. Therefore, their past experiences, knowledge, and expectation with regard to CC were discussed. Finally, the conflicts between crop and livestock farmers and their probable link with CC have also been discussed (e.g., damage to growing crops, destruction of harvest, and pressures on the fallow imposed by herds) (Hussein et al. 1999).

5.3.2 Sample selection and description

Sixteen focus groups investigations were carried out from June to August 2011 in Toumodi (8 in 9 villages) and Korhogo (8 in 4 villages), with a total of 205 respondents which represents 4% and 0.8% of all farming households in Toumodi and Korhogo, respectively. We followed the method of Krueger (1994) by continuing with the focus groups until a clear pattern emerged and subsequent groups produced only repetitious information (theoretical saturation). The resulting sample size is comparable to that of other studies which used the focus group approach (cp. e.g. Zaouche et al. 2011; Ishak and Bakar 2012). The information gathered in our focus groups was exhaustive, which was underlined by the finding that the last additional group discussion did not reveal any new item.

The ideal number of participants in a group ranges from six to ten (Zaouche et al. 2011). To build up our sample, we considered (i) the geographical location of the village, (ii) the type of farming activities, and (iii) the age of the farmer as the main selection criteria.

First, in Toumodi, the villages were randomly selected using a list of farmers obtained from the National Rural Development Support Agency (ANADER); villages in both in the forest and the savannah parts were selected, after ruling out those inaccessible by car. In Korhogo, the same process was used.

Secondly, participants in the focus groups were selected so that different farming activities were represented: we therefore selected crop farmers, livestock farmers, and those involved in diversified farming. Finally, elderly participants with maximum age about 80 years were selected because they had experienced a change in climatic elements over the past 30–40 years. This sampling approach allows researchers to compare the views of different types of farmers and to better understand the factors leading to the implementation of the strategies being practiced. The socio-cultural differences between the two areas were considered. In Korhogo (Muslim and conservative part of the country), women and men were separately interviewed, which was not the case in Toumodi.

The discussions were recorded and were conducted with the support of local extension agents and students who also translated the local languages Baoulé, Sénoufo, and Dioula to French. To avoid misinterpretation during the transcription, two agents worked together throughout all focus group discussions. Furthermore, the geographical coordinates of villages, socio-demographic characteristics, and data related to the surface of farms, the type of crop grown, and the number of animals was collected.

The average age of the participants was 45 years, and the average household size was 10 people. The level of education in Korhogo is much lower than that in Toumodi. Moreover, the average number of years of experience in crop farming and livestock production was 22.32 years and 10.20 years respectively (Table5.1). The Mann-Whitney U test (Field 2009) applied to the sample revealed significant differences between farmers with regard to crop farming experience, gender, education level, head of household status, and marital status.

Table 5.1: Characteristics of the farmer participants in the focus groups.

	Variable	Korhogo	Toumodi
	Age (year)	45.85 (15.26)	46.98 (13.37)
	Household size	11.14 (7.12)	10.59 (5.85)
	Household head (%)	61.5**	81.2
	Male (%)	54***	85
Education level***	Illiterate (%)	83.7	39.6
	Primary school (%)	13.5	32.7
	Secondary school (%)	1.9	23.8
	University (%)	0	4
	Koranic school (%)	1	0
Marital status***	Single (%)	1.9	22.8
	Married (%)	90.4	74.3
	Widower/Widow (%)	7.7	2
	Divorced (%)	0	1
	Experience in crop farming (year)	22.32** (14.32)	15.26 (10.06)
	Experience in livestock practicing (year)	10.20*** (10.28)	7.2 (5.69)
	Surface of root, tuber & starchy (ha)	0.12*** (0.36)	1.55 (1.58)
	Surface of cereal (ha)	2.72*** (2.6)	0.16 (0.35)
	Surface of vegetable (ha)	0.13 (0.29)	0.19 (0.47)
	Surface of cash crops (ha)	4.87 (5.53)	3.25 (3.83)
	Number of ruminant and porcine	6.76*** (11.78)	2 (8.18)
	Number of poultry	5.08 (10.65)	5.55 (14.36)

Numbers in parentheses are standard deviations. *** and ** denote significance on the 1% and 5% level.

5.3.3 Data analysis

The framework analysis as described by Ritchie and Spencer (1994) was used to analyze the 300 pages of transcribed notes. It involved five highly interconnected key stages: familiarization; identifying a thematic framework; indexing; charting; and mapping and interpretation. Familiarization can be achieved by listening to recorded discussions and notes and reading the transcript several times. This is followed by identification of a thematic framework by writing memos in the form of short phrases and ideas, and beginning to develop categories. Indexing involves sifting the data, highlighting and sorting out quotes, and making comparisons both within and between groups. Charting involves lifting the quotes from their original context and re-arranging them under the newly-developed thematic content. The coded data can be interpreted based on words, context, internal consistency, frequency, and extensiveness of comments (Krueger 1994). In qualitative analysis, coding the processes of identifying and connecting the passages of text and clarifying the concept or idea represented by the "node" is an important part of the analytic process.

A node (or item) is defined as a group of words, and sentences of the transcript, which are related to the same topic or subject. It could be sub-divided into small parts called sub-nodes which contain more focused information.

For this study, the frequencies of the number of quoted words or sentences are assigned to different nodes, which indicates its relative importance to other nodes. The score helps build up adequate and nuanced conclusions (Paillé 1996). As a requirement for reliability, an inter-coder was also used to establish dependability of the data analysis. The software N'vivo 9 was used to organize, code, and classify the transcript (www.qsrinternational.com/products_nvivo.aspx). The total number of nodes (equivalent to items) created for Toumodi and Korhogo was 108 and 106 respectively, grouped into 12 main nodes (Table 5.2), which covered 48% and 46% of the transcript respectively. The most represented nodes were "relevant threats in farm management," "adaptation strategies to CC," and "perception of CC." The similarity in both study areas reveals the common interests of farmers with regard to the most frequent items.

Table 5.2: Frequencies of most items quoted by farmers (% of words and sentences).

Item	**Korhogo**	**Toumodi**
	Frequency (%)	*Frequency (%)*
Relevant threats	10.82	9.78
Adaptation strategies to CC	8.59	8.23
Perception of CC	7.75	8.76
Causes of CC	4.95	3.06
Impacts of CC	4.94	4.97
Suggestions for adaptation	3.26	1.93
Actions implemented against threats	2.93	1.95
Own objectives of farmers	2.34	3.14
Conflicts between crop & livestock farmers	1.31	2.27
Opportunities in farm management	0.77	0.53
Knowledge about weather & CC forecasting	0.50	1.34
Farmers' pessimistic expectations	0.12	0.43
Total	48.28	46.39
Standard deviation	3.48	3.30

Note: the total does not equal 100 because all the 300 pages of transcript were not embedded into a node, notably the intervention of the moderator of the discussions

5.4 Results and Discussion

5.4.1 Farmers' perception of relevant threats in farm management

The relevant threats of farmers have been grouped into seven categories (Table 5.3). The analysis of the focus groups showed that the threats related to the technical farming factors are the most relevant for farmers in both study areas. This category includes the following items stated by the farmers: high cost of inputs (pesticides, herbicides, and fertilizers), financial problems, rapid growth of weeds, non-effectiveness of certain treatments against insects and weeds, poor quality of seeds, lack and high cost of farming labor, coincidence of farming activities, wildfire, and large fields compared to the low availability of household labor. The major threats related to the technical farming factors differ across study regions. In Toumodi, the most important threats are insects and diseases, followed by climate (unpredictability of climate and scarcity of rains) and farming lands (lack of farming lands and poor soil fertility), and finally lack of technical support. In Korhogo, the major threats mentioned by farmers, in order of the biggest threat to the smallest, are market access and prices, insects and diseases, and climate and animal breeding. These differences are due to differences in farming systems (e.g., the use of different crops and the focus on livestock breeding in Korhogo) and location (Toumodi is closer to the main market in Abidjan).

Table 5.3: Description of relevant threats in farm management.

Domain	Relevant threats in farm management	Toumodi		Korhogo	
		Quotation	*%*	*Quotation*	*%*
Technical farming factors	High cost of pesticides, herbicides & fertilizers	10	4.17	48	15
	Financial problems	36	15	15	4.69
	Rapid growth of weeds	12	5	15	4.69
	Non effectiveness of pesticides and herbicides treatments	7	2.92	8	2.5
	Poor quality of seeds	6	2.5	7	2.19
	Lack & high cost of farming labor	12	5	0	0
	Coincidence of farming activities	7	2.92	0	0
	Wildfire, bushfire	3	1.25	1	0.31
	Too large fields	0	0	1	0.31
Insects & diseases	Insects and diseases	30	12.5	21	6.56
	Termites in the soil	4	1.67	2	0.63
	Animal diseases	4	1.67	29	9.06
Climate	Unpredictability of climate	5	2.08	0	0
	Scarcity of rains	19	7.92	23	7.19
	Wind	2	0.83	0	0
	Burning sun	2	0.83	0	0
	Scarcity of irrigation	3	1.25	9	2.81
	No dams and rivers	1	0.42	9	2.81
Farming lands	Lack & aging of arable land	0	0	15	4.69
	Problem of soil fertility	15	6.25	3	0.94
	Lack of forest	10	4.17	0	0
	Logging companies	2	0.83	0	0
Technical support	Lack of technical support	26	10.83	22	6.88
Market access & prices	Market access and low prices	15	6.25	56	17.5
Animal	Animal damages	3	1.25	21	6.56
	Theft of animals & accident with cars	4	1.67	3	0.94
	Lack of pasture	1	0.42	0	0
	No enclosure & hen house	1	0.42	12	3.75
	Total	240	100	320	100
	Standard deviation	9.35	3.90	14.45	4.52

Source: Focus groups

5.4.2 Farmers' perception of climate change

In Korhogo, the following indicators are most frequently used by farmers to describe their perception of CC: changes and characteristics in rains patterns, changes in the local environment, and disappearance of some farming practices. Thus, indicators such as sunshine, wind characteristics, disturbance of farming seasons, and reference period are less frequently mentioned. Furthermore, compared to the farmers in Korhogo, the farmers in Toumodi perceive more intensively the impact of the disruption of key time reference period and shift in rainy seasons (Figure 5.2).

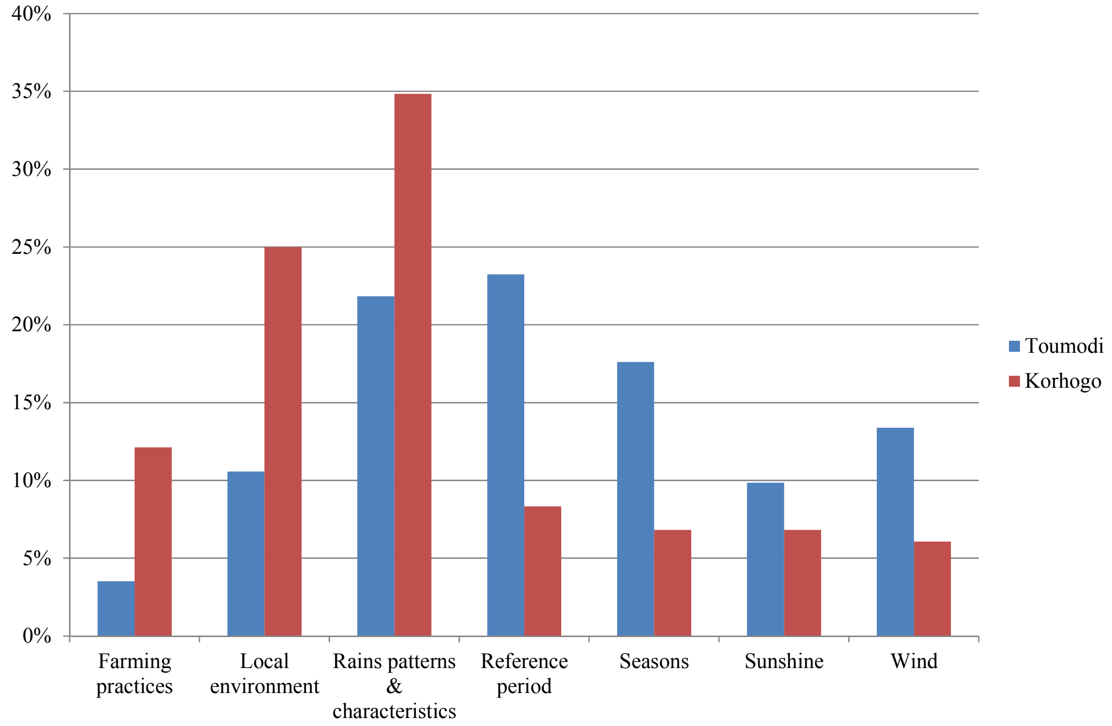

Figure 5.2: Farmers' perception of changes in climate.

5.4.2.1 Rain patterns and characteristics

Farmers have observed a decrease in the frequency and amount of rain. In these areas, rainfalls usually occur at intervals of a few weeks even during the rainy season, and they are accompanied by thunder and followed by violent winds. The intensity of rainfalls is low, and farmers even find hail after the rain. A change in the spatial distribution of rains has been observed. Also, the rainfalls are now more intense, which sometimes causes crop damage.

The changes observed in the local environment were also used by farmers to describe their perception of climate variability and change. For instance, water does not remain for a long time in shallow ponds during the dry periods anymore. Also, their forecast of rains based on the sunshine does not seem reliable; they used to consider the presence of a lot of stars in the sky at night to indicate upcoming rains, which is not a reliable indicator anymore. Therefore, farmers are not able to properly define the rainy periods. Moreover, current proliferation of unknown pests of crops and a change in fructification time have been noticed.

5.4.2.2 Seasons

It was observed that seasons have shifted and shortened. For instance, in Toumodi, the short dry season which started in August has shifted to July. In addition, farmers mentioned that the rainy seasons have become shorter over time. In the past, it would sometimes rain in the dry season, but this does not occur anymore. These assertions are confirmed by the findings of Goula et al. (2010), who reported that the duration of the growing season decreased by 30 days in the period 1951–2000. Along these lines, Ochou (2011) also attested to higher fluctuations in the end and start dates of the growing seasons.

Farmers explained changes in climate by modifications in their agricultural activities. The disruption of the agricultural calendar is proof of climate variability and change. Farmers mentioned that current onset and cessation times of the rains do not coincide with the times in their previous agricultural calendar. Consequently, they are confused about regularizing their cropping calendar and determining the most suitable crops to cultivate. The technique of crop succession and the semi-direct seeding of some crops such as cocoa (*Theobroma cacao*) are not suitable anymore to the new climatic conditions. Also, farming activities have become more sensitive to even little delays in their implementation.

Certain specific months and dates are considered as key reference indicators of climate over the years. As soon as a change occurs in these time points, farmers associate it as evidence of changes in climate. In Korhogo, August was formerly perceived as a rainy month, with rainfall levels of up to 400 mm (Beaudou and Sayol 1980). Farmers mentioned that this is no longer the case: i.e., August is currently not perceived as a rainy month. This perception of farmers is confirmed by data from the database of the National Meteorological Office of Côte d'Ivoire (SODEXAM), which show a decrease of 228 mm in August rainfall levels in the period 1971–2002. Furthermore, rainfalls now occur in August instead of July in Toumodi. The rainy season was earlier well defined, and marked by the fruits of the Shea butter tree beginning to mature.

5.4.2.3 Wind and sunshine

The intensity of the sun and the power of winds have changed. Before, the winds were less intense, but now, strong winds which precede the rains chase out the stormy clouds. The lack of data on changes in wind speeds from SODEXAM does not help to confirm farmer's assertion. However, similar increasing winds had caused more pronounced movement of sand and destroying crops in Burkina Faso, a neighbor country of Côte d'Ivoire (Nielsen and Reenberg 2010). Sunshine is stronger nowadays than it was two decades before. For instance, from 1971 to 2000, the temperature in Korhogo has increased by an average of 0.8°C every year (database from SODEXAM). Moreover, the direction of wind has changed according to some farmers. Further details of farmers' perception of CC are presented in Tables 5.4 and 5.5.

Table 5.4: Description of farmers' perception of climate change through non-climatic indicators in Toumodi.

Level	Sub-level	Description
Agriculture	Farming seasons	In the past, the rainy season was the longest. The difference between the two was small, as it rained sometimes in the dry season. The short dry season, which is a period of wind, occurred in August but has shifted to July.
	Farming practices	In the past, farmers practiced the semi-direct seeding of cocoa, but nowadays they make seedbeds. Crop succession was possible, as rains before the harvest of yam (*Dioscorea alata*) allowed farmers to sow maize in the hillocks of yam. Nowadays, any little delay in the implementation of farming activities leads to significant loss in harvest. The wild animals destroy much more crop.
Environment	Local environment	In the past, it was possible to pick up some small pieces of ice when it rained, but it does not happen anymore. The weather is colder in the rainy season than before. Fruit maturation has changed as evidenced in the case of some fruits, which are mature on one side and still green on the other. Other fruits contain a lot of chenille. There is also green moss on the leaves of mango trees, which did not occur so much before. The small rivers and dams have dried up and no longer flow during the dry season. Unknown insects are found in the farms.
Time reference	Reference period	There was no rain even in June, which is in the rainy season. This year (2011) there was no rain in July either. In July, it used to rain a lot, precisely on July 14th; now it does not rain. It used to rain in April, even until July, but now everything has changed. In the past, the early yams were harvested in July. In the past, February was the beginning of the growing season. In 2006, it did not rain much. However, in 2009, it was worse. In 1985, there was a major wildfire. In 1990, bush fires destroyed everything.

Source: Focus groups

Table 5.5: Description of farmers' perception of climate change through non-climatic indicators in Korhogo.

Level	Sub-level	Description
Agriculture	Farming seasons	The farming seasons were longer before, and there were two- or three-month intervals between two rainy seasons
		In the past, the first rains were strong and followed by the sun. They were called "Gbinwoza" or "Zewoza" which means "rain of February" in *Sénoufo*, the local language of Korhogo.
		January and February were characterized by hot winds that predict the coming rains; however, now the rain begins in May and ends in September.
	Farming practices	There is a disturbance in the agricultural calendar. The former planting dates are not anymore suitable to the new climatic conditions. Indeed, it does not rain enough during the sowing time; for instance, it often happens that the rain stops when the rice is sown.
		The lack of rain makes the space used for growing remain dry for a long period.
		The long-season (6 months) crops of yam (*Dioscorea spp.*) and rice (*Oryza sativa*) cannot be grown anymore because of lack of rain.
		Before, there were already new yams in August.
		In the past, the first rains started in March and April; the fields were already cleaned, and the hillocks of yams were built up so that the yams were already mature by August. Nowadays, the yams are progressively abandoned because it does not suit the new climate.
		The technique of crop succession is not feasible anymore. In the past, farmers could grow groundnuts followed by cotton; after the harvest of the groundnut, the furrows were used for the sowing of cotton.
		The rice could be grown twice a year, the "SATMACI" variety during the dry season and another variety in the rainy season. But now, only one harvest a year (during rainy season) can be done if the rain does not stop.
Environment	Local environment	Before, it rained enough and all the ponds and streams were filled. One could even see fishes. Moreover, water remained in shallow wells in dry periods. Nowadays, it completely disappears during the dry season.
		If it rains today, the soil dries up faster
		In the past, farmers harvested the rice and brought it to the village while it still rained, but now it stops before the harvest period.
		In the past, old men forecasted well the rain based on the intensity of sunshine and the stars in the sky. Now, the sun is not anymore an indicator of rains but rather the announcement of a freshness period.
Time reference	Reference period	It rained a lot in August and all the roads were flooded at that time; but today, August is dry
		In the past, the groundnut in some villages and the new yams were already mature in August.
		The maturation time of the Shea nuts coincided with the rainfall, which does not happen anymore.

Source: Focus groups

5.4.3 Action implemented against threats in farm management

Five different levels of intervention were identified (including the option of "no action") (Table 5.6): Implementation of farming activities, Funding of farming activities, Sale of products, and Nature of farming lands. However, no measures for fighting against bushfires and straying of animals were mentioned in Korhogo; the farmers deal with the problem of funding agricultural activities by producing charcoal. This short-term solution is a real problem, as deforestation in this area has increased in 2002 after the departure of water and forest protection agents due to the civil war (Pswarayi et al. 2010).

Poor soils in Korhogo have resulted in the search for more suitable land for agriculture. Otherwise, fertilizers, pesticides, and herbicides are applied if farmers have adequate financial means; in addition, farmers are more likely to organize themselves into cooperatives and informal groups to facilitate the sale of their products.

Table 5.6: Description of relevant actions implemented by farmers to deal with their threats in farm management.

Level	Action implemented	Toumodi		Korhogo	
		Quotation	*%*	*Quotation*	*%*
Farming activities implementation	Association of crops	2	5.26	0	0
	Use of new varieties	1	2.63	0	0
	Re sowing & re planting	5	13.16	3	5.45
	Cleaning by hand	3	7.89	10	18.18
	Farming activities quickly completed	1	2.63	1	1.82
	Sanitary treatment of farms and livestock	11	28.95	16	29.09
	Animals in pens	3	7.89	0	0
	Firewalls	3	7.89	0	0
	Group of mutual aid	2	5.26	1	1.82
Funding of farming activities	Borrow money to buy inputs	0	0	1	1.82
	Funding certain product by selling others	3	7.89	4	7.27
	Pre-financing of farming activities	1	2.63	2	3.64
	Produce charcoal to buy inputs	0	0	4	7.27
	Sell fertilizer to solve household problem	0	0	1	1.82
Nature of farming lands	Find new farming lands	0	0	1	1.82
	Soil fertilization	0	0	2	3.64
	Reducing farm size	1	2.63	0	0
Sale of products	Creation of cooperative for better market access	0	0	6	10.91
	Sell before harvest	1	2.63	0	0
No actions	No solutions	1	2.63	3	5.45
	Total	38	100	55	100
	Standard deviation	2.55	6.72	4.00	7.27

Source: Focus groups

5.4.4 Interrelationship between non-climatic threats in farm management and arising actions implemented by farmers

In Toumodi, as in Korhogo, farmers implemented more measures for farming activities (borrowing money to buy inputs, re-sowing, replanting, etc.), while threats related to damage by livestock were inadequately addressed (Figure 5.3). Therefore, farmers' range of possibilities with regard to technical farming activities is more important, while the lack of technical support is not addressed at all because it is outside the farmers' field of action. Also, the centrality of "no solutions" in Figure 2 reveals the low adaptive capacity of farmers in dealing with non-climatic threats.

