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Farmers' Perceptions towards Climate Change, and Meteorological Data in Kahuzi-Biega National Park Surroundings, Eastern DR. Congo

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Abstract:

Climate change nowadays is recognized as one of the most challenging and complex problem facing the agricultural development globally. However, the vulnerability of climate change on this sector in Africa is more than any other socioeconomic activities. This paper assesses smallholder farmers' perceptions about climate change in the surrounding areas of the Kahuzi-Biega National Park in Eastern DR Congo. We also used thirty nine-year observed climate data (1980-2019) to corroborate farmers' perceptions about climate change. The Mann-Kendall Test and SPSS were used for data analyses, while qualitative data were thematically analyzed. The results showed that from 1980 to 2019 the mean annual rainfall decreased ($R^2 = 0.11$) while temperature increased ($R^2 = 0.43$).

The major adaptation strategies identified included use of improved varieties and crop rotation (47.78%), early planting (53.33%), agroforestry practices (52.23%), planting early maturing varieties (38.89%), planting resistant varieties (46.67%), adoption of irrigation techniques (22.22%), and Integrated management of soil fertility package (65.55%). Results of logit regression analysis indicated that the access to extension services, credit, soil fertility, and land tenure are the most important factors that influence farmers' perception and adaptation. The main barriers included lack of information on adaptation strategies, poverty, and lack of information about weather. Even though the communities are highly aware of climate issues, only 44.4% of farmers have adjusted their farming practices to reduce the impacts of increasing temperature and 40.6% to decreasing precipitation, giving lack of funds as the main barrier to implementing adaptation measure.

Keywords: Climate change, farmers' perceptions, KBNP, rainfall and temperature pattern

1. Introduction

Now-a-days, climate change especially, Global climate change is threatening to undo decades of development efforts due to its negative impacts on agriculture, health, environment, roads, and buildings especially in developing countries (Mendelsohn et al. 2006; IPCC, 2007; Stern, 2007). It is a particular threat to the attainment of the Sustainable Development Goals (SDGs) and progress in sustainable development in South Kivu province in Eastern DR Congo. Increasing temperatures and shifting rain patterns across Eastern DR Congo reduce access to food and create effects that impact regions, farming systems, households, and individuals in varying ways. Thus, analyses of the biophysical and socioeconomic factors that determine exposure, adaptation, and the capacity to adapt to climate change are urgently needed so that policymakers can make more informed decisions. There is mounting evidence that smallholder farmers in developing countries are experiencing increased climate variability and climatic change.

In South Kivu, weather-related events such as prolonged dry seasons, floods, storms, mudslides, extreme rainfall, and delayed/early rains have become more frequent and/or intense. This has left most of the rural poor farmers' food insecure and their livelihoods threatened. It is expected that climate change will include more extreme events and slow onset impacts, such as changes in precipitation and temperature. Climate change is thought likely to have mainly negative impacts upon agricultural production, food security and economic development, especially in developing countries (Hannah et al. 2008). It is now well rehearsed in the literature that the impacts of climate change will be felt most by the poorest who have least resources with which to cope and whose livelihoods are disproportionately reliant on climate-sensitive natural resources. Strengthening the adaptive capacity of, and promoting specific agricultural adaptations among, smallholder farmers and organizations will enhance their ability to respond to climate change impacts. New opportunities are arising, including tapping into climate finance mechanisms, which Fairtrade organizations may be able to access to both mitigate and adapt to climate change.

Understanding farmers' perceptions regarding rain-falls had been highlighted in many studies (Simelton et al. 2013). Sub-Sahara Africa (SSA) is among the most vulnerable continents or regions to climate change impacts, because the majority of the SSA population lives in abject poverty, and are heavily dependent on rainfed agriculture for their economic and livelihood sustenance. Climate change nowadays is recognized as one of the most challenging and complex problem facing the agricultural development globally (Teshfahunegn et al. 2016). However, the vulnerability of climate change on this sector in Africa is more than any other socioeconomic activities (Fedoun et al. 2017).

Africa's one of the most important sector is the Agriculture. It holds approximately one-third of the GDP. Almost half workforce of Africa is depending on this field (Ngaira and Musiambo, 2012). Climate change threatens this economy because agriculture in Africa is climate-dependent (Mendelsohn, 2000). The African agricultural sector relies heavily on direct rainfall, and patterns in economic growth closely follow precipitation patterns. Staple crops such as wheat and corn that are associated with subtropical latitudes may suffer a drop in yield as a result of increased temperature. In addition to climate change effects, food production in SSA has not kept pace with the growing population.

Almost half reduction can be noticed by 2020. It can drastically goes up to 90% at the end of 2100. The most affected farmers will be small scale farmers. As per a report of UNDP (2006) Report on Human Development, 36% of malnourished people are from sub-Saharan Africa. This contributes 17% of the world's malnourished population. People depending heavily on the agriculture, hampered by the climate change and land degradation, fluctuating rainfall etc. (Ngaira and Musiambo, 2012).

The 4th Assessment Report of the (IPCC) Intergovernmental panel on climate change 2007 confirmed that 'Africa is one of the most vulnerable continents to climate variability and change because of multiple stresses and low adaptive capability. Climate change is the gravest and most complex problem impacting the planet and its people in the twenty-first century. Africa is particularly vulnerable to climate change. Climate change is in fact one of the most serious environmental, social and economic threats the world has ever faced affecting different sectors of life. It particularly has the potential to deepen poverty, food insecurity, poor livelihoods and unsustainable development especially in developing countries (FAO 2005; IPCC 2007). So, anticipating or adapting to climate change impacts become a necessity in order to minimize their consequences on human well-being and on the environment (Locatelli et al. 2008; Sonwa et al. 2012).

