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Perceived Impacts of Climate Change and Farmers' Choices of Adaptation Practices in the South Kivu's Marshlands

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Abstract The South Kivu province of the Democratic Republic of Congo has several marshes where smallholder farmers grow various crops including vegetables, beans and sugarcane for cash income and subsistence, but these farmers are facing the challenge of changing climate. While recent studies have reported negative impacts of climate change on agricultural food production in the study area, the determinants of farmers' choices of adaptation strategies have not been addressed so far. Field observation and farmers' interviews were conducted within 4 marshes of Kabare in the South Kivu province in order to identify the perceived impacts of climate change and the determinants of farmers' choices of adaptation strategies. Climate change impacts reported among farmers were respectively the declining of soil fertility, the occurrence of floods, and the presence of new pests such as millipedes and fall armyworm (*Spodoptera frugiperda*) which lead to crop failure, food shortage and loss of income. Climate change adaptation practices used by farmers included the cleaning of and maintaining ditches, the use of manure, mulching, and crop diversification, crop type change and late sowing. The choice of some of these strategies was significantly determined by farmers' experience, time worked per day in the farm, discussions and exchanging information among fellow farmers, livestock ownership, land-holding status and the size of the farm as well as farmers' perception of climatic risks to crops. Strong, positive and significant correlations recorded between some of these factors (*e.g*: livestock ownership, information exchanging) and adaptation strategies suggest that promoting family livestock and improving farmers' access to information systems could enhance the resilience of agricultural systems to climate change.

Keywords: *farmers, adaptation practices, marshes, climate change, Kabare*

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1. Introduction

Climate change is a global issue and perceived as a potential threat to food security worldwide. In Africa, while the number of hungry and malnourished people was already on the rise due to an increase in violent conflicts and structural issues (impassable rural roads, lack of access to services [1,2], the ongoing pandemic COVID-19 and climate change threats are expected to severely affect smallholder farmers, and this will result in reduced farmers' income as well as in disruption of food and agricultural input supply [3,4]. The combined effects of climate change and socioeconomic stressors as well as COVID-19 worsen farmers' vulnerability and reduce efforts to fight poverty. In many parts of the world, crops are frequently exposed to pest and disease outbreaks and extreme weather events such as flooding and/or long drought and strong winds which cause significant crop loss and exacerbate food insecurity [5,6]. In the Democratic Republic of Congo (DRC) where more than 70% of the population lives in rural areas and depends on the rain-fed crops for food and income [7,8], climate change threatens farmers' livelihoods and welfare of the entire population. Recent studies across whole the country have highlighted important changes in rainfall patterns, in temperature and wind trends [9,10] as well as their

negative impacts on food production [4,11]. According to Bele *et al.* [9], the major changes observed in South Kivu include more heavy rain, long dry spells, changes in seasonal rainfall patterns and unseasonal rainfall. Brevik [12] and Gezie [13] reported that these changes will accelerate land degradation problems, lower soil organic matter levels, water holding capacity, cation exchange capacity, and soil nutrient content. In the marshes of Kabare, smallholder farmers grow various vegetables (cabbage, amaranth, carrot; squash, eggplant, beans) and sugarcane, cassava and taro as well as sweet potatoes for cash and subsistence. Recent studies have highlighted the typology and the determinants of the performance of these family farms as well as the risks perceived by farmers [14,15,16], and other specialists also assessed farmers' perception of cropland degradation [17], and the adoption of agricultural technologies [18,19]. However, the perceived impacts of climate change in marshes and the determinants of smallholder farmers' choices of the adaptation strategies used on farm level have not been addressed so far. Yet, climatic disturbances were reported by many farmers in Kabare as one of the major constraints hindering agricultural food production [15,16]. We hypothesized that the determinants of farmers' choices of the adaptation strategies depend on their socioeconomic status as well as their perception of climatic threats to crops and other livelihoods. In this study, we used farmers' interviews and econometric tools to identify the perceived impacts of climate change and explore the factors influencing farmers' choices of the adaptation strategies used to withstand risks or impacts associated with the variability in climatic conditions. The specific objectives were to 1) examine the perception of smallholder farmers of climate variables trend (rain, temperature, wind), 2) identify and discuss the perceived impacts of climate change, and 3) highlight the determinants of farmers' choices of the adaptation strategies used on farm level. The results of this study will help to have an increased understanding of the farmers' choices and practices that derive from local knowledge in order to minimize crop failure in an uncertain environment.

