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Local Observations of Climate Change and Adaptation Responses: A Case Study in the Mountain Region of Burundi-Rwanda

Aline Nkurunziza [1,*], Dorine Intwarinkase Mutaganzwa [2], Willy Marcel Ndayitwayeko [3], Jacques Nkengurutse [4], Beth A. Kaplin [2], Irene Teixidor Toneu [5], Noelia Zafra-Calvo [6] and Aida Cuni-Sanchez [7,8]

1 High School of Business, University of Burundi, Bujumbura P.O. Box 1440, Burundi
2 Center of Excellence in Biodiversity and Natural Resource Management, University of Rwanda, Kigali P.O. Box 4285, Rwanda
3 University Research Centre for Economic and Social Development (CURDES), Faculty of Economics and Management, University of Burundi, Bujumbura P.O. Box 1049, Burundi
4 Center of Research in Natural and Environmental Sciences, Department of Biology, Faculty of Sciences, University of Burundi, Bujumbura P.O. Box 2700, Burundi
5 Institut de Recherche pour le Développement, Institut Méditerranéen de Biodiversité et d'Ecologie Marine et Continentale (IMBE), Aix-Marseille University, Avignon University, 13007 Marseille, France
6 Basque Centre for Climate Change bc3, Scientific Campus of the University of the Basque Country, 48940 Leioa, Spain
7 Department of International Environment and Development Studies (Noragric), Norwegian University of Life Sciences, 1430 Ås, Norway
8 Department of Environment and Geography, York Institute for Tropical Ecosystems, University of York, York YO10 5DD, UK
* Correspondence: aline.nkurunziza@ub.edu.bi or alinkuru2016@gmail.com

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Abstract: Mountain regions and their communities are particularly vulnerable to climate change impacts. However, little is known on the impacts observed and adaptation responses used in Burundi's mountain region and if these are different to those reported in the contiguous mountain region of Rwanda. This paper aims to fill in these knowledge gaps. Semi-structured interviews were conducted with 300 smallholder farmers, 150 in northern Burundi and 150 in southern Rwanda. Farmers in both countries reported negative impacts on crops, animals, and human health, with small differences between countries driven by the main cultivated crops. More adaptation strategies were used in Burundi than in Rwanda, and more farmers in Burundi were using multiple strategies. In both countries, farmers' wealth affected farmers' adaptation responses and their food security. Notably, for all wealth groups (poor, average, rich), food security was lower in Rwanda than in Burundi. We relate our findings to current agricultural intensification policies in both countries and argue for the greater involvement of local farmers in adaptation planning using, for example, science-with-society approaches.

Keywords: adaptation strategies; African mountains; farmers; food security; perceptions; wealth groups

1. Introduction

Predicted changes in climate, including increased temperatures and changing rainfall patterns, are expected to threaten food production and intensify food insecurity across Sub-Saharan Africa [1]. Mountain regions and their communities are particularly vulnerable to climate change impacts because the rate of warming is amplified with elevation [2]. The latest IPCC Cross-Chapter on Mountains highlights how climate change impacts have increased in recent decades with observable and serious consequences for people and ecosystems in many mountain regions, including in Africa [3]. This Cross-Chapter also warns that with warming above 1.5 °C, adaptation becomes more and more urgent in mountain regions [3].

In mountain regions, like in other regions with complex topography, there is still considerable uncertainty about the local and regional environmental consequences of the changing climate because of the limited spatial resolution of global climate models [4]. In such regions, climate change observations or perceptions from subsistence-oriented communities can help not only document the multiple fine-scale environmental consequences of climate change but also design effective adaptive strategies [5,6]. It is known that climate change perception is a complex process that encompasses a range of psychological constructs such as knowledge, beliefs, attitudes, and concerns about if and how the climate is changing [7]. Perception is influenced by individuals' characteristics, their experience, the information that they receive, and the cultural and geographic context in which they live, among other factors [7,8]. Notably, the perception that farmers have about climate change is a key component to understanding their adaptation decisions [9]. Apart from perceiving that the climate is changing, farmers also have to give enough weight to this perception to take action [10].

In Sub-Saharan Africa, most research on climate change observations by subsistence-oriented communities and farmers' adaptation responses in mountain regions has been conducted in East Africa [3], in particular in Tanzania [11]. Much less is known about the Albertine Rift, the western branch of the East African Rift, which covers parts of Uganda, Rwanda, Burundi, DR Congo, and Tanzania. The Albertine Rift is a climatically complex region comprising both bimodal and unimodal rainfall regime zones, as well as important rain shadow effects related to irregular topography [12]. Recent work from Uganda [12–15], Rwanda [16,17], and DR Congo [18,19] has increased our understanding of climate change impacts and farmers' adaptation responses for this region, but limited information is still available from Burundi. A recent analysis of rainfall amounts and distribution over Burundi revealed decreasing trends for both annual and seasonal rainfall, including in the mountainous region of this country [20], and an increase in extreme wet and dry events, particularly since the early 2000s [21]. These authors highlighted that extreme wet and dry events often lead to crop failure and socioeconomic losses, but they provided no details on the impacts on different crops nor on the adaptation strategies implemented by smallholder farmers.