As per Thompson and Scoones (2009); Adger (2006); Below et al. (2015), in agricultural domain, climate change is contributing the most. In SSA, extreme levels of drought are hampering the food security (Kebede et al. 2011; Songok et al. 2011). According to Porter et al. (2014), African food production is getting mostly affected by the climate change. Food access and food utilization contributes significantly in the food security literature (Misselhorn 2005). Earnings, physical condition and assets are also affecting the resident's well-being (Bashir and Schilizzi 2013) as well as the climate change impacts. A growing number of studies have been published regarding farmers' self-assessment of risk associated with climate change hazards as a key in improving climate change adaptation (IPCC, 2014; Niang et al. 2014). Perceiving climate variability is the first step in the two-step process of adaptation (Deressa et al. 2009). Exploring farmers' perception of climate variability and barriers to adaptation is, therefore, essential for adaptation research. For majority of the farmer, rainfall and temperatures affect the production of food mostly. For the farmers, droughts perceived as bad years (Ahmed et al. 2011, Rowhani et al. 2011, Sovacool et al. 2017). The literature shows, change in perception on climate change at the local and global levels (Paavola, 2008; Kilembe et al. 2012; Below et al. 2015, Sieber et al. 2015) and point out that farmers' perception are very important.

This study examined farmers' perceptions of long-term climate change, adaptation measures undertaken, and the determinants of adaptation (Table 5) decisions based on household surveys conducted in surrounding areas of the KahuziBiega National Park (KBNP). This analysis aimed to strengthen understanding about farmers' decision-making process to enable policymakers and other stakeholders to support adaptation to climate change at the farm-level. While agricultural adaptation to climate change involves more than farm-level changes in farming practices, farm-level adaptations are an essential component of adaptation of agricultural systems. To address issues and concerns, there is a need for a comprehensive assessment of farmers' perceptions and adaptations to climate change in KBNP surrounding areas.

This paper aims to better understand the extent to which the perceptions of smallholder farmers about climate change hazards can be reliable in the KBNP highland sector surrounding areas. This article seeks to: (i) identify KBNP surrounding areas farmers' perceptions of climate and climate variations, and changes; (ii) examine the nature of meteorological evidence for the perceived climate variability and change; (iii) document farmers' responses to perceived climate variability and change; (iv) discuss why discrepancies may occur between farmers' perceptions and meteorological observations of rainfall, and (v) recommend plausible policy interventions that match farmers, perceptions, experiences, adaptation strategies and coping mechanisms in the study area.

2. Material and Methods

2.1. Biophysical Description of the Study Area

Straddling the Albertine Rift and the Congo Basin, KBNP is an exceptional habitat for the protection of the rainforest and the eastern lowland gorilla, *Gorilla berengeigraueri*. Extending over 600,000 ha, are dense lowland rainforests as well as Afro-montane forests, with bamboo forests and some small areas of sub-alpine prairies and heather on Mounts Kahuzi (3,308 m) and Biega (2,790 m). The Park contains a flora and fauna of exceptional diversity, making it one of the most important sites in the Rift Albertine Valley, it is also one of the ecologically richest regions of Africa and worldwide. In particular, the most important world population of eastern lowland gorillas (or Grauer gorilla), sub-species endemic to the Democratic Republic of the Congo (DRC) and listed under the *endangered* category on the IUCN Red Data Book, uses the mosaic of habitats found in the property. The park is a UNESCO World Heritage Site, inscribed in 1980 for its unique biodiversity of rainforest habitat and its eastern lowland gorillas' population.

A corridor of 7.4 km (4.6 mi) width joins the mountainous and lowland terrain. The eastern part of the park is the smaller mountainous region measuring 600 km² (230 sq mi); the larger part measures 5,400 km² (2,100 sq mi) and consists mainly of lowland drained by the Luka and Lugulu rivers which flow into the Lualaba River. Two dormant volcanoes are set within the park's limits and lend their names to it: Kahuzi (3,308 m (10,853 ft)) and Biega (2,790 m (9,150 ft)). The park receives an average annual precipitation of 1,800 mm (71 in). The maximum temperature recorded in the area is 18 °C (64 °F) while the minimum is 10.4 °C (50.7 °F).

The KBNP harbors three main vegetation types according to the altitude, including lowland forests (stretching from 700 m to 1250 m a.s.l), sub montane forests (from 1250 m to 1800 m) and highland forests from 1800 m to 3315 m a.s.l (Fischer, 1996; Mangambu, 2013). This study covers only the highland forests (Figure. 1). The orographic effects of the Jos-Plateau and the Kagoro Hills have positive influence on the climate of the study area influencing rainfall, temperature and relative humidity.

The KBNP is established in two main climatic zones. The lowland areas undergo an equatorial climate where it rains almost throughout the year. Precipitations are high and can reach more than 2 600 mm; temperature varies between 15 and 25°C. In the highland areas and sub montane forests, the climate is characterized by 3 to 4 months of dry season and lower rainfall (mean: 1 900 mm; Fischer, 1996). The highlands are dominated by hills and marshes. They are located in the Albertine rift, a biodiversity hotspot (Plumptre et al. 2008). In terms of phytogeography, the highlands are part of the afro-montane center of endemism but the lowlands belong to the guineo-congolese center of endemism (White, 1986).