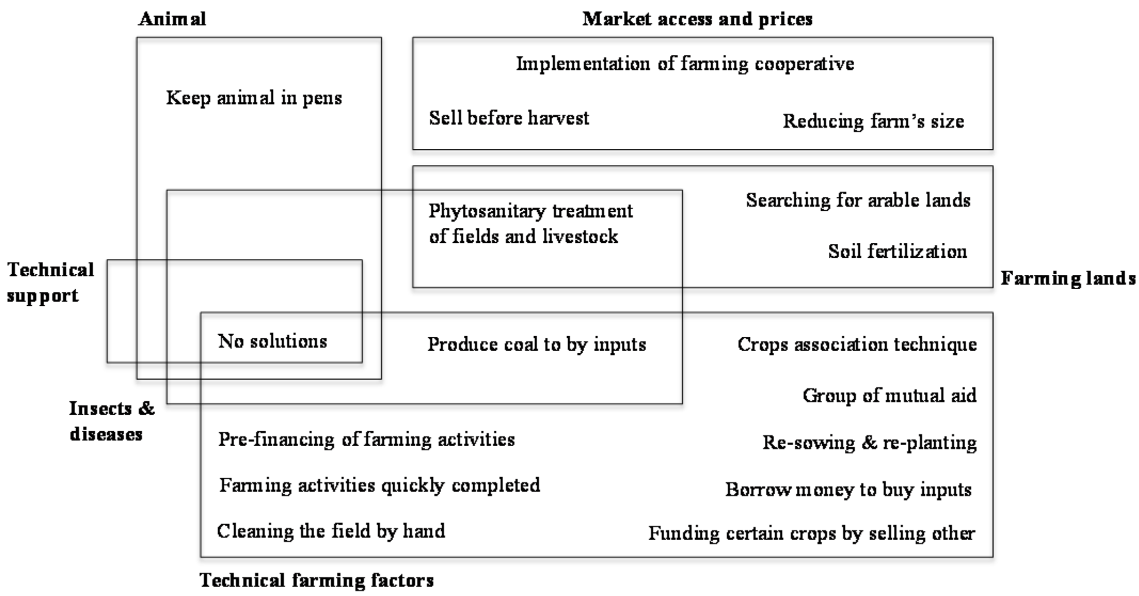

Figure 5.3: Interrelationships between implemented actions and corresponding non-climatic threats in both study areas

5.4.5 Adaptation strategies for climate change

The variety of rice (*Oryza sativa*) called 'SATMACI' was grown twice a year in Korhogo, but now, due to climate variability and change, only one harvest is possible per year. Moreover, in Korhogo, the cultivation of groundnuts (*Arachis hypogaea*) was followed by white cotton (*Gossypium hirsutum*). After harvesting the groundnuts, farmers used the old furrows for the sowing of cotton; but inadequate rains have prevented similar practice in recent times and the farmers needed to adapt. The adaptation strategies in both areas included other practices such as change in diet and worship of spirits (see Table 5.7).

Table 5.7: Description of adaptation strategies for climate change in Korhogo and Toumodi.

Adaptation strategies	Korhogo	Toumodi
Adoption of new varieties	Use of a short-cycle (3 months) white variety of groundnut and rice. The yellow maize (*Zea mays*) was used to replace the white maize	The cocoa with a 3- to 4-year vegetative cycle has been replaced with the 14- to 18–month variety. The variety of yam (*Discorea spp*) called "Brazil," which was introduced by the extension services, is still used by farmers.
Crop association or mixing cropping	Rice-maize, maize-sorghum (*Sorghum*), millet (*Panicum miliaceum*)-rice, cotton-sorghum, groundnut-maize-sorghum, groundnut-millet-rice	Cocoa-banana (*Musa spp*) and then maize, cocoa-yam-banana, cocoa-yam-cassava (*Manihot esculenta*)-banana New varieties of yams are mixed with the traditional varieties on the same field.
Agricultural calendar adjustment	Cotton is cultivated before February. Rice is sown in June instead of April. Green beans (*Phaseolus vulgaris*) and sorghum are planted in August instead of July; the white groundnut is planted in May or April instead of March.	Yams are cultivated one month earlier.
Change in the method of planting	Draft oxen are used to make large hillocks and large farms. Re-sowing is undertaken after the lack of rain, or if the sun has burnt out the germinated nuts. Much higher amount of rice seeds are used during sowing. Small hillocks of yams are made to improve rainwater infiltration in the hillocks, and trees are grown in the field.	Large holes are made for the seedbeds to facilitate water retention. The technique of re-sowing is also implemented after poor germination of crops. A safe distance is kept between plants to prevent the wind from uprooting banana trees.
Crop watering	Deep wells are built to provide water. River water is increasingly used to water crops.	The seedbeds are watered using the pumps in the village.
Livestock watering	The bovines (*Bos taurus indicus*) receive drinking water 3 times a day instead of once because of the lack of grass.	
Livestock enclosure	Instead of barbed iron which is recommended, certain stockbreeders use wood to build their enclosure.	
Animal treatments	More sanitary treatments for animals done when the financial means allow it.	
Dietary change	Yam, cassava, and millet are consumed less, and more maize is eaten.	Cassava is becoming the more basic crop because it is more suitable to the new climatic conditions.
Worship of spirits	In the past, when it did not rain, the farmers worshipped the spirits. To prevent logging of trees, the chief of the village of Kouniguékaha has put up a fetish object to frighten people	

Source: Focus groups

The adaptation levels found using focus groups appear to be rather similar in Toumodi and Korhogo (Figure 5.4). The most developed strategies concern the different methods of planting. This is followed in order by agricultural calendar adjustment, adoption of new varieties, and implementing mixed cropping. However, at the level of "water shortage solving," farmers in Korhogo have implemented more strategies than farmers in Toumodi, which shows the extent of water shortage problems in this zone. For certain adaptation levels such as "livestock system management," farmers in Toumodi appear to have adapted no strategies.

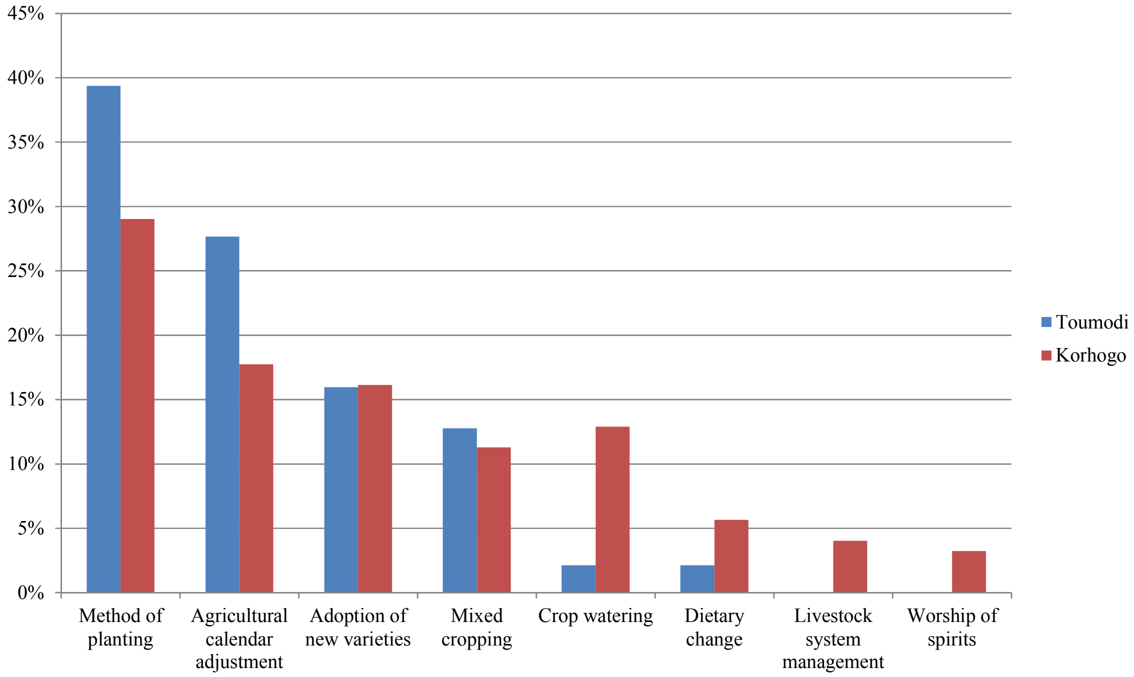

Figure 5.4: Importance of adaptation strategies to climate change in Toumodi and Korhogo

5.4.6 Identification of factors influencing farmers' adaptation behavior

Different influential factors were identified (Table 5.8). They were grouped into two levels: internal factors related to farmers and exogenous ones. Internal factors are, for instance, gender, farming experience, household size, and wealth. Exogenous factors found to be influential are, for instance, lack of contact with extension services, length of rainy seasons, and the availability of drought-resistant crop varieties. This distinction between factors has been made to help future agricultural policies to focus on identified factors to ensure implementation of climate adaptation measures.

Table 5.8: Internal and external factors influencing farmers' behavior with regard to adaptation to climate change

Type	**Factor**	**Level**
Internal factors	Gender Experience in farming activities Household size Financial goals Financial means Failure to understand rainfall forecasts Aims to adopt the best varieties Objective of early harvest Type of crop in association Ensure a safety production of at least one crop in association Harnessed culture Perceived benefits of the new technique Religion	Farmer
Exogenous factors	Lack of contact with extension services Existence of village pump Price of certain products such as cotton	Institutional
	Scarcity of rains Length of the rainy season Beginning of the first rains Stop of rains after sowing High winds Sunshine	Climate
	Availability of farming lands Soil fertility Presence of trees on the field	Lands and soil
	High price of fertilizer, seeds, farming labor	Inputs
	Adaptation of the variety to any type of soil Drought resistant variety Short-season variety Good production's quality of the variety	New varieties
	Good adequacy of corn, rice, cassava Poor harvest Disease of draft oxen Gradual disappearance of yam and millet	Farm
	Crop water requirement Availability of wood to build up animal fence Lack of pasture Draining of the wells Existence of nearby rivers or dams	Environmental

Source: Focus groups

5.4.7 Interrelationship between influencing factors and adaptation strategies

The interrelationships between identified factors and different adaptation strategies are shown in Figure 5. Different factors affecting farmers' behavior are identified and then linked to a specific adaptation measure. Therefore, some factors influence different levels of adaptation at the same time, which reflect their relative importance. Scarcity of rains and the lack of contact with extension services are the factors which influence the most adaptation strategies, followed by sunshine and financial goals. The probable interaction between different levels of adaptation cannot be excluded, but in Figure 5.5, only the interrelationships between factors and adaptation levels have been highlighted. Furthermore, change in the method of planting and mixed cropping/crop associations are the adaptation strategies related with the largest number of factors.

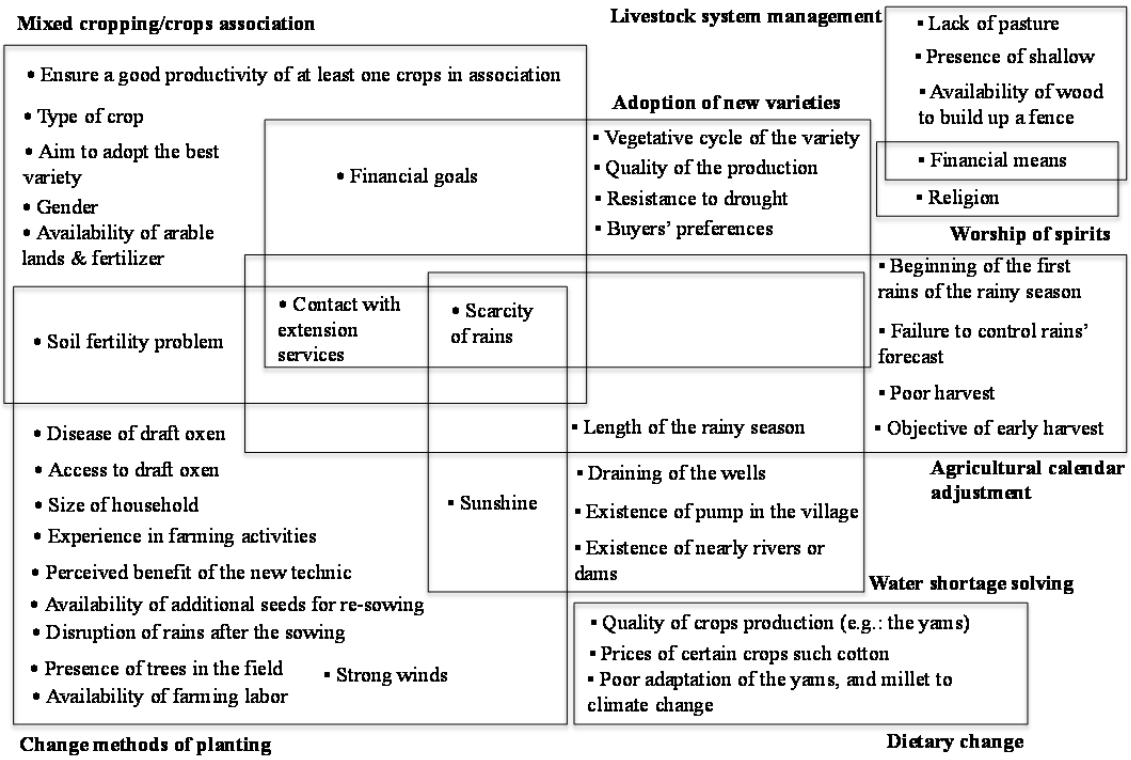

Figure 5.5: Interrelationships between influencing factors and adaptation strategies to climate change

5.5 Conclusion

CC emerged as a significant constraint for poor smallholder farmers in terms of satisfying their food needs; the present study therefore has gathered in-depth information to better understand farmers' adaptation behavior. This research thus forms the basis and contextual background for subsequent quantitative analyses on the adaptation behavior of farmers in Côte d'Ivoire. Therefore, the identified local strategies need to be enhanced by researchers. We suggest that future agricultural policies take into account farmers' perception, to provide suitable climate forecast and to improve local technical support for better adaptation to climate change, and to ensure successful knowledge transfer in the local framework.

Our analysis reveals that smallholder farmers in Toumodi and Korhogo (Côte d'Ivoire) perceive, in addition to problems related to insects and diseases, market access, prices, and changes in climatic conditions to be relevant constraints for their farming activities. To address these threats, four different levels of intervention were identified: Farming activities implementation, Funding of farming activities, Sale of products, and Nature of farming lands. Adaptation measures related to the first category were the most implemented and comprise, for instance, crop associations and re-sowing and replanting. The study also revealed the low adaptive capacity of farmers to deal with non-climatic threats because of a lack of technical support, which falls outside of their decision-making ability. Farmers strongly perceive CC through characteristics and changes in rain patterns, changes in the local environment, and the disappearance of certain farming practices. Farmers in Toumodi perceive more the impacts of CC through the disruption of key time reference period and shift in rainy seasons, than farmers in Korhogo. To adapt, they mostly change the methods of planting, adjust the agricultural calendar, adopt new varieties, and employ mixed cropping. This adaptation behavior is influenced by the factors "contact with extension services" and "scarcity of rains." Furthermore, farmers in both study areas asserted that they have no effective solutions to adopt when facing poor seed quality, strong sunshine, and new weed varieties.

Furthermore, based on our results, we suggest that for better adaptation to climate change in Côte d'Ivoire, future agricultural policies should take into account farmers' perception, to provide suitable climate forecast and to improve local technical support. Local organizations and NGOs need to work together on government extension services and also try to involve a greater number of farmers in the services and ensure proper transfer of adaptation measures.

6. Relevant drivers of farmers' decision behavior regarding their adaptation to climate change: A case study of two regions in Côte d'Ivoire[5]

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ABSTRACT

In addition to many other stressors, climate change has emerged as one of the major threats for smallholder farmers from Toumodi in the center and Korhogo in the north of Côte d'Ivoire. This study examined farmers' adaptation behavior with respect to subjective, socio-demographic, institutional, and physical variables. Focus group discussions with 205 farmers and large-scale surveys involving 800 farmers' households were conducted in both study areas for data collection. The data were analyzed using a categorical principal component analysis (CATPCA), reliability analyses, and binary logistic regression models to determine relevant influences on farmers' adaptation behavior. The results revealed that 77% of farmers perceived high increases in temperature and 75% perceived strong decreases in rainfall over the last 10 years. Farmers in Toumodi perceived more climate changes than their colleagues in Korhogo. In addition, farmers from Korhogo perceived more new pests (81%) and new weeds (87%), while those from Toumodi agreed that there were strong changes in flowering and fruiting times (54%). Furthermore, two main adaptation groups were identified: changes in the sowing management and the technical itinerary. The levels of implemented strategies differed significantly across regions. Factors such as the perceived occurrence of new pests and insects and support from national and international organizations were relevant to farmers' decision to adapt to climate change. Moreover, the agro-ecological specificities, the types of food crops, and the owners of livestock had also an influence on farmers' adaptation choices. The appropriate policy response should henceforth integrate these factors to support efficient adaptation processes in response to climate change in Côte d'Ivoire.

KEYWORDS

Adaptation behavior, Climate change, smallholders, Categorical principal component analysis, logistic regression, Côte d'Ivoire

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6.1 Introduction

CC is emerging as one of the main threats to sustainable food security in developing countries. In particular, CC is expected to affect agricultural production due to increasing temperatures, changing precipitation patterns, and more frequent extreme weather events. It is estimated that the mean global temperature will rise by 1.8–4.0 °C by the end of the twenty-first century (Izaurralde 2009), which will reduce the yields from rain-fed agriculture in some regions by up to 50% by 2020 (IPCC 2007). This is particularly relevant for Africa because livelihoods are based mainly on climate-dependent resources and environmental factors. The effects of CC in Africa will thus be disproportionate and severe (Asfaw and Jones 2010).

Located between latitudes 4°30' and 10°30' N and longitudes 2° 30’ and 8° 30’ W, Côte d’Ivoire, a western African country where agriculture drives a market-based economy, is experiencing the adverse effects of CC. Changes in climatic conditions that have already been observed in Côte d’Ivoire (MEDD 2011) are especially characterized by variations in the seasons’ start and end dates, leading to a disturbance in the agricultural calendar (Ochou 2011; Goroza 2012). Moreover, an increase in the frequency of storms and heavy rainfalls has been observed (Ochou 2011); several sources (Brou and Chaléard 2007; Kanohin et al. 2009; Goula et al. 2010) have revealed a general reduction in the annual quantity of rainfall since the seventies and a shortening of the rain seasons. Indeed, annual rainfall decreased by an average of 0.5% per year between 1965 and 1980 and by 4.6% per year in the 1980s (MET 1994; Birgit and Bruzon 2006). Furthermore, models of the change in the average daily maximum temperature for the warmest month of the year showed an increase in temperature up to 2.5°C by 2050 (Ahossane et al. 2013). Decreasing levels of rainfall affect both the bimodal rainfall pattern of the southern region and the unimodal rainfall pattern of the northern region of Côte d’Ivoire. Rural areas are the most affected by CC because agricultural activity is their main source of income (MEDD 2011). For instance, a yield loss of 5–25% of baseline for rice in the central and northeast regions of the country has been predicted by 2050 (Ahossane et al. 2013). This is of special relevance because most farmers engage in agricultural practices that depend on the amount and the seasonal distribution of rainfall.

Changes in climatic conditions are exacerbated by the development of other severe environmental problems such as large-scale deforestation. From 12 million hectares of forest in 1960, only 2.802 million hectares remained in 2007, which represents a loss of more than 75% in less than half a century (MEDD 2011).

One of the ways communities can adjust to CC is through adaptation (IPCC 2001). Common adaptation methods in agriculture include the use of new crop varieties and livestock species that are better suited to drier conditions, irrigation, crop diversification, the adoption of mixed crop and livestock farming systems, and the changing of planting dates (Deressa et al. 2009; Di

Falco et al. 2011). The main aim of almost all of these practices is to ensure that crops' critical growth stages do not overlap with dry periods or mid-season droughts. Farmers' decision to adjust their farming practices is influenced by a number of factors in addition to the climate stimulus (Silvestri et al. 2012). Past studies (Nielsen and Reenberg 2010; Deressa et al. 2009; Sietz et al. 2011; Esham and Garforth 2012) have pointed out a number of factors, including social, economic, and cultural influences, as well as government policies, the institutional environment, farmers' access to information, and cognitive domains. In addition, farm characteristics or infrastructures, access to credit and community perceptions determine farmers' adaptation behavior (Piya et al. 2013; Hisali et al. 2011; Gbetibouo et al. 2010). Indeed, multinomial logit (MNL) models have been often used to analyze influencing factors of farmers' adaptation choice (Gbetibouo 2009; Deressa et al. 2009; Hisali et al. 2011); however, the major limitation of MNL models is their assumption that practices are mutually exclusive, which is not true in reality because a single household can simultaneously adopt more than one strategy (Piya et al. 2013).

Furthermore, farmers' behavior is shaped more by their perceptions of CC and climate risk than by the actual climate patterns (Adger et al., 2009; Mertz et al., 2009). In order to develop appropriate strategies and institutional responses, it is necessary to have a clear understanding of farmers' perception of CC, the actual adaptations at the farm level, and what factors drive and constrain farmers' decision to adapt (Esham and Garforth 2012). Because adaptation is often conceptualized as a site-specific phenomenon, many authors call for more local-level analyses to gain a better understanding of the fundamental processes underlying adaptation and to better target adaptation policies by national and local governments, non-governmental organizations (NGOs), and bi-lateral donors (Smit and Wandel 2006). Such research in Côte d'Ivoire is very scarce, and understanding the determinants of a household decision to adopt a particular practice among the available choices may provide insights into the factors that enable or constrain adaptation to CC.

Based on this background, the goal of this study is to investigate farm-level adaptation to CC through farmers in two regions of Côte d'Ivoire. Specifically, the objectives of the study are: (i) assess farmers' perceptions of CC; (ii) identify the main current adaptation strategies; and (iii) determine relevant drivers of adaptation. To this end, focus group discussions and large-scale surveys were conducted in two regions of Côte d'Ivoire. Based on the derived data, we were able to analyze farmers' adaptation behavior with respect to subjective, socio-demographic, institutional, and physical variables.

The remainder of this paper is structured as follows. In section 2, the methods and data used are explained, while farmers' perceptions and adaptation strategies are presented in section 3. The results are introduced and discussed in section 3 as well. Finally, section 4 summarizes the results and concludes with policy recommendations.