2. Materials and Methods

2.1. Description of the Study Area

This study was conducted from April to June 2020 in 4 marshes (Kabirundu, Kanosha, Kavule, Nakishangizi Kiko) located in the territory of Kabare, around the town of Bukavu, in the province of South Kivu eastern DR Congo (Figure 1).

The choice of these marshy sites was motivated by 4 reasons: (1) the sites are large (± 10 hectares each) and exposed to climatic hazards such as floods, (2) they provide a good mount of vegetables and other food commodities consumed in Bukavu, (3) many women and young school dropouts work there for their financial autonomy. (4) No study has so far dealt with their farming practices and their perceptions of climate change. The study area has a humid tropical climate characterized by a rainy season from September to May and a dry season from June to August. The Figure 2 presents the ombrothermic diagram of the study area.

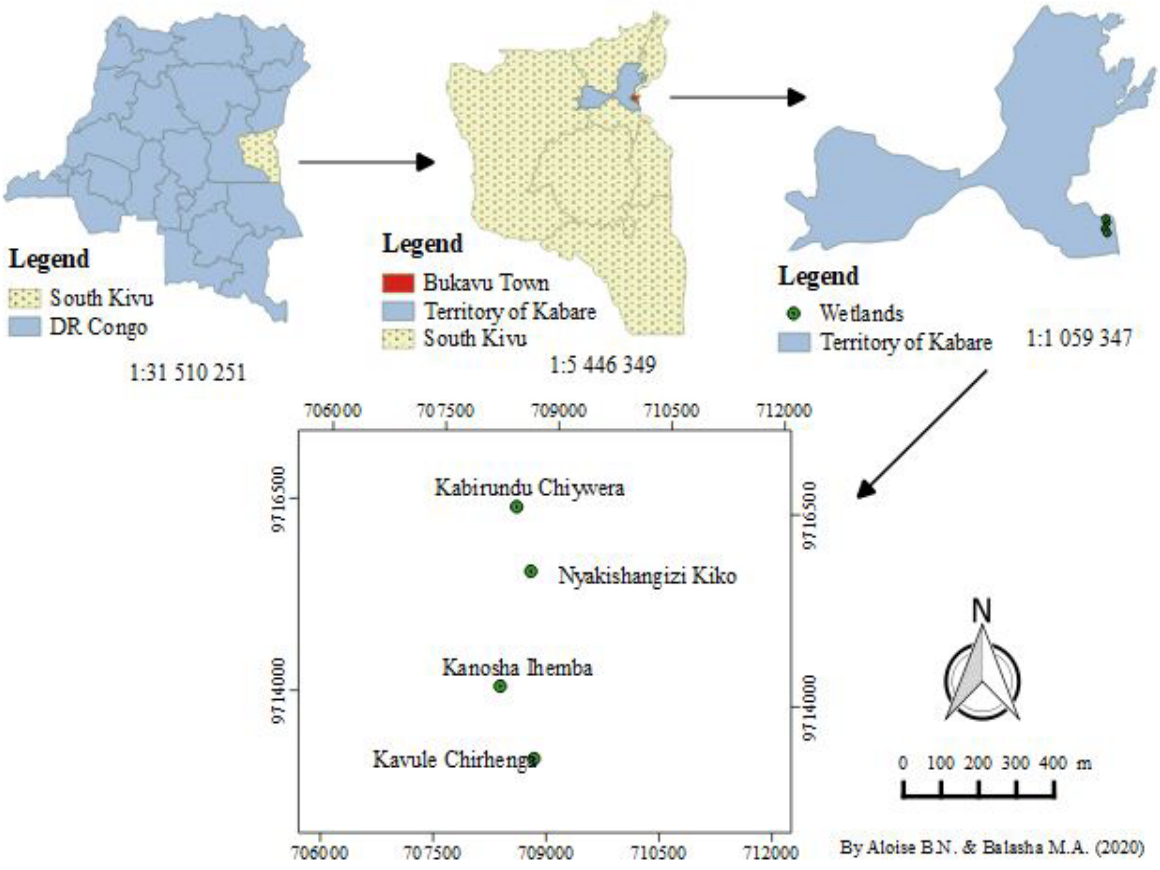

Figure 1. Map of South Kivu (eastern DR Congo) showing the marshlands studied

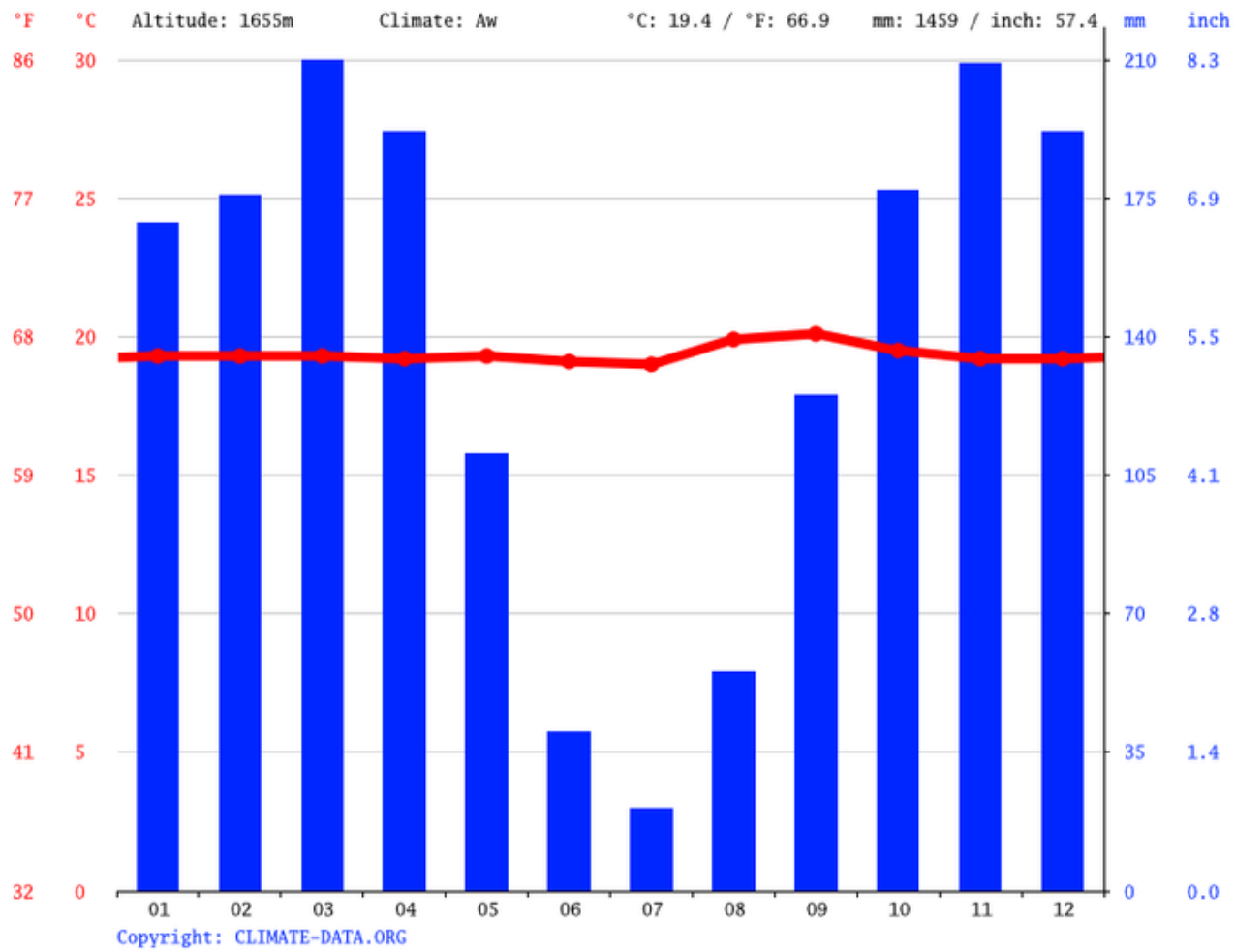

Figure 2. Ombrothermic diagram of the study area

2.2. Data Collection and Analysis

A semi-structured questionnaire was used to collect information during the field visits and interviews among 148 farmers chosen randomly within the four wetlands sites investigated (see Figure 1). Information collected included (1) farmers' socioeconomic characteristics: gender, age, access to land, sharing information with fellow farmers, farm size and crops grown as well as farming objectives) (2) the local perception of climate parameter trends (rain, temperatures and winds). The choice of climate variables in the analysis of farmers' perceptions of climate change is explained by their direct influence on crop growth and agricultural production [20,21] (3) The perceived impacts of climate change included the decrease of crop yield, loss of fertility, floods, loss of crops and income, and appearance of new pests). (4) Farmers' adaptation strategies were identified by using interviews and observing farmers' practices during our field visit (use of manure, cleaning up rivers, drainage, crop diversification, and mulching, shifting sowing dates, and the exchange of farming and weather information among farmers). Descriptive statistics were used to summarize data in frequencies and percentages. Furthermore, a binary logit model was performed to investigate the determinants of farmers' choices of the strategies used at farm level.

