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The Impacts of Climate Change on Livelihoods in Kapsokwony Division in Mt. Elgon SB-County, Kenya

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Abstract

This research examines how climate change has harmed the livelihoods of people in Kenya's Kapsokwony Division, Mt. Elgon Sub-County, by jeopardizing food production systems, resulting in decreased agricultural output, poor livelihoods, increasing poverty, and slowed economic development. The study's ultimate goal was to encourage policy discussion on long- and short-term strategies to strengthen adaptive capacity and resilience in order to improve livelihoods and ensure long-term socio-economic development. Informant and in-depth interviews (KIIs), as well as focused group discussions (FGDs), were utilized to collect primary data, while secondary data was gathered through desk-top literature and other sources. The research project resulted in capacity building, adaptive learning, community empowerment, and transformative knowledge application. The findings influenced inhabitants' attitudes and behaviors, as well as raising knowledge about the effects of climate change on their livelihoods. Long-term policies and adaptive measures to improve climate resilience, improve livelihoods, and sustain social economic development were developed using the new societal knowledge. Significantly, the research resulted in a number of technologies and ideas that might be utilized to mitigate the consequences of climate change and variability in the region. This paper is intended to mirror the impacts of climate change on livelihoods in the study area.

Keywords: Poverty, social inequity, climate resilience, transformation knowledge, vulnerability, adaptation.

1. Introduction

Climate change and its interactions with other anthropogenic stressors including encroachment, land fragmentation, degradation, and destruction of natural habitats have a significant impact on mountain ecosystems all over the world (Mano and Nhemachena, 2007; Biggs *et al.,* 2008; Amwata *et al.,* 2015). Because of poor agricultural output and changes in ecosystem services, climate change and variability can have considerable negative implications on livelihoods. Reduced soil productivity due to erosion and increased evapo-transpiration will be a result of falling agricultural production due to inconsistent, unreliable, and unpredictable rainfall. According to the IPCC (2007), any increase in global average temperature above 1.5°C - 2.5°C is projected to have major effects on land productivity, affecting lives. Crop agriculture, livestock rearing, and non-farm economic activities dominated household livelihoods in Kapsokwony Division, Mt. Elgon Sub-County. Climate change, combined with economic, political, and environmental variables, has increased vulnerability for the region's poor and less fortunate households. Poor households are the most susceptible because they confront cultural, social, and political barriers to accessing knowledge and resources, as well as restricted opportunities to participate in informed decision-making.

Climate change has affected various socio-economic sectors in the study area including crop farming, livestock raising, water resource management, health and sanitation, biodiversity and energy (Thakur and Bajagain 2019). Communities living in the research region have limited access to knowledge and resources, which is one of the most likely reasons why they are subjected to extreme occurrences caused by climate change and variability.

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Furthermore, the deterioration of ecosystems exposes communities living in these ecosystems to increasing climatic vulnerability (Travers *et al.,* 2012). Smallholder farmers must pick, employ, and capitalize on adaption technologies to improve their livelihoods and well-being while also allowing them to respond effectively to climate change's ongoing and unpredictable impacts. Adaptive strategies developed by combining scientific and indigenous knowledge are critical in the development of adaptive policies. Indigenous knowledge, based on observations, perceptions, and experiences over time, can be effectively combined with scientific information to improve climate change mitigation and adaptation methods for improved agricultural productivity and food security (Amwata *et al.,* 2018).

As a result, smallholder farmers should have access to transformation knowledge so that they can plan and prioritize their land use strategies. Food security should be given high attention in order to maintain livelihoods. This can be accomplished through effective land and natural resource management. The goal of the paradigm shift is to keep agricultural productivity and animal husbandry in balance with the effects of climate change. Farmers should be informed on the type of cattle to raise based on long-term climate change projections. Financial institutions should also be prepared to lend to farmers for agricultural investments. During extended rainy seasons or dry seasons, smallholder farmers should be counseled on when to sow and what types of crops to raise.

Cost efficiency, co-benefits, trade-offs, and practicalities are all considerations to consider while creating adaptive technology. To enhance resilience to climate shocks, the technologies to be adopted must be helpful under present climate conditions and those that may be adaptable under future climatic conditions. Top-down and bottom-up techniques to adaptation should be used, and they should be effective, efficient, egalitarian, sustainable, flexible, legitimate, robust, and repeatable. The next step is to compare scenario methods' strengths, weaknesses, and infrastructure and capacity requirements. Agriculture and livestock husbandry are the mainstays of rural livelihoods in Mt. Elgon Sub-Kapsokwony County's Division. However, crop griculture and cattle, on the other hand, are among the most sensitive economic sectors in the region to the effects of climate change. Livestock is extremely vulnerable to environmental changes and is already suffering from the effects of climate change. Droughts have become more common in the region, resulting in increased cattle morbidity and mortality due to a lack of pasture, an increase in disease occurrences, and a breakdown of marketing infrastructure (ROK, 2018).

Climate change's combined effects on agriculture and livestock have a negative influence on people's socioeconomic standing, livelihoods, and, as a result, poverty and food security. Furthermore, food security is today a global issue because the majority of people, particularly in Africa, are facing significant famine. Poor crop harvests were reported in Eastern Uganda and the Ethiopian highlands, as was the case in this study, due to unreliable and unpredictable rainfall, as well as an increase in the frequency of pests and illnesses in the region. According to a conversation with a farmer in the research area, poor crop output is mostly attributable to changing rainfall patterns and lower soil fertility.

Poverty is a multi-faceted, complex situation that extends beyond a lack of financial resources. Lack of education and skill, poor health and sanitation, insufficient access to clean drinking water, an insufficient or risk asset base, poor quality or insecure housing, weak safety nets to ensure basic consumption can be maintained when income falls or crops fail, and a lack of power and voice are all factors (Satternwaite, 2003). The climate change research community must be directly involved in knowledge generation, which is why the poor are likely to be more vulnerable to climate change impacts, yet little is known about factors that promote and strengthen resilience (Leichenko and Silva, 2014). Increased ecological degradation as a result of climate change will have a significant impact on many livelihoods. Those most vulnerable to climate change are the poorest people who live in climate-sensitive locations and have limited ability to adjust to climate change shocks (IPCC, 2007).

