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CLIMATE CHANGE AND ENVIRONMENTAL IMPACTS: WHAT PERCEPTIONS AND LOCAL ADAPTATION STRATEGIES OF FARMER-HERDERS OF THE RUZIZI PLAIN COLLECTIVITY IN THE D.R. CONGO?

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Abstract

This study aimed to analyze farmers' and breeders' perceptions of climate change impacts on the environment and production (agricultural and livestock) in Ruzizi to understand these communities' strategies and practices in the face of climate change for the local adaptation. The study used a cross-sectional design, and 300 farmers, including market gardeners and agro-pastoralists from four groups in the Ruzizi zone, were selected. These four groups' choice was considering the criteria of rainfall variability and vulnerability to climate change. The mean and frequencies and binary logistic regressions were used to analyze the data. The level of education of local communities influenced their perception of changes in rainfall and household size, significantly influencing local perceptions of the decline and late start of the season. In the Ruzizi plain's community, to adapt to the recent adverse effects of climate change, producers have implemented strategies and practices such as adopting agricultural techniques, irrigation, and possession of pits manure / composting and varietal adaptation. Recurrent droughts and deforestation have caused a reduction in plant cover, exposing soils to water and wind erosion. The peasants responded by adopting stone bunds and *zaï* and practicing organic manure/compost to restore the fertility of degraded soils to increase agricultural production. The possession of small agricultural tools significantly influenced zaï, stone bunds, and manure/compost pits. Pickaxes and hoes have remained socio-economic determinants of adaptation to climate change to reclaim degraded land in the Ruzizi plain. The producers who have plots in developed marshes and lowlands have been the most influenced by irrigation, which is one of the very promising adaptation strategies to climate change. The local communities who took part in this study perceive climate change through the drop-in rains, the increases in temperature, and the winds' violence. These climatic hazards harm the biophysical environment with repercussions on agricultural production. This study also showed that households' socio-economic characteristics influence local perceptions of climate change and adaptation practice adoption. The main adaptation strategies remained essentially adopting new agricultural techniques, irrigation, the possession of manure/compost pits, and varietal adaptation.

Keywords: Climate change, Perceptions, Environmental impacts, Adaptation strategies, Ruzizi plain

INTRODUCTION

The threat posed by climate change is increasingly perceptible to most rural households' viability, where local communities depend mainly on the exploitation of natural resources. The solid human pressure on the rare semi-arid zones makes ecosystems more vulnerable to the effects of climate change in many African countries (Sop et al., 2010).

Yesterday, it was in the West African Sahel that climate change caused significant environmental changes. Still, today, it is almost everywhere in Africa that droughts reported here and there reduce plant cover and agricultural yields and promote the extension of denuded areas (Belem et al., 2017; Ouédraogo and Thiombiano, 2012; Bambara et al., 2013). This depletion of natural resources affects local communities' survival and exposes them to food insecurity and permanent poverty. According to the Intergovernmental Panel on Climate Change (IPCC, 2007), the consequences of climate change on African countries' economies are already considerable. The situation increases—frequencies of extreme events (Hounghton et al., 2001). Indeed, the frequency of excessive rains is increasing in many areas of the Africa region. Yet, extreme climatic events hurt agriculture, livestock, and natural resources (Karimou Barké et al., 2015) on which the bulk of the economies of these victim countries are based.

In Africa, many studies have highlighted climate change perception by local populations. Burkina Faso's case where local people have perceived climate change through the decrease and irregularities in rainfall, the late start of the rainy season, the early end of the rains, and the higher frequency of pockets of drought. (Sarr et al., 2015; Nielsen and Reenberg, 2010) . In Kenya, farmers have also perceived the climate variability through the increase in average temperatures, the reduction in rainfall, the late start of the rainy season, periods of drought, or long dry spells for the last 20 years (Bryan et al., 2013). In parts of Asia, farmers have also observed a recession in rainfall, temperature increases, droughts, floods, and cyclones more frequent over the past 20 years (Uddin et al., 2017). Agricultural producers perceive climate change through its adverse impacts on-farm production and the natural environment. These farmers did not cease to point out that the decrease in rains, temperature increases, and strong winds explained between 30 and 50 % of agricultural production reduction depending on crops and areas (Mertz et al., 2010). The desiccation and mortality of ligneous plants, the decline in fruit production, the early drying up of water reservoirs, and the vegetation cover's degradation have been attributed to the adverse effects of climate change (Bambara et al., 2013) and to severe anthropogenic pressures.