3. Results and Discussion

3.1. Socioeconomic Profile of Respondents

Table 1 presents the socioeconomic characteristics of farmers surveyed within the 4 marshes. Results show that the majority of farmers were women (65%) and men counted for 35% and all farmed mainly for both cash income and food. These farmers produced various vegetable crops including squash, cabbage, amaranth, and eggplant on small farms ranging between 1 and 10 ares. They worked within their farms on average 6.2 hours per day and 53% claimed discussing farming issues and exchanging agricultural information with fellow farmers. More than half (54%) of the respondents were land owners and 46% land tenants.

Our results are in agreement with a previous study by [16] which showed that more than 65% of women in rural and periurban areas of Bukavu are involved in agriculture for cash and substance. In vegetable production sector, these women decide of the crops to grow, maintain the fields and commercialize the harvests on local markets [22,23,24]. Exchanging information among farmers is important because they share experience and discuss benefits of agricultural innovations. For instance, exchanging information and knowledge through field farmers' schools was found to increase the adoption of sustainable practices

in urban agriculture in Lubumbashi and helped farmers reduce unnecessary pesticide applications [23,25].

Table 1. Socioeconomic profile of marshland farmers (n=148)

Variables	Category	Frequency	Percentage
Gender	Men	52	35
	Women	96	65
Age groups	15-29	25	17
	30-44	50	34
	45-59	44	30
	60-75	29	19
Farmer' experience (years)	1-9	84	57
	≥10	64	43
Land -holding status	Land owner	80	54
	Land tenant	68	46
Farm size	4 ares	124	84
	5- 9 ares	22	14
	>10 ares	2	1
Hours worked Mean = 6.25	≤ 4h	11	8
	5-8h	135	91
	≥9h	2	1
Hired casual labor	Yes	116	78
	No	29	22
Exchanging information	Yes	79	53
	No	69	47
Main crops grown	Vegetables	141	95
Farming goals	Only for Subsistence	29	20
	Only for income	12	8
	Both	107	72

3.2. Farmers' Knowledge and Perception of Climate Change

Figure 3 presents farmers' knowledge and their perception of climate change. Most of the farmers (76%) observed these last 10 years changes in rainfall pattern: heavy rains (72%), late rains (56%) and short. Temperatures are increasing (67%) and it is more windy (32%) than before whereas 47% of the respondents mentioned a long dry season. Like this respondent N° 5, many farmers said: *in past years before 2000, it rained early by September, we rushed to plant cassava and sowing beans, to date, we experience a relative long dry season.*

Farmers relied on the seasonal rainfall pattern, the trend of temperature and winds to read and appreciate the climate change in their environment. This is normal because these climate variables influence the plant growth and the crops' outputs [20]. Local meteorology plays an essential role in many farming operations such as wedding and spraying pesticides [26]. Farmers' perceptions are also shaped by what they can see or feel about the climate and its impacts on crops [9,21]. However, it is not possible for us to determine whether or not these perceived changes are accurate, owing to the lack of reliable long-term climatic data in the province. Regardless of their perceptions, the changing climate threaten family agriculture because it is totally rain-dependent [5,27].

3.3. Perceived Impacts of Climate Change among Marshland Farmers

The perceived impacts of climate change among farmers are presented in Figure 4. Farmers ranked these impacts as follows: the majority of farmers observed crop failure due to floods (75%), the decrease in soil fertility (73%), the presence of new pests such as millipedes and *Spodoptera frugiperda* (68%) which lead to the decrease in crop yields (56.1%). Farmers also claimed that changes in climate conditions,(*e.g.* heavy rain, flood) disrupted farming activities (27%), led to crop rot (30%), food shortage (39%) and loss of income (47%). These Farmers' views are in agreement with many scholars' predictions that show that climate change will favor pest outbreaks and crops failure resulting in decreased yields and food insecurity [6,28,29]. Land degradation, loss of fertility and pest outbreak are among the major constraints hindering food production in the tropic [17,30]. These negative impacts raise more concerns among farming communities, especially in the DR Congo where family farming is still a main livelihood and often the unique source of income for many households [7,8,23].