Climate change experts in Ethiopia's highlands and Ruwenzori Mountains have discovered that subsistence farmers and pastoralists, who make up a substantial section of the rural population, may be badly affected by climate change. Impacts on livelihoods based on IPCC (2007) forecasts in the Eastern Himalayas (EH) show that precipitation will most likely decrease in the future. In the Eastern Himalayas (EH), Climate Change Impact and Vulnerability (CCIV), there will be a decrease in potentially good agricultural land, while others will gain from significant increases in acceptable regions and production potentials (Fischer *et al.,* 2002).

Several studies have revealed that rice, corn, and wheat production has decreased as a result of increased water stress caused by rising temperatures, increased *El Nino* frequency, and a decrease in the number of rainy days (Agarwal *et al.,* 2000; Raza, *et al.,* 2019; Fischer *et al.,* 2002; Tao *et al,* 2004).

Adaptation measures should include all aspects of livelihood and, as a result, the current needs. They should involve the implementation of NAPAs, NCCAPs, policies and programs for climate change management (Thakur and Bajagain 2019). Actions that target and lessen the vulnerabilities of impoverished communities can help poor communities adapt successfully. Communities in the region can work together to create a shared platform to address issues including catastrophe risk reduction, climate change, environmental management, and poverty reduction. Adaptive capacity is essential for improving the socioeconomic characteristics of communities and households since it encompasses changes in behavior as well as changes in resources and technology. Options that promote shock resilience and support adaptation, as well as those that represent incremental rather than radical change, are the best choices (Biagini *et al.,* 2014). If technologies are not fit for a future climate, they can be ineffective or even hazardous if there is insufficient scientific knowledge of future conditions (Biagini *et al.,* 2014).

2. Materials and methods

2.1. Study site

The Mt. Elgon environment in Kenya is one of the country's major water reservoirs, with abundant land-based resources suitable for agricultural development. The research area is situated on fertile slopes that are directly impacted by human climate change. The research area is about between latitudes 0°47'3N and 0° 52'3N, and longitudes 34° 37'3E and 34° 43'E (Figures 1 and 2). (GoK 2009). The study was place in the twelve sub-locations that make up the Kapsokwony Division in Kenya's Mt. Elgon Sub-County. The research area is located on the south eastern slopes of Mt. Elgon and spans 58.4 km^2, with a population of around 100,000 people (GoK, 2009). The population density in the area is around 475 people per square °kilometer. Its isolation is defined by a lack of road, school, hospital, communication, and energy facilities, as well as piped water. Domesticated animals (donkeys and oxen) are mostly employed for traction and transportation of farm products to market sites outside the region because to the region's weak infrastructure. In recent years, 'BODA BODA' (motor-bikes) have become the primary mode of transportation for people and farm goods.

The research was carried out in Kenya's Bungoma County, at the twelve sub-locations that make up Kapsokwony Division Mt. Elgon Sub-County (Figure 2). Chemwesuis, Bugaa, Komtiong', Kapsokwony, Kibuk, Kimobo, Nomorio, Kipyeto, Koshok, Saboncho, Sacha, and Kamuneru are among the twelve sub–locations studied (ROK 2009). To the north and west, the territory is bordered by Mt. Elgon Forest, and it stretches from upland to lowland. It shares borders with Kimilili Sub–County to the south and Kaptama Division to the east.

Agriculture is the primary source of income in the study area (FAO, 2013). The long rainy season, referred to as the MAM, and the short rainy season, referred to as the OND, are the two main growing seasons. Subsistence farming is supported by adequate rainfall during the extended rainy season. Because of its inadequacy, the current conditions during short rains do not sustain farming activities. Maize, beans, potatoes, onions, tomatoes, and green vegetables are the most common crops farmed, while cash crops like as coffee and tea are also grown for profit. Despite the fact that subsistence farming is the primary source of revenue, most households also plant economic trees for domestic use and social – economic profit. Due to uncharacteristically changing weather patterns, dwindling pastureland, and exponential population growth, crop production has decreased and animal productivity has declined in recent years (NCCAP, 2018).

Climate change is already putting a strain on the lives of the poor in the region, harming socio-economic growth and putting food security in jeopardy (FAO, 2013; World Bank, 2015). Data on rainfall and temperature were analysed to see whether there were any historical trends or fluctuation. Farm production is impacted by climate change and fluctuation patterns, resulting in low yields. Even though new seed varieties have recently been introduced, fluctuations in climate patterns have had an impact on food security as a result of low farming and livestock productivity (maize, beans, onions, green vegetables, and Irish potatoes).

Poor farm production is characterized by unpredictable rainfall, long dry intervals, soil fertility loss, wind erosion, and a drop in pasture cover.