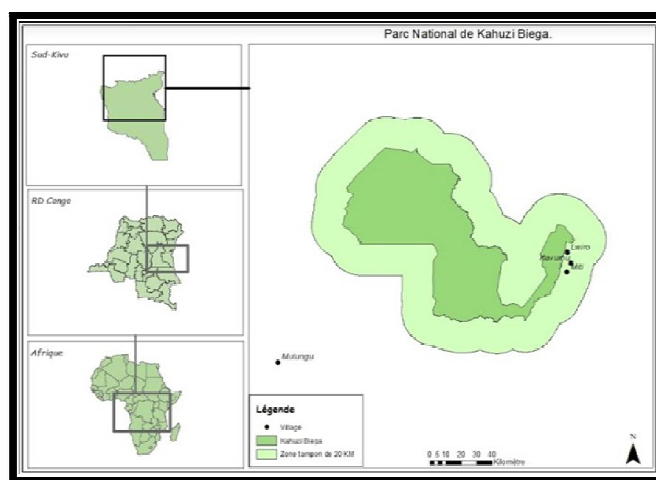


Figure 1: Map Showing the Location of Kahuzi Biega National Park and Surrounding Areas

2.2. Data Collection and Processing

Primary data were collected from September 2017 to March 2019 from the area highlighted in Figure 1. Both quantitative and qualitative data have been collected from the primary and secondary sources. Purposive sampling has been employed to collect the data. The description of the sample has been shown in the Table 1. Similar methodology has been adopted by Simelton et al. (2013) and Gebreyesus et al. (2017). After selecting the study area through purposive sampling, simple random sampling was used to select the villages. Sample size of farmers is 180. Three communities were selected based on their agricultural production and proximity with the KBNP (Ntahombagana Mitima, 2019; Nyamunyere Malira, 2019). Focus has been placed in research questions on religion, ethnicity, health statuses etc. For doing qualitative research, six focus groups were conducted. Each focus group consists of 8 to 18 farmers. A total of five themes have been focused for this study; namely: socio-economic, climate change information, perception, perception towards rain fall patterns etc.

At the initial stage, general understanding toward climate change and the level of confidence of farmers have been studied. They also requested to provide details of their strategies. Second, we asked questions on whether the governing policy gave any guidelines they are following or not. Third, through open-ended and non-prescriptive questions, benefits,

risks and barriers of integrating adaptation and mitigation strategies have been studied. The rainfall and temperature data from 1980 to 2018 were collected from AgMERRRE Meteorological dataset (2019).

Variable	Frequency	Percentage	Mean
Age Below 21	6.0	3.33	
21 – 30	10	5.58	
31 – 40	48	26.67	47.5 years
41 – 50	60	33.33	
51 – 60	28	25.56	
Above 60	28	25.56	
Gender			
Male	153	85	
Female	27	15	
Level of education			
None	64.5	35.83	
Primary	62.5	34.72	
Secondary	31.5	17.51	
Tertiary	23.5	11.94	
Years of farming experience			
1 – 10 years	18	10.00	
11 – 20 years	48	26.67	
21 – 30 years	37	20.55	37 years
31 – 40 years	57	31.67	
Above 40 years	20	11.11	
Farm size (ha)			
0.1 – 0.5ha	126	70.0	
0.6 – 0.10ha	28	15.5	0.3 ha
Above 0.10ha	26	14.5	
Household size			
1 – 10	89	49.45	6.2
11 – 20	53	29.44	
21 – 30	26	14.44	
31 – 40	12	6.67	
No of social organizations belonged			
None	60	33.33	
1 – 2	83	46.11	1 social org.
3 – 4	29	16.11	
Above 4	8	4.45	
Annual income level (CDF)			
Below CDF500,000.00	113	62.78	
500,000 – CDF1000,000.00	55	30.55	CDF391,753.20
Above CDF1000,000.00	12	6.67	
Past 5 years (CDF)			
None	118	65.28	
1,000 – 500,000	36	19.72	
501,000 – 1,000,000	18	10.28	CDF52167.6
Above 1,000,000	8	4.72	
Land tenure system			
Inherited	121	67.22	
Purchased	12	6.67	
Leased	8	4.44	
Hired	16	8.89	
Family/community	23	12.78	

Table 1: Distribution of Respondents According to Their Socioeconomic Characteristics (N = 180)

CDF: Congo Democratic Currency
Source: Field Survey Data, 2017-2019

2.3. Data Analyses

A closed ended questionnaire has been used as a data collection instrument. Statistical Package for Social Science (SPSS 25) has been used for running quantitative tests. Variability of temperature and rainfall on yearly and monthly levels has been captured from 2010 to 2019. The analysis has been done using the Mann-Kendall Test and Microsoft excel (window 19). The descriptive study has been done using descriptive statistics. A binary logit model can be use to study this type of scenario (Fosu-Mensah, 2010; Mustapha et al. 2012; Muzamhindo et al., 2015):

$$Y = f(X_1, X_2, \dots, X_6) \quad (1)$$

where Y is the adaptation status (1 = farmers who adapted, 0 = farmers who did not adapt). The multinomial logit model was used to determine the factors influencing the choice of farmers to use a particular method of adaptation to climate change (Sani, 2014, Tazeze et al. 2014).

The reduced form of the model is as follows (Loko et al. 2012):

$$Y_i = f(X_1, X_2, \dots, X_6) \quad (2)$$

where Y_i , the polychotomic dependent variable, is the adaptation method chosen by the producer and X_1 to X_6 are the explanatory variables. Based on the data collected on the adaptation strategies developed by farmers in the study area, the dependent variable (Y_i) is coded 1 for 'no adaptation,' 2 for 'Crop-livestock diversification,' 3 for 'Use of improved varieties, chemical fertilizers and pesticides,' 4 for 'Agroforestry and perennial plantation (tree, tree species),' 5 for 'Diversification of income-generating activities' and 6 for 'Multiple coping strategies.' The explanatory variables include:

X_1 = Farming experience, X_2 = Farm size, X_3 = education level, X_4 = Gender, X_5 = Percentage of farm income and X_6 = Belonging to a farmers' organization. Tazeze et al. (2012) gave more details on the hypothetical relationships between these variables and adaptation to climate change. The standardization of a category, defined as 'base category' or 'reference state,' was used to estimate the model of multinomial logical regression (Loko et al. 2012, Tazeze et al. (2012). In this study, the category 'no adaptation' was used as the base category.