Smallholder farmers can employ a wide range of adaptation strategies, including: (i) ex-ante (decisions made prior to a growing season to minimise risks), (ii) in-season (responses to perceived and forecasted weather conditions that drive adjustments to crops or cultivation practices), and (iii) ex-post (responses implemented to reduce the negative impacts of climate shocks which have already occurred) [22]. Adaptation strategies can also be clustered into two groups: on-farm and off-farm strategies. The most common on-farm strategies are the maintenance of high agrobiodiversity—to spread the risk of crop failure among species (or varieties) which are susceptible to different climatic stresses—and soil or water conservation practices [23]. Two of the most prominent off-farm strategies are off-farm labour and membership in farmers' organisations, which can facilitate improved seeds, inputs, credit and subsidies, or technical support; see [24]. For example, over 20 different adaptation strategies are used by Tanzanian mountain farmers [11]. In general, as wealthier households have greater access to land, more resources to invest in irrigation or inputs and/or better access to information and technologies, they tend to employ a wider range of adaptation strategies [11].

Recent work from Rwanda has highlighted that agricultural intensification policies can also affect farmers' adaptation, with positive or negative effects depending on household wealth [17,25]. The Crop Intensification Program (CIP) of Rwanda, implemented in 2008, aims at increasing agricultural productivity through the promotion of hybrid seeds and the increased use of agrochemicals and agro-engineering techniques, such as draining marshland and constructing terraces [26]. Through performance contracts, households submit written agreements in which they state that they will cultivate selected crops several months before the growing season begins. The farmers failing to meet their contracts or found planting non-approved crops can be publicly disgraced and even penalised [17]. The CIP discourages seed sharing between farmers, the cultivation of multiple small fields located at different elevations, polyculture, and the cultivation of certain crops such as sweet potato, cassava, ciraza, or sorghum [26]. Although polyculture contributes to households' food security throughout the year (for example, while cassava is ripening, beans can be eaten, see [27]), sweet potato, cassava, ciraza, and sorghum are perceived by local farmers as being more drought- and flood-tolerant crops than the government-approved maize or beans [25]. Although the CIP has raised crop yields, and the conventionally measured poverty rates have fallen in Rwanda in the past few years, some authors have highlighted that such agricultural intensification policies appear to be exacerbating rural landlessness, inequality, and food insecurity [27].

In Burundi, no such 'Crop Intensification Program' exists, but there is a political willingness to boost and intensify the agricultural sector. A priority of the National Agricultural Strategy (2008–2015) was the strengthening of the hybrid seed sector, through the creation in 2013 of the National Seed Control and Certification Office (*Office National de Contrôle et de Certification des Semences, ONCCS*), which was expected to boost access to and the use of improved seeds by smallholder farmers [28]. The government has also been investing in increasing farmers' access to fertilisers through the creation of a local company manufacturing organo-mineral fertilisers. Since October 2021, zero-grazing for cattle has also been promoted, with the aim of both increasing access to manure and reducing rangeland degradation (Loi N°1/21 du 4 Octobre 2018). Although these policies focus on intensifying agricultural production, contrary to Rwanda, in Burundi, there is no strict control of farmers' crop choices, so farmers may continue to practice polyculture and/or experiment with different crops (or varieties) in different seasons or years.

The mountainous region of the Congo–Nile Divide of northern Burundi and southern Rwanda offers a unique opportunity for the investigation of the effects of agricultural intensification policies on smallholder farmers' capacity to adapt to climate change. The inhabitants of both countries are from the same ethnic groups, so cultural differences, known to affect farmers' adaptation [18,19], are unlikely to be an important driver of differences in adaptation across countries. This paper aims to: (1) identify the observed changes in the climate and their impacts on the biophysical system as perceived by these farmers in northern Burundi and southern Rwanda; (2) determine which strategies they are using to adapt and who is promoting them; and (3) investigate differences in adaptation strategies and food security across wealth groups. We adjust the framework proposed by [29], in which changes in the climate itself and the impacts of climate change observed (in the physical, biological, and social systems) are differentiated. We adhere to the Framework Convention on Climate Change [30] and use climate change to refer to a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties, and that persists for an extended period. Similar to [31], we use the term local observations of climate change to refer to reports provided by local peoples about changes in the climatic system (i.e., temperature, precipitation, and wind).

We hypothesise that small differences in perceptions of climatic changes and impacts across countries will be found as both study areas are part of the same mountain range, but that larger differences in adaptation will be observed, due to divergent agricultural intensification policies affecting farmers' choices. We also hypothesise that richer households would be using more adaptation strategies and would have higher food security. This study contributes to the field with two novel aspects: (i) it is the first to document climate change impacts and adaptation strategies in Burundi's mountains, and (ii) it is the first to investigate the effects of different agricultural intensification policies on climate change adaptation of the same ethnic group.

2. Materials and Methods

2.1. Study Areas

This study was conducted with smallholder farmers living in the Congo–Nile Ridge mountainous region of northern Burundi and southern Rwanda in the Albertine Rift. In this region, the elevation ranges from about 1300 m to 2900 m asl. The region includes the montane forests of the Kibira National Park (Burundi) and the Nyungwe National Park (Rwanda), which are contiguous (Figure 1). The region has a bimodal rainfall regime with long rains in February–June and short rains in September–December [32]. Rainfall and temperature vary with topography. Around Kibira, the annual rainfall ranges between 1700 and 2000 mm [33], whereas around Nyungwe, the annual rainfall is about 1800 mm [32]. In the region, metamorphic bedrock is overlain by highly acidic soils low in nitrogen [34]. Nyungwe forest soils have been developed mainly from schists, mica schists, quartzitic schists and granites [34].