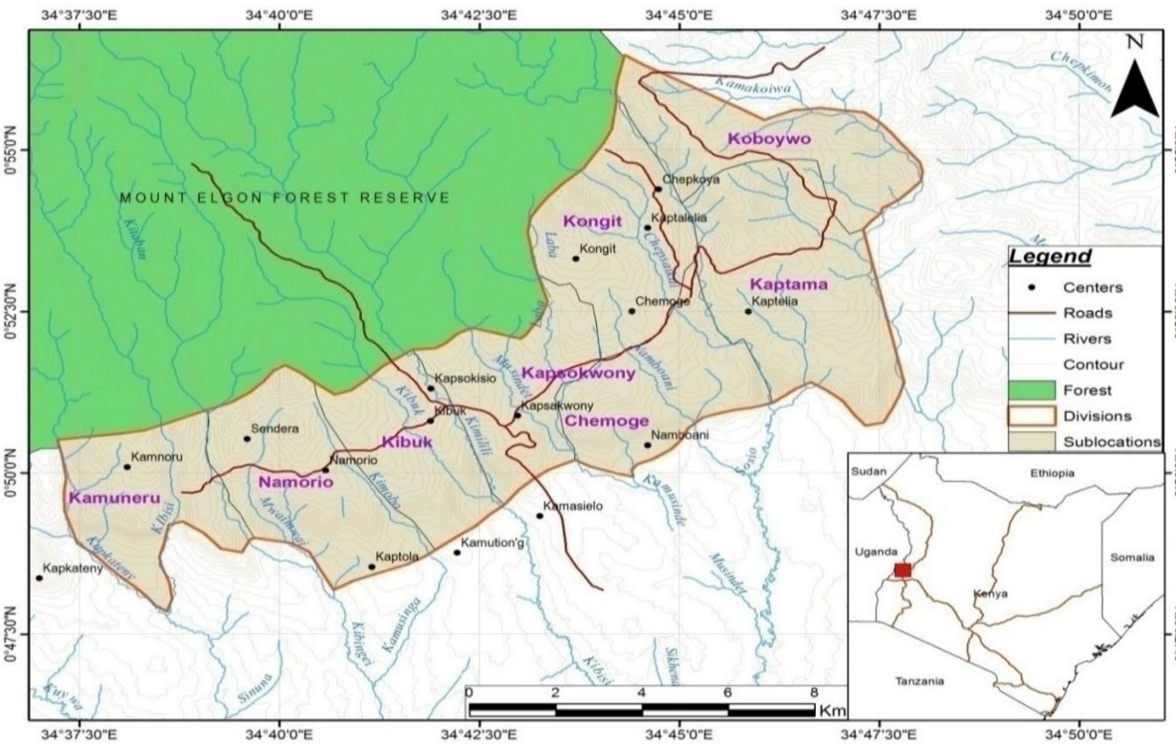

Figure 1: Map of Mt. Elgon region, Kenya showing the study areabetween latitudes (0°47'3N - 0º52'3N and longitudes 34°37'3E - 34º 43'E) (Source: Survey of Kenya)

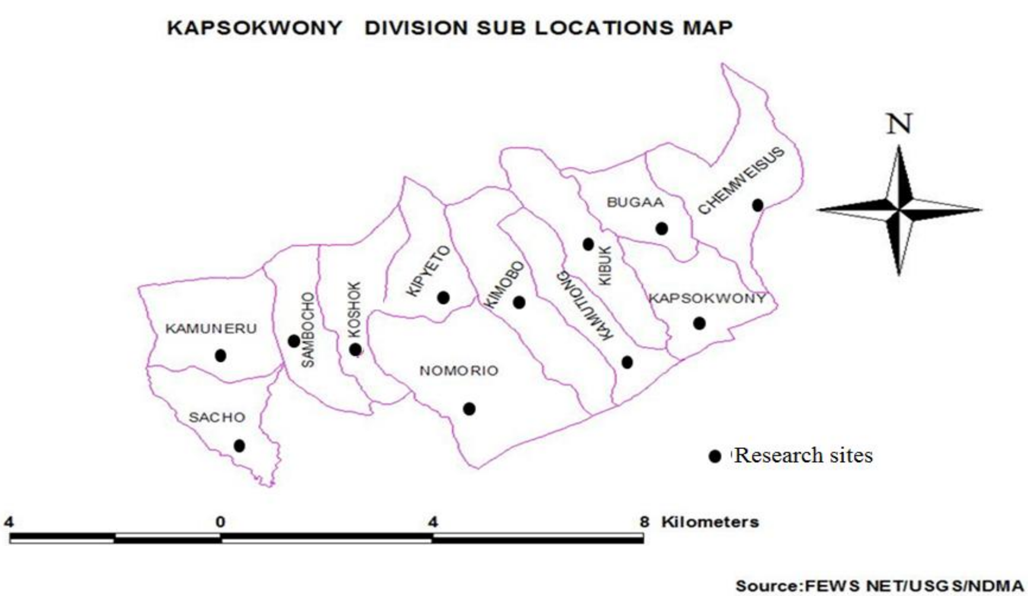

Figure 2: Map of study area showing sub-locations and research sites between latitudes (0°47'3N - 0º52'3N and longitudes 34°37'3E - 34º 43'E) ***(Source: Survey of Kenya)***

3. Methodology

3.1 Introduction

Among the data collection methods used were desk reviews, three (3) Focus Group Discussions (FGDs), six (6) Key Informant's Interviews, six (6) and six (6) Key In-depth Interviews (KIIs), and the administration of household questionnaires with randomly selected homes as respondents from the study region.

3.2 Data collection

Analysis of several policies that directly or indirectly addressed climate change issues in various national policies revealed historical tendencies in climate change concerns, according to the desk study. This took into account the research area's usage of smallholder farmers' traditional technology and indigenous climate change adaptation approaches. Furthermore, the desk study demonstrated successful adaptation strategies used by farmers in the past to combat the effects of climate change and variability.

Focus group discussions, key informant interviews, and in-depth interviews were used to gather qualitative data. Three focus groups were held in this study to learn about the impact, coping, and adaptability to climatic extremes from men, women, and youth. Key informant interviews were utilized to gather data from people with firsthand knowledge and experience of the effects of climate change on livelihoods. The goal was to get information that couldn't be gained readily through focus groups or household questionnaire surveys. In-depth Interviews with farmers were conducted in order to gather more specific information on how climate change has impacted livelihoods in the region, beyond the initial and surface-level responses, in order to properly evaluate and seek elaborate-based responses. This data was utilized to supplement the results of the household surveys (questionnaires). Participants' interactions sparked new ideas and views regarding climate hazards, such as the frequency and intensity of climate impacts changing over time.

The household questionnaire survey included largely quantitative information, but it also included open-ended questions that provided qualitative information. The poll was broken into four components. In the first half, we looked at general, socioeconomic, and demographic aspects. In two sections on dealing with extreme weather events and adaptation to gradual climatic changes, the effects of climate stressors on households, as well as their techniques to cope with and adapt to the repercussions of major weather-related occurrences, were analyzed. The final section of the survey asked open-ended questions about respondents' perceptions of vulnerability and policy options for addressing climate risks. It takes between 25 and 30 minutes to finish each questionnaire interview.