The 1980–2019 meteorological data is normally taken for baseline (AgMERRE, 2019), because this is the period when climate change effects manifested on a small-scale, if at all. This timescale was selected, on the one hand, to correlate with the long-term strategic planning period, and on the other, to avoid the ambiguity of various climate scenarios. Data were verified through a re-analysis, i.e. a test of how well the model correlates with observations after 2019. In reality, it is only possible to forecast an average annual and average seasonal temperature change, as well as changes in the minimum and maximum temperature, with a confidence interval. It is also possible to identify precipitation trends (average), mean and maximum potential wind speed. It seems like it is not too much. However, projections of any other parameters would not be reliable.

3. Results

3.1. Socioeconomic Characteristics of Sampled Households

Table 1 depicts the socioeconomic characteristics of the respondents as follows: The total sampled households were 180, of which, the majority (85%) of the respondents were males with only 15% as females. The average household size for the sampled households was 6.2. Most (36.7%) of the respondents were aged between 40 – 55 years with a mean age of 47.5 years. This shows that smallholder farmers in the study area were mostly middle-aged people who were still strong and energetic and were most likely to adopt more techniques to cope with climate change events. The farm size varied from 0.1 to 0.5 ha (0.3 ha on average) for 70.6% and 0.6 to 0.9 ha (0.75 on average) for 10.6% of rural population (Cirimwami et al. 2020). The education distribution of farmers show that were mostly illiterates. This low level of education is capable of limiting their access to accurate information on climate change and hence their adaptive capacity might be very low. The mean farm size of the food processor respondents was 1.2 ha (Cirimwami et al. 2020). Majority (50.5%) of the respondents belonged to one or two social organizations, 34.65% did not belong to any social organization while 14.85% had between 3-4 organizations. This implies that most of the farmers participated in social organizations. This will provide avenue for information sharing thereby enhancing adoption capacity. The mean annual income was CDF326, 461.00. This implies that farmers in the study area were mainly low-income earners. Majority (83.5%) of the respondents did not use any credit facility during the past five years. Only 8.7% received between CDF100,000 – CDF500, 000 as credit. Majority (56.8%) of the respondents inherited their farm lands while 43.2% used private borrowed land.

3.2. Smallholder Farmers' Perception on Temperature and Rainfall

3.2.1. Overall Perception

The farmers' attitude towards temperature and rainfall are changing in many ways. Figure 1 represents the main causes as per the perception of the farmers. Majority indicated rainfall and temperature as the main influencing factor. Regarding answering the question that what these changes consist of, rainfall disturbances, shortening of the small dry season, increasing of temperature have been answered by most of the farmers (see Figure 2). To answer the question that how the rainfall patterns had changed, all the respondents had observed changes in the overall climate pattern (Figure 3).

4. Results and Discussion

4.1. Results from Meteorological Data Analyses

4.1.1. Rainfall

As per Challinor et al (2007), the yearly rainfall and situation of pond are highly correlated. To ascertain actual farmers' perceptions on climate at a farm level, we further analyzed the wet spells. These are the number of days that received rainfall in a particular month. For the past 39 years the number of wet spells has significantly fluctuated at the decreasing trend. In general, it was noted that the rains of season A, which in time, began on September 15 and those of the season B (February-May) which started on February 15 have been postponed by 2 weeks to 1 month (specific case of lowland area). The consequences are that: corn (*Zea mays* L.) in season B is attacked by caterpillars because of the early dry season; there is resurgence of locusts against cassava; cassava pill scale. There is also an early shutdown of the rains by

campaign on the two growing seasons. The rains in May stop suddenly and go until June which is become rainy. This has led smallholder farmers to adopt a new agricultural calendar (Byenda et al. 2019). The strategy most practiced at lowland area is the adoption of plants tolerant and precocious plants while at high and medium altitudes more than 70.4% of peasants adopt no strategy. Less than 27.5% of the population use improved and early varieties and irrigation. The majority of food crops grown suffer from biotic stresses due to climatic disturbances, all the more so since more than half of those surveyed confirm that there is proliferation and appearance of new diseases and pests. These are, for example, the brown streak on cassava (*Manihot esculenta* Crantz) in lowland areas and the bacterial wilt on banana (*Musa*, sp.) in highland and medium altitudes, Crops such as rice (*Oryza sativa*), beans (*Phaseolus vulgaris*), corn (*Zea mays*, L), cassava (*Manihot esculenta*) and banana (*Musa*, sp) are also prone to diseases and pests. Sweet potatoes (*Ipomoea batatas*), on the other hand, are least attacked crop, probably because of their tolerance and elasticity. Food crops grown suffer from water deficiency, as the majority of those surveyed claim. Crops such as beans (*Phaseolus vulgaris*), rice (*Oryza sativa*) and corn (*Zea mays*, L) are the ones most affected by the lack of rains in lowland and highland areas, only the beans suffer from excess rains in medium altitudes because they only need it during the first days before flowering. Other crops such as cassava and sweet potatoes are moderately water deficient because the latter are more or less flexible, this property makes them easy to adapt to difficult conditions to survive.

Cassava (*Manihot esculenta*) is more attacked at high altitudes where many diseases are noted today; on the other hand, in medium and low altitude this speculation behaves and produces well. Most food crops grown in South Kivu suffer from water deficiency. Crops such as cassava (*Manihot esculenta*) and sweet potatoes (*Ipomoea batatas*) are moderately water deficient because the latter are more or less plastic, this property makes them easy to adapt to difficult conditions.