6.2 Methods

6.2.1 Study areas

Côte d'Ivoire is divided into two main agro-climatic regions following the pattern of temperature and rainfalls. The forest zone of the south has a sub-equatorial climate and two rainy seasons. The north is characterized by a tropical climate of the Soudano-Guinean type and has only one rainy season (FAO 2000). The dry season is now longer in the north as well as in the center of the country (Brou et al. 2005; Dje 2008). This reduces the availability of water, especially by decreasing the length of time rainfall is accessible for agriculture and thus compromising the vegetation cycles.

The study was carried out in two departments of Côte d'Ivoire, namely the Toumodi area in the center and the Korhogo area in the northern part of the country (Figure 6.1). As in most areas of the country, agricultural fields are mainly rain-fed (Birgit and Bruzon 2006; Tié Bi et al. 2010).

Toumodi is a mid-sized city and a department 230 km north of the capital Abidjan. It has an area of 2,780 km² (Ouattara 2001) and a population of 147,105 inhabitants in 2009. In 2001, 65% of the population was rural (CountrySTAT 2012). This region is a producer of yams (*Dioscorea spp.*) and other important crops such as cocoa (*Theobroma cacao*) and coffee (*Coffea robusta*). Since 2001, rubber (*Hevea brasiliensis*) and palm oil (*Elaeis guineensis*) have been gaining importance in the forest zone (PAM et al. 2012). Toumodi is located in the Sudano-Guinean area, a transition zone between the forest zone in the south and the savanna in the north. It has a humid tropical climate (*Baouléen*), with temperatures between 14 and 39 °C (Table 6.1). It is characterized by four seasons: a long dry season (November–February), a long rainy season (March–June), a short dry season (July–August), and a short rainy season (September–October), and a relative humidity of 60 to 70% (Birgit and Bruzon 2006). The average annual precipitation in the period from 1980 to 2011 was 1,113 mm. The Toumodi area includes a mosaic of environments, composed of mesophile forest (or semi-deciduous) and Guinean savanna (MEDD 2011).

Korhogo, in the Sudanean zone of the north, is located 600 km north of Abidjan, near the border of Mali. This region is closer to the desert, and vegetation is scarcer due to a drier climate. Korhogo is 12,500 km² (Ouattara 2001) wide and had 630,725 inhabitants in 2009. In 2001, 80% of the population was active in agriculture (CountrySTAT 2012). The north region cultivates mostly cotton (*Gossypium spp.)*, as well as cashew trees (*Anacardium occidentale*) and fruit trees like mango for cash crops and various food crops and livestock (Birgit and Bruzon 2006). The north region is the poorest of the country with a poverty rate of more than

70%. Korhogo is a savanna region with only one rainy season and a relative humidity of 40 to 50%. Rain-fed crops are more dominant (maize (*Zea mays*), rice (*Oryza spp.*), and groundnuts (*Arachis hypogaea*)). About 40% of farms in the region produce cotton. Perennial crops (mango (*Mangifera indica*), shea trees (*Vitellaria paradoxa*)) and livestock are also important sources of income (Birgit and Bruzon 2006). The average annual precipitation from 1971 to 2001 was 1,300 mm. The area is characterized by the intermittent presence of a cool and dry wind called "harmattan," which occurs between December and February (UFR-STRM 2009).

Therefore, the diversity of the vegetation and socio-demographic and climatic characteristics in the study areas will provide a more holistic view of CC issues.

Table 6.1: Socio-economic and biophysical characteristics of the study areas.

	Toumodi (Center)	**Korhogo (North)**
Location	6°32' N and 5°1' W	9°53' N and 6°49' W
Altitude (meters above sea level)	152	200
Vegetation	Transition forest-savanna	Savanna
Climate	Tropical humid (*baouléen*)	Tropical (*soudano-guinéen*)
Humidity (%)	60-70	40-50
Average annual precipitation (mm/year)	1,113 (years 1980-2011)	1,300 (years 1971-2001)
Range of average temperature (°C)	14-39	10-42
Rainfall regime	Bimodal	Unimodal
Dry season	Nov-Feb & Jul-Aug	Nov-April
Rainy season	March-June & Sept-Oct	May–Oct

Source: Cissé et al. 2011; Birgit and Bruzon 2006; MEDD 2011; MPARH 2003.

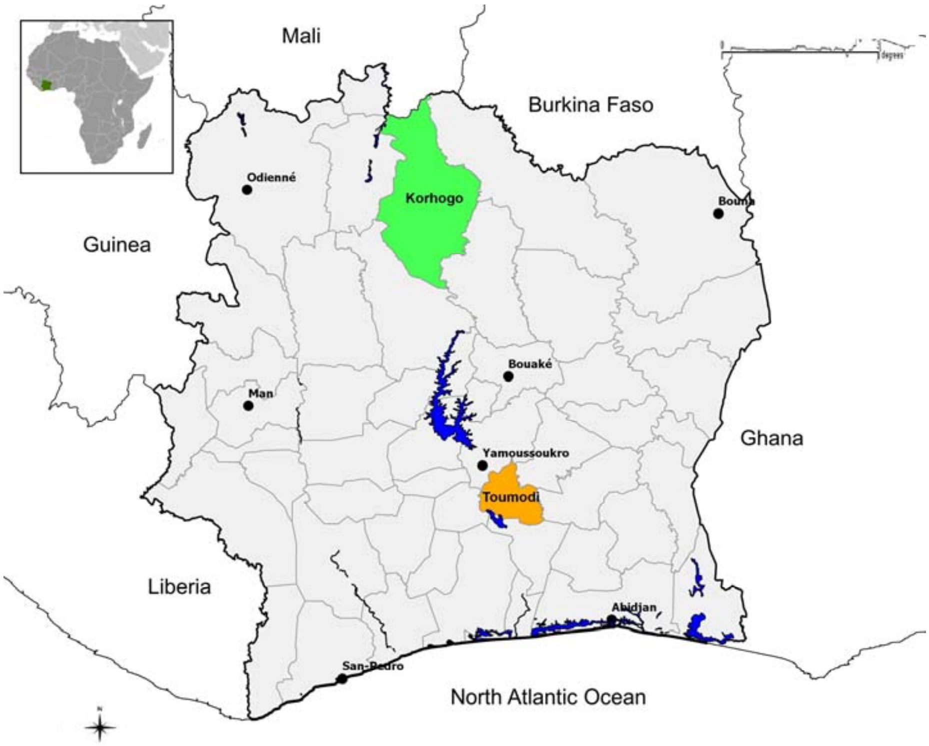

Figure 6.1: Map of the study areas.

6.2.2 Data collection

This study employed both qualitative and quantitative methodologies in the Toumodi and Korhogo regions of Côte d'Ivoire; between June and August 2011, qualitative data were collected through 16 focus groups to gain the first insights into processes shaping farmers' adaptation behavior. Focus groups are used as a method of collecting data through group interactions on a topic determined by the researcher (Morgan 1997). Sessions of about one hour, with 10 to 12 farmers, involved a total of 205 participants selected based on the geographical location of the villages, the types of farming activities, and the age of farmers. The discussions were recorded and translated in French. Furthermore, the socio-cultural differences between the two areas were considered. In Korhogo (the Muslim and conservative part of the country), women and men were separately interviewed, which was not the case in Toumodi. Krueger's (1994) method has been applied by continuing with the focus groups until a clear pattern emerged and subsequent groups produced only repetitious information (theoretical saturation). Finally, nine villages in Toumodi and four in Korhogo were investigated.

Data were analyzed using NVivo software for qualitative data analysis, which helped us to understand farmers' decision-making process regarding the management of their farms, their perceptions of CC, and how they deal with climatic risk.

The results of the focus groups were used to elaborate upon a questionnaire for the survey conducted between February and April 2012. The sample consisted of 800 farmers' households, with 400 selected from each study area using a quota sampling technique, as the last general census of farmers was conducted in 1998 (Gschwend 2005; Moser 1952). Quota sampling is particularly useful when we are unable to obtain a probability sample but are still trying to create a sample that is as representative as possible of the population being studied. Thereby, we based our sampling on the statistical data from the most important extension service, the national rural development support agency (ANADER), reflecting information on the farming populations in both regions. Indeed, quotas were computed based on 4,049 farmers from 12 villages in Toumodi and 3,700 involving eight villages in Korhogo. Significant criteria considered in the sampling process were gender, geographic location, and farming type (perennial, annual crop, vegetable, and livestock). The details of the quota sampling plan for the survey are presented in Table 6.2. Furthermore, with quota sampling methods, some biases could be introduced during the process of selecting farmers by not complying with the selection criteria. For the purpose of uniformity, the survey was conducted with the support of field assistants who were thoroughly trained in survey interviewing procedures. Moreover, interviews were conducted in compliance with quotas to improve the representation of particular strata (groups) within the population, as well as ensuring that these strata are not over-represented. Thus, attention to the geographical distribution of farmers was pointed out. Investigators have been trained to follow the instructions regarding compliance with the quotas and the geographical distribution of farmers' households. Moreover, instructions such as avoiding interviews with farmers of one type of crop farming activities and changing the period of interviews throughout the day have been considered. Finally, participants' average age was 45 years, and the average household size was 10 people. The level of education in Korhogo was much lower than that in Toumodi, while the average number of years of experience in crop farming and livestock production was 22.32 years and 10.20 years, respectively.

The survey was intended to collect information on farmers' perceptions of climate characteristics during the last decade and the effects of CC on farming and the natural environment. In this section, participants were asked about their perceptions of changes in the temperature, the amount of rainfall, and dry spell and rainfall frequencies. Moreover, we collected information on the possible causes of CC and on adaptation strategies that have already been implemented. Farmers' adaptations, their intention to adapt in the future, and the social pressure to adapt were assessed through questions about their expectations regarding implementing certain adaptation procedures and the ways in which family members could impede or motivate their decision to adapt. General household characteristics (e.g., gender of household head, education, age), and the farm type were also recorded in this survey. Information relating to each household's access to support from key agricultural institutions such as extension services, governmental and Non-governmental Organizations (NGOs), and finally, the type and frequency of advice from extension services were also integrated.

Table 6.2: Quota sampling plan for the survey

	Geographic segment		**Type of farming**		**Gender**	
	Village	*Number*	*Activity*	*Number*	*Woman*	*Man*
Toumodi (N=400)	Gofia	14	Periannual crop	31	20	80
	N'gbedjo	86	Annual crop	33		
			Vegetable	33		
			Livestock	3		
	Kadjokro	36	Periannual crop	31	20	80
	Anikro	26	Annual crop	33		
	Zahakro	38	Vegetable	33		
			Livestock	3		
	Djékanou	27	Periannual crop	31	20	80
	Laliekro	25	Annual crop	33		
	N'dakouassikro	34	Vegetable	33		
	Yao N'drikro	14	Livestock	3		
	Gbonti	26	Periannual crop	31	20	80
	Kimoukro	50	Annual crop	33		
	Ahouekro	23	Vegetable	33		
			Livestock	3		
Korhogo (N=400)	Dikodougou	70	Periannual crop	29	30	70
	Karakpo	30	Annual crop	38		
			Vegetable	17		
			Livestock	16		
	Koni	70	Periannual crop	29	30	70
	Famangaha	30	Annual crop	38		
			Vegetable	17		
			Livestock	16		
	Dagba	60	Periannual crop	29	30	70
	Sakouélé	40	Annual crop	38		
			Vegetable	17		
			Livestock	16		
	Kouniguekaha	50	Periannual crop	29	30	70
	Pokaha	50	Annual crop	38		
			Vegetable	17		
			Livestock	16		

Note: Quotas were computed based on the characteristics of farmers from the National Rural Development Support Agency (ANADER)

6.2.3 Data analysis

First, CATPCA and reliability analyses were used. Then, binary logistic regression models were applied to determine the relevant factors influencing farmers' adaptation behavior.

6.2.3.1 Categorical principal component analysis and reliability analysis

In this study, the process used to identify the most important factors of farmers' adaptation behavior consisted of two steps. First, we conducted a CATPCA to reduce the dimensions of the dataset to a smaller set of uncorrelated components and to determine the underlying latent dimensions within groups of factors. Thereby, four different subsets of variables related to subjective, socio-demographic, agronomic, and institutional factors were separately reduced.

The CATPCA also helped us to avoid problems of multicollinearity in the subsequent regression analyses. Furthermore, the variables were assigned to components based on their largest loading, and then Cronbach's alpha coefficient was calculated to determine the scale reliability of the dimensions. The coding of variables used for the CATPCA and the descriptive statistics are presented in Tables 6.3 and 6.4. The analyses were carried out using SPSS 17.0 for Windows (Statistical Package for Social Sciences, SPSS Inc.).

Table 6.3: Descriptive variables coding

Variables	Description
Study area	1 = Toumodi, 2 = Korhogo
Root, tuber or starchy farmer	1 = the household head is a producer of root, tuber or starchy, 0= otherwise
Cash crop farmer	1 = the household head is a producer of cash crop, 0= otherwise
Cereal farmer	1 = if the household head is a producer of cereal, 0= otherwise
Experience in crop farming	Experience in years 1 = [0; 10], 2 = [11; 20], 3 = [21; 30], 4 = [31; 40], 5 = [40; +[
Age of head of household	1 < 30 years, 2 = [31; 60], 3 = [61; +[
Size of household	1 ffi 5 members, 2= [6; 10], 3= [11; 15], 4 = [16; 20], 5 = [21; +[
Bovine ownership / Small ruminant & porcine ownership	1 = owner, 0 = otherwise
Frequency of dry spells / Frequency of rainfall	1 = high decrease over the last decade, 2 = average decrease, 3 = no change, 4 = average increase, 5= high increase
Length of rainy seasons / Length of dry spells	1 = high decrease over the last decade, 2 = average decrease, 3 = no change, 4 = average increase, 5= high increase
Effect of CC on cereals / Effect of CC on roots & tubers	1 = high negative impact, 2 = average negative impact, 3 = non-significant, 4 = average beneficial, 5= highly beneficial
Disturbance of the farming calendar	1 = high significant disturbance, 2 = average disturbance, 3 = non-significant disturbance
Yield variations	1 = high significant variation, 2 = average, 3 = non-significant
Perceived new insect pests / Perceived new weed species	1 = strongly agree, 2 = somewhat agree, 3 = do not know, 4 = somewhat disagree, 5 = strongly disagree
Contact with development projects / Ministry of Agriculture / NGOs / International organization / Swiss Centre of Research / National Centre of Research / ANADER	1 = often, 2 = rarely, 3 = never
Climate information from television	1 = the household head obtained information from television, 0 = otherwise
Membership in a farming cooperative	1 = the household head is a member of a farming organization, 0 = otherwise

Table 6.4: Descriptive statistics of variables selected

Variables	Mean	SD	Min	Max
Frequency of dry spells	4.56	0.58	1	5
Length of rainy season	1.34	0.59	1	5
Frequency of precipitation	1.37	0.52	1	4
Length of dry spells	4.70	0.53	1	5
Perceived new insect pests	1.72	1.12	1	5
Perceived new weed species	1.68	1.15	1	5
Effect of CC on roots & tubers	1.40	0.57	1	4
Effect of CC on cereals	1.31	0.57	1	4
Disturbance of the farming calendar	1.24	0.50	1	4
Yield variation	1.42	0.58	1	4
Contact with ANADER	2.15	0.92	1	3
Contact with Ministry of Agriculture	2.81	0.46	1	3
Contact with international organization	2.86	0.44	1	3
Contact with development projects	2.80	0.50	1	3
Contact with NGOs	2.67	0.67	1	3
Contact with National Centre of Research	2.84	0.47	1	3
Contact with Swiss Centre of Research	2.79	0.44	1	3
Study area	1.50	0.50	1	2
Root, tuber or starchy crop farmer	0.63	0.48	0	1
Climate information from television	0.47	0.50	0	1
Bovine ownership	0.25	0.43	0	1
Membership of a farming cooperative	0.40	0.49	0	1
Small ruminant and porcine ownership	0.42	0.49	0	1
Cereal farmer	0.76	0.43	0	1
Experience in crop farming (category)	2.32	1.08	1	5
Age (category)	2.02	0.50	1	3
Size of household (category)	2.40	1.04	1	5
Cash crop farmer	0.83	0.38	0	1

6.2.3.2 Logistic regression

The factors derived from the CATPCA were employed to explain farmers' behavior regarding their adaptation to CC in a binary choice model. Factors were retained for the regressions if their eigenvalues were > 1 and the Cronbach's alpha was greater than 0.5. Farmers' decision to adapt was modeled using a binary logistic regression (following Field 2009). Table 6.5 shows the groups of variables and their associated hypotheses with regard to their influence on adaptation to CC based on the literature review.

Table 6.5: Variables and Associated Hypotheses**.**

Variables		**Hypotheses**
Physical	Agro-ecological zone	The agro-ecological zone captures heterogeneity in ecological conditions (Tambo and Tahirou 2012; Silvestri et al. 2012).
Socio-demographic and agronomic	Experience in crop farming	The experience of the head of the household is expected to influence the decision to adapt (Igoden et al. 1990).
	Household size	The influence of the household size on adaptation is assumed to be positive (Yirga 2007) or negative (Croppenstedt et al. 2003; Nhemachena and Hassan 2007).
	Livestock ownership	Livestock could play a very important role by serving as a store of value and by providing traction and manure required for maintaining soil fertility (Yirga 2007). It is an indicator of wealth (Solano et al. 2000), so higher-income farmers may be less averse to taking risks.
	Type of farm	It is assumed farm type influences farmers' behavior. Maddison (2007) asserted that subsistence farmers are more capable of perceiving changes in climate, while Gbetibouo (2009) showed the opposite.
	Social network	Members of farmer associations may have better access to information, credit and inputs and are, therefore, more likely to adopt technology than non-members (Tambo and Tahirou 2012).
Subjective	Perception of CC	Perception of CC is assumed to be a necessary prerequisite for adaptation (Hansen et al. 2004; Thomas et al. 2007).
	Perception of CC impacts	When farmers perceive CC and consider it to affect their livelihood, they are expected to be more likely to take adaptation measures (Esham and Garforth 2012; Adger et al. 2009).
Institutional	Access to extension services	Access to extension services and information are expected to facilitate decision making with regard to adaptation to CC (Bryan et al. 2009; Deressa et al. 2009; Gbetibouo 2009; Maddison 2007; Tambo and Tahirou 2012).
	Climate information sources	Lack of information is assumed to be one of the major reasons for not undertaking any adaptation strategy (Di Falco et al. 2011). It is expected that farmers who have heard or read about CC and its negative consequences are likely to take up adaptation measures (Tambo and Tahirou 2012).

6.3 Results and Discussion

6.3.1 Farmers' perception of and adaptation strategies to climate change

Farmers' perceptions of CC were strong in both study areas: 77% of farmers perceived high increases in temperature, and 75% perceived strong decreases in rainfall over the last 10 years. Farmers noticed an increase in the frequency and length of dry spells, while they believed the frequency and length of rainfall and rainy seasons were still decreasing. However, 27% of farmers in Toumodi (52% in Korhogo) moderated their assertions related to the intensity of CC through a perceived average increase in dry spells, and 23% (46% in Korhogo) perceived an average decrease in rainfall (see Figure 6.2). The chi-square tests applied to the study areas revealed significant differences between farmers in Korhogo and Toumodi with respect to their perception of changes in climatic conditions, except for perceived changes in the amount of rainfall. More specifically, farmers from Toumodi seemed to perceive more CC than their colleagues in Korhogo. This could be explained by the fact that farmers in Korhogo have to deal with climatic threats such as water scarcity more often, which makes it more difficult for them to recognize changes. In contrast, farmers in Toumodi perceived any change in climate as a serious threat. This result also confirmed the findings from the focus groups, which showed the level of farmers' perceptions of CC was higher in Toumodi than in Korhogo (Comoé et al. 2012).

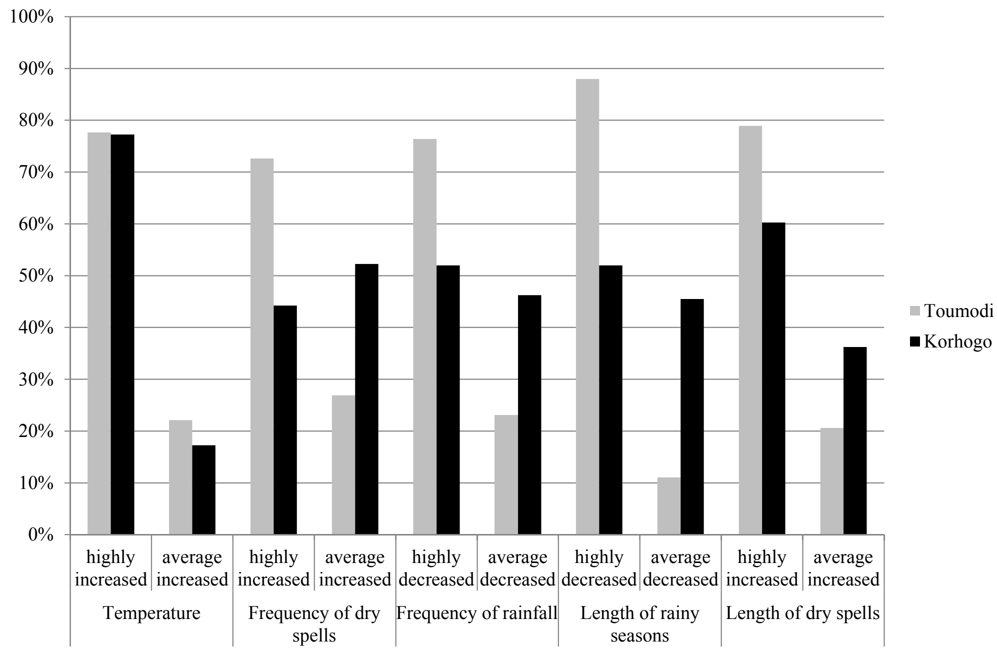

Figure 6.2: Farmers' perception of long-term temperature changes, rainfall, and dry spells in Toumodi and Korhogo (% of respondents).

Note: Number of observation (N) = 798. The variables were coded using a five-point scale from "highly decreased" to "highly increased"; only two out off three responses are shown in figure 6.2

In addition to their perceptions of changes in rainfall and temperature, we asked farmers to give their views on statements about changes in their environment. In general, we found that farmers in both regions had a strong perception of changes in their local environment. For instance, 90% of farmers in Toumodi and 85% in Korhogo strongly agreed that rainfall was unpredictable. It is worth noticing significant differences in the views of farmers from both study areas concerning the emergence of new weed species and new insect pests in agriculture and the changes in flowering and fruiting times. Farmers from Korhogo perceived more new pests (81%) and new weeds (87%), while those from Toumodi agreed that there were significant changes in flowering and fruiting times (54%).