Ouédraogo et al. (2010) indicated that local communities in countries were affected by climate change. A study carried out in Côte d'Ivoire has shown that local communities' responses to rainfall constraints are local modification of the calendar and cropping options and a growing opportunity for the diversification of income and crop sources. New eating habits (Kouassi et al., 2015). Innovative adaptation practices of agricultural producers in certain semi-arid zones of the Sahel are the expansion of irrigation systems, adjustment of crop sowing periods according to localized climate forecasts, plant selection, and planting. In place of crops more tolerant to climatic stresses associated with agroforestry (Sarr et al., 2015). In Rwanda, Burundi and the DRC, especially in certain exposed areas of Bushi in South Kivu, adaptation measures for agricultural households in the face of climate variability are the adoption of improved crop varieties, the heavy use of fertilizers, investing in improving land management practices and changing the timing of farming activities for some growers and others are using organic manure, changing planting dates and expanding of the irrigation system (Nzigidahera B, 2006)

The community of the Ruzizi plain in South Kivu, D.R. Congo, is one of the regions with a deficit in cereal production due to agro-pedoclimatic constraints and the solid demographic explosion. Thus, local communities are exposed to the risk of permanent food insecurity and growing poverty due to their low capacity to adapt to climate change. An assessment involving aspects of the perception of climate change, environmental effects, and local adaptation strategies is necessary to fully understand how local communities in this community cope with the adverse consequences of climate variability and change. Such an assessment will also make it possible to identify the determining factors of perception and adaptation.

RESEARCH METHODS

Type and scope of the study

The study used the cross-sectional study design to analyze the perceptions and coping strategies of small farmer-breeders to climate change and environmental impacts, the community in the Ruzizi plain. The study environment is the Ruzizi plain's chiefdom collectivity, made up of 4 groups, including Kabunambo, Kagando, Kakamba, and Luberizi. This community is between 3 ° 13'18.4 South Latitude and 29 ° 9'55.4 Longitude East to South with an altitude of 836 m. The North Limit is between 02 ° 51'59.1 South latitude and 29 ° 02'11.0 East longitude. The average monthly air temperature is between 22.5 ° and 25 ° C; monthly average daily maximum temperatures increase at the end of the dry season (30.5 ° to 32.5 ° in September) while monthly average daily minimum temperatures are lowest during half of the dry season (14.5 ° to 32.5 ° ° to 17 ° C in July). The monthly relative insolation generally oscillates between 35 and 60% from October to April, and between 50% and 80% from May to September, and July being the sunniest month (Luzolo M, 2008).

The Ruzizi plain's community is covered with sandy and clayey soil that supports xerophilic vegetation consisting mainly of shrub savannas, the grassy layer of which constitutes the main agro-pastoral and agricultural reserves in the community (Dupriez H et al., 2003). The economy of the community of the Ruzizi plain is based on agriculture and animal husbandry. Agriculture is the main activity, as it supports more than 90% of local communities. The most cultivated crops are mainly cassava, maize, paddy rice, vegetables, sweet potatoes, beans, sorghum, etc. Animal husbandry is also thriving in this community. We find the development of small trade around the Luberizi market and others in the communities of Bafulero villages with which it trades. During the rainy season, local communities engage in intensive agriculture, but men engage in the charcoal making during the dry season. This welding activity allows farmers to have enough to meet the needs of their households.

Collection of data and Data analysis

Surveys were carried out in the four groups of the Ruzizi plain collectivity. These groups' choices considered the criteria of rainfall variability and vulnerability to climate change, and therefore, all the groups were concerned. In each grouping of the plain's community, 30 agricultural and pastoral households were randomly selected from a list of people meeting well-defined criteria (explained in the following paragraphs) for the individual interviews and 180 people.

The questions focused on the perception of climate change indicators and environmental and agricultural impact indicators. Climate change indicators are meteorological parameters whose evolution over time reflects climate change. It should be noted that the questions put to producers and breeders on their perception of climate change are consistent with the indices of the Expert Team on Climate Change Detection Monitoring and Indices (Zhang and Yang, 2004).

The environmental impact indicators are the perceptible signs of the biophysical environment's degradation of natural vegetation, agricultural lands, plant productions, and their causes. The questionnaire, therefore, focused on agricultural producers' opinions concerning the increase, decrease, or variation in the yields of the main crops (sorghum, beans, but) during the last 15 years in their grouping and the explanatory factors. The drop-in profit per plot is an indicator of the level of soil fertility. The questionnaire also focused on adopting adaptation strategies and practices of agricultural producers in the face of climate change and their causes. These are the abandonment of crops or crop varieties, adoption of crops or crop varieties, change in cropping systems, sowing practices or cropping calendar, etc.

The study used descriptive statistics such as the mean and the frequencies; the factors that influence the local perception of the rainy season's disruption were analyzed through a binary logistic regression.

RESULTS

Socio-economic characteristics of households

The surveyed population is made up of 76 % men and 24 % women. The average age of heads of household is 55 years old. The average household size is 13 people. More than half (57.6 %) of heads of household are illiterate. Rainfed agriculture is the main economic activity in the area (99.3 %). Animal husbandry and market gardening are secondary activities practiced respectively by 31.3 % and 18.7 % of the local population. The majority of producers (68.7 %) reported subsistence-oriented, while 30.3 % indicated sales-oriented. Half of the households are members of a peasant organization. Two-thirds of producers (62 %) said they have benefited from training in agricultural techniques. Small ruminant breeders represent 51.7 % of the local community. Large ruminant breeders with more than 12 head of cattle represent 12 % of small producers. Almost half of the producers (50.8 %) have access to agricultural inputs (improved varieties, fertilizers, etc.). A small number of producers (10.3 %) have access to credit / have already benefited from support from a non-governmental organization.