3.3. Data analysis

Participatory and qualitative research techniques such as Climate Vulnerability and Capacity Analysis (CVCA), Focus Group Discussion (FGDs), Key Informant’s Interview and Key In-depth Interviews (KIIs) as well as participant observation and predictions applied in the research were subjected to statistical, descriptive and thematic analysis. The findings were then presented as means, frequencies, percentages, tables, charts and narratives.

4. Results

4.1. Introduction

The majority of rural livelihoods in the study region are based on agricultural activity. Agricultural systems, on the other hand, are reliant on rainfall and temperature. Crop farming, livestock rearing, and non-farm economic activity such as selling farm products, livestock, and economic trees dominate household livelihoods in the Kapsokwony Division of Mt. Elgon Sub-County. Climate change is anticipated to have a negative impact on rural livelihoods. Prolonged droughts, which cause stressed crops, can exacerbate the issue. Because they have to wait longer before planting, the people in the study region have seen a change in rainfall and temperature patterns. Some responders have said unequivocally that lengthy droughts can dissuade them from planting. To address the effects of climate change on food security, livestock productivity, and hence livelihoods, traditional adaptive and new technologies were combined.

4.2. Demographics, livelihoods and vulnerabilities

The study's participants' characteristics were determined. This was in accordance with the reality that residents of the research area have varying perspectives on climatic variability and its effects on their agricultural systems and livelihoods in general. The respondents' characteristics included sex, married status, educational levels, and relationship to household heads. Other factors were birthplace, year of birth, and vocations. They were also questioned about their ethnicity, the number of children they had, their religion, and the structure of their home. They were also probed to see if they owned the land they were cultivating.

The findings and comments in this chapter were based on the study area's second particular purpose, which was to determine the long-term viability of livelihoods impacted by climate change. The key topic addressed in this chapter was: How do the effects of climate change and livelihood activities differ between households in Mt Elgon Sub-County's Kapsokwony Division? The study relied on 398 livelihood surveys, which were distributed to heads of families with a 100% response rate, to successfully address this question. Descriptive statistics of the study population gave background characteristics answers, whilst correlation analysis was utilized to determine the amount of association within the research communities. In the meanwhile, multivariate statistics were used to predict the anticipated impact of each livelihood variable on household livelihoods, land usage, agricultural systems, livestock raising, and food security, as well as income-generating activities, extreme coping events, and climate change impacts.

4.3. Socio-economic characteristics of survey groups

The characteristics of the respondents in the research region were determined using descriptive statistics. This was in accordance with the reality that residents of the research area have various perspectives on climatic variability and its implications for their agricultural systems and livelihoods. The respondents' characteristics included sex, married status, educational levels, and relationship to household heads. Other factors were birthplace, year of birth, and vocations. They were also questioned about their ethnicity, the number of children they had, their religion, and the structure of their home. and whether or not they owned the land they farmed. Survey group characteristics are significant because they reflect how respondents react to changes in weather patterns and the environment. Changes in weather patterns influence livelihood activities, informed decision-making, and natural resource planning and management.

4.3.1. Sex of the respondents

The men and women who answered the livelihood questionnaire in this study were between the ages of 35 and 60. The data analysis of the home questionnaire revealed that males made up the bulk of the respondents (n = 210, 53.13%), while females made up (n = 188, 46.88%). As illustrated in Figure 3, this results in a difference of roughly 6.25%. When women were asked where their male counterparts were, the most prevalent response was that men were absent for one reason or another. Despite the fact that women were not the heads of households, their response rate remains high due to missing or deceased spouses or the fact that they are single mothers.

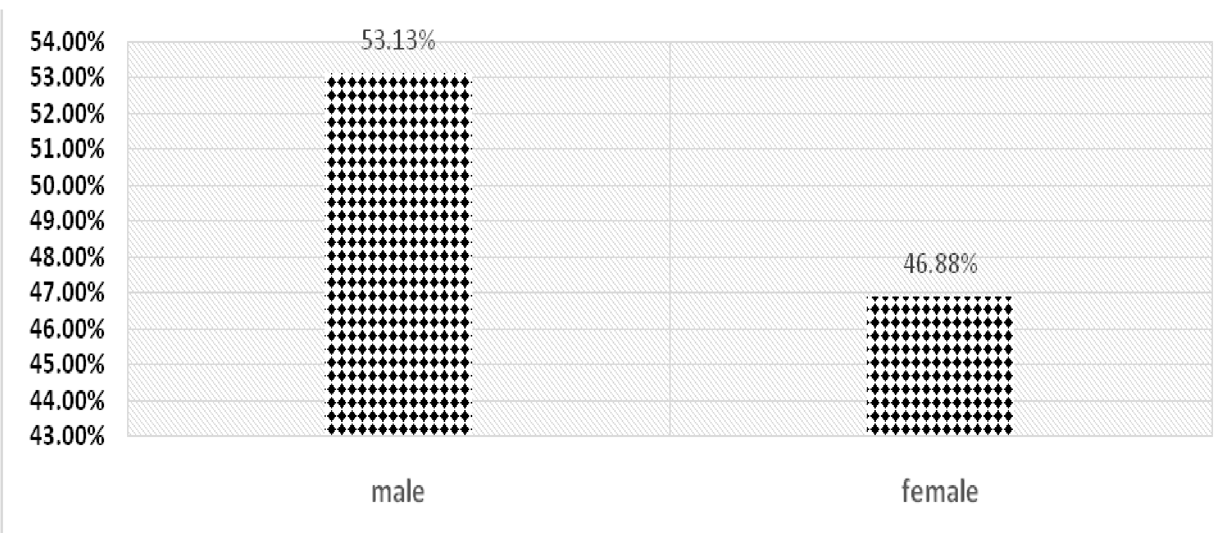

Figure 3: Sex of the respondents (Source: Figure generated by S. B. using 'Microsoft Excel').