6.3.2 Adaptation strategies to climate change

Focus groups were used to identify specific adaptation strategies to CC; and the survey confirmed these strategies on a large scale. Figure 6.3 shows all identified strategies in crop farming and livestock production as well as non-farming strategies.

6.3.2.1 Crop farming systems

Eight strategies were identified in the crop farming system, and these were divided into two main groups. The first was adaptation through sowing management, which included "the technique of repeating sowing," "the use of more seeds during sowing," and "making large holes for seedbeds to facilitate water retention." The second adaptation strategy was done through changing the technical itinerary, which is defined as logical and orderly techniques implemented on a farm to help it achieve its production goal (Sebillotte 1974). This definition takes into account the coherence and interactions of the techniques and the explicit reference to a production target. The levels of implemented strategies differed significantly across regions, except for the adoption of vegetables with a short growing season. The latter finding demonstrated that farmers in both study areas were open to adopting new varieties that are more suitable to the new climatic conditions. Moreover, "adjusting the agricultural calendar," "the technique of repeating sowing," "the use of more seeds during sowing," and "changes in the size of hillocks" were implemented more in Korhogo, while "planting varieties of crops in association," "making large holes for seedbeds," and "keeping much more trees on the field" were more dominant in Toumodi.

6.3.2.2 Livestock production system and diet

Regarding the adaptation of livestock systems, two main strategies were mentioned: the reduction of animals to ensure there is sufficient grass available during dry spells, and better health monitoring. The second strategy was implemented to increase animal mobility to facilitate access to pasture. Of the two study areas, Korhogo was the first where farmers implemented both strategies, with a significant difference in farmers from Toumodi regarding the strategy of "moving animals to maximize access to pasture and water." The north is a pastoral area compared to the center; therefore, farmers in Korhogo have developed the capacity to deal with environmental constraints caused by CC over the years. Concerning the modification of food habits, one could assert that although farmers are still linked to their staple foods of rice and yams, they showed more interest in consuming cassava in Toumodi and maize in Korhogo. Indeed, their staple foods are becoming vulnerable to the new climatic conditions; therefore, they need to adapt their diet with crops that are more resistant to dry spells, such as cassava.

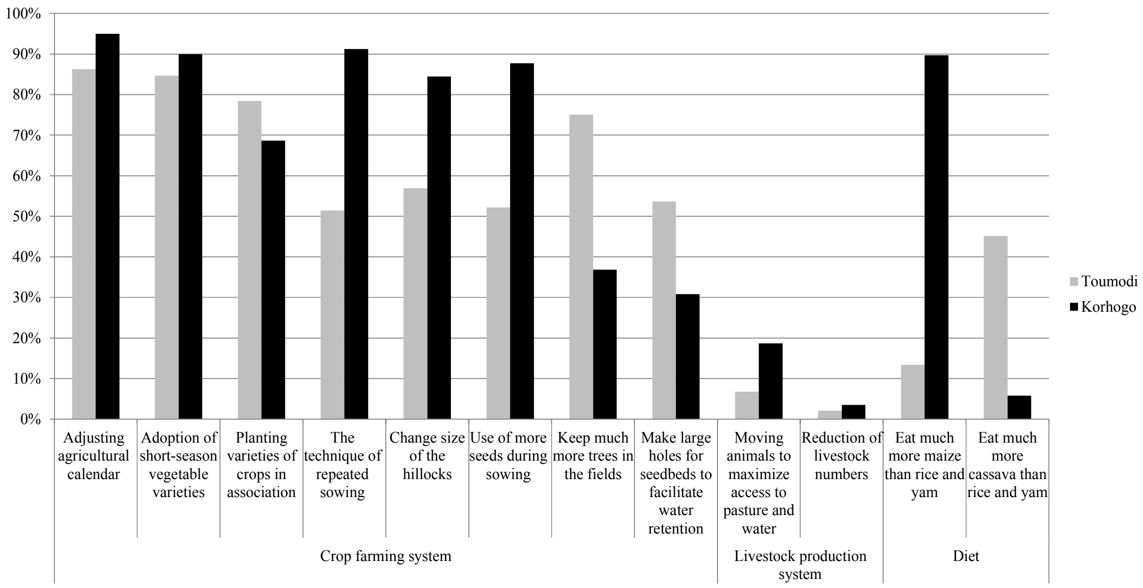

Figure 6.3: Strategies for coping with climate change in Toumodi and Korhogo.

6.3.3 Results of CATPCA and reliability analysis

6.3.3.1 Variations of farmers' perception of climate change

Perceived changes in rainfall patterns (C 1) and the perceived occurrence of new pests and weeds (C 2), the two components illustrated in Table 6.6, show a 64% total variance of data.

The first component represents the variables related to changes in length and frequency of rainfall, and the second component includes the occurrence of pests and weeds. The variable related to changes in dry spells was positively loaded for C 2, while those related to rainfall had a negative loading; as coded (high decrease to high increase), this revealed a perception that there has been an increase in the frequency and length of dry spells and a decrease in the length of rainy seasons and the frequency of rainfall.

6.3.3.2 Variables of perceived effects of climate change

Regarding how farmers perceived the effects of CC on their farming activities, the following variables, “the effect of CC on roots & tubers,” “the effect of CC on cereals,” and “disturbances in the farming calendar” were identified and loaded on one component. The results of the CATPCA and reliability analyses are presented in Table 6.6. The component C 3 was strongly correlated with the perceived effects of CC on food crop productivity and the disturbance of the farming calendar.

6.3.3.3 Variables related to extension support

The CATPCA and the reliability analyses were applied to variables related to extension support, and the results are presented in Table 6.6. One component showed a 45% variance in the dataset. The variables were all positively loaded on component C 4, “received support from national and international organizations.”

Table 6.6: Results of CATPCA of variables related to climate change perception and effects, and extension support

Components	Variables related to climate change perception (N=799)	Component loadings
Perceived changes in rainfall patterns (C 1) (= 0.62)	Frequency of dry spells	0.75
	Length of rainy seasons	-0.75
	Frequency of rainfall	-0.75
	Length of dry spells	0.62
Perceived occurrence of new pests and weeds (C 2) (= 0.51)	New insect pests in agriculture	0.88
	New weeds species seen	0.87
	Variables of perceived climate change's effects (N=783)	
Perceived effects of changes in production and farming calendar (C 3) (= 0.68)	Effect of CC on roots & tubers	0.86
	Effect of CC on cereals	0.79
	Disturbance of the farming calendar	0.70
	Variables related to extension support (N=795)	
Received support from national and international organizations (C 4) (= 0.80)	Contact with development projects	0.76
	Contact with NGOs[1]	0.71
	Contact with National Centre of Research	0.69
	Contact with Ministry of Agriculture	0.68
	Contact with Swiss Centre of Research	0.68
	Contact with international organization	0.66
	Contact with ANADER[2]	0.55

[1] Non-governmental Organization

[2] The national rural development support agency

6.3.3.4 Variables related to farmers and physical characteristics

The variables loaded on two components showed a 47% variance in the dataset (Table 6.7). The two components we interpreted were agro-ecological zone, food crops, and livestock (C 5) and characteristics of the head of the household (C 6). The negative loading in the case of the variables "root, tuber, and starchy food farmer" and "climate information from television" indicated that the farms in the component C5 were less oriented to the production of root, tuber, and starchy crops, and farmers did not acquire climate information from television. In addition to cereal production, farmers owned livestock, which was an indicator of wealth.

Table 6.7: Results of CATPCA of variables related to farmers and physical characteristics.

	Rotated component loadings		
	Agro-ecological zone, food crops and livestock (C 5)	**Household head characteristics (C 6)**	**Total**
Study area	**0.90**	-0.08	
Root, tuber, or starchy food farmer	**-0.76**	0.21	
Climate information from television	**-0.71**	0.12	
Bovine ownership	**0.69**	0.25	
Member of a farming cooperative	**0.61**	0.10	
Small ruminant and porcine ownership	**0.52**	0.22	
Cereal farmer	**0.52**	0.02	
Experience in crop farming	0.05	**0.76**	
Age	-0.13	**0.68**	
Household size	0.08	**0.68**	
Cash crop farmer	-0.11	0.40	
Eigenvalues	3.30	1.85	5.15
% of variance	30.05	16.79	46.84
Cronbach's alpha	0.77	0.50	0.89

Note: Entries in bold indicate the dimension onto which each item was loaded. Number of observation (N) = 756

6.3.4 Factors influencing farmers' behavior related to adaptation to climate change

Table 6.8 provides the estimated results for the logistic models that were used to identify factors affecting the probability of farmers' decision to adapt to CC through changes in sowing management. It also shows the odds ratios that represent the estimated changes in the odds of the adaptation strategy adopted that is caused by a one unit increase in the respective explanatory variable while holding all other variables fixed at their mean values. The overall fit of the logit-specifications was good, with Nagelkerke's R-square ranging between 0.27 and 0.38.

The results indicated three main components affecting the probability of adaptation: "the perceived occurrence of new pests and weeds," "receiving support from national and international organizations," and "agro-ecological zone, food crops, and livestock." Of the three adaptation strategies, only the technique of making large holes for seedbeds was negatively correlated with the perception of changes in rainfall patterns. As such, this technique was adopted when farmers perceived a decrease in the length of the rainy seasons and the frequency of rainfall. Furthermore, perceiving new pests and weeds motivated the adoption of re-sowing and making large holes for seedbeds, while it negatively influenced the use of more seeds. Indeed, farmers asserted that the method of using more seeds was inefficient when there was a problem with pest attacks and invasive weeds. Therefore, the decision to adapt occurred when farmers made the link between CC and its negative impacts. While farmers reported that they did not receive regular support from national and international organizations, the results showed that such support positively influenced the adaptation to CC. The agro-ecological zone of Korhogo was more likely to positively influence the re-sowing technique and the use of more seeds, while Toumodi was suitable to water retention through large holes for seedbeds. Indeed, cereal production is more suitable to the north than the center, which could explain farmers' propensity to adopt techniques to deal with the poor germination of seeds. Furthermore, the less the farmers grew roots, tubers, and cereals, the more likely they were to adapt by using the re-sowing technique and more seeds. However, making large holes for seedbeds positively influenced farmers' decision to adapt when producing roots and tubers. This technique is implemented for some crops such as cocoa, which was associated with yams. The ownership of animals positively influenced adaptation through the management of sowing. The results also showed that farmers' age, experience in crop farming, and household size included in component C 6 were not significant in the decision to adapt. This finding is opposite to what Gbetibouo et al. (2010) found, as experimental farmers are highly skilled in farming techniques and management and are able to spread risk when facing climate variability by exploiting strategic complementarities between activities. Finally, being a member of a farming association positively influenced adaptation, while access to climate information from television did not positively influence adaptation. Indeed, according to farmers, the information they obtained from television did not include any advice regarding adaptation methods, but rather provided only general information related to the temperature and rainfall for the next day.

Table 6.8: Results from the logistic regression of farmers' adaptation to climate change through sowing management.

	Adaptation through sowing management		**The technique of repeated sowing**		**Use of more seeds during sowing**		**Make large holes for seedbeds to facilitate water retention**	
	B	*Odds ratio*	*B*	*Odds ratio*	*B*	*Odds ratio*	*B*	*Odds ratio*
Constant	2.88***	17.79	1.50***	4.48	1.32***	3.74	-0.42***	0.66
Perceived changes in rainfall patterns (C 1)	-0.10	0.91	0.01	1.01	-0.13	0.88	-0.20**	0.82
Perceived occurrence of new pests and weeds (C 2)	0.57**	1.76	-0.39***	0.68	0.91***	2.48	-0.37***	0.69
Perceived effects of changes in production and farming calendar (C 3)	-0.06	0.94	-0.07	0.93	-0.28**	0.76	0.58***	1.79
Received support from national and international organizations (C 4)	-0.54**	0.58	-0.65***	0.52	-0.26**	0.79	-0.96***	0.38
Agro-ecological zone, food crops, and livestock (C 5)	1.35***	3.86	1.16***	3.18	1.22***	3.38	-0.79***	0.45
Household head's characteristics (C 6)	0.01	1.01	-0.10	0.90	0.07	1.07	-0.04	0.96
Number of observations	726		727		727		726	
Nagelkerke R Square	0.27		0.36		0.36		0.38	

, and * denote significance at the 5% and 1% level. B is the estimate.

The results of the estimates for the logistic models to explain farmers' adaptation behavior through the management of their technical itinerary are presented in Table 6.9. The components "the perceived occurrence of new pests and weeds" and "agro-ecological zone, food crops, and livestock" were significant to all adaptation strategies through the technical itinerary management. Moreover, four other variables influenced several specific adaptation strategies in different ways. Indeed, the adoption of the crop association technique was positively influenced by the perception of the frequency and length of dry spells, while changes in the hillocks size were guided by the perception of changes in rainfall and rainy seasons. Piya et al. (2013) found the ability of households to perceive rainfall changes to be an important determinant of adaptation. Furthermore, the positive correlation between the perception of a significant increase in insect pests and weeds and overall adaptation strategies indicates that this was a relevant influencing factor of farmers' adaptation decision. In general, the agro-ecological zone of Korhogo seemed to be an environment where households have the higher propensity to change their technical itinerary, except for the strategy of keeping more trees in the fields, which was favorable in the Toumodi area. Indeed, the specific location as an important determinant of adaptation choices has also been reported by Piya et al. (2013) and Deressa et al. (2009). The strategy of changing the technical itinerary was encountered in root and tuber production. Farmers are believed to have learned this technique from television. Furthermore, the farmers who owned animals and grew cereals were more motivated to change their technical itinerary. Bryan et al. (2013) found similar results demonstrating that farmers engaged in both crop and livestock production were likely to change their crop variety. Regarding the component "household head characteristics," the adoption of short-season vegetable varieties was significantly influenced by an increase in experience, age, and household size; however, the crop association technique was adopted more frequently by young farmers. The influence of household size on the use of adaptation methods can be seen from two angles. First, households with large families may be forced to divert part of the labor force to off-farm activities in an attempt to earn income to ease the consumption pressure imposed by a large family. Second, a large family size is normally associated with a higher labor endowment, which would enable a household to accomplish various agricultural tasks (Yirga 2007; Deressa et al. 2009).

Table 6.9: Results from the logistic regression of farmers' adaptation to climate change through technical itinerary.

	Adaptation through technical itinerary		**Keep much more trees in the fields**		**Adjusting agricultural calendar**		**Crops association**		**Change size of hillocks**		**Adoption of vegetable varieties with short growth cycle**	
	B	*Odds ratio*	*B*	*Odds ratio*	*B*	*Odds ratio*	*B*	*Odds ratio*	*B*	*Odds ratio*	*B*	*Odds ratio*
Constant	3.99***	53.87	0.25**	1.29	2.62** *	13.75	1.27***	3.55	1.26***	3.54	2.17***	8.78
Perceived changes in rainfall patterns (C 1)	0.17	1.18	-0.03	0.97	-5 e-3	1.00	0.70***	2.01	-0.28**	0.76	0.07	1.07
Perceived occurrence of new pests and weeds (C 2)	1.03**	2.80	0.48***	1.61	0.56**	1.74	0.94***	2.55	0.83***	2.28	0.63***	1.88
Perceived effects of changes in production and farming calendar (C 3)	0.01	1.01	0.12	1.13	-0.01	0.99	0.18*	1.20	4 e-3	1.00	-0.20*	0.82
Received support from national and international organizations (C 4)	0.01	1.01	0.21**	1.23	-0.38*	0.68	-0.56***	0.57	-0.36**	0.70	-0.02	0.98
Agro-ecological zone, food crops, and livestock (C 5)	2.04***	7.73	-0.74***	0.48	0.87***	2.38	0.29**	1.33	0.98***	2.67	0.64***	1.90
Household head's characteristics (C 6)	0.02	1.02	0.11	1.12	0.06	1.06	-0.23**	0.80	0.23**	1.26	0.34**	1.40
Number of observations	727		727		727		739		727		727	
Nagelkerke R Square	0.30		0.26		0.14		0.26		0.30		0.11	

*, **, and *** denote significance at the 10%, 5%, and 1% level. B is the estimate

6.4 Conclusion and policy implications

The objectives of this study were to identify and analyze the factors that influence farmers' adaptation behavior regarding CC. The results have shown that farmers have strong perceptions of changes in climatic conditions and their local environment. We found significant differences between farmers in the study areas with respect to their perceptions of changes in climatic conditions, except for their perceived changes in rainfall. Farmers in Toumodi perceived more changes in climate characteristics than those in Korhogo. Furthermore, between 23–27% of farmers in Toumodi (resp. 46–52% in Korhogo) perceived both an average increase in the frequency of dry spells and an average decrease in rainfall frequency.

Regarding the perception of the impacts of CC, farmers from Korhogo perceived more new pests and weeds than farmers from Toumodi who, however, strongly agreed that there were changes in flowering and fruiting times. The study also identified eight major adaptation strategies, which were divided into sowing and technical itinerary management. The levels of implemented strategies differed significantly across regions, except for the adoption of short-season crops.

The decision to adapt occurred when farmers linked CC to its negative impacts. For instance, the perceived occurrence of new pests and weeds motivated the adoption of re-sowing and making large holes for seedbeds, while it negatively influenced the use of more seeds. Moreover, it was only when farmers perceived a decrease in the length of rainy seasons and frequency of rainfall that they decided to make large holes for seedbeds. Surprisingly, age, household size, and experience in crop farming were not significantly related to the decision to adapt through sowing management. Concerning adaptation by changing the technical itinerary, the "perceived occurrence of new pests and weeds" and "agro-ecological zone, food crops, and livestock" were significant to all strategies. The adoption of the crop association technique was positively influenced by perceptions of the frequency and length of dry spells, while changes of hillock size were influenced by perceived changes in rainfall and rainy seasons. The potential wealth through owning animals and cereal was a positive factor related to adaptation. Moreover, the agro-ecological zone of Korhogo motivated farmers' adaptation, except for the technique of keeping significantly more trees in the fields, which was favorable in the Toumodi area. Increases in experience, age, and household size significantly influenced the adoption of new varieties with a short growing cycle, while the crop association technique was more frequently adopted by young farmers. A different direction of influence of these household characteristics was found in the literature; for instance, Shiferaw and Holden (1998) found a negative relationship between age and the adoption of improved soil conservation practices, whereas Deressa et al. (2009) showed that older farmers were more likely to employ adaptation strategies in the face of changes in climate-related variables. Although certain adaptation strategies were implemented in both study areas, the advice on adaptation strategies extended by national and international organizations has to take into account farmers' perceived impact of CC, the agro-ecological zone, and farmers' characteristics. An additional way of extending information could be through television and other media, as the results revealed that these had a positive influence on adaptation behavior.

This study confirmed that adaptation might be conceptualized as a site-specific phenomenon to better target adaptation policies. Future policy has to aim at providing adaptation technologies through agro-ecology-based research (Deressa et al. 2009). Investing in agricultural extension at a national level and promoting NGOs and international organizations would be one of the best ways to improve farmers' adaptation, as our findings revealed the importance of support from these institutions in the adaptation process. Indeed, Bryan et al. (2013) found that autonomous adaptation is insufficient to address the threats posed by CC. The rural poor need more support from the government, NGOs, and the private sector to enable them to move beyond short-term coping measures in response to climate shocks and to invest in long-term change. In Côte d'Ivoire, furthermore, adaptation that includes taking action to reduce risk as well as taking advantage of opportunities should be based on local NGOs in the north and the performance of ANADER and the Ministry of Agriculture in the Center, as Schmitt (2012) identified them as the most influential actors in these regions. Indeed, having access to extension increases the probability of choosing portfolio diversification by 4% (Gbetibouo et al. 2010). In addition, it is imperative to solve the lack of data on climate forecasts at the local level in Côte d'Ivoire by improving farmers' access to weather and climate-related information and their knowledge of the best adaptation strategies. Furthermore, in most developing countries such as Côte d'Ivoire, climate is infrequently integrated with development policy and investment decision-making. It needs to be revised to take into account farmers' perceptions of the CC issue and their adaptation behavior at the local level.

7. Characterization of farmers based on adaptation barriers to climate change in two regions of Côte d'Ivoire[6]

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ABSTRACT

Most developing countries like Côte d'Ivoire are still in the very early stages of identifying appropriate responses to the risks of climate change. This tends to limit the practical experience of mainstreaming climate change adaptations into the national development planning. This study aims to identify and characterize farmers based on various barriers to climate change adaptations in order to elaborate targeted policy recommendations and proper knowledge transfer. The selected barriers include farmers' evaluations of the feasibility of adaptation strategies, their intention to adapt to climate change, the perceived social pressure, and agro-economic barriers. These barriers were measured with 800 interviews with farmers in two regions of Côte d'Ivoire. Data was analyzed using principal component analysis and cluster analysis. The resulting four clusters included: *innovators, early adaptors, late adaptors,* and *non-adaptors*. Additionally, the farmers were profiled using socio-demographics, their farm's characteristics, information accessibility, and climate change causes. Implications and recommendations for each group were elaborated focusing on incentive policies to enhance awareness and adaptation intention, and facilitating access to credits and extension advice through farmers' associations and cooperatives. This paper concludes by formulating methods of appropriate knowledge transfer in a framework designed for the local conditions.

KEYWORDS

Climate change, Barriers to adaptation, Farmers' characterization, Agricultural policy, Côte d'Ivoire

[6] Comoé H., Barjolle D., Siegrist M. (2013). Characterization of farmers based on adaptation barriers to climate change in two regions of Côte d'Ivoire. Manuscript submitted for publication.

7.1 Introduction

The African continent has been highlighted as a region particularly vulnerable to climate change (CC). This is primarily due to its low adaptive capacity and its sensitivity to many of the projected climatic changes (IPCC 2007; Callaway 2004). The situation could worsen when a 4 °C warmer climate is reached as predicted by the World Bank report (2012). Therefore, mainstreaming of further environmental issues, especially CC aspects within agricultural policies, is now essential for Africa's developing countries such as the Côte d'Ivoire. Indeed, with regard to the challenges of CC, adaptation was found to be one of the major solutions. Adaptation to CC as defined by the Intergovernmental Panel on Climate Change (IPCC) is an adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (IPCC 2007). Historically, societies have developed distinct means of reacting to and coping with their environmental surroundings (Jones 2010). However, at the present time, constraints of a different nature are observed that are very likely to dampen stakeholders' capacities, and decision-makers' capabilities, to achieve policy efficacy and economic efficiency for adapting to CC (Eakin 2000). Major constraints at the farmer's level include the lack of weather and climatic information, a lack of technical knowledge about adaptations, poor potential for irrigation, lack of appropriate seeds, insecure property rights with a lack of market access, lack of money, shortage of labor, and land shortages (Maddison 2006; Deressa et al. 2008). Farmers often mention the lack of adequate financial resources as an important factor constraining their use of adaptation measures which entail a significant investment (e.g., new irrigation systems), improved or new crop varieties, and diversification of farm operations (Smit and Skinner 2002; Adger et al. 2007). Moreover, the lack of understanding the true causes and mechanisms of CC may distort perceptions of risk and hinder the implementation of any adaptive measures (Osberghaus et al. 2010).