Perceptions of Climate Change Indicators

Indicator of changes in precipitation

Members of local communities remember heavy and regular rainfall in the past and long rainy seasons. When the local communities say that: " in the past, when we noticed in the morning that the sky was cloudy, we were sure that it was going to rain during the day. This reflected a regularity of the rains. They were thin and could last for several hours on the same day. For the moment, local communities are seeing a disruption of the rainy season. Indeed, 76.7 % of those questioned noted a decrease in annual rainfall, and 50.7 % found that the rains were irregular. A high mention (99 % of responses) of aborted showers reflects this irregularity. Some people we met even mentioned this rainfall variability from one group to another.

According to 76.3% and 92.7% of the local community, the rainy seasons have a late start and an earlier end. According to local communities, this early stopping of the rainy season sometimes occurs around the flowering-maturation period of crops, " Two to three rains are often lacking well distributed in time to allow crops to complete their cycle. The recent rains are heavier and last only a few moments during the day.

Dry sequences are more frequent and of long duration. The most observed by local communities are those of [10-13] and [15-18] days because of their negative impacts on crops. A dry sequence is a day or a period without rain. This period ends on the eve of the next rain.

Rainy years and dry years have alternated over the past 15 years. This alternation is perceived through its positive or negative impacts on agricultural yields. Local communities do not perceive an increase in rainfall in recent years in their entity, but rather rainfall extremes.

Extreme temperature indicators

Those interviewed for this study recognize that the days and nights have become hotter and hotter (Figure 1). This increases the daily maximum and minimum temperatures observed throughout the year. Local perception indicates that the classic cold season is warming (71 % of respondents) and tending to shorten (85 % of respondents). Local communities perceive the warming of temperatures through its impacts on their activities. High temperatures in June, July, and August influence the fields' preparation (spreading organic manure, picking up small rubble for the creation of stone bunds, making *zaï* holes, etc.). The premature drying out of water reservoirs is partly linked to temperature increases which cause them to evaporate.

As for winds, eddies, and dust mists, these are purely new phenomena in the region. The appearance of high winds is a recent phenomenon for local communities. According to 98% of the people we met, the winds became more violent and frequent (Figure 1). They manifest themselves in the form of tornadoes during the rainy season and cause significant damage to homes and even crops. The increasing violence of the whirlpools is reported by many of the community in groupings (95%). Besides, almost all of the local community (91 %) report that dust mists are more frequent as the rainy season approaches and can persist for several days, especially in the afternoons. These dust mists are the basis of incalculable damage in the villages.

Factors determining the perception of changes in precipitation

The socio-economic characteristics of households influence the perception of local communities of climate changes. Table 4 presents the marginal effects of binary logistic regressions on the determinants of local communities' perception of the disruption of the rainy season. The% of good prediction of these models is 76.67 % for the late start of the season, 77 % for the decrease, and 92.67 % for the early end of the rains. These values reflect a judicious choice of predictor variables. The Education / education variable positively affects the perception of the rains' late start at the 10 % level.

The more educated are more interested in calendar dates or the start of school holidays, which generally coincide with the season's start. The less educated don't tell the difference between an early or late season. The education level of the head of household is a chronological benchmark. Household size positively influences the fall's perception and the late start of the rainy season at the 1 % level. Large households' heads perceive the fall and the late onset of the rains more than small households' heads. The farmer organization variable (PO) positively influences the perception of rainfall drop at the 5 % threshold and negatively the late start and early end of the rains.

Village groups benefit from information or training on adaptation to climate change, most often provided by the few agents of non-governmental organizations (NGOs) who support food security projects in the area. The variable number of cattle (Nbovins) positively affects the perception of the drop and the early stopping of rains at respective thresholds of 10 % and 1 %, and negatively the late onset of rains (threshold of 1 %). Holders of large herds perceive the drop and the early end of the rains better than small herders because of the extraordinary efforts required to lead the hordes to rivers and lowlands searching for green grasses.

Internal perceptions of environmental change indicators

Agricultural producers have identified eight indicators of environmental change. Bare soils (77.3 %), gravelly soils (9.7 %), erosion gullies (7 %), silting up of fields (8.7 %), and the proliferation of *Striga sp*. (7 %) in fields of corn, sorghum, beans, etc. are indicators of agricultural land degradation (Table 5). The reduction of herbaceous plants (30.7 %), drying out, and mortality of woody plants (20.3 %) are visible signs of land degradation on natural vegetation. The low agricultural yields (40.7 %) are an indicator of soil degradation. The causes of these changes are mainly the decrease in rainfall (82 %), the action of strong winds (37.3 %), water erosion (34 %), and intensive deforestation (24.3 %). These are added harmful agricultural practices such as the absence or reduction of the fallow period, bush fires, low inputs of organic and mineral fertilizers, low use of farming techniques, etc. The natural vegetation cover that protected the soils has declined sharply, leaving these soils under the effect of erosion.

