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Adapting to Change: Understanding Rwanda's Socioeconomic Resilience in the Face of Climate Variability

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Abstract This research examines the socioeconomic impacts of climate change and natural disasters on livelihoods in Rwanda, a country highly dependent on agriculture and natural resources. Rwanda's economy and rural communities are particularly vulnerable to climate-related disruptions, including erratic rainfall, droughts, and floods. These changes affect crop yields, food security, and healthy water problems, influencing economic instability, hunger, migration patterns, and loss of human lives. By assessing case studies and delving into recent data on climate change in Rwanda and its effects, this study provides a detailed analysis of the specific ways climate change challenges socioeconomic well-being in Rwanda and recommends more resilient strategies for mitigation and adaptation. The methodology applied is qualitative and quantitative analysis with a diachronic comparison of the effect of climate changes and natural disasters, at least from 2010 until August 2024. We find out that throughout time, the impact of climate change increased, ranging from an increase in heavy rains in North, West and Southern Province, causing loss of lives and damaging infrastructure, including houses of people, roads and bridges, especially from 2021 to 2023. In this period, both the human and material costs increased, and 209 people died in 2023. There have been displacement as well as hunger and drought in Eastern and part of central and Southern provinces, including which hunger was called shira-umuteto (be resilient) from 2015 to 2017. The findings aim to offer policymakers insights, suggesting strategies to mitigate climate impacts and sustain socioeconomic development in Rwanda.

Keywords Climate Change Effects, Natural disaster, Rwanda Socioeconomic Development, Livelihood, Displacement, Hunger, Adaptation and Resilience

1. Introduction

Climate change significantly threatens socioeconomic stability worldwide, and Rwanda is no exception. As a landlocked, low-income country with a predominantly agrarian economy, Rwanda faces heightened vulnerabilities to climate-induced challenges. The country's reliance on rain -fed agriculture makes it particularly susceptible to the impacts of climate variability, such as erratic rainfall, prolonged droughts, and increased frequency of floods. These climatic shifts directly influence agricultural yields, food security, health outcomes, and even migration patterns, as individuals and families relocate to cope with environmental changes. Buheji and Muhorakeye (2023b).

Rwanda's government and national and international stakeholders have recognised these challenges and has undertaken various initiatives, such as self-sufficiency practices, to counteract the adverse effects of climate change, Buheji and Muhorakeye (2023a). Key interventions include implementing climate-smart agriculture practices, establishing early warning systems, and promoting sustainable land management. Additionally, Rwanda's Green Growth and Climate Resilience Strategy underscores the country's commitment to building resilience against climate change while ensuring sustainable socioeconomic development. However, substantial gaps persist despite these efforts, particularly concerning urban planning and employment diversification. Buheji (2018).

Over the years, it has been proven that climate change is a global challenge requiring an integrated global response and the principle of common but differentiated responsibilities and respective capabilities. Rwanda is committed to taking urgent action to mitigate and adapt to the effects of climate change. As part of UNFCCC, Rwanda has joined the Paris

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Agreement to limit temperature rise to 2℃ with an effort to reach 1.5℃ compared to pre-industrial levels.

In May 2020, Rwanda submitted its revised NDC, in which the country has committed to a Greenhouse gas (GHG) emissions reduction target of 38% from the Business As Usual (BAU) levels projected from 2015 to 2030 (REMA, 2023). Rwanda took measures to adopt, for instance, electric cars and motorbikes, planting trees and making use of sustainable farming and construction. These aim to reduce the socioeconomic effect of climate change and natural disasters. However, little is known about the socioeconomic costs that Rwanda is facing.

Therefore, this study aims to provide a comprehensive analysis of the effects of climate change and natural disasters on socioeconomic livelihoods in Rwanda, with a focus on human lives, agriculture, and construction. Using a diachronic approach, this research examines data from 2010 to August 2024, tracking the evolving impacts of climate change and exploring potential avenues for mitigation. By synthesising quantitative and qualitative insights, this study seeks to offer evidence-based recommendations that policymakers can use to fortify Rwanda's resilience to climate change and promote sustainable development. Buheji (2018).