The aim of this study is to identify and characterize various groups of farmers based on the barriers preventing them from properly implementing adaptive strategies for CC and to elaborate on targeted policy recommendations for an effective adaptation to CC. Based on the characteristics of various groups of farmers, we will elaborate on the knowledge transfer with regard to CC adaptation. Indeed, the most binding constraints during the process of transferring agricultural innovations occur at the adoption stage. At this stage there are several factors potentially impeding poor farmers from accessing and using new technologies (Lybbert and Sumner 2012). Systematically identifying barriers to adaptation can serve to advance our understanding of the process and assist in decision-making (Moser and Ekstrom 2010). Policymakers need to be aware of these barriers, provide structural support to overcome them, and concurrently work toward fostering individual empowerment and action (Adger et al. 2007). Furthermore, any intervention should factor in the characteristics of the farmers. Therefore, we have used cluster analysis (CA) as the method to achieve the study goal. Cluster analysis is used for analyzing similarities and differences in a target population and will help to classify farmers based on their patterns of behavior according to a set of relevant factors. This type of analysis will also assist in developing hypotheses about which factors or concepts might be causally related (Adlaf and Zdanowicz 1999). Therefore, it is important to conduct cluster analysis to assist in deciding which variables are relevant to the analysis from the perspective of discriminating between different types of farmers.

The research questions for this study include:

(i) Which factors are perceived to be a constraint for an effective adaptation to CC?

(ii) What recommendations are most appropriate for farmers to motivate them to actively participate in adapting to CC?

(iii) How should the transfer of knowledge be made, concerning strategies of adaptation, so that farmers will implement them conscientiously?

7.2 Methods

7.2.1 Study areas

This study was conducted in the Toumodi area in the center and Korhogo in the north of the Côte d'Ivoire. Toumodi is characterized by a bi-modal rainfall regime and is located in a transition zone between the forest and the savannah. It has a relative humidity of 60 to 70%. Korhogo is in the Sudanean zone of the north and is a savanna region with a single rainy season and a relative humidity of 40 to 50% (Birgit and Bruzon 2006; Tié et al. 2010; MEDD 2011). As in most areas of the country, agricultural fields are mainly rain-fed in both study areas and characterized by subsistence farming with crops such as maize, rice, groundnut, and yam (Birgit and Bruzon 2006; Tié et al. 2010).

7.2.2 Data collection

The study sample consisted of 800 farmers' households, with 400 selected from each study area by using the quota sampling method (Moser 1952; Gschwend 2005). We based our sampling on statistical data from the most important extension service, the national rural development support agency (ANADER), which reflects information on the farming populations in both regions. Criteria considered in the sampling process were gender, geographic location, and type of farming (cereals, roots and tubers). Data collection took place from January to April 2012.

The survey was intended to collect information on farmers' perceptions of climatic characteristics during the last two decades and the effects CC have had on farming and the natural environment. We also collected information on the possible causes of CC and on adaptation strategies that have already been implemented. Moreover, farmers' intentions to adapt in the future and the related social pressure were assessed. These were assessed through questions concerning their expectations regarding the implementation of certain adaptation strategies and the ways in which the social environment could impede or motivate their decision to adapt. General household characteristics (e.g., gender of the household head, education, age, etc.) and the type of farm was also recorded in this survey. Finally, information relating to the household's access to support from key agricultural institutions was also integrated into the data. The range of farmers' ages was between 31 and 60 years. In general, the households were large and about 43% of the sample has a size ranging between 6 to 10 members, but the average household size of the overall sample is around 10 members. The average education level of the farmers was very low (2.2 years) with an average agricultural experience of approximately 19.5 years (Table 7.1).

Table 7.1: Demographic profile of farmers by study area (in percentages).

		Toumodi	Korhogo	Total
Age	≤30	6.1	16.5	11.3
	31-60	82.0	68.0	74.9
	≥61	11.9	15.5	13.7
	Mean age	47.2	44.6	45.9
Size of household	1-5	17.0	20.0	18.5
	6-10	46.1	39.2	42.6
	11-15	25.2	22.0	23.6
	16-20	9.2	12.7	10.9
	20+	2.5	6.1	4.3
	Mean household size	9.6	10.7	10.2
Education (years)	No formal education	48.7	75.8	62.3
	1-5	18.7	12.8	15.7
	6-10	30.1	10.3	20.1
	>10	2.5	1.3	1.9
	Mean education level	3.1	1.3	2.2
Experience in crop farming (years)	≤10	20.8	26.7	23.8
	11-20	46.0	33.2	39.5
	21-30	20.0	22.7	21.4
	31-40	11.2	11.1	11.1
	≥41	2.1	6.3	4.2
	Mean experience	18.6	20.3	19.5
Number of farmers		398	400	798

7.2.3 Data analysis

Two methods, the principal component analysis (PCA) and the cluster analysis, have been widely used in studies dealing with the characterization of farmers (Köbrich et al. 2003; Carmona et al. 2010; Bidogeza et al. 2009). In this study, a PCA was conducted using three primary evaluations comprised of 16 variables including: (i) evaluation of the feasibility of adaptation strategies and their intention to adapt (6 variables); (ii) evaluation of social pressure regarding adaptation to CC (3 variables); and (iii) agro-economic barriers to adaptation (7 variables). The Kaiser-Maier-Olkin (KMO) and the Bartlett's sphericity tests were used to check the suitability of the variables for PCA, with a KMO value of greater than 0.5 and the significance of the Bartlett's sphericity test at $p \leq 0.05$ (Hair et al. 2006; Field 2009).

To increase the interpretability of the results, the varimax rotation was used. Cronbach's alpha and mean scores were calculated for the subscales questionnaire to assess the internal consistency of the constructs (Field 2009; Joffre and Bosma 2009). The internal consistency describes the extent to which all the items in a test measure the same concept or construct and hence, it is connected to the inter-relatedness of the items within the test.

Finally, a hierarchical cluster analysis was conducted using the standardized factors scores from the PCA as variables to characterize various types of farmers based on their related adaptation barriers to CC. The Ward's method was applied and the squared Euclidean distance was used as the proximity measure in the clustering procedure (Field 2009). In applying this method, the three main elements of the analysis were: deciding the number of clusters (groups), determining the membership of each group, and profiling the characteristics of each group. Indeed, in the case of scale profile variables, we applied ANOVA tests for the comparison of average cluster scores. SPSS (17.0) statistical software packages were used for all analyses.

7.3 Results and discussion

7.3.1 Principal component analysis (PCA) and scale reliability

Farmers were asked to indicate on four-point scale how easy or difficult it is for them to implement five specific adaptation strategies. The answers ranged from 1 (*very difficult*) to 4 (*very easy*). PCA extracted two factors which demonstrated high (> 0.7) and moderate (> 0.5) loadings on the original factors and accounted for 65.81% of the variance in the original data (Table 2). Factor interpretations were as follows: Factor 1 was the *Perceived feasibility of adopting new varieties, change of planting methods, and mixed cropping technique*; and Factor 2 was the *Perceived feasibility of change of calendar and land use*. The reliability of the questionnaire typology related to the feasibility of adaptation strategies was good as measured with a Cronbach's alpha with a range of 0.5 to 0.7. This data together with the means and standard deviations of the variables constituting the two factors are presented in Table 7.2.

Table 7.2: Factor loadings of perceiving climate change strategies feasibility after varimax rotation.

Items			*Factor*	
How easy or difficult would it be for you to perform the following adaptation measures?	*Mean*	*SD*	*1*	*2*
Adopt improved varieties	3.30	0.76	0.77	
Change the method of planting[a]	3.09	0.86	0.75	
Mixing crops / crops association	2.91	1.41	0.71	
Change in land & soil use[b]	2.46	0.85		0.72
Adjust the agricultural calendar	2.70	1.04		0.58
Eigenvalues			2.15	1.14
Explained variance			43.10	22.71

[a] using of nursery, using of draft oxen, re-sowing, wide holes for nursery for water retention

[b] increase/decrease farm's size, move on different sites, change tillage method, planting of trees.

Note: N varied between 782 and 785.

Individuals and groups may have different risk tolerances as well as different preferences for adaptation measures depending on their worldviews, values, and beliefs (Adger et al. 2007). The intentions of farmers to perform an adaptation strategy was investigated using a five-point scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). There is no reason why the intention to adopt various adaptation strategies should be correlated. Therefore, we computed an index of *intention behavior* by adding farmers' intentions related to the five adaptation strategies. These indexes demonstrated how much a farmer expects to perform an adaptation strategy and ranged from 14 to 25. In a codified manner, the higher the index is, the higher the intention to implement adaptation strategies. The means and standard deviation for these measures are presented in Table 7.3.

Table 7.3: Means and standard deviations of farmers' intentions to implement adaptation strategies.

Items		
How much do you expect to implement the following adaptation strategies?	*Mean*	*SD*
Adopt improved varieties	4.69	0.54
Change the method of planting	4.53	0.62
Mixing crops/crops association	4.11	1.12
Change in land and soil use	3.73	1.23
Adjust agricultural calendar	4.72	0.63

Note: N varied between 793 and 796.

The social pressure regarding adaptations to CC was assessed through three items which loaded onto a single factor (Table 4). Items were ranked on five-point scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). The resulting factor has been labeled *perceived social pressure* and explains 59.94% the variance of the original data with a good internal consistency (Cronbach's alpha = 0.64). This data along with the means and the standard deviations are presented in Table 7.4.

Table 7.4: Factor loadings of social environment pressure regarding adaptation to climate change after varimax rotation.

Items			*Factor*
What social pressure do you perceive could motivate you to adapt or prevent you from adapting to CC?	*Mean*	*SD*	*1*
Villagers do not approve of your decision to change varieties	1.56	0.78	0.82
Many farmers like you are willing to change their farming practices[a]	1.39	0.65	0.80
Villagers think that you should not adapt to CC	1.77	0.97	0.71
Eigenvalues			1.8
Explained variance			59.94

[a] This item has been recoded from 1= *strongly agree* to 5= *strongly disagree*

Note: N = 798.

Various agro-economic barriers were listed and farmers were asked to indicate, on a three-point scale ranging from 1 (*not very important*), 2 (*important*), and 3 (*extremely important*) how important some barriers were to impeding their adaptation behavior. The items are highly loaded (> 0.6) onto two factors which explained 59.57% of the total variance (Table 5). The internal reliability is good with the Cronbach's alpha of 0.71 and 0.66 for factors 1 and 2, respectively. Furthermore, the factor interpretations are as follows: 1 (*Financial barriers*) and 2 (*Lack of skills and resources*). The means and standard deviations of all items constituting the two factors are also presented in Table 7.5.

Table 7.5: Factor loadings of perceiving agro-economic barriers of climate change adaptation after varimax rotation.

Items			*Factor*	
What are the levels of importance of the following factors as main barriers for you to effectively adapt to CC?	*Mean*	*SD*	*1*	*2*
High cost of inputs (fertilizers, pesticides, herbicides)	2.45	0.66	0.77	
Instability of prices at regional level	2.41	0.69	0.77	
High cost of farming labor	2.00	0.74	0.70	
Unavailability of farming lands	2.25	0.69	0.66	
Lack of knowledge of adaptation measures	2.48	0.60		0.80
Lack of access to extension advices	2.44	0.66		0.80
Lack of improved seeds	2.55	0.61		0.69
Eigenvalues			2.33	1.84
Explained variance			33.28	26.29

Note: N varied between 796 and 798.

7.3.2 Cluster analysis

7.3.2.1 Description of clusters based on factors scores and ranking factors

After records with missing data were removed, 775 farmers were retained in the cluster analysis. Farmers were clustered based on six identified variables which have been standardized, and a four cluster solution was adopted. The agglomeration schedule suggested three- or four-cluster solutions. The decision on the final number of clusters was made with consideration to a meaningful interpretation of the individual clusters (Köbrich et al. 2003). Table 7.6 presents the average factor scores and rankings of the four clusters.

Farmers in cluster 1 (9.68%) were favorable to a change of the agricultural calendar and land use, despite the social environment which is perceived to be averse to CC adaptations. Furthermore, farmers in this group had the highest intention behavior which shows their determination to adapt despite the existence of financial barriers. Thus, we identified the farmers in this cluster as the *innovators*.

Cluster 2 had the highest number of farmers (*n* = 368; 47.48%) who perceived the adaptation strategies as feasible. Moreover, their intention to implement these strategies was not insignificant, which is stimulated by a favorable social environment and no financial barriers. The major barrier for this group was the lack of skills and resources related to adaptation strategies. Therefore, we identified the farmers in this cluster as the *early adaptors*.

The *late adaptors* (24%) compared to the *early adaptors* have almost the same level of adaptation intention behavior. However, one of the differences between the two groups is related to the perception of the feasibility of adaptation strategies. Indeed, *late adaptors* perceived the changes in calendar and land use difficult to implement. Moreover, their adaptation behavior was hampered by a combination of financial barriers and a lack of skills and resources. This group of farmers shows the highest factors scores for both agro-economic barriers which may prevent them from responding quickly as *early adaptors* would do.

Finally, the group identified as *non-adaptors* (18.84%) are characterized by their skepticism regarding adaptation strategies. In general, they had difficulty perceiving the feasibility all five specific strategies. Therefore, they have the lowest score for intention behavior which shows they are the least motivated to adapt to CC even though their social environment is very favorable to adaptation. Furthermore, financial problems bring an additional barrier to this group making them the least oriented toward CC adaptation.

Table 7.6: Average factor scores by cluster.

	Innovators (n = 75)	**Early adaptors** (n = 368)	**Late adaptors** (n = 186)	**Non-adaptors** (n = 146)
1. Perceived feasibility of adopting new varieties, change of planting method and mix cropping technique	-0.44a	0.36b	0.56c	-1.39d
2. Perceived feasibility of change of calendar and land use	0.21a	0.61b	-1.05c	-0.30d
3. Intention behavior	1.00a	0.12b	0.03b	-0.83c
4. Perceived social pressure	1.66a	-0.04b	-0.24c	-0.49d
5. Financial barriers	0.23a	-0.60b	1.02c	0.22a
6. Lack of skills and resources	-1.65a	0.40b	0.48b	-0.82c

Note: Different letters indicate significant differences between particular farmers' group, $p<0.05$, using the Game-Howell post-hoc test.

7.3.2.2 Cluster profiling using socio-demographics, farm's characteristics, information access and location

The validation of the clusters depends on a set of additional variables related to socio-demographics, farm characteristics, information access, and location. As presented in Table 7.7, ANOVA F-tests revealed significant differences between clusters for all categories (socio-demographic, farm characteristics, information access, and location).

Regarding socio-demographic characteristics, the *late adaptors* were the oldest (50.59 years) and most experienced in crop farming (22.66 years) compared to the other groups. Their adaptation behavior could be justified by the fact that they are rather attached to certain farming practices which may be difficult to forsake. Therefore, they are averse to risk with relation to adopting new strategies. Younger farmers and well-educated farmers were *early adaptors* while the biggest household sizes were typically found to be *non-adaptors*. *Innovators* furthermore, had average values of socio-demographic characteristics compared to all other groups. Concerning farm characteristics, farmers in general practice diversified agriculture growing a mix of cereals, roots, and tubers. The highest share of roots and tubers (41.87%) mainly characterized the *innovators* who have devoted a small share to cereals. The highest share of cereals (38.67%) and acreage (11.3 ha) for the farming season of 2010–2011 were found with the *non-adaptors*. Thus, the high acreage could explain the *non-adaptors*' reluctance to the adaptation process since implementing new strategies would generate additional labor and costs. Furthermore, the smallest difference between the share of roots and tubers and the share of cereals was observed in the *early adaptors*. They cultivated both cereals (28.10%) and roots and tubers (14.17%); thus, by combining both types of crops, they attempted to compensate for the loss of one crop by the profit gained with another crop.

Late adaptors have the most contact with extension services and some of them were members of farming cooperatives. This may seem paradoxical but can be explained by the fact that the extension advice is not oriented towards adaptation to CC; indeed, extension agents have not yet been trained on adaptation so they could not put sufficient emphasis on adaptation strategies to support enough farmers. Furthermore, the specificity of each study area is an important factor in grouping farmers. *Early adaptors* and *late adaptors* are a combination of farmers from both study areas with a few more farmers from Toumodi in the *early adaptors'* group and more from Korhogo in the *late adaptors* group. However, a significant difference is seen between the *innovators* and *non-adaptors* groups. Most of the farmers in the *innovator* group were from the Toumodi region, while the *non-adaptors* group contained more farmers from Korhogo.

Table 7.7: Comparison of farmers' segments based on socio-demographics, farm's characteristics and extension support.

	Innovators (n = 75)	Early adaptors (n = 368)	Late adaptors (n = 186)	Non-adaptors (n = 146)	F-test	sig.
Socio-demographics						
Age of farmer (years)	47.72a,b	43.64a	50.59b	44.62a	13.56	***
Size of household	10.45a	9.78a	9.90a	11.30a	2.76	**
Education (years)	2.36a,b	2.67a	1.61b,c	1.23c	9.76	***
Experience in crop farming (year)	18.39a,b	17.12a	22.66c	22.18c,b	14.43	***
Farm's characteristics						
Acreage (ha) farming season 2010-2011	3.49a	8.06b	7.05b	11.30c	22.63	***
Share of cereal (%)	7.07a	28.10c	32.04b,c	38.67b	31.88	***
Share of root and tuber (%)	41.87a	14.17c	9.45b	8.63b	93.72	***
Extension information access						
Contact with extension services[1]	0.68a,b	0.52a	0.74b	0.68b	10.28	***
Membership of farming cooperative[2]	0.05a	0.44b	0.46b	0.43b	14.96	***
Study areas[3]	1.05a	1.45b	1.52b	1.87c	58.83	***

[1] coded 1= contact with extension services and = 0, otherwise.

[2] Coded 1= membership of farming cooperative, and 0, otherwise

[3] Coded 1= Toumodi and 2= Korhogo

*** and ** denote significance at the 1% and 5% level, respectively.

Note: Different letters indicate significant differences between particular farmers' group, p<0.05, using the Game-Howell post-hoc test.

7.3.2.3 Cluster profiling using perceived climate change causes by farmers

Different groups of farmers were characterized based on their explanations of the causes of CC. They were asked about the causes of CC using a five-point scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*).

Innovators linked the causes of CC to both spiritual phenomena and human actions through deforestation and poor farming practices, which destroy soil and deplete water resources (Table 7.8). Indeed, their realism goes against the assertion that whether or not one believes God creates extreme weather events, people should not react to those events (Schmuck 2000). *Early adaptors* related CC more to the lack of rivers and dams and poor farming practices than to spiritual causes and deforestation. This view is much closer to that observed in the *non-adaptors*. Furthermore, all of the causes seem to be relevant to the *late adaptors* with the exception of poor farming practices.

Table 7.8: Comparison of farmers' segments based on climate change causes.

	Innovators (n = 75)	**Early adaptors** (n = 368)	**Late adaptors** (n = 186)	**Non-adaptors** (n = 146)	**F-test**	**sig.**
Spiritual causes (Bible prophecy, worship spirits, etc.)	4.31a	2.72c	3.75b	3.00c	34.55	***
Deforestation	4.93a	4.63b	4.92a	4.84a	8.74	***
No rivers and dams	3.09a	4.08b	4.22b	4.62c	40.55	***
Poor farming practices which destroy the soil and deplete water resources	4.56a	3.28b	2.83c	4.03d	42.69	***

*** denote significance at the 1% level.

Note: Different letters indicate significant differences between particular farmers' group, $p<0.05$, using the Game-Howell post-hoc test.

7.3.3 Implication and knowledge transfer about adaptation to CC

7.3.3.1 Implication

(i) Innovators

A specific package of extension advice has to be built up for this group of farmers. The focus should be on strategies such as adopting new varieties, changing planting methods, and mixed cropping techniques which have been perceived as difficult to implement. Due to the high intention to adapt within this group, the effort to sensitize them should be less than that of other groups. The involvement of *innovators* in farming cooperatives could be very beneficial as they will be motivated by the behavior of the entire membership.

(ii) Early adaptors

The feasibility of all adaptation strategies and even less the financial problems do not constitute a real barrier for the majority of farmers of this group. It is the lack of skills and resources that needs to be improved by better access to extension support and new varieties. Moreover, extension advice should integrate, as for all farmers, the explanation of the causes of CC.

(iii) Late adaptors

The extension advice towards this group needs to focus on the advantages of changing the farming calendar and land use (e.g., farm size, move to different sites, change tillage method, planting of trees). It should take into account the low level of education by facilitating exchanges in local languages. Moreover, a policy to enhance access to credits should be promoted to solve the financial barriers, which appear to be one of the most important barriers to adaptation. The fact that some of these farmers belong to farming cooperatives is an asset in facilitating the dissemination of adaptation information.

(iv) Non-adaptors

This group has the lowest index of intention behavior; therefore, more incentive policies should be built for this target group. It will also need to integrate explanations of the real causes of CC, the actual and future impacts on agriculture, and how important it is to adapt. Less expensive adaptation strategies should also be broadcast to these farmers. Furthermore, access to credits should be facilitated for non-adaptors. This could be done by encouraging farmers to create associations or cooperatives to facilitate credit repayments.

7.3.3.2 Knowledge transfer about adaptation to CC

Planning for the adaptation of the least-developed countries has been facilitated through the development of the National Adaptation Programmes of Action (NAPAs) which identifies priority activities that must be implemented in the immediate future in order to address urgent national CC adaptation needs (Burton et al. 2002; Huq et al. 2003). Côte d'Ivoire must prioritize its national agricultural research systems and ensure that these systems are functional by taking into account the typology of farmers based on their adaptation barriers to CC. As Moser and Ekstrom (2010) argued, these barriers can be overcome with a concerted effort, creative management, changes in thinking, prioritization, and related shifts in resources, land use, and institutions. Furthermore, one advantage for the Côte d'Ivoire is that the network structures of institutional agricultural organizations are rather strong. This is due to their overall good cohesion along with vertical and horizontal integration being strong, especially in Korhogo (Schmitt 2012).