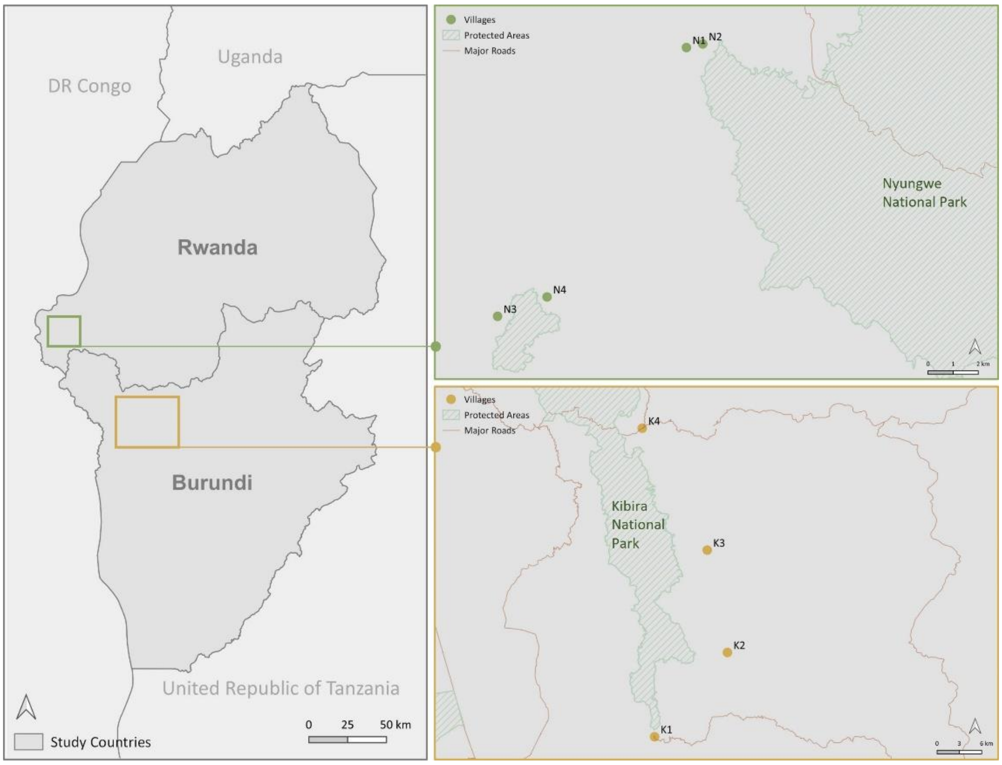

Figure 1. Study areas with the location of the villages sampled.

Local communities living in this mountainous region are farmers of Bantu origin and Twa hunter-gatherers of Pygmy origin. Our study focuses on farmers of Bantu origin. These farmers rely on rain-fed agriculture for their livelihoods, but they might also raise animals, typically pigs or cows. Cows hold high value in the local culture (for example, they are used as a dowry in marriage and are also a symbol of wealth and prestige). Tea is often grown as a cash crop in large plantations where smallholder farmers can work as labourers, but some farmers also have a few tea bushes on their farms. In Burundi, all tea is sold through the Burundi Tea Office (*Office du Thé du Burundi*), whereas in Rwanda, several tea cooperatives organise the trade of tea.

The area around Kibira has a high population density: 475 people per km^2 [35]. The average farm size is less than 1 hectare, and the main crops are maize, bush beans, Irish potatoes, and sweet potatoes [36]. The area around Nyungwe also has a high population density: 336 people per km^2 [37]. The average farm size is also less than 1 hectare, and the main crops are maize and climbing beans [38]. Although maize porridge (named *Ubugali bw'ibigori* or *Umutsima w'ibigori* in Kirundi) and beans are the main staple food for farmers around Kibira (pers. Obs. 2021), this is not the case around Nyungwe, as maize porridge is not traditionally consumed in Rwanda [38].

2.2. Data Collection and Analysis

In both study areas (the Kibira area in Burundi and the Nyungwe area in Rwanda), four villages located at different elevations were surveyed (Figure 1). These were selected based on accessibility by road and close proximity to the park boundary. In each village, we first conducted exploratory focus group discussions (FGDs) with 4–5 elders. These discussions were used to adapt a common semi-structured questionnaire to each study context and to build trust among community members. During the FGDs, we also gathered information on agents of change promoting some adaptation strategies in the village (the government, NGOs, or local communities without external support). Then, in each village selected, we conducted semi-structured questionnaires to 37–38 randomly selected household heads aiming to interview about 50% male and 50% female household heads (n = 150 in total per study area). In each village, households were selected by walking the main street and selecting every third household to the right. If the household head was not available, the next-door neighbour was targeted. We first interviewed the household head who opened the door (male or female), until we reached the targeted gender quota for that village, and then we asked to interview the other gender in the subsequent households.

Questionnaires addressed household characteristics and assets, climatic changes observed, impacts on the biophysical domain, adaptive strategies used to cope with or adapt to observed changes, household food security, food quality, and access to clean water during the previous year (see Supplementary Material). The methodological approach (first FGDs, then questionnaires in the same villages) and the questionnaire used follow the guidelines of the project Local Indicator of Climate Change Impacts, a project focused on providing data on the contribution of local and indigenous knowledge to climate change research (see [39]). The same approach has been used to survey smallholder farmers in other mountainous regions of Africa [11,19,40].