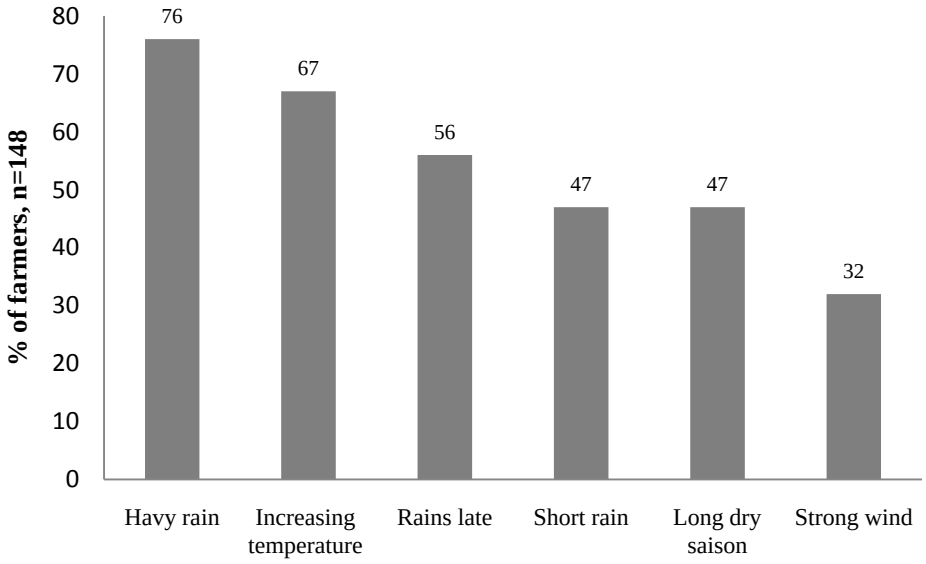

Figure 3. Farmers' knowledge and perception of climate change

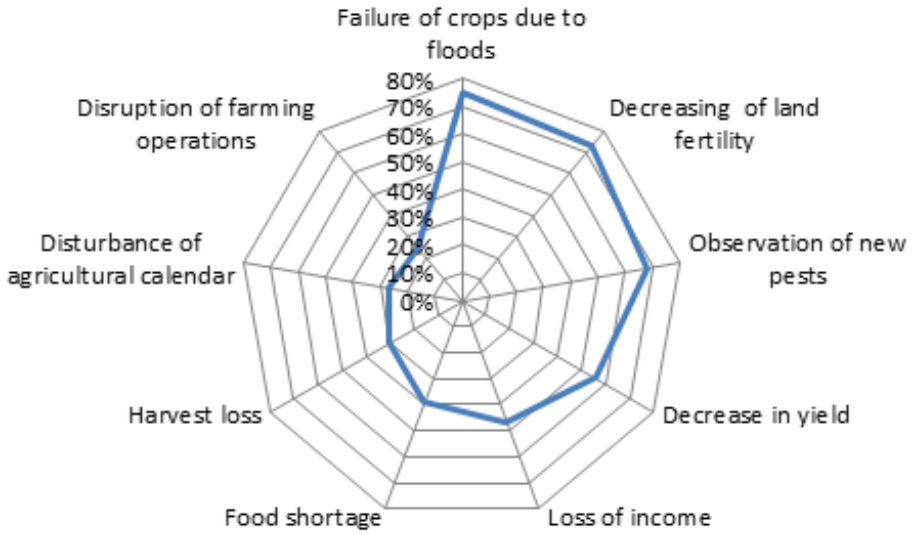

Figure 4. Perceived impacts of climate change among smallholder farmers in Kabare marshlands (n=148)

3.4. Climate Change Adaptation Strategies and Determinants of Farmers' Choices

Farmers used various adaptation measures to withstand hazards associated with the change or variability in climatic conditions (Table 2). All farmers maintained /drained ditches (water canals) crossing their farms before plowing and planting. Almost of farmers used manure and mulch to respectively fertilize crops and protect soil from erosion and minimize water evaporation. A large part of these farmers diversified crops (82%) whereas the change of crop type was reported among 58% of the respondents. More than half of the farmers (53%) confirmed often discussing and exchanging information with fellow farmers on farming practices, soil fertility and pest management and the trend of prices of agricultural food commodities on local markets.