2. Literature Review

2.1. The General Impact of Climate Change

Climate change results from annual and long-term changes in average weather patterns (NASA, 2024). Changes are mainly observed through statistical data taken by geographical experts. They observed that from the 19th century up to the 21st century, global warming has slightly increased to 1 degree Celcius worldwide. However, regional effects are different and can increase exposure from one side to another depending on some effects of wind, cyclical ocean situations like El Nino and La Nina, and the Pacific Decadal Oscillation (NASA, 2024).

Human factors, including burning coal and petroleum for industrial energy and machines and deforestation, may slightly decrease greenhouse gas levels—a natural creation that reduces the X-rays and hits from the sun to the earth. National Geographic Education (2024) of the USA highlights that some effects are caused by human factors, including burning the forest in the Western part of the USA, Boise National Forest, Idaho. Some evidence of climate change has been violent wind, such as hurricanes, heatwaves, wildfires, floods, droughts, and heavy rain. National Geographic Education (2024).

There have been over 170 scientific studies on the role of human-induced climate change on 190 extreme weather events worldwide since 2004. Moreover, the researchers have found that climate change has increased the risk of wildfires in the western United States, extreme rainfall in China, and drought in South Africa (National Geographic Education, 2024). This drought in southern Africa did not only reach South Africa. Still, other countries, including Zimbabwe, Zambia, Malawi, Namibia, Lesotho, and parts of Mozambique and Angola, were also affected. (Aljazeera, October 15, 2024).

This drought in southern Africa caused almost 30 million people to starve and 21 million children to be malnourished, according to the WFP (World Food Program). More than 27 million lives were affected by the worst drought in a century, with 21 million children malnourished, according to WFP. "UN mentioned that millions of people across Southern Africa are going hungry due to drought, causing humanitarian catastrophe (Aljazeera, October 15, 2024).

2.2. How Climate Change is Affecting Poverty in Africa?

Climate change significantly impacts poverty in Africa, where many communities are highly vulnerable due to economic dependence on climate-sensitive sectors such as agriculture. Agriculture is the primary livelihood for many people in Africa. Climate change leads to unpredictable weather patterns, droughts, and floods, reducing crop yields and threatening farmers' food security and income. Ajaj et al. (2024).

Climate change can disrupt food production, increasing food prices and decreasing availability. This exacerbates malnutrition and poverty, particularly among low-income households. Climate-related disasters can damage infrastructure, disrupt markets, and hinder economic growth. As businesses and livelihoods are affected, the overall economic stability of communities declines. Climate change contributes to the spreading of diseases such as malaria and cholera due to changing ecosystems and weather patterns. Health crises can lead to increased healthcare costs and loss of productivity, pushing families deeper into poverty. Slater et al. (2007).

Changes in precipitation patterns lead to water scarcity, affecting drinking water supplies and agricultural irrigation. This scarcity can hinder economic activities and increase stress on vulnerable populations. This exacerbated vulnerabilities, leading to forced migration as people fled from areas affected by extreme climate events. This displacement can lead to overcrowding in urban areas, strain public services, and increase poverty levels.

Women, children, and marginalised communities are becoming more vulnerable. Due to existing socio-economic inequalities, they often bear the brunt of climate impacts. They may have less access to resources and decision-making power, further entrenching poverty. Besides, many of these communities lack the financial and technological resources needed to adapt to climate change effectively. This limits their ability to build resilience and respond to climate-related challenges, perpetuating a cycle of poverty. Buheji and Muhorakeye (2023a), Slater et al. (2007).

Potential ecosystem degradation and biodiversity loss can affect Rwandan communities that rely on natural resources for their livelihoods, such as fishing and foraging. This loss can further threaten food security and income.