4.3.2 Marital status

According to Figure 4, the majority of respondents (n = 271, 70%) were in monogamous marriages, followed by polygamous marriages (n = 59, 15.36%), for a total of (n = 330, 85.94%). The widowed accounted for (n = 33, 8.59%), while the remaining 18 (4.69%) were single, and those who had split or divorced accounted for (n = 3, 0.78 %), totalling (n = 21, 5.47%). Because of the cohesion within the families, respondents in monogamous marital status are more likely to consult and quickly agree on various family concerns than those in polygamous or single married status. The region was also highlighted for having Christian farmers, as indicated in (Table 5) below, who made up 100% of the respondents.

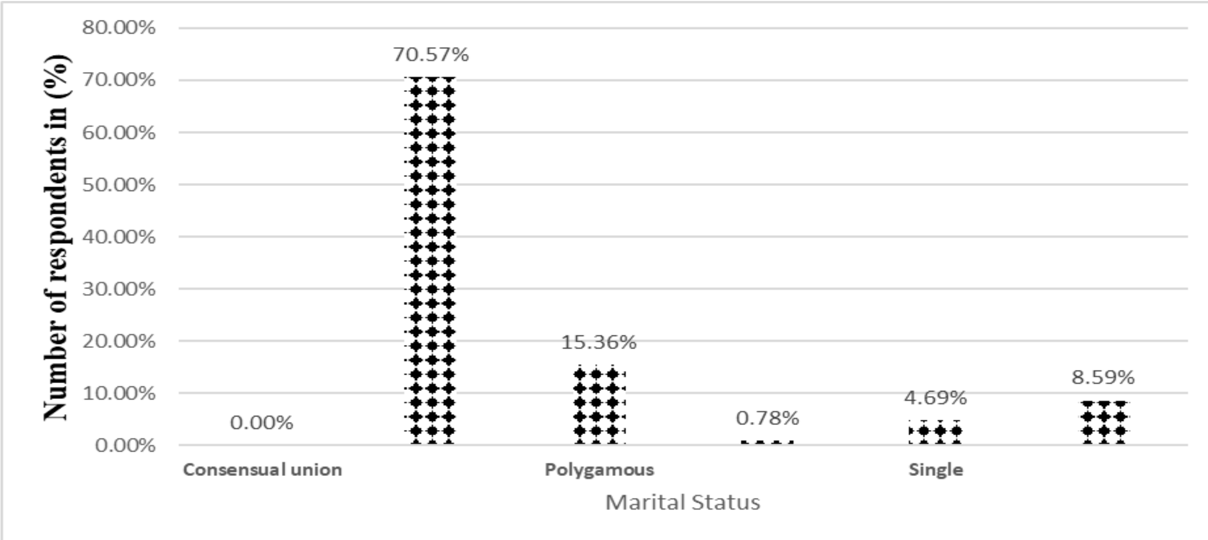

Figure 4: Marital status (Source: Figure generated by S. B. using 'Microsoft Excel').

4.3.3. Education of respondents

As shown in Table 1, the majority of the respondents had had formal primary education (n = 194, 48.74%), while those who had received secondary education (n = 140, 35.17%). In the same Table 3, the results show that (n = 17, 4.27%) of the respondents had received no education. Those with a technical or vocational education accounted for just (n = 16, 4.02%) of the total respondents, while those with a tertiary education accounted for (n = 25, 6.28%). Overall, respondents' literacy levels in the research area are poor and unsatisfactory.

Table 1: Education of respondents

Education of respondents	Frequency	Percentage (%)
Literacy Course	6	1.56
None	17	4.27
Primary	194	48.74
Secondary	140	35.17
Technical/Vocational	16	4.02
Tertiary	25	6.28
Total	**398**	**100.00**

4.3.4. Religion of respondents

All the respondents interviewed during the study professed Christianity and none was a Muslim, Buddhist or Hindu.

4.1.1 Livelihood sources

Crop production (n = 150, 37.69%) and economic trees (n = 123, 30.90%) were determined to be the two (2) main sources of livelihood for households (Figure 5). Farm labour (n = 56, 14.07%) and livestock husbandry (n = 54, 13.57%) are two other livelihood sources or activities done by residents in the research region. Non-farm activities are also practiced by communities in the research region (n = 15, 3.77 %). Non-farm operations are agri-businesses in which farm and animal products are sold for a profit to supplement primary sources of income.

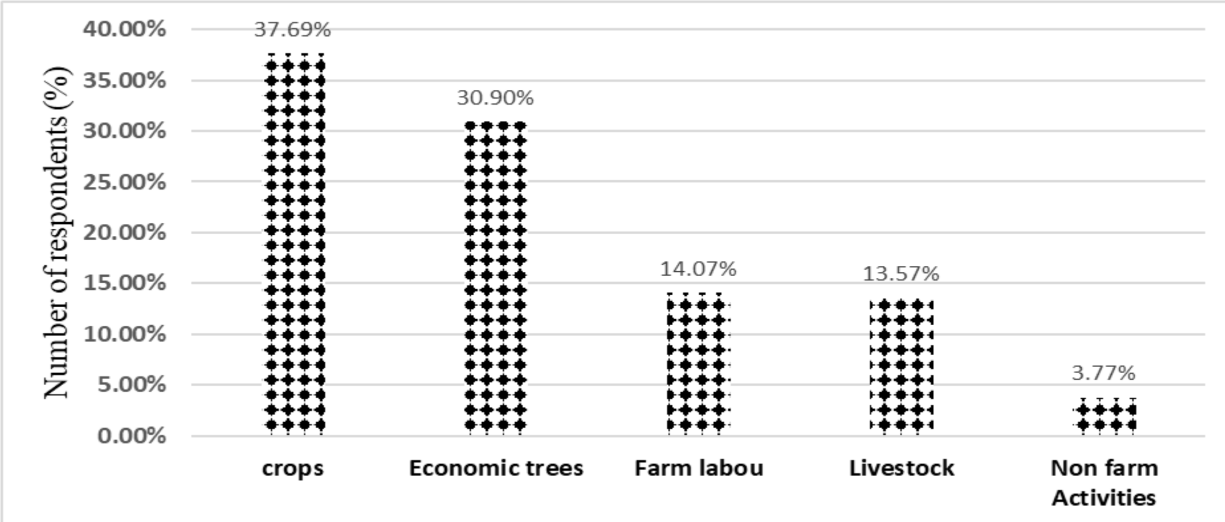

Figure 5: Livelihood sources (Source: Figure generated by S. B. using 'Microsoft Excel').