Furthermore, more must be done to improve longer-term seasonal forecasts and to develop more effective forecasts of slow-onset events. Policies to support the diffusion of this information and to help interpret these forecasts in terms of their agronomic effects must be carried out by extension services, non-governmental organizations (NGOs), and local farmers' associations and cooperatives. NGOs should play a dominant role in building awareness and capacity at the local level. Moreover, local farmers' associations and cooperatives can help by building farmer networks and facilitating training. They can also provide feedback to researchers and policy makers on matters of concern or difficulties that may arise. Apata et al. (2009) asserted that policies must aim at promoting farm-level adaptation through emphasis on early warning systems and disaster risk management as well as effective participation of farmers in adopting better agricultural and land use practices.

Regarding the adoption of new varieties, several varieties and traits offer farmers greater flexibility in adapting to CC. These traits may include conferring tolerance to drought and heat as well as early maturation to shorten growing seasons and reduce exposure to the risks of extreme weather events (Karaba et al. 2007). Crops, varieties, and traits resistant to pests and diseases will improve the farmers' ability to adapt to CC. To the extent that these varieties reduce the need for pesticides, they also reduce carbon emissions by decreasing pesticide demand as well as the number of in-field applications (Lybbert and Sumner 2012). As farmers' low incomes do not allow access to sufficient pesticides, this option seems to be one of the best. Researchers might focus on early maturation, a trait that can reduce farmers' drought risk in the latter stages of the growing season.

Improving rural education, additional farmer training and extension, and similar measures may also be CC policies in disguise since they are likely to improve a farmer's ability to adapt to CC (Lybbert and Sumner 2012). For instance, the technique of conservation or reduced-tillage agriculture aims at building up organic matter in soil and creates a healthy soil ecosystem by not tilling the soil before each planting. Seeds are planted using seed drills that insert seeds to a precise depth without otherwise disturbing the soil structure. By increasing the organic matter in soils, conservation agriculture improves the moisture capacity of the soil and thereby increases water use efficiency (Hobbs and Govaerts 2009). Extension agents should be trained first on the adaptation strategies in order to transfer the knowledge through farmers' cooperatives and association networks.

7.4 Conclusion

As one of the few studies focusing on CC adaptation in Côte d'Ivoire, our paper provides a real insight on farmers' characterizations based on their barriers to CC adaptation. Thus, the evaluation of the feasibility of CC strategies, the local social pressure, the intention to adapt, and the perceived agro-economic barriers resulted in four groups of farmers. The characteristics and profiling of the groups using socio-demographics, farm characteristics, information access, and CC causes lead us to think about more targeted policy actions in a local framework context. The specificities of each study area also need to be taken into account. Barriers at the farmer's level need to be overcome by integrating climate adaptation into other policy domains. More specifically, policymakers should fund agricultural research and extension to develop effective and suitable adaptation strategies to CC. To make extension support effective, policies should consider incentives to enhance private and NGO sector participation in the process of CC adaptation. Furthermore, improved recording of daily weather data and seasonal forecasting, development of crop varieties resilient to CC, and making these changes accessible through an improved communication network using local stakeholders will be helpful in supporting farmers to properly adapt to CC. All these adaptation policies need to be coupled with CC mitigation policies like reforestation and forests conservation to get more impacts at the global level.

8. Social networks analysis of the Ivorian agricultural sector regarding adaptation to climate change[7]

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ABSTRACT

In the context of climate change in developing countries, smallholder farmers need strategies and institutional support for adaptation. The goal of this paper is to identify and analyze stakeholder networks in the agricultural sector of Côte d'Ivoire to evaluate the institutional support surrounding farmers. A research study was undertaken to make an empirical diagnosis of strengths and weaknesses in the social networks in two regions, Toumodi and Korhogo, in order to facilitate the future implementation of adaptation strategies. We identified central actors and evaluated networks with measures such as cohesion and centrality. The network structure appeared to be highly dependent on one major actor in the Toumodi region, while the regional network relied more on a group of diverse actors in the Korhogo region. Therefore, in Toumodi, we suggest encouraging actors forming cooperatives to reduce centralization and increase network cohesion and integration, which are the favorable network configuration for policy implementation. Thereby, sharing experimentation and knowledge could enhance adaptation to climate change.

KEYWORDS

Social Networks, Adaptation, Climate change, Agriculture

[7] Schmitt, E., Comoé, H., Barjolle, D. (2013). Social Networks Analysis of the Ivorian agricultural sector regarding adaptation to climate change. Manuscript revised and re-submitted.

8.1 Introduction

Subsistence farmers in Sub-Saharan Africa are especially vulnerable to global warming as they rely on traditional farming and calendars inherited from their ancestors. They are currently disoriented because of the discrepancy between their cultural calendars and climate conditions (Brou and Chaléard 2007). Thus, adaptation strategies to help these communities cope with environmental changes are essential (IPCC 2007). Rosenzweig and Parry (1994) showed that it is only with institutional support for adaptation strategies that the effects of climate change (CC) on food security can be offset; that is, a fruitful farming season that produces all of the necessary crops for survival. In Sub-Saharan Africa, the institutional capacities need to be consolidated significantly to respond to this challenge. The main goal of our research is to evaluate the ability of stakeholder networks to support farmers' capacity for CC adaptation in two counties of Côte d'Ivoire. Specifically, local stakeholders are identified, and a diagnosis of the actual networks is made in order to help actors accompanying the future implementation of CC adaptation strategies. Thus, in-depth knowledge about stakeholders will be acquired in both study regions, and three types of relations will be studied in detail: information exchanges, collaboration and financial transfers. We will address the following questions: (i) What are the relationships between stakeholders and the grouping effects between them? (ii) Which stakeholders are taking a central position and facilitating the most support for farmers? and (iii) How is the information about CC diffused in the networks, as well as (iv) what are the strengths and weaknesses of the networks with regard to CC? Furthermore, these questions are explored and compared between the two study regions.

Many authors have worked on either case studies or models to assess the sustainability, robustness or resilience of social-ecological systems and enounced some useful characteristics to analyze the actors' networks in Côte d'Ivoire while revealing the need for more empirical observations (Bodin and Norberg 2005; Bodin and Crona 2009; Bodin and Prell 2011).

8.2 Theoretical Background

Social networks analysis (SNA) offers a guided way to identify actors (i.e. individuals, groups or organizations) and to analyze their relationships (Scott 2004). This method can help analyzing social capital and relationships in a quantitative way and allows building up figures for the determination of strengths and weaknesses in sometimes very complex structures (Bodin and Prell 2011; Ziervogel and Downing 2004). Thus, regular patterns of information exchange may be considered as "social networks", with actors as "nodes" in the network and relationships between the actors as "links" between these "nodes". There are different types of resources being shared between the actors: tangibles such as goods, services or money, and intangibles such as information, social support or influence (Haythornthwaite 1996). Actors' interacting links are also called "ties" (Scott 2004). The "social network approach" (SNA) examines both the content and the pattern of relationships in order to determine how and what "resources" flow from one actor to another; two principles that network analysts often use to examine actors' networks are as follows:

- Cohesion is measured by the concepts of *density* and *centralization,*
    - The *density* of a network indicates the degree proportion to which members are connected to all other members. It is calculated as the ratio of the number of actual links in a population to the number of possible links in the population.
    - *Centralization* measures the extent to which a set of actors is organized around a central point; thus, a high *centralization* is when one central actor is connected to everyone else and all others have few connections (Hanneman and Riddle 2005).
- *Centrality scores* indicate which actor or actors have influence or power in a social network. The *centrality* of an actor is measured most simply by counting the number of relationships maintained by the actor in a social network. The occupant of the central position is known as the "network star". This position gives the "star" a great deal of access to information from others in their network (Scott 2004). By facilitating, controlling or inhibiting the flow of information from one site to another in the network, central actors can maintain, create or prevent the creation of information pathways. A useful measure to grasp this idea is the *betweenness centrality***,** which translates the extent to which an actor sits between others in the network. As an intermediary, actors with high betweenness can fill an important information role as a broker or gatekeeper, filtering and importing information into the network (Burt 1992b; Nohria 1992; Haythornthwaite 1996; Hanneman and Riddle 2005; Bodin and Crona 2009). The actors with high centrality scores are at the cores of networks and are the most important for the coordination and prioritization of joint actions (Bodin and Crona 2009). Their role as bridging elements also gives them the role of providing access to external resources and the knowledge and of supporting support to actors to initiate action. The centrality scores of actors can be used similarly as dependent variables in t-tests to verify the influence of characteristics of actors on their potential to create relations. The difference in the centrality scores is considered significant when the same difference occurs in less than 5% of random cases.

A "well-structured" network provides information benefits in terms of access to information, timing and referrals. Access involves not just receiving valuable information, but also having those in the network who can use it. The well-structured network can act as a screening device in the face of information overload, provide opportunities to others and deliver information

(Burt 1992a). Ingold et al. (2010) and Isaac and Dawoe (2011) further argue that a high local adaptive capacity is dependent on high vertical and horizontal integration, which means that several sectors and political levels should be represented in the center of networks.

All network measures can be obtained after entering the relational data into the software package UCINet (Borgatti et al. 2002), including Netdraw, for visualizing the networks and producing figures.

8.3 Method

8.3.1 Description of the study areas

The study took place within a larger project on CC adaptation strategies in Côte d'Ivoire (Comoé et al. 2012; Schmitt 2012). In accordance to this project, two administrative departments of Côte d'Ivoire were chosen as case studies: Toumodi in the center of the country, 230 km north of Abidjan and Korhogo in the north, at the Malian border. They will allow drawing comparisons from different socio-political and climatic contexts and thus analyzing their possible consequences on the adaptive capacity of actors' networks. The area of the department of Toumodi is of 2'780 km^2 and it counted 147'105 inhabitants in 2009, of which 65% are active in agriculture (CountrySTAT 2012). The climate in Toumodi offers two rainy seasons and is at the interface of dense forest and savanna. The size of the department of Korhogo is bigger, at 12'500 km^2 and has a population of 630'725 inhabitants, of which 80% are active in agriculture (CountrySTAT 2012). There is only one rainy season in Korhogo and an ecosystem typical of savanna. Due to the climatic difference between the two regions, agricultural systems vary from agro-forest cultures in the center (mainly cocoa), to cotton and livestock in the north, in addition to mango and cashew trees.

Politically, the northern half of the country, including the department of Korhogo, was under the control of a rebel group from 2002 to 2007. During this time, the governmental agencies had to leave the north region and many perturbations occurred for the existing actors. Major international organizations like the United Nations Food and Agriculture Organization (FAO) and the United Nations Development Program (UNDP) installed a management base in the region for humanitarian work. The political crisis continued until 2011, three months after the new presidential election, period during which tensions and conflicts occurred in many parts of the country. Since then, efforts on the reunification of the country have been made and important reforms are under way, especially concerning agricultural institutions organized around crop sectors. The cocoa sector is being sanitized of corruption and new institutions are being created. The cotton and cashew sectors are also undergoing reforms to select the viable organizations, especially for cooperatives that proliferated during the crisis.

8.3.2 Survey design and data gathering

The SNA starts with the elaboration of a list of actors, which are, in this study, formal entities, such as farmers' associations (named cooperatives), governmental and non-governmental organizations (NGOs), companies, agronomic research institutions, etc. The criterion of selection of actors for the purpose of this research is that actors had to conduct agricultural or rural development activities in the two case study areas. Some actors are based in Abidjan but conduct important activities in the regions and they were also considered belonging to the regional networks.

The precise list was completed first by desk research, and then by seven preliminary interviews with major and available organizations in the field. In the following text, the actors will be generically named "organizations". In Toumodi, 47 actors were identified in total, including those based in Abidjan, and comprised the different kind of organizations as described in Table 8.1. In Korhogo, 53 organizations were identified and are also detailed in Table 8.1. There are more actors in Korhogo because of its higher administrative level and because of the international organizations who came during the crisis.

Table 8.1: Summary of the type of actors found in the two regions

Type of organization	Toumodi	Korhogo
Governmental offices	8	10
Ministries sub-divisions	5	7
Local authorities	3	3
Research and development structures	9	12
NGOs	1	3
Extension services	1	3
Research centers	3	2
Development agencies and projects committees	4	4
Cooperatives and farmers' associations, IPAs	17	18
In cash crops	11	14
In food crops or breeding only	6	4
Retailing companies	8 (7 in cocoa)	5 (only cotton)
Locally founded	3	3
International	5	2
International organizations	5	8
Foundations or international banks	2	3
Divisions of the United Nations (UN)	2	2
Bilateral collaboration, international NGO	1	3
Total	47	53

The data have been collected through face-to-face structured interviews that were conducted between February and April 2012. 30 interviews were conducted in Toumodi and 38 in Korhogo. Five more were conducted with actors in Abidjan, leading to an overall response rate of 73%. The questions prepared for the interviews related to several types of relations described in Table 8.2: (i) information exchanges about CC or about adaptation techniques; (ii) collaboration, whether technical or strategic or both; and (iii) financial exchanges, such as payment for services or direct trade of commodities or donations. The questions related to information exchange reveal which actors generate, block, diffuse or receive information about CC, and most importantly who does not get in contact with information. The network on strategic collaboration helps understanding which actors create projects and design policies in the sector and technical collaboration shows who is responsible for the implementation, of adaptation strategies for example, on the field. The financial exchanges reveal which actors have the ability to invest in programs and who receive most funding. These elements help establishing a diagnosis of their ability to support farmers to cope with environmental changes.

Table 8.2: Types of relations studied and operationalization.

Type of links	Question in interview	Data transformation, result type
Exchange of information About CC About adaptation techniques	With whom do you exchange relevant information?	Relational data: Binary and directed (receive from/give to)
Collaboration Strategic Technical	With whom do you have joint activities in projects, planned, or other?	Symmetrization of data (select maximum value). Relational data: binary, undirected
Financial flows Services and mandates Commercial Donations	With whom do you have financial links?	Relational data: binary and directed (receive/give)
Quality of relations (conflicts)	What is the quality of the relations you have? (good/conflict)	Relational data: valued and directed
Influence reputation Present In the future	Which are the most influential actors (between 5 and 10) concerning agricultural development in your region?	Influence score (average of number of times cited by others)

Questions also include an element on the quality of links in order to determine if organizations experienced tension or good relations with each other. Organizations were also asked to cite the most influential actors concerning CC adaptation in their region. We collected information on the identity of the organization (activity, age, type of crop), their vision of CC and agriculture, strategies they wish to implement, their priorities and, finally, their difficulties with strategy implementation.

8.4 Results

8.4.1 Stakeholders' relationships pattern

The relational measures in networks are summarized in Table 8.3, according to the types of relationships analyzed that were presented in Table 8.2. Generally, densities were below 20%, which can be considered a low density for networks (Scott 2004). Networks in Korhogo have a slightly higher density, especially in the **information networks**, except for *information exchanges concerning adaptation techniques*. This should be put in perspective with the fact that, in both regions, the density of specific information networks is very low (1.6-3.9%). The collaboration networks have even lower densities than information networks (7.2-9.2%), and specific collaboration networks ranged around the very low level of 3-4% of density. The **economic networks** had the lowest densities because they involve only a small number of actors. Measures of centralization were spread on a large range, from 3.5-65.6%, with the *general information exchanges* network in Toumodi being the most centralized. Information networks are more centralized in Toumodi, and **collaboration networks** are more centralized in Korhogo, except for the *technical collaboration* network.

Table 8.3: Network density and centralization

	Density		**Centralization**	
	Toumodi	**Korhogo**	**Toumodi**	**Korhogo**
Information exchanges	11.5	17.8	65.56	37.82
Climate change	2.3	3.6	22.46	15.91
Techniques	3.9	1.6	40.39	11.8
Collaboration	7.2	9.2	26.7	42.38
Strategic	3.0	3.0	17.34	22.81
Technical	3.7	4.4	39.28	23.38
Economic networks				
Mandates	1.8	2.4	32.66	23.15
Trade	1.2	0.5	13.48	7.01
Donations	0.2	0.2	4.15	3.54

Figure 8.1 presents the networks of information exchanges in Toumodi and Korhogo. The cores' "nodes" are clearly dominated by research and development ("R&D) structures" and "decentralized governmental offices".

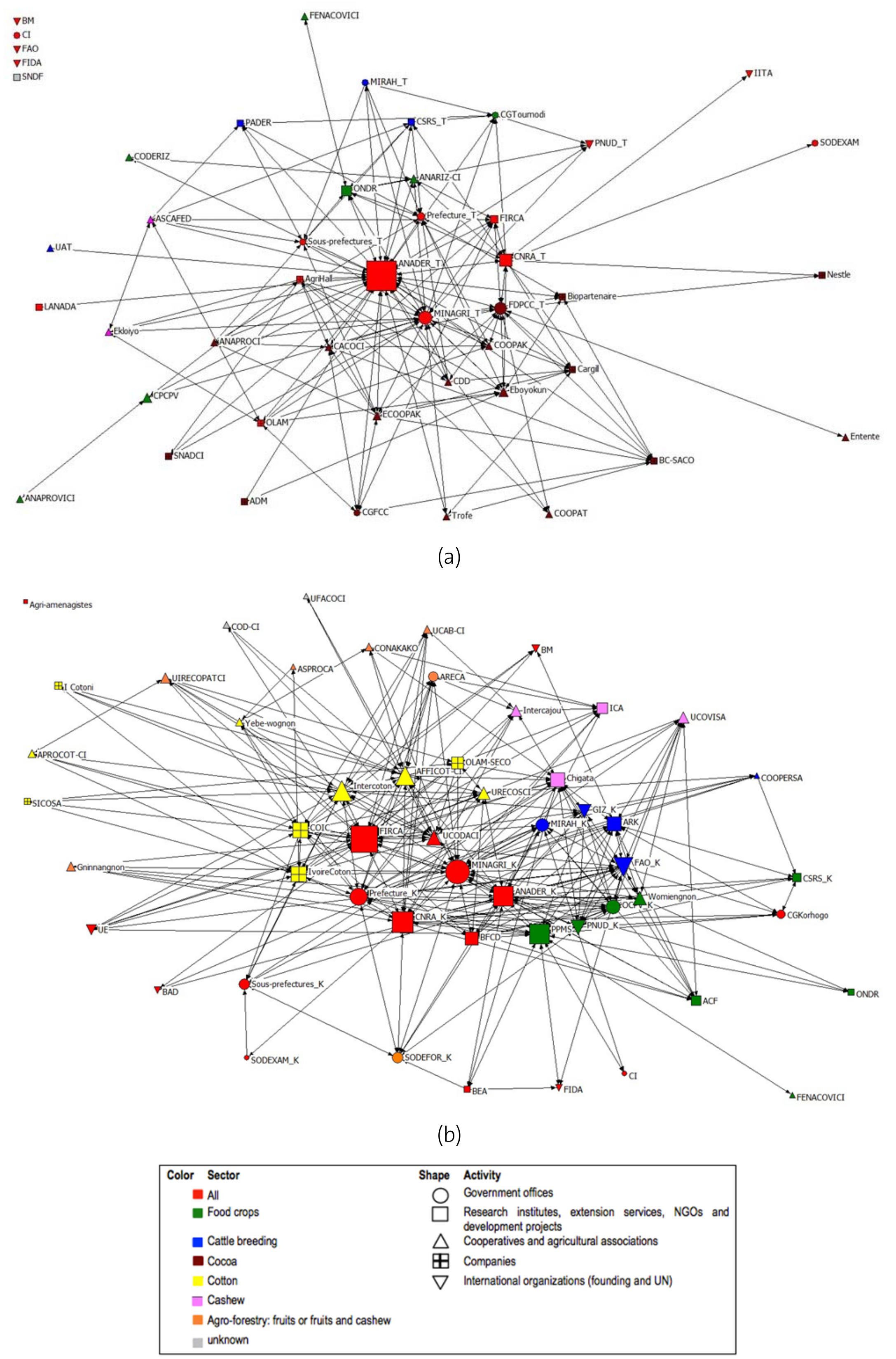

Figure 8.1: Networks of information exchanges in Toumodi (a) and Korhogo (b).

Actors active in the food crops and livestock groups are generally less represented than the ones active in producing the dominant cash crop, as reflected by the high number of cooperatives in the cocoa sector for Toumodi (resp. cotton for Korhogo.). Farmers also regroup in associations by sectors, like the ANARIZ-CI for rice. There is an important national federation of all sectors, the ANOPACI[8]. Furthermore, companies and farmers are sometimes regrouping in a common federation, which is designated as an "inter-professional association" (IPA), which is an association of interest groups related to a particular commodity in a particular country (Shepherd et al. 2009).

In Toumodi, the density of links is generally higher with for research and development (R&D structures) organizations and for "decentralized offices of national organizations," such as the local offices of the national extension services (ANADER) or the local representation of the Ministry of Agriculture (MINAGRI). It means that all other types of actors tend to communicate more with this particular type of actors. In the *strategic collaboration* network, however, the density of ties is higher within "local" and "governmental agencies."

By regrouping actors according to their type of main crop, the only grouping effect can be observed in the *general information* network, especially among cooperatives for cocoa, and in the *strategic collaboration* network. In the *trade network*, the densities are logically revealed to be higher between cooperatives and companies, than between the other actors.

In Korhogo, similar patterns exist, but grouping effects were the most visible in the *general information* network. Actors communicate more in the same crop sectors, except for cooperatives, which have the most relationships with companies. Governmental agencies tend to turn more to international organizations concerning *information about CC* or *adaptation techniques* and for *strategic collaboration*. International organizations are also tightly linked to "R&D structures" in the specific information exchanges. Interestingly, density of ties of all groups is higher with national organizations in the *strategic collaboration* network, like in Toumodi.

In Figure 8.1 shows an area of higher density at the center of the networks, called the core. This core is generally composed of actors with the highest degrees of centrality and the most links to others. In Korhogo, there is a higher diversity of organizations at the cores of networks, with the presence of more NGOs, IPAs, companies and international organizations, while these actors are rather in the periphery of Toumodi's networks. This presence of a high diversity of

[8] The list of all organizations and their complete names, as well as their main characteristics, can be consulted in Annex (Table A1).

actors in the center of networks translates of a higher horizontal integration in Korhogo. Concerning vertical integration, all hierarchical levels are present with local offices of local, national and international organizations in both regions, except for international organizations, which are absent in Toumodi. They were all based in either Abidjan or Bouaké and have only sporadic activities in the region of Toumodi.