2.3. Climate Change in Africa's Education

Climate change has profound implications for education in Africa, affecting both the availability and quality of educational

opportunities for students and youth. For example, extreme weather events such as floods, droughts, and storms can damage school buildings and facilities, disrupting educational services. Schools may become unsafe or uninhabitable, forcing closures and displacing students. Climate change can exacerbate existing inequalities in access to education, particularly in rural and marginalised communities. Families may prioritise immediate survival needs over education, pulling children out of school to assist with livelihood activities or due to increasing mobility from climate-related migration. Buheji and Muhorakeye (2023b) mentioned how drought can lead to health challenges such as heat stress, waterborne diseases, and respiratory illnesses, affecting student attendance and performance. Poor health outcomes can lead to higher dropout rates and lower educational attainment. However, climate change can create opportunities for educational institutions to adapt their curricula to include environmental education and climate awareness. Teaching students about climate change, sustainability, and resilience can empower future generations to address these challenges and engage youth more in socioeconomic issues, Buheji (2023). Climate change can necessitate enhanced training for teachers to address the new challenges that students face. Investing in teacher training and educational resources about climate adaptation and resilience is essential for effective education.

Local communities play a crucial role in education. Engaging communities in climate action and resilience-building can create supportive networks for students and families, enhancing educational outcomes. Schools may need to adopt remote learning solutions in response to climate-related disruptions. However, access to technology and reliable internet can be limited in many parts of Africa, creating disparities in educational quality and access.

Integrating climate change into education policies and strategies is essential for addressing its impacts. Governments and organisations can invest in climate-resilient education systems, training, and research to better prepare future generations.

2.4. How Climate Change is Affecting Rwanda's Socioeconomic Landscape?

Climate change profoundly affects Rwanda's socioeconomic landscape, particularly in agriculture, health, migration, and employment. Rwanda's dependence on rain-fed agriculture makes it highly vulnerable, with studies showing that climate variability disrupts crop yields, leading to food insecurity and reduced household income (Nzeyimana et al., 2021). Additionally, climate-driven health risks, such as the spread of malaria and waterborne diseases during droughts, strain public health resources and diminish workforce productivity. Mukeshimana et al. (2020).

Migration is another significant outcome, as rural populations increasingly relocate to urban areas due to recurrent floods and soil erosion. This internal migration exacerbates urban challenges, including housing shortages and job scarcity (Uwizeyimana & Bizimana, 2023), as many labour forces quickly unproductive farming due to drought, fertile land scarcity, and unpredictable rainfall, Buheji and Muhorakeye (2023b). Economic disruptions in climate-sensitive sectors, such as agriculture and tourism, further undermine job stability and income distribution, especially for youth, Buheji (2023), Ingabire & Nsanzimana (2022).

In response, Rwanda has implemented adaptation strategies such as climate-smart agriculture, sustainable land management, and early warning systems, which show potential in building community resilience. Government initiatives like the Green Growth and Climate Resilience Strategy aim to enhance these adaptive capacities, although gaps remain, particularly in urban planning and employment diversification (Niyonsenga et al., 2021).

Moreover, climate change impacts extend beyond immediate environmental changes, driving significant economic and social transformations. For Rwanda, climate disruptions translate to diminished agricultural productivity, jeopardising food security and reducing income for the predominantly rural population. Additionally, climate-induced water scarcity exacerbates health risks and limits access to clean water, disproportionately affecting vulnerable communities. The increased occurrence of extreme weather events, such as floods and landslides, leads to the displacement of populations. It creates strains on urban centres, where migrants often face limited access to employment, housing, and essential services. (REMA, 2024).

2.5. Realising the Potential of Climate Change on Rwanda Tourism

Rwanda has a unique opportunity to leverage climate change as a catalyst for enhancing its tourism sector while promoting sustainability and conservation. Through ecotourism, Rwanda can capitalize on its goodwill value through its rich biodiversity, including the famous mountain gorillas. Climate change even raises Rwanda's goodwill value through focused awareness initiatives that can promote ecotourism programs aimed at conservation efforts, attracting visitors who are interested in environmental sustainability and wildlife preservation. Buheji and Mushimiyimana (2024).