4.3.6. Crop production

The respondents in the study region cultivate maize 352 (91.67 %), beans 296 (77.08 %), and bananas 107 (27.86 %), totaling 755 (100 %) households who till these crops (71.61 %). A closer look at crop output (Table 2) found that maize and beans are the most prevalent food crops grown in the research area due to the favorable environment. Other crops that produce little can be deemed to be poorly adapted to the current climate. Changes in agricultural yield perceptions can be ascribed to changes in environmental circumstances, poor farming methods, and inferior seed kinds sown, as well as the lack of usage of chemical fertilizers.

Table 2: Crop production in the study area

Crop Production	Frequency	Percentage (%)
Bananas	107	10.39
Beans	296	28.74
Coffee	53	5.15
Irish Potatoes	72	6.99
Maize	352	34.17
Onions	63	6.12
Other	39	3.79
Vegetables	48	4.66
Total	**1030**	**100.00**

4.3.7. Sale of crops

Various categories had the biggest number of respondents who sold crops, but the two categories with the greatest approximate half and more than half contributed to slightly more than half of the respondents 198 (51.56 %) (Table 3). However, the two groups with the lowest number of responses were less than half and everything, with 45 (11.72%) and 23 (5.99%) respondents, respectively, for a total of 68 (17.71%).

Table 3: Sale of crops

Sale of crops	Frequency	Percentage (%)
Less than half	45	11.31
More than half	94	23.62
Approximate half	109	27.39
Everything	26	6.53
Hardly anything	65	31.15
Total	**398**	**100.00**

5.2.4 Perceptions of change in threats (20 years)

Figure 6 shows how people's perceptions of dangers have changed over the last 20 years. The number of respondents who said the threats were the same as before was (n = 103, 26.82%), while those who said they were completely missing were (n = 14, 3.65%). Respondents who thought threats were about the same in 20 years (n = 91, 23.70%) and those who said threats are a lot (n = 79, 20.57%) were similarly divided. Those who indicated that threats did not exist at all in the previous 20 years made up (n = 0, 9.11%). Another set of respondents said that threats had occurred in the recent 20 years, but that they had been minor (n = 62, 16.15%). The cumulative totals of threats were perceived to be (n = 194, 50.52 %) illustrated the fact that the majority of respondents in the study area had perceived climate change and variable threats in the last 20 years, as shown in the chart. However, because the fraction of missing replies was modest (n = 14, 3.65%), it had little bearing on the interpretation of the results.

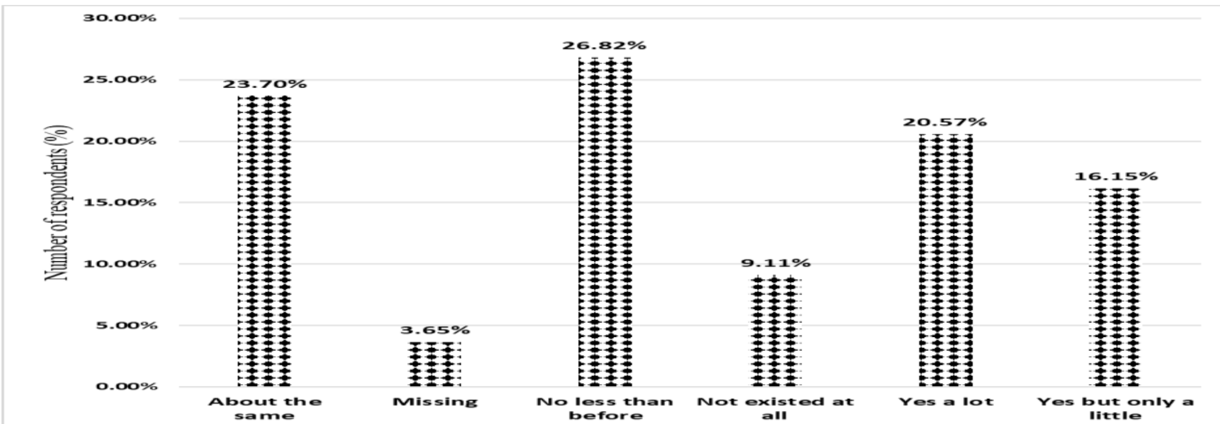

Figure 6: Perceptions of respondents to changes in climate threats (20 Years) (Source: Figure generated by S. B. using 'Microsoft Excel').

4.4 Respondents perceptions on sustainability of livelihood impacts of climate change

Another group of respondents (n = 62, 16.15%) claimed that threats had happened in the last 20 years, but that they were small. As indicated in the chart, the majority of respondents in the research area perceived climate change and varying hazards in the last 20 years. However, because the number of missing responses was small (n = 14, 3.65%), it had little impact on how the results were interpreted.

"Due to a changing environment, vegetation was severely impacted in 2015, and livestock had little to eat. Because the residents lack the expertise and abilities to care for highly productive livestock species, they are rarely bred in the region. As an adaptation technique by herders to manage climate shocks and pressures, the majority of the animals grazed in the forest are sold before the onset of the dry period. **Informant interview with the Head of Livestock Production Unit Kapsokwony Division on 11thFebruary, 2016.**

Focus Group Discussion held with the youth representatives from the study area stated that:

"Focus Group Discussions (FGDs) with youth representatives on the 24th of June 2016 revealed a reduction in agricultural productivity and shrinking livestock production due to diminishing water supplies and pastureland loss." Moving livestock into the forest is a creative way for farmers to gain access to pasture and water. Another adaptation technique is to sell animals at the end of the year in order to generate some revenue and lower the number of animals before the planting season." **FGDs conducted for all the youth representatives in the study area on 24th June, 2016.**

In-depth interview with a small holder farmer on 31stJanuary, 2016. He stated as follows:

"Food production in the region was plentiful about 20 years ago due to fertile soils and favorable climatic conditions. Food production has decreased dramatically in recent years as a result of poor and unpredictable rainfall. Soil erosion has become a problem, particularly on fertile mountain slopes ideal for cultivation. Due to low crop output, some households can only eat one meal every day. Because of the scarcity of pastureland and the scarcity of water resources, livestock rearing per family has decreased dramatically." **In-depth a farmer interviewee on 31stJanuary, 2016.**

He stated as follows:

"Farm output has plummeted, and I was only able to harvest five (5) bags of maize from one acre of land this year, compared to the 20 bags I produce every other year." I have to buy food from the National Cereal Board (NCB) or anybody else to feed my family. The soils have lost their fertility and have become acidic, making them less productive." **In-depth a farmer interviewee on 7th January, 2016 (Bugaa Sub- location).**

5. Discussion

According to the study's findings, changes climate patterns have had a significant influence on the livelihoods of people living in the studied area. Poor households are the most vulnerable individuals and groups because they have limited livelihood options and low adaptability due to a lack of information and reproductive assets. These groups are also unable to access resources due to cultural, societal, and political barriers, and they do not participate in the making of informed decisions. Crop production (37.69%), planting of economic trees (30.90%), and livestock husbandry were the three most common livelihood sources at the household level, as shown in Figure 1 (13.57%).

Communities have observed unpredictable rainfall and rising surface temperatures that are affecting food production through FGDs and KIIs based on meteorological historical data. Crop failure and limited greenery for cattle are the result of unreliable, unpredictable rains and a prolonged drought. Food production systems are stressed by traditional traditions and inadequate land preparations, poor farming methods, and limited financial resources for investment, all of which have an influence on livelihoods. According to a key source interviewed throughout the research who is also the region's head of agricultural production, there is a demand for climate change knowledge. Almost all households rely on rain-fed subsistence agriculture as their primary source of income. Farm labor (14.7%) and non-farm income activities are among the coping mechanisms used (3.7%).

Non-income activities, on the other hand, are rarely undertaken due to a lack of skills and a lack of education. Farmers must also concentrate their efforts on the commercialization of surplus crop produce. As a result, if there is a boom in production due to favorable weather, households should focus on agri-businesses. A balance must be struck between climate change consequences and agricultural practices in order to improve livelihoods and sustain socioeconomic development. Subsistence farming, in which households cultivate crops for food and sell the surplus to make an income, accounts for the majority of livelihood activities in the region (Table 1). Because most people do not produce enough food, they are vulnerable to the effects of climate change. The region's main food crops include maize, beans, Irish potatoes, green vegetables, onions, and bananas. Coffee and tea are cash crops, meaning they are farmed and sold for profit. Some families practice intercropping or mixed farming to make the most of their available land and increase production.

Rural residents in the research area rely on rain-fed agriculture, which is projected to result in a loss in crop output due to irregular and unpredictable rainfall, rising temperatures, and insufficient farming methods. Horticultural crops such as tomatoes, onions, and cabbages, as well as green vegetables, are planted to improve food production. Leafy vegetables and new crop varieties have also been recorded in FGDs and KIIs as a measure of diversification in terms of crop failure.

As a result, the types of crops planted are influenced by trends and fluctuations in rainfall from season to season and year to year, as well as temperature variations. Similar situations exist in similar places such as Kenya's Mount Kilimanjaro, Ethiopia's Ruwenzori, and Chad's Tibesti mountains.

As shown in Table 2, a large number of households sold farm products for a variety of reasons, the most important of which was to generate money to meet other basic family needs. Crops are sold at low rates during harvesting, and some households may sell everything and end up with nothing to eat. For survival, such homes must rely on friends, family, non-governmental groups, and the government. Some of the households with nothing to sell may not have land on which to grow crops. Due to high poverty levels, some households may have land but lack economic empowerment and productive assets. As a result, a paradigm shift is required so that communities can be empowered to reduce risks/challenges by increasing adaptive ability and strengthening resilience in order to protect livelihoods and reduce poverty. For example, community empowerment can be achieved by providing access to climate information, implementing early warning systems, adopting participatory attitudes and behaviors, increasing agricultural production, diversifying cropping, improving marketing policies, and implementing effective natural resource management. This is a common metaphor in most parts of the world, especially in tropical mountains where climate change and rising poverty levels are playing havoc on people's livelihoods.

According to the findings of the study, respondents' perceptions of agricultural yields declined little (38.52 %) or significantly (20.83 %) in the previous year, depending on the prevailing environmental circumstances. Changes in ambient weather conditions, bad farming methods, and the planting of substandard types of seeds without the use of chemical fertilizers can all be blamed for the shift in crop yield perceptions. One of the reasons communities in the research region are sensitive to climate change and variable extreme occurrences is that they have limited access to climate knowledge and services. Residents are generally sensitive to the effects of climate change due to low income, unemployment, low literacy, poor health and sanitation, low livelihood resilience, a weak financial basis, and child hunger and malnutrition. Households must adopt contemporary farming methods such as planting improved crop types and applying chemical fertilizers to successfully adapt to low crop yield trends in a changing climate.

Livelihood activities / alternatives such as charcoal burning and selling, planting and selling of economic trees, minor agri-businesses, and casual laborers in order to increase their overall income and improve their household's well-being (Table 3). Various homes in the research region were primarily responsible for all of these activities. Another coping mechanism employed by members of households, which is frequent among the young generation y who relocate to seek greener pastures outside of their homes, is to use humor and better work possibilities, particularly after completing secondary education. Youths from disadvantaged rural homes frequently migrate to metropolitan centers within the County and to adjacent counties where survival opportunities are thought to be higher. These findings are congruent with those of (Mak *et al.,* 2021), who demonstrated that migration is a last-resort livelihood option and a source of cash for people wanting to improve their well-being in resource-poor nations.