Some rainfall also initiated from airstreams of Atlantic origin (Latif et al. 1999; Tierney et al. 2011). Precipitation trends of the Great Lakes Region, also affected overall assessment (e.g. Stampone et al. 2011). Herrmann and Mohr (2011) identified variability in precipitation seasonality. Lyon and DeWitt (2012) had identified oceanic forcing as a dominant causative factor. The trend for decreasing rainfall during the long rains season over the past decade across East Africa identified by Lyon and DeWitt (2012). As indicated in Shongwe et al. 2011, there is a strong model consensus that precipitation will increase significant over the course of the 21st century in direct response to anthropogenic warming of the global atmosphere in the GLR. Taken collectively, the models indicate more intense wet seasons, increased intensity of high rainfall events and for less severe droughts (Shongwe et al. 2011), but significant increases are not projected to begin for several decades. Key aspects related to atmosphere's water vapor, temperature etc. of the consensus scenario developed from multiple model simulations of evolving future climatic states across the GLR, including KBNP surrounding areas.

Land use/land cover changes remain significant drivers of climatic change at local scales, but also in aggregate for the whole region. Changes in land surface type drive important changes in radiative transfers, evapotranspiration and runoff. Conversion of forests to croplands in particular causes marked changes in climatological characteristics across the deforested areas.

4.1.2. Temperature

The mean annual temperature patterns increased increasingly at a rate of $R2 = 0.43$ while those of January, February, and March increased significantly at $R2 = 0.03$, 0.07 , and 0.22 respectively. This particular trend reflects what happens in global temperature scenarios, as presented in various climate models (IPCC, 2012, IPCC, 2014). No trend in diurnal maxima has been observed in western Kenya demonstrate (Christy et al. 2009); these patterns therefore match signals from many other terrestrial environments (IPCC, 2007).

Figure 1 shows that 84 % of farmers interviewed perceived a long-term change in temperature through increasing temperature. This means that farmers are well aware of climate change, as more than 80% of farmers interviewed perceived an increasing temperature and a decreasing precipitation trend. This is in line with the finding of Gbetibouo (2009), who reported that majority of the respondents in three regions of Limpopo River Basin of South Africa, respectively, were well aware of changes in long-term climate patterns particularly increased variability in precipitation. The perceived rise in temperatures were attributed to the depletion of the forest resources, increased population, and to other factors. A limited number of the respondents could not give any reason for the cause of the perceived change in temperatures. To verify farmers perceived long-term change in temperatures, the historical annual mean temperature data for the study area from 1980 to 2019 (39 years) were analyzed. This confirmed a slightly increasing trend in temperature particularly in 2016; 2017 and 2019 (Figure 4)

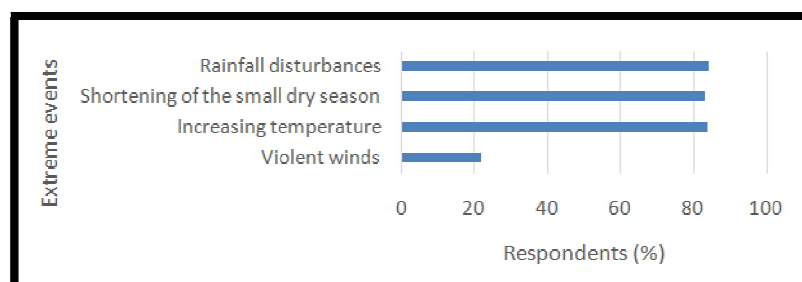


Figure 2: Farmers Perception of Change in Temperature (%) during the Past 20 Years in KBNP Surrounding Areas

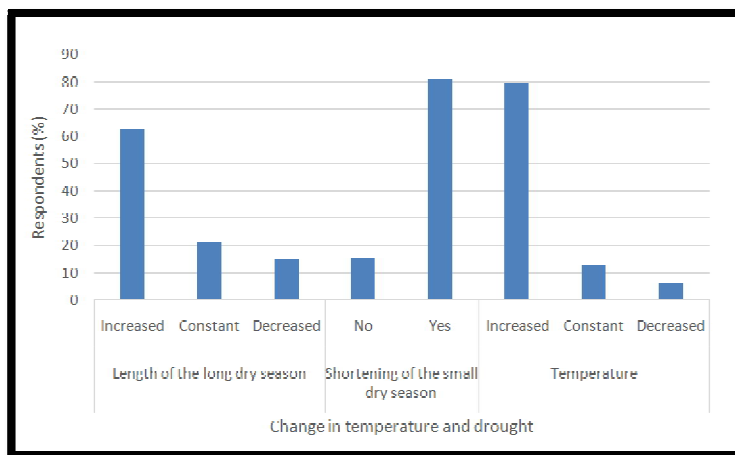


Figure 3: Farmers Perception of Change in Temperature and Drought (%) during the Past 20 Years in KBNP Surrounding Areas

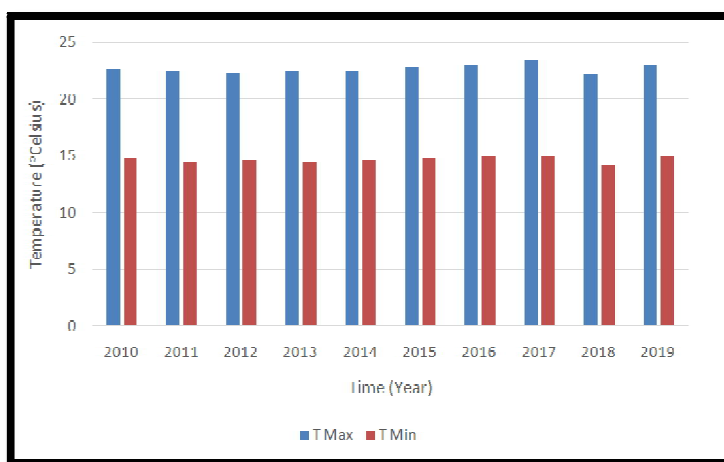


Figure 4: Historical Mean Annual Temperature (C) in the KBNP Surrounding Areas (2010-2019)

Farmers’ perceived change in precipitation was mainly in terms of its distribution within the growing season. Sixty seven percent of the respondents perceived late rainfall pattern. A verification of farmers’ perception on precipitation using historical annual rainfall data showed a decreasing trend (Figure. 6) with high rainfall value in 2011 (2024.95 mm) and in 2018 (1940.17 mm). Thus, the distribution of rainfall within the season is more important than annual value. Eighty one percent of respondents perceived a shortening of the small dry season while 61.4% perceived the rainy season length decreasing (Figure 5) and the total of 62.7% perceived the length of the long dry season increasing (Figure 3).