The exploratory FGDs and the interviews were carried out in Kirundi (Burundi) or in Kinyarwanda (Rwanda) and were facilitated by the first two authors between April and August 2021. All study participants (FGDs and interviews) were selected on a voluntary basis and were first informed that the aim of the study was to better understand climate change impacts and adaptation practices. The percentage of respondents per study area (Burundi or Rwanda, 150 respondents at each site) was the main unit of analysis. First, we explored differences across study areas (Burundi versus Rwanda), and then we explored differences within the study areas by pooling respondents into wealth groups (poor, average, wealthy) based on a wealth index created from ten asset indicators [41,42]. The ten assets were identified by the FGDs in each country. Assets which varied most across the households (over 25% of households did not own them) were weighted 0.25 greater than those more commonly found. In Burundi, the ten assets considered were (in increasing order of being common): a motorbike (1.3% of the respondents), >3 ha of land (4%), a high-quality house (concrete floor) (6%), a shop (6%), >1 ha Eucalyptus plantation (6.6%), solar panel (23.3%), at least 1 cow (32.6%), at least 1 pig (54%), a radio (71.3%), and being a homeowner (92%). In Rwanda, the ten assets considered were (in increasing order of being common): an android phone (1% of the respondents), a car (3%), a motorbike (3%), a shop (5%), an extra house to rent (7%), >1 ha land (9%), >5 cows (11%), a TV (41%), a radio (44%), and a 'nice floor' (cement, tiles, or local plaster 55%). In Rwanda, all respondents owned their homes.

Cross-tabulation tables and chi-square tests were used to determine significant relationships between wealth groups and adaptation strategies, following [11]. We used the wealth group as an explanatory variable and adaptation strategies as response variables. We used a significance level of $p < 0.05$. SPSS v28 was used for all data analysis.

3. Results

3.1. Household Characteristics and Assets

Some differences were observed in the household characteristics across the countries (Table 1). In Burundi, the average household size was larger, but the average farm size was smaller than in Rwanda. Additionally, poor households in Burundi owned no large animals, and most rich households relied on farming, whereas this was not the case in Rwanda, where even poor households owned large animals, and few rich households relied on farming. In terms of schooling, 66% of the respondents in Burundi had never finished primary school, whereas this was 29% in Rwanda.

Table 1. Household characteristics of the participants in this study. Large animals referred to pigs (54% and 53% of the respondents in Burundi and Rwanda, respectively), cows (32% and 31%), or goats (0% and 1%).

Burundi		Adults	Farm (ha)	Large Animals	Main Activities	Wealth Items
Poor	n = 19	2.6	0.26	0%	79% farming	<4 items
Average	n = 108	2.7	0.5	37%	100% farming	4–5 items
Rich	n = 23	3.6	1.86	74%	100% farming	>5 items
Rwanda		**Adults**	**Farm (ha)**	**Large Animals**	**Main Activities**	**Wealth Items**
Poor	n = 44	1.7	0.45	54%	72% farming	none
Average	n = 88	1.8	0.73	54%	60% farming	1–4 items
Rich	n = 18	1.6	1.5	72%	22% farming	>4 items

3.2. Climatic Changes Observed and Impacts

In general, similar climatic changes were reported by farmers in both countries. Most respondents (>60%) reported increased temperatures during both dry and rainy seasons, the late onset of the long rains, more dry spells during the long rains, fewer foggy days, and fewer hailstorms (Figure 2). More respondents in Burundi mentioned an increase in extreme floods due to an increase in both heavy rains and local deforestation, whereas more respondents in Rwanda highlighted an increase in showers during the dry season (Figure 2).

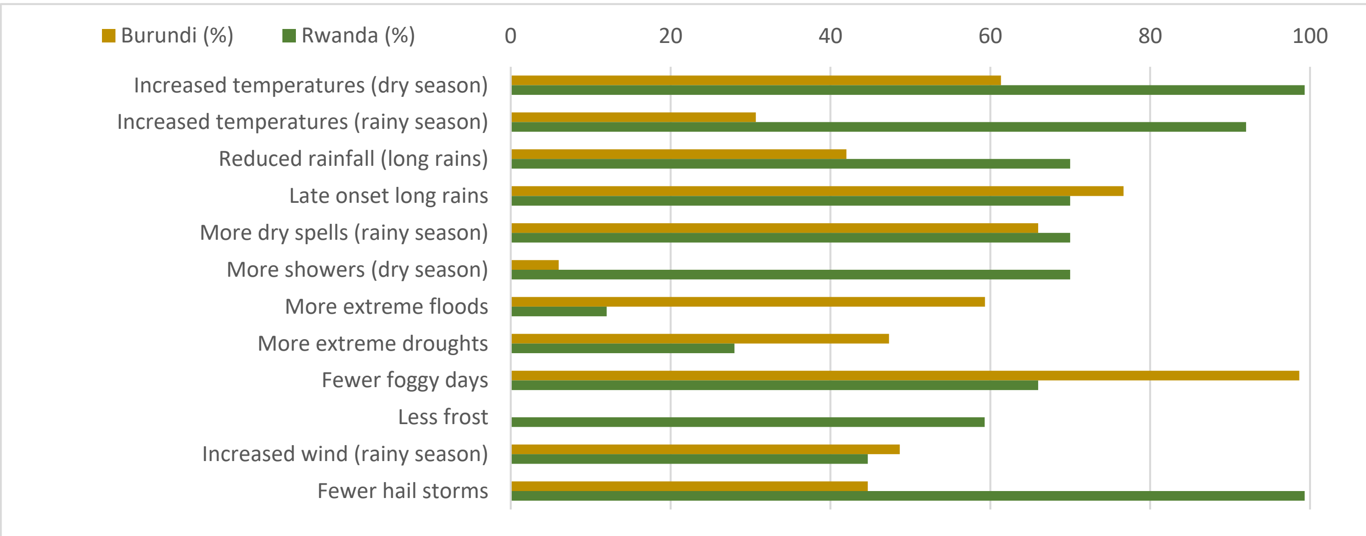

Figure 2. Observed changes in climate in terms of the percentage of respondents in each study area (Burundi n = 150, Rwanda n = 150). Note that we did not ask about reduced rainfall during the short rains, but some respondents in both countries mentioned such changes, something which requires further investigation.