By adopting and showcasing sustainable tourism and experience economy practices, Rwanda can position itself as a leader in eco-friendly tourism. Investments in renewable energy, waste management, and sustainable agriculture can enhance the tourist experience while benefiting local communities. Buheji and Ahmed (2024).

Climate change has spurred interest in more diverse tourism experiences, including hiking, bird watching, and cultural tourism. Rwanda's varied landscapes and climates provide ample opportunities for adventure tourism that can adapt to changing conditions.

This might also have a positive impact, shifting local cultures and practices. Tourists may be intrigued by how communities adapt to these changes, leading to a rich cultural exchange and an understanding of climate resilience. Buheji and Ahmed (2024).

Increased global awareness of climate change can drive tourism to destinations that actively engage in addressing these issues. The country can attract environmentally conscious tourists by promoting Rwanda's conservation efforts and climate actions.

Since the Rwandan government has emphasized the importance of tourism as a key economic driver, more investments in building infrastructure that is resilient to climate change, such as sustainable hotels and transport options, can enhance the tourist experience and ensure long-term viability. Such programs and initiatives would involve more local communities in conservation and climate resilience tourism initiatives, which would create job opportunities and empower residents. This can foster a more authentic tourism experience for visitors, Buheji and Ahmed (2024). Therefore, highlighting Rwanda's unique climate adaptation strategies and its commitment to sustainability in international marketing campaigns can differentiate it from other tourist destinations.

2.6. Rwanda Resilient Actions towards Climate Change

In recent years, in response to the growing climate change challenges to the economy, Rwanda has put in place a legal, policy and strategic framework to deal with climate change and climate variability-induced risks and economic losses through (among other approaches) reducing vulnerability and building resilience to the impacts of climate change. REMA (2024), Buheji (2018).

Rwanda's adaptation and resilience priorities draw upon the Green Growth and Climate Resilience Strategy adopted in 2011 with a time horizon 2050. The key adaptation actions are: (1) Sustainable intensification of agriculture, (2) Agriculture diversity in local and export markets, (3) Integrated Water Resources Management (IWRM) and planning, (4) Integrated Land Use and Management, (5) Efficient, resilient transport systems, (6) Ecotourism, Conservation and Payment of Ecosystem Services, (7) Sustainable Forest and Agroforestry, (8) Disaster and Diseases Prevention, and (9) Climate Data and Projections. REMA (2024).

2.7. Climate Change Mitigation

Over the years, climate change has been a global challenge requiring an integrated worldwide response and the principle of common but differentiated responsibilities and respective capabilities. Rwanda is committed to taking urgent action to mitigate and adapt to the effects of climate change. As part of the UNFCCC, Rwanda has joined the Paris Agreement to limit temperature rise to 2℃ and aim to reach 1.5℃ compared to pre-industrial levels. REMA (2024).

In May 2020, Rwanda submitted its revised NDC, in which the country has committed to a Greenhouse gas (GHG) emissions reduction target of 38 % from the Business as Usual (BAU) levels projected from 2015. The NDC indicated that GHG emissions will more than double under the BAU projection from 5.3 MtCO2 e in the base year (2015) to around 12.1 MtCO2 e in 2030. With the domestically supported unconditional mitigation measures, 2030 emissions are forecast to rise to around 10.2 MtCO2 e, representing a reduction against BAU of around 16%. Since 1970, the temperature has continued to increase slightly. REMA, (2024); Muhire et al. (2024).

The study's focus on agriculture, health, migration, and employment reflects how climate change shapes socioeconomic outcomes. Agriculture remains a cornerstone of Rwanda's economy, accounting for a significant portion of GDP and employment. However, climate variability disrupts traditional farming patterns, leading to inconsistent crop yields and economic instability in rural regions. Health sectors are similarly impacted, as climate change contributes to the proliferation of diseases like malaria, as well as waterborne diseases in times of flooding, overwhelming healthcare resources and reducing productivity. Buheji (2018).