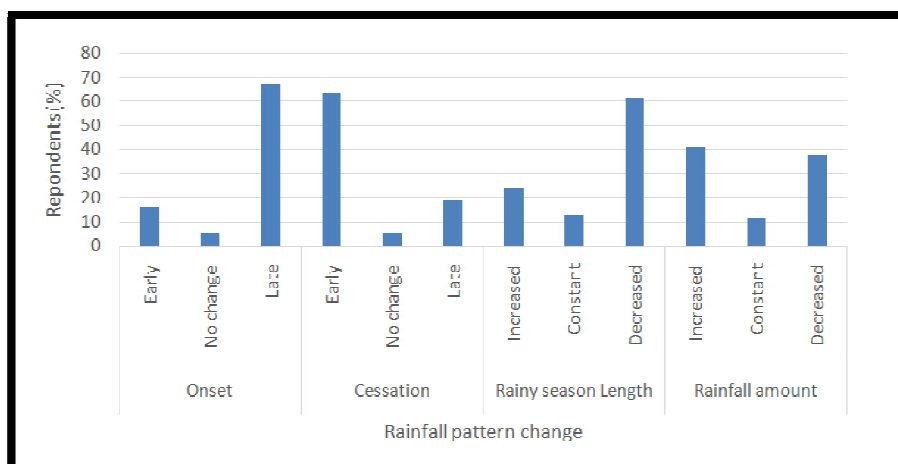


Figure 5: Farmers Perception of Changes in Precipitation (%) during the Past 20 Years in KBNP Surrounding Areas

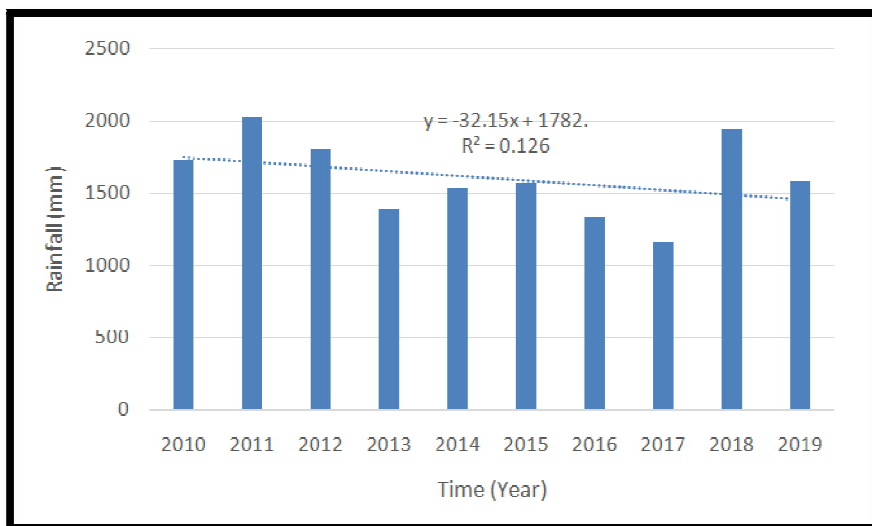


Figure 6: Historical Mean Annual Rainfall (Mm) in the KBNP Surrounding Areas (2010-2019)

4.1.3. Determinants of Farmers’ Choice of Adaptation Strategies

The analysis of multinomial logical regression to determine the factors influencing the choice of farmers to use a particular method of adaptation to climate change revealed that farming experience and educational level significantly affected the use of different methods of adaptation (Table 3 and Table 5).

- Farming experience: outcome indicated that farming experience is significantly affected with the all strategies.
- Educational level: this has positive and strong effect on the dependent variable. All adaptation strategies are influenced by this factor.
- Farm size: Farm size had a positive and significant impact on multiple coping strategies. The larger the farm, the more farmers opted for the combination of several coping strategies.
- Gender of household head: The results indicate that being female, as a household head, increases the chance to choose diversification of income-generating activities as adaptation to climate change.

4.1.4. Spatial Clustering of Climate Change Perceptions

As shown in the above section, a large number of farmers believe the climate has become hotter and drier. As suggested by Maddison (2007), this perception might be a case of prominence bias in questionnaires dealing with climate change. It’s likely that some respondents provided answers during the interview that the enumerators were more interested in hearing. Thus, validation of the respondent’s assessment of climate change with his/her neighbors’ responses would provide more confidence that the responses were objective and not subjective. We employed Moran’s I test for spatial autocorrelation with an inverse distance weights matrix on the portion of farmers who perceive particular types of climate change within a given area. The results (Table 2) suggested that neighboring farmers agree that temperature is increasing and rainfall is decreasing with a change in the timing. These results are evidence that farmers are capable of perceiving changes in climate.