Similar impacts in the biophysical domain were also reported by farmers in both countries. Numerous respondents (>40%) reported more landslides, a reduction in maize and beans' yields, an increase in pests and diseases for these crops (particularly fall armyworm for maize and rust and sooty mould in beans), and that people were overall less healthy (Figure 3), which was attributed to an increase in malaria prevalence and influenza in

Burundi (in Rwanda, the respondents did not specify a particular disease). Some respondents also reported reduced cow milk production and an increase in livestock diseases, particularly foot-and-mouth disease (Figure 3). About 20% of the respondents (which is all the households in Burundi and Rwanda engaged in tea farming) reported a reduction in tea-leaf yields, which they attributed to an increase in tea mosaic virus.

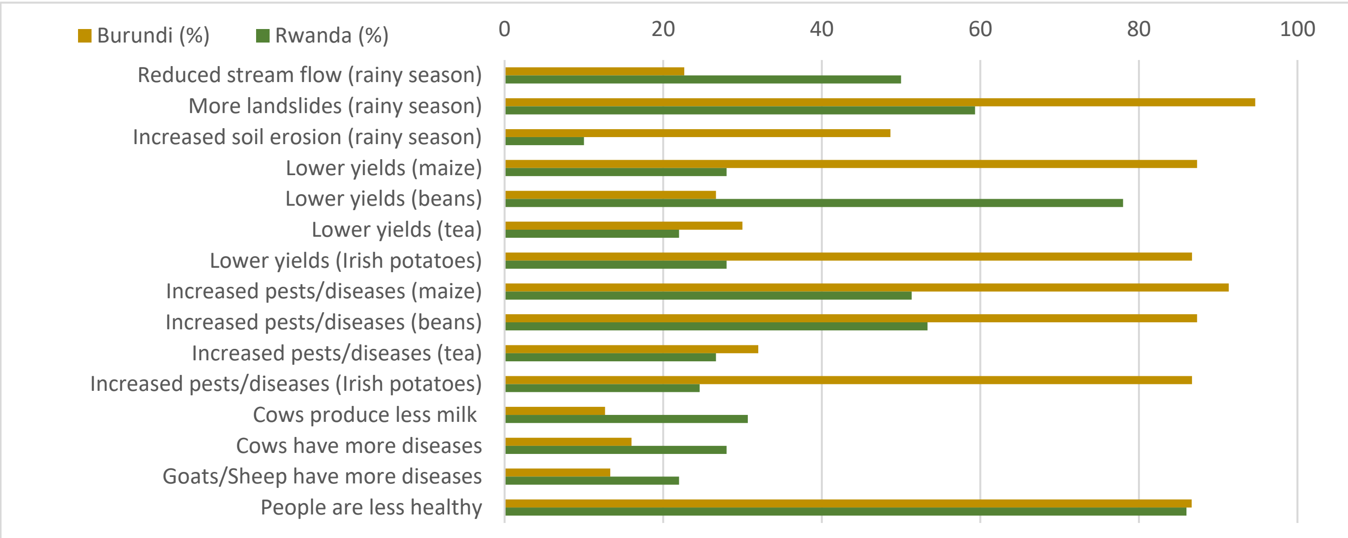

Figure 3. Observed impacts in the biophysical domain regarding the percentage of respondents in each study area (Burundi n = 150, Rwanda n = 150).

The main differences across the countries were that in Burundi, the most-cited impacts were more landslides and lower yields of maize and Irish potatoes, whereas in Rwanda, the most-cited impacts were lower yields of beans (note that in the study area in Rwanda, beans are the main crops promoted by the government).

3.3. Adaptation Strategies

Study respondents in both countries reported mainly using on-farm adaptation strategies (Figure 4), including ex-ante (for example, using improved seeds), in-season (for example, sowing seeds twice if they die), and ex-post (for example, selling firewood), Whereas 23 adaptation strategies were reported in Burundi, 17 were reported in Rwanda. In general, most respondents in both countries had increased the use of improved varieties (particularly early maturing maize), inputs (fertiliser, pesticide), irrigation, and soil conservation techniques (Figure 4). Over 40% of the respondents had also diversified into paid labour outside the household or into animal rearing. Notably, for most strategies, a larger percentage of farmers in Burundi than in Rwanda were reporting using those strategies, which could be related to their greater freedom of choice for experimenting.

Some important differences were also observed between countries: changing farm location (to the vicinity of a stream in order to be able to irrigate), growing new crops, and sowing seeds earlier (due to uncertainty in rainy season length) were mentioned by more farmers in Burundi, whereas the use of terraces and veterinary care and diversifying into vegetable or fruit production were cited by more farmers in Rwanda (Figure 4). Both in Burundi and Rwanda, irrigation refers to hand-made canals which are often individually managed—except in one village in Burundi in which they were collectively managed. In both countries, the use of chemical fertilisers and pesticides is promoted and subsidised by the government.