Producers perceive the impacts of climate variability on their productions through low yields. Thus, 69 % of producers have noticed a drop-in sorghum yields, corn, and beans over the past 15 years. According to them, this decrease is attributable primarily to the early end of the rains (68 %), to the dry spells (40 %), but also the reduction of soil fertility (46 %), the action of strong winds (18%) and attacks from *Striga sp. (* 19 %) (Figure 2). On the other hand, 15 % of producers instead noted an increase in cereal yields. According to them, this increase is attributable to new agricultural techniques, organic manure, and improved seed varieties. Almost all of the producers (91 %) adopted new crops or crop varieties. These are traditional short-cycle varieties or improved seed varieties. Some producers (16 %) observed a variation in cereal yields depending on the year in their localities. Agricultural producers do not have the same apprehension of the impact of climate variability on their productions.

Community practices of adaptation to climate change

To adapt to climate change, producers have adopted several agricultural practices (Figure 3). Producers have abandoned certain cash crops such as cotton and tobacco in favor of cereals such as sorghum and corn and legumes such as beans, soybeans, and peanuts. Likewise, the long-cycle varieties of sorghum, soybeans, and corn have been replaced by short-cycle types. The reasons for this abandonment are recurrent droughts, reduced rains, and the scarcity of fertile land. On the other hand, we note the adoption of new varieties of new crops such as sweet potato, cassava, tomato, and a tendency to increase rice cultivation, which is practiced in irrigation around water reservoirs and even in some small marshes towards the shallows. The reasons given by the producers are changes in the eating habits of the communities, the possession of a plot in a lowland or perimeter developed with the support of NGO projects, and the search for other sources of income. Producers have also made changes in sorghum, beans, and maize cropping systems. Beans were often grown in combination with sorghum and maize, but today, these three crops occupy separate plots, especially with improved varieties. The producers (73 %) exploit the lowlands for the production of vegetable crops such as tomatoes, onions, carrots, etc., and the marshes for the production of rice/paddy.

Producers (56%) produce more organic manure from manure pits installed near villages and compost pits established in compost production fields. They are used to restore the fertility of overexploited soils. Most producers (91 %) reacted by adopting techniques such as stone bunds (80%), manual *zaï* (79 %), and half-moons (15%). Animal husbandry is increasingly integrated into agriculture. Animal droppings and household waste are used in the production of organic manure, while other components are involved in compost production. The sale, which is most often done during the lean season, allows the purchase of food. Fallowing is still practiced by 31 % of producers with a period not exceeding three years. It tends to decrease because of the solid human pressure on arable land. The off-season irrigation practiced by 50% of producers is done around water reservoirs and certain rivers for vegetable and cereal crops such as rice and corn. This acquisition is most often made by rental for non-holders of plots. This income allows them to meet their basic social needs such as children's education, health care, etc.

Determinants of adoption of adaptation strategies

The local perception of this phenomenon partly guides the adoption of measures to adapt to climate change. The percentage of good prediction of these models is 66.67 % for the possession of manure pits, compost pits, and the adoption of irrigation, 79.39 % for the adoption of *zaï,* and 80.67 % for the cords. The variables Decline and Delay affect the probability of adopting irrigation at the 5 % threshold. The reduction and the late start of the rains can cause yield losses, affecting producers' agricultural income. Off-season irrigation appears to be an adaptation option in the face of this uncertainty. The Irregularity and Early variables influence negatively and respectively the practice of stone bunds and *zaï*. These two variables do not have a direct effect on the adoption of adaptation practices. Yet, these techniques have been adopted by growers in response to declining fertility in most soils. This reduction is attributable to the adverse effects of climate change and poor agricultural practices.

Socio-economic variables influence the choice of adaptation strategies to climate change. The Petitoutil variable positively affects the adoption of manual *zaï* at the 1 % probability threshold, stone bunds, and manure/compost pits' construction at the 10 % threshold. Of course, you need hoes and pickaxes to dig the *Zai* holes and pits for composting, break up the rubble, collect the stones, arrange them into strings, and remove the soil from the pits. The OP variable negatively affects the practice of *zaï*. Being a peasant organization member does not encourage the producer to adopt manual *zaï,* which is instead a traditional technique for the rehabilitation of degraded lands. The OP variable has a positive effect on the possession of a manure / composting pit at a threshold of 1 %. The Credit and Training variables significantly affect this practice at the 10 % threshold. Most producers are organized in groups and can receive training in organic manure production techniques or composting. Besides, the construction of pits and the production of compost may require a wage labor force. Support from NGOs enables communities to work together in farmer groups to overcome these financial constraints. The Gender variable positively influences the practice of irrigation (at the 5 % threshold) insofar as men are more involved than women in this activity and have more land access than the latter. This access is most often by rental. The Exploitation and Training variables positively influence the probability of adopting irrigation at respective thresholds of 1 % and 5 %. Producers who have received training in market gardening techniques and who own a cash farm are more influenced by this practice, unlike those who have not benefited from it and do not have this type of operation. The socio-economic characteristics of households influence the choice of adopting an adaptation strategy more than the perception concerning the significance of these results.