8.4.2 Central actors

In Toumodi, we found that the high centralization is linked with the presence of central actors who tend to be recurrently central in most networks. The ANADER is unequivocally the most central actor, taking the highest centrality scores in almost every network. The MINAGRI is also very central, especially in the *strategic collaboration* network. The National Centre for Agronomic Research (CNRA) is central too, although they do not have a local office in Toumodi. The local offices for cocoa (FDPCC) and for rice development (ONDR), as well as some cooperatives from different sectors, complete the list of central actors (Appendix).

In Korhogo, the diversity of central actors is higher in the different networks. The Inter-Professional Fund for Research and Agricultural Support (FIRCA) is the most central in the *general information* network. The local authority, the *Préfecture*, was also mentioned as an important actor, especially in the *collaboration network*. The United Nations Organizations created the "Food Security and Nutrition Group" (GSAN), which brings together local stakeholders in a formal, regular coordination group under the supervision of the FAO. It includes the influential local NGO "Animation Rurale de Korhogo" (ARK), the local rural engineers' bureau BFCD, the CNRA, the German bilateral cooperation (GIZ), the MINAGRI and related offices, as well as the ANADER and others.

8.4.3 Climate change information

The social networks analysis shows that the information concerning CC and adaptation techniques follows different patterns in both study areas. In Toumodi, the extension services ANADER is one of the few partners providing information about CC to cooperatives; the others include one cocoa company and the Inter-Professional Fund FIRCA. Scientific research organizations do not communicate directly to the cooperatives in the network, but rather only between each other. The meteorological institution is at the very periphery of the network and thus does not communicate sufficient information. The *information network relating to adaptation techniques* in Toumodi counts more links than in Korhogo, indicating that actors communicate more directly on techniques like on how to prepare the fields, irrigation, treatments, etc. than on CC (causes, effects, etc.).

Furthermore, there is a core of "R&D structures" exchanging information about adaptation, but their links to the farmers go almost exclusively through the ANADER.

In Korhogo, the structure is quite different. A high number of farmers' organizations are also excluded from any information about CC. The most central actor is the National Center for Agronomic Research (CNRA), who has a regional office in Korhogo. Moreover, actors in the cotton sector are also rather central and form a sub-part in the *information network about CC and relating to adaptation techniques*. However, it is primarily large companies and associations that share information. Despite the fact that the meteorological service has a regional office in Korhogo, they are also outside the network. In the *information network about adaptation techniques*, ANADER gains a more central position, mainly linking other "R&D structures". The CNRA and a cotton company "IvoireCoton" also provide many actors with information.

In Toumodi, the t-tests on the influence of actors on their probability to share links in the *CC information networks* show that the only type of actors with a significantly higher chance to have access to information related to CC is government-related actors, which includes ANADER and CNRA. Furthermore, it is clear that companies do not share many links in the *information about CC* network. During interviews, however, certification programs were mentioned, and these could have direct or indirect beneficial effects for the adaptation to CC, as they bring technical support to farmers.

In Korhogo the same tests show that belonging to some type of crop or working at the national, regional or local level does not have a significant influence. Companies are much more present in the *information about CC* network, but only in the cotton sector.

8.5 Discussion

8.5.1 Strengths and weaknesses for climate change adaptation in Toumodi

In Toumodi, the low density limits the potential for collective actions between actors (Bodin and Crona 2009). A higher density, coupled with a low centralization would be a sign of network cohesion (Bodin and Prell 2011), which is a positive sign for coordinated actions in a network, but it is not present in Toumodi. The high centralization moreover adds on the fact that the network is not cohesive in Toumodi. It is more a type of network centralized around one major actor, which is more efficient for the resolution of simple problems, as the central actor can "prioritize and coordinate activities" and also diffuse information faster (Bodin and Crona 2009). The coordination ability of the most central actor is really important in times of change and is determined by their access to knowledge and experiences (Bodin et al. 2006), but these networks are very vulnerable to the removal or attacks on the central nodes (Janssen et al. 2006). However, the high centralization in the network *information about adaptation techniques* in Toumodi is strong as it goes along with a higher density. This might be due to the ANADER, taking advantage of its central position to diffuse more information to all actors. In addition to its formal mission, ANADER also exerts a high influence on the field (93.1% of reputational score), and this can facilitate implementation and legitimacy (Bodin and Crona 2009). The network is, however, totally dependent on the capacities of ANADER and on the resources allocated.

A weakness of the network is that cooperatives, particularly in the food crop sector, always appear at the periphery of network, and bonds between cooperatives and farmers' associations are weak and can prejudice the building of trust and consensus, in addition to maintain low density. A higher cooperation with companies could also be a factor in resolving conflicts, and structures like IPAs are a good vector of mediation along the food value-chains, like it is the case in Korhogo.

The level of vertical and horizontal integration in Toumodi is thus penalized by the lack of diversity in central actors. However, as the most central ones are "R&D structures", which are active at a decentralized level, like the ANADER, MINAGRI or CNRA, they should be able to play a role of bridging links and transmit research results and technologies in the domain of agricultural development and adaptation, as long as the existing diffusion channels are used efficiently.

But, the *information network related to CC* in Toumodi does not include many farmers' organizations, as well as international organizations and research institutes. Thus, the regional network is not efficient at making the bridging link between knowledge at the international level and farmers in the field. Financial support, however, would be necessary to improve the diffusion of this information and elicit active support from ANADER, which is currently overseeing this knowledge distribution. As some companies are setting up diverse certification programs in the context of sustainable development and supporting farmers in different ways, coordination with and between companies should be increased to make support more efficient and coordinated.

8.5.2 Strengths and weaknesses for climate change adaptation in Korhogo

In Korhogo, the network is less vulnerable to changes because it has higher densities and lower centralization, especially in the information networks, and the Food Security and Nutrition Group (GSAN) fosters multiple central links on a group rather than on one actor. The GSAN is a very positive structure for the sharing of experiments in the field and on new techniques. It is also a good way to collect feedback on experiences and to learn from previous mistakes. It is possible that this situation is the result of the past decade's crisis and the weakening of governmental offices and ANADER, which incited other actors like NGOs or the FAO to take action and become central. Bodin et al. (2006) demonstrated that networks with low centralization including diverse structures have a higher ability to solve complex problems, which is a clear advantage for the coordination of farmers' support towards CC adaptation.

The risk, however, is that after the end of the crisis, international organizations will decide to leave and the network will centralize slightly more around national organizations. Still, Korhogo exhibits more diversity in local organizations at its core, and this is a strength (Ingold et al. 2010). The implication of companies and IPAs in the center of networks, in projects and in the diffusion of information regarding CC in Korhogo is also a valuable strength and offers farmers a more divers support for the adaptation to new climatic and environmental conditions.

8.5.3 Comparison of the two regions and recommendations

The globally low density in both regions is an obstacle to collective action, and the increase in links would be necessary to improve the capacity of farmers to get useful information, to be more aware about CC, to know more about possible adaptation strategies and finally, to adopt new techniques to cope with the consequences of CC. However, we posit that the density of real-world networks is naturally much lower than in models, especially in developing countries where exchanges and access to social gathering are more difficult and costly. Luzi et al. (2008) conducted a comparison between Egypt and Ethiopia water policy networks, and they obtained similarly low densities for information exchange networks (15% and 16%, respectively) with similar actors and centralities. Successive reforms and tensions, as in Korhogo, were also given as a reason for weaker cohesion and the presence of more diverse actors.

The development strategies in countries like Côte d'Ivoire, which is nationally centralized are decided mostly by the national offices or even from international level organizations. This can be spotted in the networks, as in both regions, the network *strategic collaboration* has a lower density than *technical collaboration*. Furthermore, the local *strategic collaboration* is more oriented towards local cooperatives for their own economic and strategic development but does not really include the local representation of governmental and non-governmental agencies. A reinforcement of local decision and policy-making power could encourage bottom-up rather than top-down steering if local cross-sectoral actors would be more involved in the *strategic network*. Such approaches involve a more successful and sustainable use of resources (Bodin and Norberg 2005). The implication of regional boards in national committees, such as the “Food Security Cluster” already in place in Abidjan, could foster exchanges and the integration of the regional diversity. The presence of supporting international organizations in Korhogo, in contrast to Toumodi, might be an asset in the planning of measures for adaptation to CC, as their influence and links with governmental agencies can be exploited for the purposes of diffusion and dissemination of their knowledge. The transfer of information concerning CC to farmers is essential in the initial steps of adaptation, as it raises awareness. Comoé et al. (2012) show that farmers in these two regions perceive changes in their environment, especially changes in the seasonality of rains, and attribute the cause to deforestation or changes in their practices. They are looking for new techniques of adaptation of the cultural cycles. Farmers in both study areas also expressed the specific need to access extension information on weather forecasts (Schmitt 2012), and a more central position of the meteorological services would facilitate the supply diffusion of forecast information to farmers with forecast information. As recommended by Ziervogel and Downing (2004) in their study on weather information diffusion in Lesotho, to reach farmers at the local level the involvement of NGOs will be more efficient and equitable. Furthermore, the strategy of one NGO in Korhogo, which set up an information system about cashew prices through the short messages system (SMS), could be capitalized and used by more NGOs. This kind of tool deserves consideration, as it was also a necessity expressed by local actors in Côte d'Ivoire, and better coordination allows sharing of this kind of adapted innovation.

8.6 Conclusion and policy implications

This study presents empirical evidence of strengths and weaknesses of social networks configurations in the context of CCs in Côte d’Ivoire. The two study regions present rather different patterns that have been linked to the different regional contexts. We suggest encouraging actors to increase density for joint action through working groups to reduce centralization and, thus, increase networks’ cohesion and integration.

It was found that the cores of networks in both regions are composed of mostly “R&D structures”, which should use this position to diffuse information widely.

In Toumodi, the diffusion of information relies on one actor (ANADER), a situation in which the network is more vulnerable. Indeed, if the ANADER is removed from Toumodi for political, financial or other reasons, as much as 25% of the links in the network would be removed and more actors would be isolated from information. Future implementation of more local offices of international organizations and national NGOs in Toumodi would alleviate this risk and make this network more resistant. Furthermore, the bonds between farmers’ cooperatives and other actors groups were found to be weak in both regions and reinforcing these links could have several positive effects. First, it would create trust and solidarity between farmers' interest groups. Second, it could reinforce the centrality of these groups in the networks and increase horizontal integration, which would help them to defend their interests and increase global cohesion. Central actors benefit from the financial support of the government, as all of them, except cooperatives, have part of their financial resources and mandates.

In Kohrogo, the *Intercoton* is already mediating between cotton producers and retailers. Their central position makes them an important actor, and it should be a model for other sectors, especially because they also increase cohesion in the network. The food crop sector was found to be especially weakly represented and to have very few dedicated organizations, which might be prejudicial towards food security policy making. In order to support adaptation of farmers and communities, a larger integration of food crops associations and institutional support for their maintenance are necessary. However, the integration of more and new actors might not be an easy task due to local constraints. Political instability strongly impacted actors and changed the institutional landscape, and this reveals the need for stable governmental services and budgets.

In both regions, regional boards could be created in collaboration with the local authorities. These new boards should increase direct interactions between the "R&D structures", the cooperatives, the meteorological services and the major companies. MINAGRI could take the lead in inviting all organizations, as it seems to be the most legitimate coordinator for doing that. Moreover, policy-makers should, thus, promote the integration of key stakeholders for the diffusion of information about CC and possible adaptation strategies to the farmers, with the support of the major organizations. The meteorological services should have more resources to diffuse information to the farmers; the participation of local farmers' associations should be promoted; and the federation and inter-professions should be reinforced at the national level. Cooperatives play an important role and cooperation with a strong extension service and NGOs could generate sharing of experimentation and knowledge among the farmers and with the other key providers of knowledge.

Finally, SNA is an appropriate method to analyze and diagnose social and institutional networks. After presenting recommendations based on empirical evidence, it would be most interesting to study networks like in Toumodi and Korhogo on a long-term basis and explore their changes in response to external constraints. This could also lead to the development of more reliable indicators and criteria for the assessment of sustainable networks.

9. Synthesis

The aim of the thesis was to contribute to food security through farmers responding better to CC. Therefore, an in-depth understanding of farmers' behavior related to CC and the institutional context surrounding them was essential. In this synthesis chapter, the main results are summarized regarding the thesis's research questions. Then, the policy implications of our findings are discussed, and an outline for future research is presented based on the limitations of our approach.

9.1 Answers to research questions

9.1.1 What are the relevant threats in managing farms with a particular focus on climate-related threats?

Of the overall identified threats, climate-related threats ranked third, after the threats related to technical farming factors (high cost of input, financial problems, rapid growth of weeds, etc.) and insects and diseases. Farmers in both study areas also reported lack of market access, low purchase prices, and lack of technical support were threats. However, in the study areas, the threats were ranked slightly differently. These differences are due to differences in farming systems (e.g., the use of different crops and the focus on livestock breeding in Korhogo) and location (Toumodi is closer to the main market in Abidjan). Apart from technical farming factors, which are common threat in both study areas (38.76% and 29.69% in Toumodi and Korhogo, respectively), in Toumodi, the most important threats are insects and diseases (15.84%), followed by climate (13.33%), farming land (lack of farming land and poor soil fertility) (11.25%), and lack of technical support (10.83%). In Korhogo, the major threats mentioned by farmers are market access and prices (17.5%), insects and diseases (16.25%), climate (12.81%), and animal breeding (11.25%).

Although climate-related threats are not minor threats for farmers, these threats have not been considered in research programs. Moreover, the lack of studies on climate issues and climate databases did not allow further description of CC and its impact on fields. However, our research, which revealed farmers' empirical knowledge of CC through a strong perception, pointed out the phenomenon of all stakeholders' growing awareness. That will certainly lead to concrete actions at the local and national levels.

9.1.2 How do farmers perceive climate change?

In Chapters 5 and 6, farmers' perception of CC was investigated. Most farmers have a strong perception of the changes in climatic conditions. Moreover, farmers have climatic and non-climatic indicators for appraising CC. In Chapter 5, the findings of the analysis of qualitative data gathered through focus groups revealed seven indicators usually used by farmers. In Korhogo, the most frequently used indicator to describe farmers' perception of CC was the changes in rain patterns and their characteristics, changes in the local environment, and the disappearance of some farming practices. For farmers in Toumodi, however, the indicators were the disruption of the key time reference period and a shift in rainy seasons.

In Chapter 6, significant differences in farmers' views in both study areas concerning the emergence of new weed species and new insect pests in agriculture and changes in flowering and fruiting time were revealed. Farmers from Korhogo perceived more new pests (81%) and new weeds (87%), while those from Toumodi strongly agreed that flowering and fruiting times have changed (54%).

Concerning rain patterns and their characteristics, the rains were reported to be more intense even causing crop damage sometimes. Moreover, a change in the spatial distributions of rain has been observed. Through changes in the local environment, farmers referred to the fast drying of shallow ponds during the dry seasons; in addition, the current proliferation of unknown crop pests and a change in fruiting time have been observed. Finally, indicators such as sunshine intensity and the presence of stars in the sky are no longer reliable.

Farmers observed that seasons have shifted and shortened, and the rainy seasons have become shorter over time. For instance, in Toumodi, the short dry season that started in August has shifted to July. This shift was confirmed by Goula et al. (2010), who reported that the duration of the growing season decreased by 30 days in the period 1951–2000. Moreover, higher fluctuations in the start and end dates of the growing seasons were revealed by Ochou (2011).

The disruption of the farming calendar is proof of climate variability and change. The technique of crop succession and the semi-direct seeding of some crops such as cocoa (*Theobroma cacao*) are not suitable for the new climatic conditions. The risk of a poor harvest due to a short delay in implementing farming activities was mentioned as a key indicator of CC. Moreover, specific months and dates are considered key reference indicators of climate over the years; their change is evidence of the changes in the climate. Thus, August in Korhogo is no longer rainy; this empirical observation was confirmed with a comparison of the average August monthly rainfall of up to 400 mm in 1980 (Beaudou and Sayol 1980) with the database of the National Meteorological Office of Côte d'Ivoire (SODEXAM). The comparison shows a decrease of 228 mm in the August rainfall levels for the period 1971–2002. July has become rainier; thus, the rainfalls have shifted from August to July.

Furthermore, in both study areas, the sunshine is stronger today than it was two decades ago. For instance, from 1971 to 2000, the average annual temperature in Korhogo increased by an average of 0.8°C every year (SODEXAM database). However, some assertions were difficult to confirm due to a lack of data on wind power. Farmers asserted the power of the winds have changed, and become more intense.

The chi-square tests applied to the study areas in Chapter 6 revealed significant differences between farmers in Korhogo and Toumodi regarding their perception of changes in climatic conditions, except for perceived changes in the amount of rainfall. More specifically, farmers from the center seemed to perceive more changes in climate than their colleagues in the north. Farmers in the North have to deal more often with restrictive climatic conditions, which increases the difficulty of recognizing changes. In contrast, farmers in the center perceived any change in climate as a serious threat.

9.1.3 How do they deal with climate uncertainties in general and more specifically with climate change issues?

An overview of the strategies implemented by farmers was performed through focus groups, and these strategies were confirmed on a large scale with the survey.

In Chapter 5, farmers mainly attempt to adapt to CC by adjusting their agricultural calendar, adopting new short-season varieties, and using mixed cropping techniques. Farmers used farming and non-farming strategies to deal with climate variability and change. Thus, eight strategies were identified in the crop farming system and divided into two main groups (Chapter 6); the first group included strategies related to sowing management (re-sowing, using more seeds during sowing, and making large seedbed holes to facilitate water retention) and the second one to the change in technical itinerary (retain more trees in the fields, adjust to the agricultural calendar, crops association, change hillocks' size, adopt short-season varieties). A detailed description can be found in Chapter 5. Furthermore, regarding the adaptation of livestock systems, two main strategies were mentioned: a decrease in the number of cattle to have enough grass available during dry spells and better health monitoring. The second strategy was to increase animal mobility to facilitate access to pasture. These strategies were mostly implemented in Korhogo where livestock practices have been developed for many years.

As non-farming strategies, a change in diet was mentioned; farmers started to eat more cassava in Toumodi and maize in Korhogo although they still prefer their staple foods, rice and yams.

Our study revealed most farmers had a real adaptive capacity. The risks of climate-related threats could increase further if local institutions do not support farmers in their ongoing efforts.

9.1.4 Which factors are relevant for farmers' decision behavior regarding adaptation?

The approach for analyzing the factors of farmers' adaptation behavior consisted of two steps. First, internal and external factors were identified, and the interrelationships between factors and adaptation strategies were figured out (Chapter 5). Second, factor relevance was tested using categorical principal component analysis, reliability analysis, and logistic regression models (Chapter 6). Different components were built up related to farmers' perception of CC, the perceived effects of CC, extension support, and farmers and physical characteristics. Moreover, eight major adaptation strategies were identified and then divided into sowing and technical itinerary management. The findings revealed three significant components of farmers' decision behavior through changes in sowing management: the "perceived occurrence of new pests and weeds," "received support from national and international organizations," and "agro-ecological zone, food crops, and livestock." The direction of factors' effects on adaptation strategies is as follows:

- the levels of implemented strategies differed significantly across regions, except for the adoption of short-season crops;
- the decision to adapt occurred when farmers made the link between CC and its negative impacts;
- experience in crop farming, age, and size of the household were not significant in the decision to change sowing management;
- the physical context, which is linked to the geographic localization and the type of crops, motivates adaptation; moreover, the human context such as involvement in farming associations and support from national and international organizations positively influences adaptation.

Regarding the management of the technical itinerary, the overall strategies are influenced by "perceived occurrence of new pests and weeds" and "agro-ecological zone, food crops, and livestock", while four other variables influenced specific adaptation strategies in different ways:

- cognitive factors such as the perception of the frequency and length of dry spells and the perception of changes in rainfall and rainy seasons positively influence adaptation;
- farmers who owned animals and grew cereals were more motivated to change their technical itinerary;
- “the adoption of short-season vegetable varieties” was significantly influenced by an increase in experience, age, and household size.

9.1.5 How can farmers be characterized related to adaptation barriers?

Farmers were identified and characterized based on their evaluations of the feasibility of adaptation strategies, their intention to adapt to CC, perceived social pressure, and agro-economic barriers. A principal component analysis and cluster analysis used to analyze data from the survey revealed four groups: *innovators* (9.68%), *early adaptors* (47.48%), *late adaptors* (24%), and *non-adaptors* (18.84%). These groups were profiled using socio-demographic characteristics, farm characteristics, information accessibility, and CC causes.

The *innovators* are characterized by the highest intentional behavior to adapt to CC, even if a constrained social environment and financial barriers arise. This group is favorable to a change in the agricultural calendar and land use (change in farm size, tillage method, planting trees, etc.). The *innovators* have an average value of socio-demographic characteristics compared to all other groups. However, the innovators devoted the highest share of land to roots and tubers (41.87%). Finally, innovators linked the causes of CC to spiritual and human actions. Although all farmers usually practice diversified agriculture with cereals, roots, and tubers, *early adapters* are characterized by the smallest difference between the share of roots and tubers and the share of cereals. This group includes younger and well-educated farmers who related CC to the lack of rivers and dams and poor farming practices rather than spiritual causes. Furthermore, the oldest and most experienced farmers were found in the group of *late adapters*. Contact with extension services and the involvement of some in farming cooperatives are an asset for this group to facilitate the process of adaptation.

Finally, the *non-adapters,* with the biggest household sizes, had a very low index of intentional behavior regarding adaptation. Moreover, the highest share of cereals (38.67%) and acreage (11.3 ha) for the 2010-2011 farming season could explain these farmers’ reluctance to change their practices. Furthermore, spiritual and human actions except poor farming practices seemed relevant causes of CC.

9.1.6 What institutional conditions surround farmers at the local and national levels? Are the networks well established? Are there strengths and weaknesses in the networks in the two study regions?

The research question was answered by using a social network analysis (SNA) with actors from the agricultural sector surrounding farmers. Apart from the fact that both study areas have the same regional and government ministries, national extension services, and research centers, Korhogo has slightly more international and development organizations, NGOs, and governmental agencies. The findings revealed that in Toumodi the network structure was highly dependent on one major actor while a group of diverse actors appeared central in the networks in Korhogo. The National extension service (ANADER) had the highest centrality scores in almost every network in Toumodi; it was followed by the Ministry of Agriculture, especially in strategic collaboration. Although in Korhogo there were more diverse organizations at the cores of the networks, with integration of more NGOs, international organizations, and inter-professional associations (IPAs), these actors were in the periphery of Toumodi's networks. The Inter-Professional Fund for Research and Agricultural Support (FIRCA), the local authority (the *Préfecture),* and the Food Security and Nutrition Group (GSAN) appeared central in different networks in Korhogo. Therefore, there was more horizontal integration in Korhogo. Furthermore, although it does not appear that actors communicated more with similar actors in Toumodi, those in Korhogo exchanged more in the same sectors and types, except for cooperatives. Furthermore, governmental agencies tend to turn more to international organizations concerning *information about CC* or *adaptation techniques* and for *strategic collaboration*. In Toumodi and Korhogo, a high density of ties with national organizations in the *strategic collaboration* network was found.