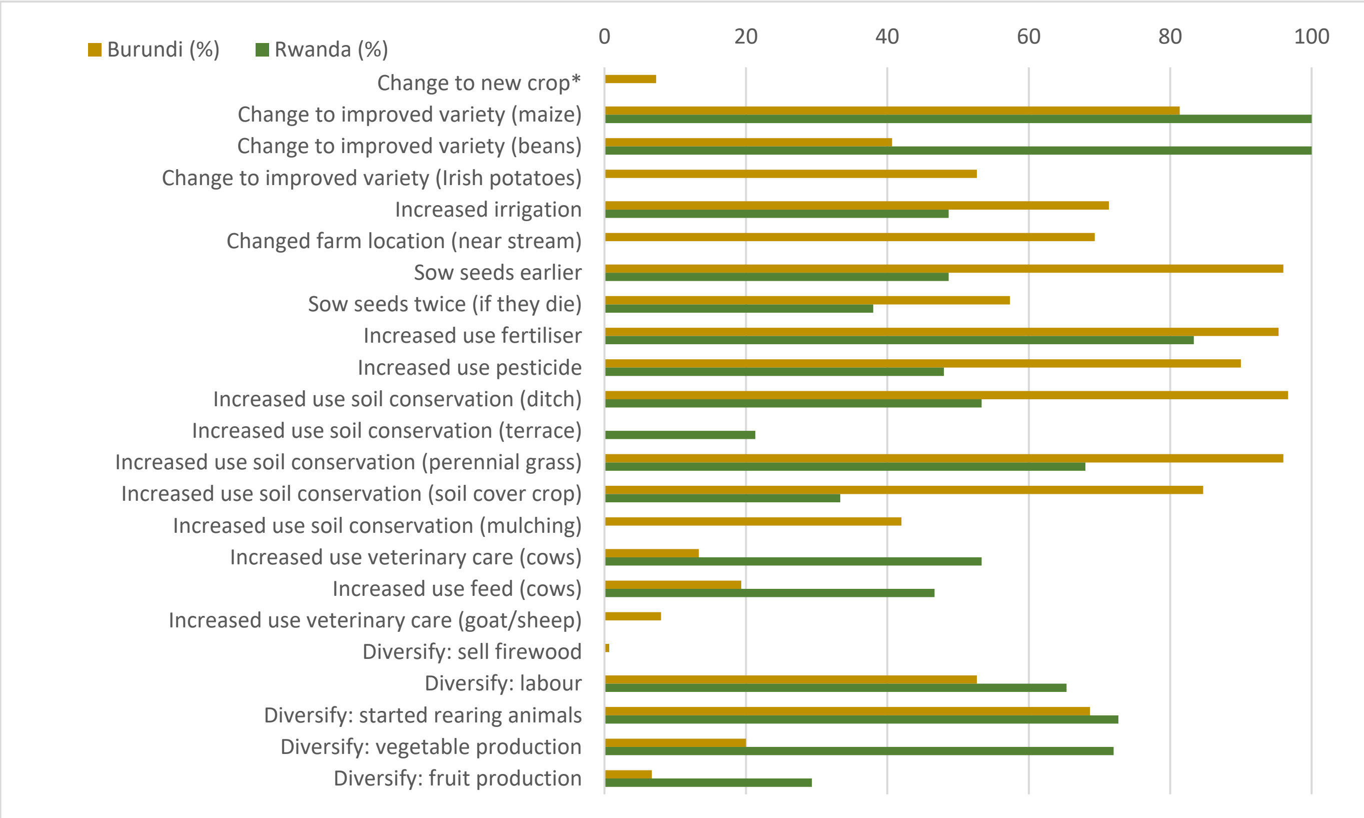

Figure 4. Adaptation strategies used regarding percent of respondents in each study area (Burundi n = 150, Rwanda n = 150). * New crops refer to sweet potatoes, cassava, or wheat. Note that we did not ask about improved Irish potatoes in Rwanda.

In Burundi, most strategies had been initiated by local farmers except the use of improved maize (promoted by an NGO) and soil conservation techniques (promoted by government extension services). In Rwanda, most strategies had been initiated by the government or NGOs enforcing the same choices of the government, including improved varieties, the increased use of inputs, soil conservation techniques, veterinary care for cattle, and supplementary feed for cattle.

In Burundi, the respondents obtained improved seeds from the market (41.6%), farmers' associations (37.3%), or from buying them from ISABU (*Institut des Sciences Agronomiques du Burundi*, 14%), whereas in Rwanda, farmers obtained improved seeds from the market (58%) or from an NGO (26%). In both countries, over 95% of the respondents relied on their own traditional ecological knowledge to determine when to sow their crops.

3.4. Wealth Effects on Adaptation and Food Security

Wealth had a significant effect on the adaptation strategies used in both countries ($p < 0.05$). These effects were more evident in Burundi, where fewer poor farmers used improved seeds, irrigation, and pesticides or diversified into animal rearing or vegetable farming but engaged more in labour (Table 2). In Rwanda, fewer poor households used pesticides or soil conservation techniques or invested in fruit farming compared to richer households (Table 3).

Table 2. Differential adaptation responses by wealth groups by farmers around Kibira, Burundi (n = 150). % refers to the % of respondents within each wealth group. Bold refers to significant differences across wealth groups at $p < 0.05$, using cross-tabulation tables and chi-square tests.