DISCUSSION AND CONCLUSION

The climate change of the Ruzizi plain decreases and has an irregular rains season, the higher frequency of dry sequences remains the same as that raised by communities in other African countries as stated by researchers (Sarr et al., 2015; Nielsen and Reenberg, 2010; Ouédraogo et al., 2010). Our study highlights a tendency to accentuate extreme climatic events (heavy rains, temperature rises, violent winds) in recent years in the community of the Ruzizi plain. Indeed, Hounghton et al. (2001) predict an increase in the frequencies of extreme climatic events with global warming. The IPCC (2007) also indicates that extreme weather events will become more frequent and intense during Africa's coming decades. Because of these predictions, we can say that the perceptions of climate change by the Ruzizi plain community's local communities are in line with climate trends.

The level of education influences the local perception of changes in precipitation in southern Mali. Its perception of a shift in rainfall pattern increases with the producer's level of education (Sanogo et al., 2016). Our results show the household's size, which significantly influences local perceptions of the decline and the late start of the season. These results are supported by the arguments such that with recurrent droughts aggravated by the decline in fertility of most soils that cause yield losses, large households are no longer able to meet their large group's food demanded by the family. This plunges producers into the preoccupation with waiting for the start of the following rainy season. Also, in other skies, other researchers have mentioned, which is why households whose living conditions depend on the climate manage to detect changes at the start of the season more easily than modifications in the distribution of rainfall and frequency of droughts (Kosmowski et al., 2016). Also, among farmers in Bangladesh's coastal areas, household size significantly influences the perception of climate change (Uddin et al., 2017).

The breeders feel the consequences of rainfall disturbance because of the availability of water and green grass for the herds. According to the Ruzizi plain's reality, the Ruzizi plain collectivity is one of the entities most exposed to the deficit of green grass for packs and currently remains one of the areas at potential risk of land conflicts between herders and herders' farmers because of obstruction of access corridors to water points by farmers. Livestock is suffering the adverse effects of climate change in this region of South Kivu due to short green grass and stagnant water points for long periods of the year, which causes a drop in the frequency daily watering and grazing of animals. Our results do not contradict those of Kenya researchers, who showed that among Turkana pastoralists in Northwest Kenya, livestock ownership (Opiyo et al., 2016). A producer who belongs to a farmer group has more advantages to be informed about climate change and its adverse effects on the environment than one who does not belong to a farmer group. Indeed, these organizations are frameworks for exchanges and training. Information circulates more easily between these groups' members, argued a knowledgeable researcher (Barry, 2016).

The literature maintains that extreme climatic phenomena are fundamental catalysts for the degradation of the biophysical environment. Most of these signs are cited by other researchers more than 25 years ago as indicators of land degradation in Africa's arid and semi-arid areas (Slootweg et al. 1995). Several other studies in West Africa have shown the same results as ours, pointing out that bare soils appear when fields, which have become unproductive due to erosion and reduced fertility, are abandoned without conservation measures. These studies support that the extension of bare soils, gravelly soils, and erosion gullies cause a decrease in cultivable areas and grazing areas (Da et al., 2008; Zombré, 2006; Sawadogo et al., 2008).

The study has shown that the majority of producers have noticed a drop in their yields. The sudden end of the rains prevents crops from completing their cycle. Likewise, the dry sequences that occur during the grain filling phase significantly affect the yield. Most of the plains community's soils are poor in organic matter, strongly affecting agricultural products. Strong winds also damage crops. This also meets other studies' results in different skies (Kosmowski et al., 2015; Sarr et al., 2015). In the semi-arid regions of Burkina Faso, Chad, and Niger, producers have seen declining millet and sorghum yields. This decrease is attributable to climate variability and change's adverse effects, and the decline in soil fertility.

The surveys showed that some producers instead observed an increase in agricultural yields mainly due to farming techniques and improved varieties of seeds. In Beni, on the other hand, the determinants of the adoption of innovative agroecological practices are the increase in crop yields, the improvement of producers' income, the provision or not of material and human resources, and the training of actors (Coulibaly, 2018). In the Ruzizi plain's community, to adapt to climate change's recent adverse effects, producers have put in place strategies and practices. The most important is adopting agricultural techniques, irrigation, possession of manure/compost pits, and varietal adaptation. Recurrent droughts and deforestation have caused a reduction in plant cover, exposing soils to water and wind erosion. The result was a decline in soil fertility, reducing agricultural yields and affecting the income of producers. The latter reacted by adopting techniques such as stone bunds and *zaï*. Different practices have been implemented by local communities in this area, most often with the support of multiple food security projects under the direction and technical support of NGOs and decentralized technical services of the Congolese government. Organic manure/compost is used to restore the fertility of degraded soils to increase agricultural production.