As hunger and starvation hit most of Africa, one solution to coping with climate change's socioeconomic effect is setting up a sustainable agriculture mechanism. According to Shelef et al. (2018), sustainable agriculture has four pillars: land management, resource management, human interface, and the ecosystem interface. These pillars must work together to make agriculture more productive and people resilient to climate change's adverse effects, including hunger and drought. As Rwanda's economy relies on agriculture subsistence, reform in that sector and other sectors would enhance more adaptive results to climate change. This includes adopting new species regarding crops and animals and adequately managing the existing local species. Shelef et al (2018). Mitigation also includes relocating people where necessary, increasing the chance of rain, planting trees, and setting up early warning mechanisms for landslides, floods and droughts. Buheji and Muhorakeye (2023b).

3. Methodology

The methodology used in this research is both qualitative and quantitative. In qualitative research, we used observation and interviews with experts and people affected by climate change, such as farmers and the REMA expert, in December 2024. The researchers also attended and listened to the feedback and content on the conference on climate change in Africa organised by UPAFA (Universite Privee Ababe Francophone) that took place in Kigali in 2024.

Moreover, in terms of quantitative analysis, the researcher analysed the assessment done by MINEMA, the ministry in charge of environmental management in Rwanda. The quantitative report highlights the specific number of affected people, the risk encountered in previous years, the flood, rain, and landslide incidents, etc.

The research does not attribute all socioeconomic effects as the sole result of climate change. It concurs with the interviewees from REMA that some of the effects are caused by other natural phenomena apart from the changes in the climate per se. However, we urge that most of the impact, such as heavy rain and drought, have been incidentally

caused by climate change, as we mentioned earlier, as long as Rwanda's climate change has increased to 1.4℃ compared to a global increase of 1℃ in the last three centuries. The effect of this change is highlighted in the following part. The findings analyse the data through a diachronic comparison approach, especially from 2010 until August 2024, as per data from MINEMA.

4. Findings

In this research, the findings hinge on the following points: (1) the socioeconomic effect of climate change and natural disasters on Rwanda, (2) mitigation and adaptation strategies, and (3) recommendations from 2010 up to now, and climate change cases such as heavy rain, increase in temperature or heat, and drought.

4.1. Trends of Temperature Indicators Change

Table (1) represents the concomitantly analysed effects on the socioeconomic livelihood of the people in Rwanda, such as people's displacement, crop production and yield effect, and other socioeconomic effects, including fear of delays in rain, psychological effect on thinking and discourse effect.

Typically, rains vary from relatively heavy rain from September to December and heavy rain from March to May each year between (est. of 700 to 1400), from the East, which has less rain, to the West and North, with rain and landslides.

Rwanda's temperature has increased by 1.4℃ higher than the global average of 1℃, according to NASA 2024 and the government of Rwanda, from the 1970s to the present. The data says that it may increase up to 2.℃ in the 2030s.

Table (1). General Overview of Climate Change Effect in Rwanda and Qualitative Analysis Of these Effects

Timeframe	Climate change situation			Socioeconomic Effects		
Annual period of effect	Rainfall levels in mm annual average and landslides and floods	Temperature	drought cases	crop production effect and infrastructure damage	Displacement due to flooding and land sliding	loss of human lives
2010	1,212	1.4℃	East Mostly affected Bugesera District			
2011	1,212	1.4℃	Some effect in Eastern provinces Nyagatare, Ngoma and Bugesera District			
2012	1,212	1.4℃				
2013	1,212	1.4^{o} C			Moving people from swampy land	
2014	1,212, with a shortage of rain in East and Southern parts of the country	1.4℃				
2015	1,212, Shortage of rain	1.4℃		Hunger countrywide		
2016	1,212	1.4℃		Hunger and adaptation through resilient crops including cassava		
2017	1,212	1.4℃				
2018	1,212	1.4℃				
2018	1,212	1.4℃				
2019	1,212	1.4℃				
2020	1,212	1.4^{o} C		Increasing adaptation to drought through new crops including sweet potatoes, beans (*Shyushya*) and cassava		
2021	1,212	1.4℃				
2022	1,212	1.4℃				
2023	1,212, Cases in North and West Provinces Case of flood during May 2 to 3 in North West and South province	1.4℃		Roads and bridges were damaged to high coast in North, West and some part of the South provinces, costing around 110 billion Frw	Affected families were displaced and government relocated them to more safe zones.	131 people died in land slides

Source: Authors, data from different sources, including the World Bank Group, 2024, Meteo Rwanda, Sebaziga et al. (2020), and REMA (2023).