	Rich (%)	Average (%)	Poor (%)
Changed to new crop	**0**	**10.1**	**0**
Change to improved variety (Irish potato)	73.9	51.9	**31.6**
Change to improved variety (maize)	82.6	87.0	**47.4**
Change to improved variety (beans)	43.5	38.9	47.4
Increased irrigation	73.9	74.1	**52.6**
Changed farm location (near stream/swamp)	65.2	75.9	**36.8**
Sow seeds earlier	100.0	96.3	89.5
Sow seeds twice (if they die)	56.5	57.4	57.9
Increased use fertiliser	95.7	96.3	89.5
Increased use pesticide	100.0	90.7	**73.7**
Increased use of soil conservation (diversion ditch)	95.7	98.1	89.5
Increased use of soil conservation (perennial grass)	100.0	97.2	84.2
Increased use of soil conservation (soil cover crop)	100.0	85.2	63.2
Increased use of soil conservation (mulching)	47.8	41.7	36.8
Increased use of veterinary care (cattle)	30.4	12.0	0.0
Increased use of feed (cattle)	34.8	19.4	0.0
Increased use of veterinary care (other animals)	13.0	6.5	10.5
Diversify: labour	17.4	57.4	**68.4**
Diversify: animal rearing	87.0	71.3	**31.6**
Diversify: vegetable production	21.7	20.3	**15.7**
Diversify: fruit production	4.3	7.4	5.0

Table 3. Differential adaptation responses by wealth groups by farmers around Nyungwe, Rwanda (n = 150). % refers to the % of respondents within each wealth group. Bold referes to Significant differences across wealth groups at $p < 0.05$, using cross-tabulation tables and chi-square tests.

Rwanda	Rich (%)	Average (%)	Poor (%)
Increased irrigation	33.3	46.6	59.1
Changed farm location (near stream)	5.6	3.4	4.5
Sow seeds earlier	22.2	50.0	56.8
Sow seeds twice (if they die)	33.3	35.2	**45.5**
Increased use fertiliser	72.2	87.5	79.5
Increased use pesticide	51.1	52.3	**22.2**
Increased use soil conservation (diversion ditch)	59.1	47.7	38.9
Increased use soil conservation (terrace)	25.0	18.2	11.1
Increased use soil conservation (perennial grass)	73.9	61.4	55.6
Increased use soil conservation (soil cover crop)	26.1	45.5	38.9
Increased use of veterinary care (cows)	48.9	63.6	50.0
Increased use of complementary feed (cows)	43.2	52.3	50.0
Diversify: labour	69.3	59.1	61.1
Diversify: started rearing animals	79.5	61.4	66.7
Diversify: vegetable farming	77.3	68.2	55.6
Diversify: fruit farming	36.4	25.0	**5.6**

In Burundi, households' food security and food quality (during the previous year) increased with increasing wealth groups, with most rich households reporting having both food security and 'good' food quality. This was different in Rwanda, where only 50% of the rich households reported food security and only 11% reported 'good' food quality (Table 4). In general, access to clean water was also greater in Burundi than in Rwanda for the different wealth groups (see Table 4).

Table 4. Households' food security, 'good' food quality and access to clean water (during the previous year) according to wealth groups around Kibira in Burundi (n = 150) and Nyungwe in Rwanda (n = 150). % refers to the % of respondents within each wealth group in that study area.

	Burundi	Rwanda
Food security		
poor	26	11
average	76	16
rich	95	56
'Good' food quality		
poor	58	20
average	82	18
rich	100	11
Clean water access		
poor	63	39
average	97	49
rich	100	78

4. Discussion

4.1. Climatic Changes Observed and Impacts

As we hypothesised, climatic changes were comparably perceived across the Burundi-Rwanda border. The respondents reported not just increased temperatures, the late onset of the long rains, and more dry spells during the long rains but also fewer foggy days and fewer hailstorms. Other studies from Kenya and DR Congo have shown that different socio-cultural groups living in the same mountain region tend to report comparable climatic changes [18,43]. The climatic changes reported in this study agree with farmers' perceptions of climatic changes elsewhere in Rwanda and eastern DR Congo. In Rwanda, farmers in the Nyamagabe district (east of Nyungwe) reported increased uncertainty in the start and amount of rainfall during rainy seasons [17], whereas farmers around the Virunga mountains (north Rwanda) reported the late onset of the rainy season [16]. Farmers in Mt Kahuzi and the Itombwe mountains (in eastern DR Congo), also in the Albertine Rift but to the west of our study area, also reported fewer foggy days and fewer hailstorms [18,19]. In Burundi, farmers' perceptions agree with [20], which showed decreasing trends for both annual and seasonal rainfall in the mountain region of Burundi.

Comparable impacts in the biophysical domain were also reported by farmers in both countries, which are also in agreement with the climate change impacts reported by farmers in other studies in the Albertine Rift region. Increased soil erosion associated with heavy rains was also reported by smallholder farmers living around the Virunga mountains, Mt Kahuzi, and the Itombwe mountains [16,18,19]. This was sometimes linked to the local deforestation of natural forests, as was the case for some of our study respondents in Burundi. In Rwanda, 'local deforestation' was not mentioned as a driver of increased soil erosion as natural forests are only found within well-enforced protected areas (Pers. Obs. 2021). Reduced crop yields and increased disease prevalence were also reported as consequences of changing rainfall patterns in the Virunga mountains, Mt Kahuzi, and the Itombwe mountains [16,18]. Notably, in our study areas, perceived changes in crop yields could be related to nutrient depletion in the soils, due to the continued cultivation of the same fields over time (fallow systems are not currently practised in Burundi or Rwanda). In Rwanda, this could also be related to changes from polyculture to monoculture, as monoculture, promoted by national agricultural programs, has been the norm for over 10 years. In both countries, some respondents also reported reduced cow milk production and an increase in livestock diseases, which was also reported by farmers in the Itombwe mountains [19]. In Burundi, reduced fodder availability due to changing rainfall patterns was linked to reduced milk production in cows, whereas in Rwanda, reduced fodder availability was not mentioned as a driver of reduced milk production, as zero-grazing has been the norm for over 10 years.