The possession of small agricultural tools significantly influences zaï, stone bunds, and manure/compost pits. Pickaxes and hoes are socio-economic determinants of adaptation to climate change to reclaim degraded land in the Ruzizi plain. This is also the case in Benin, wherein a study it was proved that the possession of tools (such as plows, carts) and the availability of land are socio-economic determinants of the adaptation of agricultural producers to climate change. In soil fertility management (Sabaï et al., 2014). In the last fifteen years, there has been a strengthening of producers' capacities through training which has aroused enthusiasm for several agricultural practices in the community of the plain. Producers who have plots in developed marshes and lowlands are more influenced by irrigation, which is a well-known income-generating activity in the region. Other farmers have adopted the same practices as very promising adaptation strategies to climate change (Zorom et al., 2013).

The Ruzizi plain's local communities that we had to meet within the framework of this study perceive climate change through the drop in rains, the increase in temperature, and the violence of the winds. These climatic hazards harm the biophysical environment with repercussions on agricultural production. This study showed that household socio-economic characteristics influence local perceptions of climate change and adaptation practice adoption. The main adaptation strategies remained essentially adopting new farming techniques, irrigation, the possession of manure/compost pits, and varietal adaptation.

New agricultural practices and the use of organic manure allow the rehabilitation of degraded lands to increase farmers' agricultural yields. Irrigation provides additional income to producers. The use of new varieties of seeds or improved seeds allows an intensification of agricultural production. These current strategies developed by the producers of the plain's community make it possible to make profitable their exploitation. Adopting an adaptation strategy by a producer depends on his perception of climate change and its causes, its negative impacts on the biophysical environment, and the means at his disposal to provide solutions.

Thus, for the community of the Ruzizi plain, there is a need to strengthen the adaptation and resilience capacities of agricultural producers through capacity-building sessions on adaptation to climate change within farmer groups and farmers' organizations. These will help improve their perception of this phenomenon and help them better develop their adaptation strategies. Providing agricultural equipment would strengthen their capacity to rehabilitate degraded lands, which remain visible even to a simple unscientific passer-by.

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APPENDICES

Table 1: List of climate parameters and indicators related to vulnerability and climate change

Climatic parameters	Climate change indicators
Rainfall	Decreased rainfall, intensity, irregularity, late start, early stopping, frequency, and duration of dry spells
Temperatures	Hot days, hot nights, cold days, cold nights, length of cold period
Winds	Violence and frequency
Swirls	Violence and frequency
Dust mists	Frequency and persistence

Table 2: List of model variables and expected signs of the parameters

Variables	Type of variables	Description	
Perception	Qualitative	Dependent variable: 1 if there is perception and 0 otherwise	
Explanatory variables of the model			Expected sign
Age	Quantitative	Number of years of the head of household	Positive
Sex	Qualitative	Takes the value 1 if the producer is male and 0 otherwise	Positive
Level of education	Qualitative	Takes the value 1 if the producer is at least literate and 0 otherwise	Positive
Membership of a peasant organization	Qualitative	Binary variable: 1 if the producer belongs to a peasant organization and 0 otherwise	Positive
Household size	Quantitative	Number of people in charge of the household	Positive
Herd size	Quantitative	Number of cattle owned by the head of household	Positive
Support in the form of credit	Qualitative	Takes the value one if the producer has access to credit and 0 otherwise	Positive or negative

Table 3 : List of model variables and expected results on the adoption of zai, stone bunds, manure pits, and irrigation practices

Variables	Type of variables	Description	
Adoption	Qualitative	Dependent variable : takes the value 1 if an adaptation strategy is adopted and 0 otherwise	
Explanatory variables of the model			Expected sign
Perception variables			
Decreased rains	Quantitative		Positive
Rainfall irregularity	Qualitative		Positive
Late start of the rains	Qualitative		Positive
Rains stop early	Qualitative		Positive
Socio-economic variables			
Gender of household head	Qualitative	Takes the value 1 if the producer is male and 0 otherwise	Positive or negative
Age of household head	Quantitative	Number of years of the head of household	Positive or negative
Level of education	Qualitative	Level of education of the head of household: 1 if the producer is at least literate and 0 otherwise	Positive
Membership of a peasant organization	Qualitative	Takes the value 1 if the producer belongs to a farmer organization and 0 otherwise	Positive
Household size	Quantitative	Number of people in charge of the household	Positive or negative
Support in the form of credit	Qualitative	Takes the value 1 if the producer has access to credit and 0 otherwise	Positive
Training	Qualitative	Takes the value 1 if the producer has already received training and 0 otherwise	Positive
Type of Farm	Qualitative	Takes the value 1 if the producer owns a cash farm and 0 otherwise	Positive
Small tools	Quantitative	Takes the value 1 if the producer has at least one pickaxe or shovel and 0 otherwise	Positive