- Prolonged droughts are frequent in the east and southeast regions.
- Droughts can lead to famine, food shortages, and displacement of people.
- In 2016, drought-affected Rwanda's Eastern Province, leaving many households food insecure.
- Severe flooding and landslides followed an extended drought in Rwanda in early May 2021.

Rwanda's average temperature varies according to its topography. Low temperatures are observed in the regions of high altitude, with average temperatures ranging between 15 and 17 C. In some parts of the volcanic region, temperatures can go below 0 C. Moderate temperatures are found in areas with intermediary altitudes where average temperatures vary between 19 and 21 C. In the lowlands (east and southwest), temperatures are higher, and the extreme can go beyond 30 C in February and July-August (REMA, 2024).

Nkurunziza (2024) noted that Disasters cost the country approximately $300 million in direct effects annually, according to the Ministry in Charge of Emergency Management (MINEMA). This proves that a touch of climate change is having a remarkable impact on the country's budget and the lives of citizens.

Climate change impact studies, although they are still uncertain on the frequency and severity of adverse weather events, have shown that the effects are significant for low-input farming systems, such as subsistence farming that are located in marginal areas and due to socio-economic, demographic, and policy trends have the least capacity to adapt to changing climatic conditions (Slater et al., 2007). As a result, agricultural activities are prone to risks and uncertainties of various natures, including biophysical, abiotic, climatic, environmental, biotic (pests, diseases) and economic (FAO, 2012). Many of these risks have a climatic component, and most of them will be affected by climate change, either in intensity, scope or frequency.

Siriet al. (2008) point out a testimony of a significant threat concerning the aggressiveness and capriciousness of climate variability that Rwanda is experiencing in the region where the Nile Basin had an increase of about 0.2℃ to 0.3℃ per decade during the second half of the century, while in Rwanda temperatures increased by 0.7℃ to 0.9℃. This will adversely impact agriculture, resulting in poor health status and dependence on climate-sensitive resources like wetlands. Consequently, resilient efforts are required to ensure agricultural sustainability, which is difficult to achieve. Buheji (2018).

Figure (1). Illustrates the flood in Rwanda 2023 (*Source: REMA, 2023*)

4.2. Analysis of Climate Change Effects and Natural Hazards in Rwanda from 2018-2024

This quantitative data analysis highlights human loss (death), injured persons, damaged crops, forests, houses, churches, markets, bridges, etc., in Rwanda from 2018 until August 2024. The data have been retrieved from the MINEMA data portal.

Table (2) below shows that in seven years, Rwanda lost 1,273 people, and climate and natural hazards caused 2,112 injuries. There are 48,808 destroyed and damaged houses. The data shows that agriculture has been heavily affected, as there has been damage to crops of 33,103.74205 per Ha in addition to damage in forests of 757 per Ha. Churches and roads have been heavily affected, and that is one of the reasons the government set up restrictive measures to renovate the churches this year.

The data in Table (3) shows precisely the types of causes of the aforementioned damages since 2018. These are heavy rain, landslides, etc.