Perception of temperature	Moran I statistics	Perception of rainfall	Moran I statistics
Increased temperature	0.044**	Increased rainfall	-0.013
Decreased temperature	0.002	Decreased rainfall	0.125**
More or less extreme	0.001	Change in the timing	0.051**
No change	-0.003	Change in frequency of droughts/floods	-0.007
		No change	0.003

Table 2: Moran’s, I Test Spatial Correlation of Climate Perception
 Note: ** Significant at 1% Level * Significant at 5% Level

Types of adaptation measures used by the respondents Table 3 shows the various adaptation measures practiced by the respondents. These include the practice of organic farming (65.33%), use of resistant varieties (53.33%), agroforestry practice (52.67%), crop diversification (48%) and early planting of crops (46.67%), among others. These measures are aimed at maximizing yields and ensure food security. Crop diversification which implies growing a number of different crops in the same plot or in different plots reduces the risk of complete crop failure as different crops are affected differently by climate events. Nhemachena and Hassan (2007) reported that farmers are using crop management

practices that include use of irrigation, water and soil conservation techniques and varying planting and harvesting dates to ensure that critical, sensitive growth stages that do not coincide with very harsh climatic conditions in the season.

Types of adaptation measure	Frequency	Percentage
Use of improved varieties and crop rotation	86	47.78
Early planting of crops	96	53.33
Agroforestry practices	94	52.23
Planting early maturing varieties	70	38.89
Planting of resistant varieties	84	46.67
Adoption of irrigation techniques	40	22.22
Integrated management of soil fertility package	118	65.55

Table 3: Distribution of Respondents According to Types of Adaptation Measures Used (N=180)
Multiple Responses Source: Field Survey Data (2017-2019)

Basically, the resilience strategies developed by households are the adoption of the Integrated Management of Soil Fertility package, agroforestry practices, early planting of crops, use of improved varieties and crop rotation combined with the reorganization of the agricultural calendar (Byenda et al. 2019; Cirimwami et al. 2019).

4.1.5. Determinants of Adaptation Measures to Climate Change

Regression analysis (in table 6) shows that farming experiences, number of extension contacts per year, income level and type of land tenure system are significant factors at 10% confidence interval. Age, educational level, and farm credit amount are also significant at this confidence interval. The more the farming experience the more adaptation strategies can be taken by the farmers. The R square value of 0.653 (Table 4) implies that about 65% of the adaptive capacity of the respondents was determined by their socio-economic characteristics.

Model	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	Std. Error			
Factor	50.598	13.034	-	4.658	.000
Age in years	-.603	.271	-.287	2.672	.034*
Sex of resp.	6.854	6.028	.084	1.364	.308
Farm exp in years	1086	.313	.479	4.158	.001***
Years of schooling	-.696	.388	-.148	1.797	.089*
Farm size in hectares	-.032	.328	-.007	-.099	.921
No. of persons in household	-.51.5	.111	-.036	-.232	.322
No. of extension	-.145	.028	-.326	- 5.142	.000***
No. of social organizations	1.333	1.489	.060	.895	.372
Annual income in CDF	2.99E 005	.000	.354	5.184	.000***
Amount of credit received in CDF	-2.66E 005	.000	-.145	2.297	.023*
Type of tenure System	-4.009	1.112	-.228	3.605	.000***

Table 4: Results of Regression Analysis on the Effects of Selected Socioeconomic Characteristics of the Respondents on Their Adaptive Capacity
R² = 0.653, *= Significant at 10%, ***= Significant at 1%

4.1.6. What Will Be the Major Ways in Which Rural People Adapt to Climate Change?

Rural people, in accordance to their knowledge, resources, and networks, adapt to climate change. But governments and other outside have to assist them.

4.1.7. Limits and Constraints to Rural Adaptation

As per the study, high yield maize in Zambia, production and price risks can create problem and can prevent rural households from getting benefitted from technological change (Langyintuo and Mungoma, 2008). A household with better market access generally has higher income (Cunguara and Darnhofer, 2011). Learning, marketplace, credit, and information about adaptation are essential to study (Hassan and Nhemachena, 2008).

Bryan et al. (2009); Deressa et al. (2009); Ringer (2010), studied the perception and uncertainty levels regarding accessing to information. Moumouni and Idrissou (2013) did studies on the agricultural technologies.

Explanator Variables	Use of Improved Varieties Agroforestry and perennial plantation chemical fertilizers and pesticides		Crop-livestock Multiple Coping Strategies		Diversification of income generating activity	
	B (coef) Sig (P-value)	B (coef) Sig (P-value)	B (coef) Sig (P-value)	B (coef) Sig (P-value)	B (coef) Sig (P-value)	B (coef) Sig (P-value)
Farming experience	0.314	0.006 *	0.328	0.004 *	0.384	0.001*
Farm size	-0.002	0.892	0.232	0.564	0.603	0.139
Educational level	2.009	0.019 *	2.300	0.007 *	2.211	0.010*
Belonging to farmers' Organization	-0.183	0.877	-0.920	0.462	-1.607	0.230
Percentage of farm income	-0.055	0.257	-0.004	0.927	-0.014	0.771
Gender	-1.687	0.215	-1.688	0.241	-2.041	0.189
	4.203	0.035 *	-1.577	0.304		
Base category			No adaptation			
Number of observations			180			
LR Chi ²			148.526			
Log likelihood			-135.602		Prob	
> Chi ²			0			

Table 5: Determinants of a Farmer's Choice to Use a Specific Climate Change Adaptation Strategy
* And ** Significant at 5% and 10% Probability Level, Respectively

4. Discussion

4.1. Farmers' Perceptions of an Adaptation Strategies to Climate Change

Apart from 20%, other farmers are perceived a change in the climate, which indicates that they are well aware. This is in-line with other studies (Fosu-Mensah 2010, Mustapha et al. 2012, Muzamhindo et al. 2015). Rainfall delays, before time termination, bad rainfall distribution are the most common changes. These findings are in line with many studies in Benin (Loko et al. 2012), Niger (Assoumana et al. 2016), Nigeria (Mustapha et al. 2012) and Kenya (Gebreyesus, 2017). Similar type of study has been conducted in Tanzania and Senegal has been reported (Cochet et al. 2017). But this result is contradictory with the study done by Fosu-Mensah (2010) where only a few farmers have developed adaptation strategies. Adaption strategies include use of improve fertilizers, re-planning of agricultural calendar, checking and proper management of soil fertility (Maddison, 2007; Nhemachena and Hassan, 2007; Bryan et al., 2009; Fosu-Mensah (2010; Mustapha et al. 2012; Loko et al. 2013). Many other studies also talk about these types of adaption strategies (Tazeze et al. 2012, Loko et al. 2013, Sani and Chalchisa, 2016). This research also revealed that educational level significantly influenced all adaptation strategies, lust like it is maintained in some other studies (Tazeze,2012;Assoumana, 2016; Gbetibouo (2009; Gbetibouo, 2009). Farm size also has association with selecting strategies. This is in-line with Sani &Chalchisa (2016).