Figure 1 : Indicator of perception of climate change

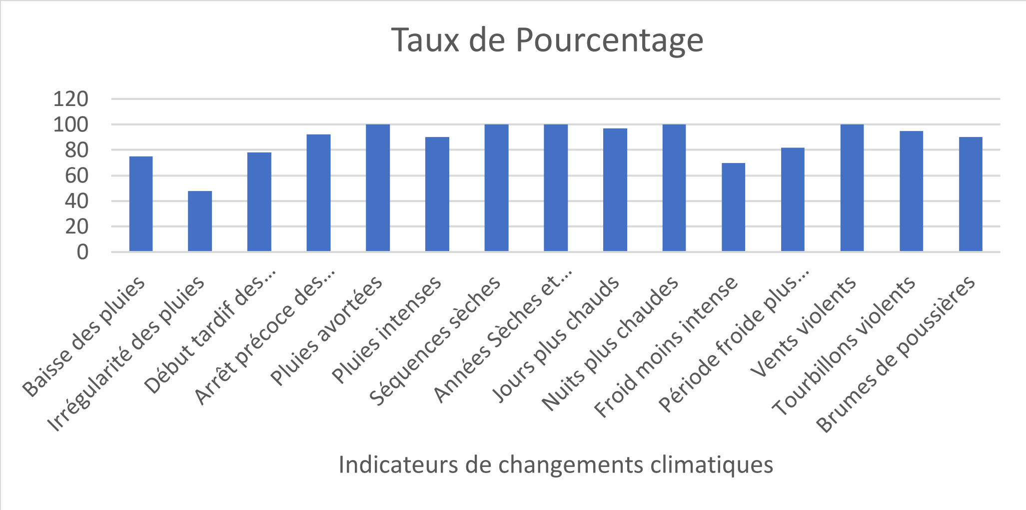

Table 4 : Marginal effects of binary logistic regression on the determining factors of the communities' perception of the disruption of the rainy season

Rainfall	**Drop**			**Late start**			**Early stop**		
Variables	dy / dx	Z	P> | Z |	dy / dx	Z	P> | Z |	dy / dx	Z	P> | Z |
Sex	-0.011	-0.19	0.851	-0.085	-1.47	0.141	-0.031	-1.61	0.106
Age	-0.0024	-0.88	0.381	-0.0016	-0.59	0.556	0.0005	0.61	0.540
Education	-0.073	-1.48	0.140	0.103	1.92	0.055 *	0.0103	0.56	0.575
Household size	0.0125	3.58	0.000 ***	0.0065	1.70	0.0088 ***	-0.0013	-1.16	0.246
Credit	-0.146	-1.21	0.225	0.0721	0.97	0.331	-0.023	-0.79	0.432
OP	0.126	2.44	0.015 **	-0.178	-3.47	0.001 ***	-0.041	-2.18	0.029 **
Cattle	0.0074	1.72	0.085 *	-0.0103	-3.25	0.001 ***	0.0056	2.78	0.005 ***
Number of observations	300			300			300		
Wald chi2 (7)	33.43			23.93			14.47		
Prob> chi2	0.0000			0.0012			0.0435		

Nickname R2	0.0853	0.1035	0.1356
% correctly classified	77.00 %	76.67 %	92.67%

* significant at the 10 % level, ** significant at the 5 % level, *** significant at the 1 % level

Table 5 : Parameters and indicators of environmental modifications

Settings	Indicators of environmental changes
Pedological	Appearance and extension of bare soils Appearance and extension of gravelly soils Silting of cultivation plots Appearance and extension of erosion gullies
Ecological	Appearance and proliferation of *StrigaSp.* in cultivation plots Decrease in herbaceous plants Desiccation and / death of trees
Agronomic	Low agricultural yields