4.2. Adaptation Strategies

Some important differences in adaptation strategies were observed between countries, as we also hypothesised. More strategies were reported in Burundi, and more farmers in Burundi were using multiple strategies. This is likely to be driven by greater freedom of choice for experimenting among farmers in Burundi—because of different agricultural policies and lower law enforcement than in Rwanda. Farmers often prioritise their household's food security over income maximisation [27], so implementing multiple adaptation strategies contributes to minimising risks. For example, more farmers in Burundi than in Rwanda changed their farm location or grew new crops. These options are not available in Rwanda, as current agricultural policies, which are highly enforced, limit both crop choice and farm locations [17]. Notably, more farmers in Rwanda were diversifying into vegetable or fruit production. This could be due to both (i) better access to urban markets for those crops in Rwanda and/or (ii) lower government control of such actions (compared to staple crop choice). It should be noted that in the long term, the increased cultivation of water-demanding horticultural crops could threaten farmers' adaptive capacity if future climatic changes reduce water availability [43].

All adaptation strategies mentioned by our study respondents have been reported in other mountain regions in the Albertine Rift. For example, increased irrigation and the increased use of inputs, the increased use of soil conservation techniques, and increased income diversification were also documented by farmers in the Itombwe mountains [19]. Around Mt Kahuzi, growing new crops or crop varieties, cultivating larger farms (to compensate for lower yields), rearing animals, or complementing farming with other off-farm activities were also mentioned [18]. Changing planting dates, soil conservation practices, irrigation, and agroforestry were mentioned by farmers in the Rwenzori Mountains [15]. Cultivating larger farms (to compensate for lower yields) or agroforestry were not mentioned in either Burundi or Rwanda, due to high population density and land scarcity.

4.3. Wealth Effects on Adaptation and Food Security

We also hypothesised that richer households would be using a larger number of adaptation strategies and would have higher food security. We found that this was clearly the case in Burundi, where fewer poor farmers used improved seeds, irrigation, and pesticides or diversified into animal rearing or vegetable farming, and where food security and food quality (during the previous year) increased with increasing wealth. In Rwanda, wealth effects were less conspicuous, particularly for food security, as only 50% of the rich households studied in this country reported food security, and only 11% reported having 'good' food quality. Previous work in Rwanda highlighted that agricultural intensification policies appear to be exacerbating food insecurity among rural farmers. Reference [25] showed that households living in areas of higher CIP intensity were more likely to run out of food earlier than they were ten years ago. Reference [27] reported that 27% of the poor and 13% of the rich farmers they interviewed suffered from food scarcity—a percentage which is even higher in our study area in Rwanda. These authors suggested that it was essential to consider options for easing the requirements of compulsory crop cultivation for households lacking the requisite generic capacities to adapt successfully—something we also recommend.

With regard to food quality, the low response of 'good' food quality among rich households in Rwanda is likely to be driven by a lack of access to their preferred foods. Preferred foods may have always been expensive (for example imported products), but as some participants noted, some traditional food products have become more expensive in the past few years (for example, sweet potatoes, as few farmers in Rwanda cultivate these now). Other studies have documented a change in rural farmers' diets following the CIP in Rwanda [27]. As highlighted by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), food is not just a matter of filling stomachs, it has a cultural dimension [44]. Further work on changing diets related to CIP, and the cultural implications of these changes, is recommended.

4.4. Limitations and Future Research Avenues

Our study approach has some limitations. First, we only studied four villages per country. Although biophysical and socioeconomic differences across the villages within each area studied (Kibira or Nyungwe) are rather limited (for example, market access or the presence of external agents of change), it is possible that by including more villages, other adaptation strategies could be identified. Secondly, we focused on climatic changes as the main challenge to farmers' livelihoods, but other drivers of change such as youth migration to urban centres are likely to act synergistically with climatic change, constraining adaptation options due to, for example, labour constraints. Indeed, climate change, population change, new technologies, globalisation, agricultural policies, and social change are all exerting increasing influence on rural smallholder farmers [27]. Additionally, we have only analysed households' food security and quality, and access to clean water in the previous year. More research on longer timescales and on different aspects of wellbeing, including material, relational, and personal wellbeing dimensions, is recommended. We report a range of on-farm and off-farm adaptation strategies, which could inspire adaptation options in other African mountains. However, we did not investigate their long-term sustainability, such as the potential negative ecological impacts of monocropping (such as reduced soil fertility or an increase in pest outbreaks), something which also requires further investigation.

5. Conclusions

This research has provided a cross-border study on local climate change observations and adaptation strategies used by smallholder farmers in the same mountain region. The results show that farmers in both Burundi and Rwanda report similar climatic changes and impacts on crops, animals, and human health, but that more adaptation strategies are used in Burundi, and more farmers in Burundi are using multiple strategies. This is likely to be driven by greater freedom of choice for experimenting in Burundi because of different agricultural intensification policies and lower law enforcement than in Rwanda. Results show that in both countries, the farmers' wealth affected their adaptation response and their food security. For all wealth groups (poor, average, rich), food security and 'good' food quality was found to be lower in Rwanda than in Burundi. Previous work in Rwanda already emphasised that agricultural intensification policies appear to be exacerbating food insecurity among rural smallholder farmers. The government of Burundi should consider these findings and ensure that their agricultural intensification policies do not exacerbate food insecurity among rural farmers. Given the high spatial variation in climates and soils in mountain regions with complex terrains, high farmer agency might help farmers become more resilient to climate change. This does not imply a lack of technical or external support, but rather, the greater co-production of knowledge among stakeholders, more 'science with society' rather than 'science for society' approaches [45].

Supplementary Materials: The following supporting information (questionnaire used) can be downloaded at: https://www.mdpi.com/article/10.3390/land12020329/s1.

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