Table (2). Quantitative Analysis of Climate Change from MINEMA (Rwanda)

year	deaths	injured	Houses destroyed; and damaged	Crops per Ha	Forest damaged per Ha	Lost cattle; and other livestock	Road sections	churches	factory
2024	23	26	190	198.76	92	6; 3	1	1	1
2023	243	406	2501; 7454	2176.3178	41	74; 1134	32	30	7
2022	205	401	4156	1917.74425	73	85; 116	72	60	4
2021	116	248	4808	198.76	92	6; 3	1	1	1
2020	298	414	8098	4661.5	458	132; 3365	154	22	1
2019	134	271	5691	10610.45	1	113	30	50	0
2018	254	346	15910	13337.21	0	815	32	26	0
Total	1,273	2,112	48,808	33,103.74205	757	5,852	322	190	14

Source: Authors, data provided by MINEMA, Rwanda, December 2024

Table (3). Illustrates Three Years of Published Specific Causes & Effects of Climate Change in Rwanda

Causes	2021			2022			2023		
	Deaths of humans	Houses destroyed and heavily damaged	Crops damaged per Ha	Deaths of humans	Houses destroyed and heavily damaged	Crops damaged per Ha	Deaths of humans	Houses destroyed and heavily damaged	Crops damaged per Ha
Floods	3	29	373	33	93	445.09	74	4,205	351.4778
Landslides	2	58	13	24	140	10.4	87	2972	788.705
Lightening	59	8	0	57	12	0	43	11	0
Heavy Rain	47	2247	2875.72	12	1572	564.95	3	373	300.85
Wildfire	0	5	4.57	0	0	3	0	0	254.84
Strong Wind	0	144	52.5	2	1803	140.6	2	1806	269.905
Total	111	2,491	3,318.79	128	3,620	1,164.04	209	9,367	1,965.7778

Source: Authors, data gathered from MINEMA, December 2024.

4.3. Cumulative Cost of Human Lives, Houses and Crops per Ha from 2020-August 2024 Climate

Despite the Rwandan government managed to implement various policies and strategies to mitigate the effects of climate change, such as investments in climate resilience, sustainable agriculture practices, and infrastructure improvements, the cumulative cost of human lives, houses, and crops in Rwanda has been significant due to this change. The country has experienced various climate-related challenges, such as increased rainfall variability, droughts, and rising temperatures. For example, climate change has led to health issues, malnutrition, and increased vulnerability to diseases, influencing the overall mortality rates. Floods and landslides, particularly in regions like Northern Rwanda, have caused fatalities and displacement.

The changes in extreme weather events resulted in the destruction of villages and rural area infrastructure, including homes. Heavy rains often lead to floods and landslides, which can displace communities and cause property damage in certain areas.

Agriculture is a vital sector in Rwanda, employing many of the population. Climate change has affected crop yields due to droughts, pest outbreaks, and soil erosion. This impacted food security and farmers' livelihoods, making them more vulnerable. Thus, the cumulative economic cost includes loss of productivity, reduced agricultural outputs, healthcare costs from climate-related diseases, and disaster relief and rebuilding expenses.

To gain a comprehensive understanding of the costs and impacts, the researchers used the December MINEMA (2024) published assessment to correctly estimate the type of impact climate change is having on Rwanda.

The table above highlights that human lives due to climate change and natural hazards increased in Rwanda, from 111 deaths in 2021 to 209 deaths in 2023. This pace was too high due to other regional climate change factors linked with heavy rain from El Nino and La Nina facts wind from the Indian Ocean, which also caused floods in Rwanda, Kenya, and other parts of East Africa.

The first killer in terms of natural hazards associated with climate change is Rwanda's landslides. As the rain increases, the sloppy mountainous area of Rwanda partly collapses and takes the lives of many. Landslides took the lives of 87 people in 2023.

Climate change and natural hazard effects heavily affect the agriculture sector and construction. The data shows that heavy rain in 2021 damaged crops, and the strong wind of 2022 damaged houses.

5. Discussion

This study investigates the socioeconomic costs of climate change and natural disasters in Rwanda, a vulnerable nation heavily reliant on agriculture and susceptible to climate variability. As climate-induced challenges such as erratic rainfall, prolonged droughts, and increased flooding intensify, they disproportionately affect agricultural yields, food security, health outcomes, and contribute to migration patterns. Despite the Rwandan government's proactive measures, including the Green Growth and Climate Resilience Strategy and a commitment to reducing greenhouse gas emissions, significant gaps remain in urban planning and employment diversification.