Figure 2 : Perceptions of factors affecting cereal yields

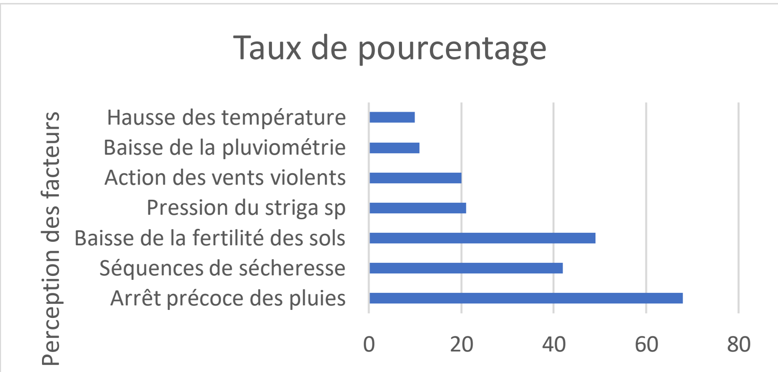

Figure 4 : Farmer practices of adaptation to climate change

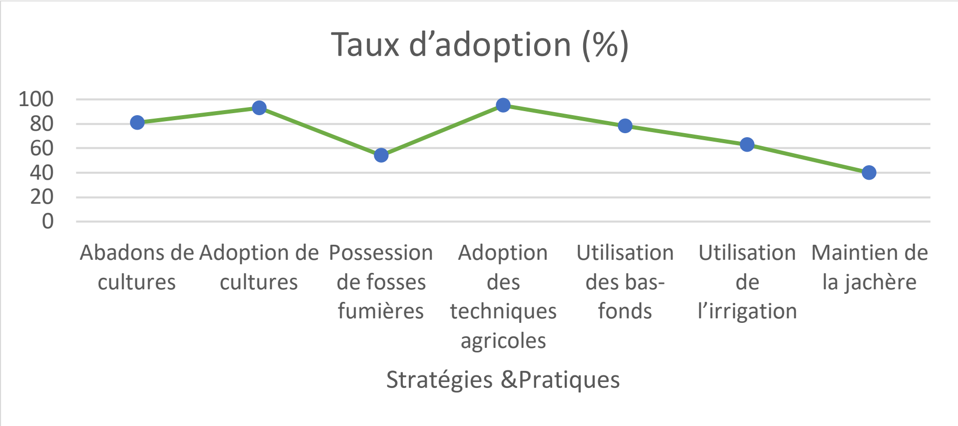

Table 6 : Marginal effects of binary logistic regression on factors determining the adoption of zai and stone bunds

Practice	*Zai*			Stone bunds		
Variables	(dy / dx)	Z	P> ∣Z∣	(dy / dx)	Z	P> ∣Z∣
Drop	-0.046	-0.92	0.357	-0.051	-1.05	0.295
Irregularity	-0.039	-0.84	0.402	-0.121	-2.67	0.007 ***
Late	0.039	0.61	0.540	-0.008	-0.17	0.865
Early	-0.132	-3.11	0.002 ***	0.127	1.22	0.223
Sex	0.036	0.60	0.550	-0.021	-0.39	0.699
Age	-0.004	-1.60	0.111	-0.001	-0.57	0.568
Education	0.009	0.19	0.853	0.017	0.37	0.708
Household size	0.004	1.24	0.216	0.002	0.97	0.333
Credit	-0.095	-0.95	0.343	-0.007	-0.09	0.927
Farmer organization	-0.106	-1.90	0.058 *	0.040	0.76	0.447
Operation	0.060	1.07	0.286	0.023	0.44	0.658
Training	0.040	0.77	0.441	0.057	1.10	0.273
Small tools	0.291	3.99	0.000 ***	0.118	1.93	0.054 *
Number of observations	300			300		

Wald Chi2 (13)	43.29	25.53
Prob> Chi2	0.0000	0.0197
Nickname R2	0.1328	0.0859
Percentage correctly classified	79.39 %	80.67 %

* significant at the 10 % level, ** significant at the 5 % level, *** significant at the 1 % level

Table 7 : Marginal effects of binary logistic regression on determining factors of possession of manure / compost pits and adoption of irrigation

Practice	**Manure pits**			**Irrigation**		
Variables	dy / dx	Z	P> | Z |	dy / dx	Z	P> | Z |
Drop	-0.098	-1.32	0.186	0.145	1.84	0.065 *
Irregularity	-0.058	-0.89	0.374	-0.111	-1.63	0.102
Late	-0.022	-0.28	0.780	0.47	1.94	0.053 *
Early	-0.008	-0.07	0.947	-0.092	-0.71	0.477
Sex	-0.065	-0.76	0.446	0.214	2.55	0.011 **
Age	-0.003	-0.93	0.355	-0.001	-0.31	0.758
Education	-0.028	-0.42	0.675	-0.011	-0.16	0.869
Household size	0.002	0.47	0.641	-0.007	-1.61	0.108
Credit	0.191	1.85	0.064 *	0.067	0.55	0.582
Farmer organization	0.202	2.65	0.008 ***	0.113	1.48	0.139
Operation	0.089	1.16	0.248	0.216	2.71	0.007 ***
Training	0.119	1.65	0.099 *	0.149	2.04	0.042 **

Small tools	0.131	1.81	0.070 *	-0.011	-0.15	0.880
Number of observations	300			300		
Wald Chi2 (13)	41.24			35.82		
Prob> Chi2	0.0001			0.0006		
Nickname R2	0.1092			0.1155		
% correctly classified	66.67 %			66.67 %		

* significant at the 10 % level, ** significant at the 5 % level, *** significant at the 1 % level