4.2. Implications of Farmers' Choices

Farmers' choices on adoption of given adaptation strategies could have two purposes; either for expected profit or avoiding risk. All strategies developed by farmers to adapt to climate change fit into these two purposes. Another major strategy is agroforestry and perennial plantation. Many studies have shown that agroforestry may offer many economic and environmental benefits (Zoysa and Inoue, 2014). According to Zoysa and Inoue (2014), agroforestry has an important role in climate change adaptation by enhancing resilience to climate impacts on farming systems. Torquebiau (2013) reported that agroforestry has a double potential to address climate change issues: greenhouse gas mitigation strategy through carbon sequestration and sustainable adjustment to changing conditions (because agroforestry systems can be called perennial farming systems). More than an adaptation strategy, agroforestry is a mitigation strategy. Agroforestry is a landscape-scale approach, thus favors synergy between adaptation and mitigation Torquebiau (2013). Apart from its socioeconomic benefits (Bugayong, 2003), agroforestry, through its effects on soil conservation, protection of biodiversity, carbon sequestration (Murthy et al. 2016) is the most sustainable strategy.

4.3. Barriers to Effective Adaptation

Several studies carried out in Africa pointed out many barriers, which challenged the ability of farmers to adapt to climate change. The main barriers identified are: institutional factors, access to credit, lack of information and irregularity of extension services (Juana et al. 2013, Assoumana et al. 2016) reported that the institutional factors that influence adoption of new technologies are access to information via extension services (climate information and production technologies) and access to credit. According to the same author, farmers who have significant extension contacts have better chances of being aware of changing climatic conditions as well as adaptation measures in response to the changes in these conditions. This is confirmed by the findings of Assoumana (2016). Sani &Chalchisa (2016) further.

In South-Kivu province and particularly in KBNP surrounding areas, adjustment strategies are especially reactive and their adoption by agroeco systems exploiters is very slow and in the government programs, the adjustment of the

sector of the feeding production to climate change is not yet among priorities (Byenda et al. 2019). The good news for DRC is that, the inherent resilience of the country ecosystems gives hope for sustainable development pathways into the future. Indeed, the government of the DRC has recently incorporated climate change in its development policy documents. Implementation of the United Nations Framework Convention on Climate Change, management and protection of forests and the environment to enhance their rights and improve their living conditions can be achieved.

5. Conclusions and Policy Implications

This study indicated that the farmers of the KBNP surrounding areas are well aware of the climate change perception and its impacts on the agricultural production. This study also highlighted that their family also has the perception regarding the climate change (Cochet et al. 2017). For implementation of proper policies, adequate knowledge and understanding of risks are very important (Juana et al. 2013).

A number of policy conclusions can be drawn from this study. First of all, it is important to analyze the impacts of climate change on agriculture and simultaneously understand the drivers behind farmers adaptation. Secondly, the current attention given to climate adaptation has the potential to go hand-in-hand with the long-term policy priority in increasing production and reducing vulnerability among poor farmers in developing countries. The great potential for effective policy intervention is particularly evident from the factors that affect climate change adaptation. Many of the significant factors can be addressed as part of rural development programs, such as literacy, formal extension, access to formal credit and provision of information about climate variables and adaptation options.

One particularly important issue of climatological is that the trend for declining rainfall in the rainy season. This generally happens in opposition with climate model projections that increases in rainfall (Funk et al. 2008). It might be influenced by Pacific Ocean sea surface temperature patterns (Lyon and DeWitt, 2012). The pattern of land use and the conversion of wild lands are most serious threats (Plumptre, 2012). For farmers it is a long-back continuous problem (Thornton et al. 2009). Building up resilience reduces vulnerability to a wide range of hazards and in this way helps farmers and communities prepare for the uncertainties ahead.

Among possible consequences from climate change impacts on food provision and agriculture derived from these findings and other climate-related factors are the following: (i) Agricultural yield, the model depicts substantial losses for maize and bean yields throughout the Albertine Rift; (ii) Wildlands conversion to farmland. The building stresses upon cultivation appear to be maximized at lower elevation, particularly in the densely populated areas proximal to the KBNP highland sector. At the same time, highland areas currently occupied by some of the region's remaining stands of montane forest are shown to offer increasing potential for cultivation (Belfiore, 2010; Plumptre, 2012).

However, in most PAs surroundings, two or more factors have already manifested urging immediate action, even before the comprehensive climate assessment of the territory is accomplished. Where this is the case, climate information can help appropriately substantiate investment demand and develop future scenarios. Statistically, an investment demand for climate change adaptation is 20–30 or more times lower, than climate change damage estimate where no adaptation measures are taken (Semenov et al. 2012).

Future research can be conducted on the topic of microeconomics of the adaptation process especially on practical adaptation options, not only for agriculture but also for non-agricultural livelihoods. On the climate change in rural areas, there is also a need to conduct research. More research is needed on vulnerability, to identify the most vulnerable areas, populations, and social categories.

The availability of micro panel data can provide more robust evidence on both the role of adaptation and its implications for productivity. Future research efforts should also be devoted to the distinction of the different adaptation strategies and the identification of the most successful ones for both the medium and longer term.

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