Regarding the transfer of CC information to farmers, it follows different patterns in the study areas. In Toumodi, the ANADER is one of the few partners supplying information about CC to cooperatives. The *information network relating to adaptation techniques* in Toumodi counts more links than in Korhogo. In Korhogo, the National Research Centre (CNRA), large companies, and associations in the cotton sector were the most central actors in exchanging information about CC. However, the national meteorological institution (SODEXAM) was outside the information network in both study areas.

9.2 Implications for policy-makers

CC is global and long-term and involves complex interactions between climatic, environmental, economic, political, institutional, social, and technological processes (Shah et al. 2008). Therefore, we must think nationally but act locally in a more community-oriented manner (Hope 2009). The agro-ecological zones and farmers' characteristics appeared to be relevant in adaptation behavior. Furthermore, African governments must intensify efforts to formulate and implement strategies for adapting to the impacts of CC, and must incorporate those strategies into overall development policies and public investment decisions (Hope 2009). Côte d'Ivoire likewise needs to mainstream CC into development policies and plans.

Our findings suggest that future agricultural policies should consider farmers' perception, to provide a suitable climate forecast and to improve local technical support. Local organizations and NGOs need to work together on government extension services, to involve a greater number of farmers in the services and to ensure the appropriate transfer of adaptation measures. The strong perception of CC and the local environment by farmers is a necessary valuable asset. The fact that farmers are already embedded in the process of seeking viable and effective adaptation solutions should be supported by correct climate data forecasting; the main national meteorological institution, which is outside the information networks, must be better funded and involved in the adaptation process through the extension services at the local level. However, although seasonal climate predictions appear to offer substantial potential to improve risk management, the forecasts seldom reach poor smallholder farmers in a usable form, i.e., in a comprehensive package of information and support (Hansen et al. 2006; 2011, Patt et al. 2007; Vogel and O'Brien 2006). Therefore, strengthening local end-users' adaptive capacity to use climate forecasts and other assessments results for planning their activities is extremely important as the first requirement for successful adaptation.

The Government of Côte d'Ivoire should increase funding for agricultural research and extension to support the development of appropriate technologies and management practices designed to optimize productivity in the face of CC. In this line, the focus of future research in the short and medium term should be to further develop improved varieties of major crops that are adaptable (drought-tolerant) to the changing climate and are compatible with associated crops. In addition, determining appropriate times and patterns for planting in the changing climate should be addressed based on the capitalization of farmers' knowledge across the regions. At this point, collaboration between research institutions in the national agricultural research systems and advanced institutions in the north could be fostered to share expertise bilaterally. However, at the national level, concrete policy options including subsidies and incentives for making crop varieties or improved farming practices available need to be initiated.

Policy interventions must promote more interaction among researchers, extension agents, NGOs, and farmers to facilitate better communication flow in all directions. Improved integration of farmers' cooperatives could generate sharing of experiments and knowledge to better adapt to CC as adaptation should fit with existing farms' management systems and objectives. Indeed, climate is not frequently integrated with development policy and investment decision-making. The policy must be revised to include the cognitive aspects of adaptation to CC at the local level.

The overall effort to adapt to CC should be accompanied by decreased deforestation and forest degradation as it may result in important co-benefits, including poverty reduction and conservation of biodiversity. Thus, the introduction of tree crops can provide food, fodder, and energy and enhance cash income, as well as contribute to retaining soil moisture and improving land quality. This will, in turn, open up new cropping opportunities for farmers (Ingram et al. 2008).

As adaptation never occurs in an institutional gap, it is also important to articulate different scales: institutional (local, national, regional) but also temporal (short, medium, long term) to be realistic about the implementation and representation capacity of local institutions. Institutional functions include gathering and disseminating information, mobilizing and allocating resources, developing skills and building capacity, providing leadership, and relating to other decision makers and institutions (Agrawal et al. 2009). Therefore, the approach for enhancing adaptation in Côte d'Ivoire must consider the specific networks that will benefit from its strengths. Adaptations may be based on local NGOs, farmers' cooperatives in the north, and the performance of ANADER with the decentralized office of the Ministry of Agriculture in the center to make the networks more resistant. Policy-makers should promote integrating key stakeholders to diffuse adaptation information to farmers, with the support of national offices; reinforcing the links between farmers' cooperatives and other actors groups in both regions could create trust and solidarity between farmers' interest groups and increase horizontal integration and global cohesion.

9.3 Discussion on the research approach and on further research

CC is a new field of research in Côte d'Ivoire. Therefore, the research we conducted in this thesis could not refer to many previous studies, especially to allow comparisons of farmers' perception of CC and its impact on crops yield and local environment. In addition, we have suggested local intervention although CC is a global issue; thus, the number of study areas in our case study seems insufficient. Therefore, further studies might be initiated in other regions of the country to facilitate the implementation of adaptation policy measures.

The focus groups used in this research are a valuable tool for exploring CC perception, and how farmers cope, especially if the focus groups are combined with other methods such as a quantitative survey to better understand farmers' adaptation behavior. Furthermore, the limitation of cluster analysis, where it fails to incorporate relevant or includes irrelevant variables (Punj and Stewart 1983), has been taken into account. Although studies related to CC in Côte d'Ivoire are scarce, variables were included based on a clear rationale and theory with relevant studies on farmers' barriers regarding CC. However, repeating the study in the coming years would help assess the stability of clusters over time and gauge the degree to which particular groups are growing or decreasing in size (Gorton et al. 2013). This could be done by further integrating adaptation cost; much less information is available about the costs and effectiveness of adaptation measures than about mitigation measures. These adaptation costs are not fully understood, partly because effective adaptation measures are highly dependent on specific geographic and climate risk factors as well as institutional, political, and financial constraints (IPCC 2007).

This thesis helped to get an in-depth understanding of farmers' perception and adaption behavior regarding CC. Several areas of debate and contention exist, particularly for health, the water sector, and certain ecosystem responses. More research on such areas is clearly needed (IPCC 2007). Further research could explore and foster agricultural-health links through multi-level participatory approaches. Thus, we will identify and promote good agricultural practices and disease prevention and control strategies that are readily adapted to the social-ecological context. Indeed, evidence of links between agricultural practices and the prevalence rates of tropical parasitic diseases have already been demonstrated. Moreover, there is growing evidence that climatic variations and change are already influencing the distribution and virulence of crop pests and diseases, but the interactions between crops, pests, and pathogens are complex and poorly understood in the context of CC (Gregory et al., 2009). Links between land-use changes, climate stress, and possible feedback are not yet clearly understood (IPCC 2007). Therefore, the face of demographic growth and CC and strategies for better management of resources such as water and land could foster better agricultural productivity and enhance food security, while reducing the health risks and vulnerability of local communities. Livestock management concerns should be investigated as CC will also have significant impacts on the emergence, spread, and distribution of livestock diseases through various pathways (Baylis and Githeko 2006). Further research should also be conducted to monitor and predict the spread of pests and diseases affecting plants (Farrow et al. 2011), livestock, and humans.

There are also considerable uncertainties regarding the magnitude and direction of climate change, particularly at the downscaled, local level. Developing and improving regional and local-level climate models and scenarios could improve the confidence attached to the various projections. Indeed, the need to further develop regional climate models and sub-regional models at a scale exists, which would be meaningful to decision-makers and to include stakeholders in framing some of the issues that may require more investigation (IPCC 2007).

Going forward, researchers must continue to refine these projections using a range of approaches and relate the forecasts to agricultural productivity (Jarvis et al. 2011), specifically in the context of Côte d'Ivoire.

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Annex

Table A1: Table of actors' names and centrality scores.

Note: The two tables provide information about actors' names and types and their centrality scores for a) Toumodi and b) Korhogo. The first column gives the full name of all actors translated from French to English. The second column presents their abbreviation used in the networks of Figure 1. Appendices _T and _K indicate the locations of organizations in CC the regions of Toumodi and Korhogo, respectively, for those with offices in these regions. The next two columns provide more details on the type of actor; first their role and second the agricultural sector in which they are active. The influence score (5^{th} column) is calculated by the number of times an actor was mentioned as being influential divided by the number of actors interviewed. The last two columns provide the in-degrees and out-degrees of actors in the network of information exchanges and in the network of information exchanges about CC. The in-degrees is the number of links arriving at the actor (e.g. the number of actors a node is receiving information from) and the out-degrees is the number of links leaving the node (e.g. the number of actors a node is giving information to). The actors have been classified according to their centrality (most to least).

a) Toumodi

Complete name (translation)	Abbreviation	Role[1]	Sector[2]	Influence score	Degree info in/out	Degree info cc in/out
The National Agency for Rural Development Support	ANADER_T	extension	All	93.1	30/33	10/11
Ministry of Agriculture	MINAGRI_T	Gov.	All	75.9	21/20	3/3
Found for Development and Promotion of activities from the Producers of Coffee and Cocoa	FDPCC_T	R&D	cocoa	24.1	14/14	1/1
National Centre for Agronomic Research	CNRA_T	Research	All	24.1	9/13	5/5
Cooperative "Eboyokun"	Eboyokun	Coop.	cocoa	41.4	11/10	1/1
Enterprise agricultural cooperative of Kpouébo	ECOOPAK	Coop.	cocoa	3.4	8/10	2/2
Prefecture (local authority)	Prefecture_T	Gov.	All	41.4	10/6	1/1
AgriHall	AgriHall	Comp.	All	3.4	4/10	3/3
National Office for rice Development	ONDR	R&D	Food	17.2	9/9	3/3
Cooperative "Cacoci"	CACOCI	Coop.	cocoa	37.9	9/7	1/1
Under-prefectures (subdivisions)	Sous-prefectures_T	Gov.	All	31.0	9/6	0/0
Interprofessional Found for Agricultural Research and Advice	FIRCA	R&D	All	17.2	8/7	2/2
Cargill Inc.	Cargill	Comp.	cocoa	6.9	8/5	1/1
Barry Callebaut- African Cocoa Society	BC-SACO	Comp.	cocoa	10.3	8/4	2/2
Cooperative Association of Women from Djékanou	ASCAFED	Coop.	cashew	3.4	6/7	3/3
OLAM- Outspan	OLAM	Comp.	cash	13.8	6/7	1/1
Swiss Centre for Scientific Research in Côte d'Ivoire	CSRS_T	Research	Food & breed.	10.3	4/7	1/1
General Council of Toumodi	CGToumodi	Gov.	Food	27.6	7/2	1/0
Cooperative of Agricultural Producers of Kimoukro	COOPAK	Coop.	cocoa	17.2	6/6	0/0
National Association of Rice producers in Côte d'Ivoire	ANARIZ-CI	Assoc.	Food	13.8	6/6	3/3
Management Committee for the Coffee-Cocoa sector	CGFCC	Gov.	cocoa	13.8	4/6	1/0
Biopartenaire	Biopartenaire	Comp.	cocoa	6.9	5/5	1/1
Cooperative Dialogue of Djékanou	CDD	Coop.	cash	20.7	5/5	0/0
Development Project of the region "Lacs"	PADER	Project	Food &breed.	3.4	5/4	1/1
Cooperative "Ekloiyo"	Ekloiyo	Coop.	cashew	6.9	5/4	0/0
Ministry of Animal and Fish Resources	MIRAH_T	Gov.	Breed.	31.0	2/5	1/1
National Association of Producers of Coffee and Cocoa	ANAPROCI	Assoc.	cocoa	6.9	1/5	0/0
Cooperative "Trofé"	Trofe	Coop.	cocoa	20.7	4/4	1/1
United Nations Development Program	PNUD_T	Interna.	All	0	4/4	0/1
Cooperative for Production and Commercialization of Food Crops	CPCPV	Coop.	Food	10.3	4/4	0/0
Agricultural Cooperative of Toumodi	COOPAT	Coop.	cocoa	17.2	3/2	0/0
Departmental Cooperative of Rice Producers	CODERIZ	Coop.	Food	6.9	2/1	0/0
SNADCI Ltd.	SNADCI	Comp.	cocoa	6.9	2/1	0/0
Nestle	Nestle	Comp.	cocoa	0	2/1	0/0
Archer Daniels Midland Co.	ADM	Comp.	cocoa	3.4	1/2	0/0
Society for Management and Development of Airports, Aviation and Meteorology	SODEXAM	Gov.	All	3.4	1/1	1/1
Cooperative "Entente"	Entente	Coop.	cocoa	6.9	1/1	0/0
National Laboratory for Agricultural Development	LANADA	R&D	All	10.3	1/1	0/0
International Institute of Tropical Agriculture	IITA	Interna.	All	0	1/1	0/0
Union of Farmers from Toumodi	UAT	Coop.	Food &Breed.	0	1/1	0/0
National Association of Food Crops producers in Côte d'Ivoire	ANAPROVICI	Assoc.	Food	0	1/1	0/0
National Federation of Food Crops Cooperatives in Côte d'Ivoire	FENACOVICI	Coop.	Food	0	1/1	0/0
State of Côte d'Ivoire	CI	Gov.	All	6.9	0/0	0/0
International Found for Agricultural Development	FIDA	Interna.	All	3.4	0/0	0/0
World Bank	BM	Interna.	All	0	0/0	0/0
Food and Agriculture Organisation	FAO	Interna.	All	0	0/0	0/0
Sinznoudjanfouè	SNDF	NGO	unknown	0	0/0	0/0
MEAN				14.9	5.3/5.3	1/1

c) Korhogo

Complete name (translation)	Actor	Role[1]	Sector[2]	Influence score	Degree info in/out	Degree info cc in/out
Interprofessional Found for Agricultural Research and Advice	FIRCA	R&D	All	26.3	29/28	5/5
Ministry of Agriculture	MINAGRI_K	Gov.	All	63.2	26/22	4/4
National Centre for Agronomic Research	CNRA_K	Research	All	55.3	22/24	9/9
The National Agency for Rural Development Support	ANADER_K	extension	All	68.4	20/21	5/3
Project to Support Small Horticulture of the “Region Savanes”	PPMS	Project	Food	34.2	20/20	0/0
Umbrella Organization from the Cooperatives of the Cotton Sector	AFFICOT-CI	Assoc.	Cotton	23.7	19/20	8/8
Cotton Inter-Professional Association	Intercoton	IPA	Cotton	28.9	20/19	6/6
Food and Agriculture Organization	FAO_K	Interna.	Food& breed.	28.9	19/20	4/8
Ivorian Cotton Company Ltd.	COIC	Comp.	Cotton	31.6	14/17	6/5
Prefecture (local authority)	Préfecture_K	Gov.	All	28.9	17/14	4/3
Chigata	Chigata	NGO	Cashew	13.2	13/16	0/0
Ivoire Coton	IvoireCoton	Comp.	Cotton	36.8	14/15	6/6
United Nations Development Program	PNUD_K	Interna.	Food	36.8	13/14	6/6
Rural Animation of Korhogo	ARK	NGO	Food &breed.	60.5	13/13	3/3
Office to Support Commercialisation of Food Crops	OCPV_K	Gov.	Food	2.6	13/13	0/0
Union of Cooperatives for Agricultural Development	UCODACI	Coop.	All	7.9	13/13	0/0
Cooperative “Womiengnon”	Womiengnon	Coop.	Food	21.1	12/12	3/4
Ministry of Animal and Fish Resources	MIRAH_K	Gov.	Breed.	26.3	12/12	1/0
German International Collaboration Society	GIZ_K	Interna.	Food& breed.	31.6	12/9	0/0
Development and Extension Formation Bureau	BFCD	R&D	All	50.0	11/11	1/0
OLAM-SECO	OLAM-SECO	Comp.	Cotton	28.9	10/11	2/2
Regional Union of cooperative enterprises of the Region « Savanes »	URECOSCI	Coop.	Cotton	36.8	10/10	2/5
Union of cooperatives For Food Crops in the Region « Savanes »	UCOVISA	Coop.	Food	13.2	8/9	1/0
African Cashew Initiative	ICA	NGO	Cashew	13.2	8/8	1/1
Regulation Agency for Cotton and Cashew	ARECA	Gov.	Cash	13.2	7/8	3/4
Society for Forest Development	SODEFOR_K	Gov.	forestry	13.2	8/7	2/2
Cashew Inter-Professional Association	Intercajou	IPA	Cashew	7.9	8/7	0/0
Under-prefectures (subdivisions)	Sous-préfecture_K	Gov.	All	13.2	8/5	0/0
Interregional Union of cooperatives for tropical agricultural products	UIRECOPATCI	Coop.	Cash	18.4	7/7	2/2
European Union	UE	Interna.	All	26.3	7/6	1/2
Action Against Hunger	ACF	Interna.	Food	26.3	7/6	0/0
Swiss Centre for Scientific Research in Côte d'Ivoire	CSRS_K	Research	Food	23.7	6/5	4/4
Cooperative “Gninnangnon”	Gninnangnon	Coop.	Cash	2.6	6/5	0/0
General Council of Toumodi	CG Korhogo	Gov.	All	15.8	6/4	2/2
Union of agricultural cooperatives from « Bafiné »	UCAB-CI	Coop.	Cash	15.8	4/6	0/0
Association of Professionals from the Cotton Sector	APROCOT-CI	Assoc.	Cotton	7.9	5/5	3/3
Cooperative “Yebe-wognon”	Yebe-wognon	Coop.	Cotton	26.3	5/4	0/0
Cooperative of cattle breeders of the Region « Savanes »	COOPERSA	Coop.	Breed.	0	2/5	0/0
I Cotoni del Firello	ICotoni	Comp.	Cotton	2.6	4/4	2/2
World Bank	BM	Interna.	All	10.5	4/4	1/1
Cooperative « Narnougou » of Karkoro-Komboro	CONAKAKO	Coop.	Cash	7.9	4/4	1/1
Industrial Cotton Company from Savanna	SICOSA	Comp.	Cotton	5.3	3/4	1/1
Bio-Economy Africa	BEA	NGO	All	0	3/4	0/0
National Office for rice Development	ONDR	R&D	Food	10.5	3/3	0/0
African Development Bank	BAD	Interna.	All	5.3	3/3	0/0
Cooperative “COD-CI”	COD-CI	Coop.	unknown	5.3	3/3	0/0

Korhogo (continued)

Complete name (translation)	Actor	Role[1]	Sector[2]	Influence score	Degree info in/out	Degree info cc in/out
International Found for Agricultural Development	FIDA	Interna.	All	13.2	3/2	0/0
State of Côte d'Ivoire	CI	Gov.	All	7.9	2/2	0/0
Umbrella Organization of cooperatives of Côte d'Ivoire	UFACOCI	Coop.	unknown	5.3	2/2	0/0
Society for Management and Development of Airports, Aviation and Meteorology	SODEXAM_K	Gov.	All	10.5	1/2	0/0
Association of cotton and Cashew Producers	ASPROCA	Coop.	Cash	2.6	1/2	0/0
National Federation of Food Crops Cooperatives in Côte d'Ivoire	FENACOVICI	Coop.	Food	0	1/1	0/0
Agri-aménagistes	Agri-aménagistes	R&D	All	10.5	0/0	0/0
MEAN				20.3	9.3/9.3	1.9/1.9

Note:

[1] Gov. = governmental, R&D = Research and Development, Interna. = international organization, Coop. = farmers' cooperative, Comp. = company, Assoc. = association

[2] Breed. = breeding, "Food" includes all food crops such as rice, maize, tubercles, vegetables. "Cash" includes all cash crops oriented to exports like cocoa, coffee, cotton and cashew.

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Curriculum Vitae

Personal

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Areas of Expertise

Climate change adaptation in agriculture, farmer's decision-making process, food security in developing country, food crop and livestock supply chain, field work, quantitative methods of applied research

Education

02/2010 – (05/2013)

PhD Program

ETH Zurich

Agri-Food and Agri-Environmental Economics Group
Title of PhD project:

Contribution to food security by improving farmers' responses to climate change in northern and central areas of Côte d'Ivoire
Method:

Focus group discussions, personal interviews, quantitative surveys, qualitative data analyses, statistical regressions model of farmers' decision behavior

2007 – 2008

Diploma of Specialized Studies in Rural Economy (DESS)

University of Cocody, Abidjan, Côte d'Ivoire
Title of Diploma Thesis:

Performance analysis of the system of the supply market of Abidjan in livestock from Korhogo in northern Côte d'Ivoire
Method:

Supply chain analysis

1996 – 2002

Diploma in agronomic engineering (specialization in Agricultural Economics)

Ivorian Institute of Technology (INP-HB), Côte d'Ivoire
Title of Diploma Thesis:

Analysis of the institutional aspect of the dissemination of modern rice varieties and seed management in rural areas": ADRAO, Rice Center for Africa. *(see References)*
Method:

Statistical regression analysis of diffusion of innovation, secondary data analysis

1996	**Baccalaureate D (Scientific)** *Scientific High School, Yamoussoukro, Côte d'Ivoire*

Awards

2003	**Major of the 33^{rd} promotion of Agro-Economist engineers** of the Ivorian Institute of Technology, Yamoussoukro, Côte d'Ivoire.

Professional Experience

02/2010 – (05/2013)	**PhD student and research assistant** *ETH Zurich* *Agri-Food and Agri-Environmental Economics Group* Activities besides research: ▪ Supervision of student theses ▪ Guest lectures in courses
07/2008 – 03/2009	**Scholarship holder of Swiss Confederation** Main activities ▪ Thesis project writing for the Research Fellow Partnership Program (RFPP) of ETH ▪ Scientific papers writing ▪ Courses attending at ETH Zurich
12/2007 – 06/2008	**Head of the Focal Point "Economy and Rural Sociology"**, within the Food Security and Nutrition Axis at the Swiss Centre of Research (CSRS), Côte d'Ivoire.
2005 – 2008	**Responsible** for the analysis of the livestock / meat chain within the project funded by the Swiss Centre for International Agriculture (ZIL).
2004 – 2006	**Project Manager** of "Action with high symbolic value" funded by the Swiss Agency for Development and Cooperation (SDC) in the Central and Northern Côte d'Ivoire. Swiss Centre of Research (CSRS), Côte d'Ivoire.

Languages

French	Mother tongue
English	Spoken good, written good

Computer Skills

Microsoft Office	Word, Excel, Power Point
Statistical software	Excel, SPSS
Qualitative software	NVivo
GIS software	QGIS