Table 2. Climate change adaptation strategies developed by farmers

Farmers practices	Frequency	Percentage
Maintance of ditches	148	100
Use of manure	146	99
Mulching	140	95
Crop diversification	122	82
Change of crop type	86	58
Early harvest	65	44
Late sowing	54	37

The findings of this study also show that farmers can combine several adaptation strategies on the same plot to minimize risks and threats to crops. This is consistent with a study conducted in Kenya, where Asayehegn [29] reported that the negative effects of climate change on households' livelihoods lead farmers to test different climate change adaptation measures. The choice of the adaptation measures are often positively correlated with farmer socioeconomic status and climate information that have farmers [5, 29]. Table 3 presents the determinants of farmers' choices of the adaptation strategies to climate change. Although positive and strong correlations were recorded between different variables examined, only the variables that were statistically significant are interpreted and discussed. The results in Table 3 show that farming experience (if more than 5 years) increased the likelihood of crop type change and crop diversification at 10% significance level compared to the base category. Farming experience helps to stimulate response to the negative effects of climate change on agriculture. This is because more experienced farmers are assumed to have better knowledge about weather information and its implication on agricultural practices [31]. Our findings also demonstrate that owning a livestock within farmer' household influenced positively and significantly farmer' decision to diversify crops. This is because the livestock generates income to purchase necessary agricultural inputs and provides manure to fertilize crops [32,33]. Access to land and the size of plot cultivated were found to influence farmers' decision to diversify crops and harvest early. This is consistent with Makate *et al.* [34] who argued that accessing land as a resource is a major factor that determines the number of crops that can be grown and harvested on given piece of land.

The cleaning of water canals and the drainage made swampland flooded cultivable and such operation help to reduce the risk of pollution and crop failure [35]. Farmers mulched and applied manure because they both maintain and improve soil proprieties. For many farmers, the mulching is the cheapest and easiest way to limit the emergence of weeds and water evaporation during the dry season and protect vegetables from strong heat. This is in agreement with many scholars [30, 36] who recommend the use of mulching and organic matters because both combined have the potential to improve soil proprieties, biological activities and prevent soil degradation. Resorting to sustainable agricultural practices as recommended by these latter authors constitutes also a strategic and an inexpensive way to minimize production costs in developing countries where the increasing prices of agricultural inputs often prevent smallholder farmers from adopting and using new agricultural technologies.

Therefore, strengthening farmers 'knowledge of the issues addressed and improving their access to information will strengthen the resilience of smallholder agriculture and local food systems threatened by climate change [4,9,37].

Table 3. Parameter estimates of the determinants of adaptation practices among marshland farmers

Variables	Manure Coef.	Mulching Coef.	Early harvest Coef.	Crop type change Coef.	Drainage Coef.	Crop divers. Coef.	Late sowing Coef.
Gender	-0.663	0.437	0.591	0.162	-0.117	0.642	0.051
Farmer experience	-0.839	1.063	0.323	-0.688*	0.375	-1 .284*	-0.393
Available labor	-0.137	-0.347	0.322	-0.203	-0.097	0.501	0.199
Farming goal	18.688	-0.094	0.621	-0.532	0.797	0.608	-0.473
Livestock ownership	1.136	0.676	-1.007	0.021	-0.521	1.591*	-0.060
Climatic risks	17.581	0.751	0.633	0.456	-1.310	0.844	1 .370*****
Exchanging infos	0.698	0.909	0.073	-0.526	-1.910**	-0.642	0.615
Land-holding status	-0.734	0.099	-0.801*****	0.150	0.086	0.594	-0.202
Time worked /day	1.147	-1.640*	0.217	0.538	-0.021	2.441	0.454
Farm size	1.680	0.547	-0.226	0.255	-0.529	1.119*****	0.015
Constant	29 .724	-5.141	-0 .827	0 .949	2.949	-11.514	-1.261

Number of observation: 148, Coef. = coefficient, * and **, Significant at 10 and 5% probability level, respectively.

4. Conclusion and Recommendations

This study focused on agriculture within marshes and used farmers' interviews to identify the perceived impacts of climate change. It has also examined the determinants of farmers' choice of different strategies used at farm level to withstand risks associated with the variability in climatic conditions. The results show that the majority of farmers have perceived changes in rainfall and temperature trends, and experienced the effects of a changing climate since entering the 2000s. Findings also showed that the major concerns reported by farmers included the decline of soil fertility and the occurrence of new pests as well as floods which jeopardize farmers' livelihoods. Several strategies are currently used, often in combination in order to respond to these perceived impacts. Farmers' choice of adaptation practices is determined by both their socioeconomic status and the perception of climatic threats to crops. The resilience of agriculture in marshlands will require a technical support to strengthen farmers' knowledge of the agro-ecological practices and pest as well as flood management. It will be interesting to incorporate farmers 'endogenous knowledge into any project or resilient program aiming to address agricultural problems within marshlands.

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