Utilizing a diachronic approach, this research analyzes data from 2010 to August 2024 to understand the evolving impacts of climate change. Employing both qualitative and quantitative methodologies, the study synthesizes insights from experts, affected individuals, and governmental reports. Findings indicate that climate change has led to the loss of human lives, destruction of property, and degradation of agricultural productivity, costing the nation an estimated $300 million annually. The paper proposes evidence-based recommendations aimed at enhancing resilience and promoting sustainable development in Rwanda. Through improved agricultural practices, community engagement, and infrastructure investments, the study emphasizes the urgent need for integrated approaches to address the socioeconomic effects of climate change and bolster adaptation strategies for the future.

The qualitative finding shows that the socioeconomic effect of climate change is high in Rwanda in terms of damages caused by drought in the South and East provinces

and those caused by landslides in the North and West provinces. The data analysed qualitatively support the quantitative ones provided in MINEMA and concur that landslides, floods, heavy rains, and wildfires, mostly resulting from climate change and natural hazards, heavily affected Rwanda's socioeconomic livelihood in terms of destruction of houses, killing people, and damaging crops.

This research concurs with previous ones, such as Muhire et al. (2024), who highlighted that given the increase in temperature in Rwanda and the rise in population, quick and strong measures are needed to mitigate the effect of drought in East and South Rwanda and issues of heavy rain and landslides in North and West as well as in other highland zones. It is necessary for the community, government, and stakeholders of socioeconomic development to do so.

If the country does not take measures, the drought that hit another region of Africa, especially in the southern region, as mentioned in this research, can also hit Rwanda. The measures include continuous reform and modernisation in agriculture and ways of saving harvests more durably and sustainably. Though Rwanda made a progressive step in agriculture, the research highlights that this pace needs to be tripled for climate adaptation mechanisms.

The research also concurs with the proposal to strengthen urbanisation in Rwanda, improve housing planning, and use durable materials to establish measures of adaptability, resilience, and self-sufficiency in the construction sector (Mushimiyimana & Buheji, 2024). Construction mechanisms adaptable to each area of the country and its geographic aspect are recommended.

Addressing climate change's impacts on poverty in Africa requires integrated approaches that focus on building resilience, promoting sustainable agricultural practices, improving access to resources, and enhancing the adaptive capacity of vulnerable communities. Changes in climate can also affect livestock health and productivity, impacting pastoral communities. Droughts and extreme weather can decimate herds, threatening the livelihoods of pastoralists.

6. Conclusions

This research was conducted to know the socioeconomic costs of Rwanda due to climate change and natural hazards. The combination of both is crucial because, as the officer in the REMA mentioned, climate change affects natural disasters, but not all natural disasters are caused by climate change. That is why we adopted that theme to assess the effects of climate change and natural disasters on Rwanda's socio-economic livelihood. Moreover, this was the fruit of an international conference organised by UPAFA from Mali in Rwanda this year, where the Institute for Advanced Studies (SIAS) Rwanda was invited to present the socioeconomic effect of climate change in Rwanda.

Both qualitative and quantitative analyses highlight that Rwanda has been heavily affected by an increase in global warming increase of 1℃ since the industrial era, which the country surpasses as it has a warming increase of 1.4℃. Therefore, the effects such as landslides, floods and drought affect Rwanda, killing hundreds of people and damaging thousands of houses and crop production. The landslides alone in 2023 took the lives of 87 people and damaged almost 3000 houses, while heavy rain destroyed crop production in 2021.

The researchers recommend that there should be measures including modernizing and intensifying agriculture to diminish the risk of hunger. The consideration of differences in the landscape, as east and South are more affected by drought, and North and West by the heavy rain, need to be considered in setting up community resilience strategies, including farming and house construction strategies. We recommend further research on the psychological effect of climate change in the community, the real community cost of climate change and natural hazards and the possible benefits that can be extracted from climate change if adaptation measures are well done. We also recommended community-level adaptation capability and a bottom-up framework for setting resilience and adaption mechanisms to climate change and natural disasters.

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