According to the Head of Livestock Production in Kapsokwony Sub-statement County's during the Informant interview on livelihood sustainability, livestock rearing is also a prevalent practice, although households have drastically reduced their herds from tens to one or two animals due to dwindling pastures. During the months of July to December, several households with ten to twenty herds of animals drive them into the forest for irrigation and foliage / pasture in order to fatten them and sell them at the end of the season for a large profit as a survival strategy. This has occurred from changes in rain patterns coupled with a rise in surface temperatures. Herders sell the majority of the animals grazing in the forest before the beginning of December as an adaptive approach to deal with climate shocks and pressures. Organic livestock production may be the greatest path forward for smallholder farmers in the region to increase food security and enhance incomes. Communities in the research region to augment their depth of indigenous knowledge with scientific technical information in order to effectively adapt.

To achieve beneficial outcomes, actions aimed at modifying livelihood structures should be taken a step further by choreographing laws, policies, culture, institutions, and processes. More income, increased well-being, reduced vulnerability, enhanced food security, and sustainable use of natural resources are examples of livelihood outcomes. This includes making informed judgments about when to sow crops and what type of animals to raise in order to improve livelihoods. Climate forecasts, both long and short term, are among the data needed. It also involves short-term and long-term decisions such as when to sell cattle and economic trees, as well as what to do with family assets in the event of climate-related disasters.

Climate data can play a critical role in transforming livelihoods in any of these situations. Climate projections for the long and short term, seasonal forecasts, and early warnings of threats are all examples of knowledge that is needed. Long- and short-term climate projections, seasonal forecasts, and early warnings of risks are all instances of knowledge that is required. Good planning, effective natural resource management, and the implementation of innovative adaptive methods and recommended robust regulations can all help to ensure the long-term viability of livelihoods threatened by climate change. Poor individuals in the region are more exposed to climate change whims because they are less aware of actions that build and maintain resilience (Leichenko *et al.,* 2014).

The economic and poverty trap implications of climate change, as well as adaptation techniques and poverty alleviation, must all be examined (Leichenko *et al.,* 2014). When choosing traditional technologies, smallholder farmers must strike a balance between those that are useful under current climate conditions and those that may be more adaptable under future climate conditions. To respond to the effects of climate change, a combination of scientific and traditional technologies should be used to aid adaptation (Biagini *et al.,* 2014).

Farmers in the research area are currently employing ineffective adaptation techniques. As a result, effective indigenous emergent technologies and ideas for climate change adaptation must be identified and documented. The future is positive or robust as a result of population growth and related factors. As a result, policy ideas must account for this. According to a study, land shortages and a rising population inhibited a community's initiative to plant trees in the Ruwenzori (KRC, 2012).

As an adaptation approach, there isn't enough practical advice on how to boost tropical production's adaptive ability (Guariguata *et al.,* 2012). The appropriate coping adaptive procedures are those that build resistance to climate effects or shocks and permit adaptation, including those that signal advanced revolutionary change and those that do not (Biagini *et al.,* 2014). It's also worth emphasizing that if new adaptive technologies aren't appropriate for the future climate, they may be ineffective or even dangerous if there isn't enough scientific transformation data (Biagini *et al.,* 2014).

During the months of April, May, June, and July, members of households may consume one meal per day rather than the typical three; they carry out crop diversifications, grow new crop varieties, employ chemical fertilizers, and practice mixed farming and crop diversification. Inadequate harvest, poor pasture regeneration for livestock, protracted droughts, and declining water supplies, all of which are linked to climate change, are blamed for the change in behaviour. The way forward is to improve local community copying practices in order to ensure food security by boosting resilience and adaptability. Respondents offered practical ways for farmers in the research area via focus groups and key informant interviews. Planting drought-resistant, fast-maturing crops, for example, is one of these agribusiness intensification tactics. Smallholder farmers should also be advised to plant only certain crops during the months of May and June, and financial institutions should be established to provide loans to farmers to improve agricultural productivity.

In related investigations conducted in Eastern Uganda and the Ethiopian highlands, it was shown that the same bad agricultural harvests reported in this study were caused by erratic and unpredictable rainfall, as well as an increase in the frequency of pests and illnesses in the region (Guariguata *et al.,* 2012). According to a conversation with a farmer in the research area, poor crop output is mostly attributable to changing rainfall patterns and lower soil fertility. Planting trees, for example, can help with environmental and natural resource conservation while also boosting livelihoods, but land scarcity has proven to be a hurdle in the study location. Land scarcity and an increasing population inhibited community development in the Ruwenzori highlands, according to a similar study. As an adaptation approach, there isn't enough practical guidance on improving tropical production's adaptive capacity to climate change (Guariguata *et al.,* 2012). Another comparable study conducted by Shemdoe *et al.,* (2009) in Tanzania's Lushoto and Mpwapwa Districts indicated that climate change and variability have an impact on subsistence farmers' food production.

Although proposals for improving the adaptive ability of rural farmers in the study region are offered here, it cannot be stated that the government does not have some measures in place. The government already has a number of initiatives in place, including those supported by the United Nations, such as FAO, KEFRI, ILRI, KFS, and KETRI as well as those managed by the Ministry of Agriculture and Natural Resources. Farmers can contact with extension officers via an SMS (Short Message Service) line dedicated to agricultural learning and information sharing (Spear and Chappel 2018).

It would be advantageous if this innovative platform for information sharing could be promoted further, for example, on the radio (Thomas, 2018). Smallholder farmers, on the other hand, would benefit from increased access to extension services, particularly in areas where there is no radio or cellular phone network. These communities require agricultural assistance, as well as training and market access to enable them to diversify their livelihoods beyond agriculture practices (Spear and Chappel 2018).

Overall, to enhance livelihoods and sustain socio-economic growth in the study region, multiple complementing actions are required. These measures include: Intensification of agriculture systems; Assess capacity-building options for agricultural communities in the study area to adapt to climate change impacts; Identify and document behavioral shifts toward climate change adaptation measures at individual and institutional levels; Analyze the effects of climate variability on subsistence farmers' food production and health;

Dictate distinct rural communities' short and long-term adaption strategies; Develop a strong framework to support policy decisions in crop/livestock production and Make policy recommendations for increasing adaptive capacity and climate change resilience.

6. Conclusions

Climate change and variability have an impact on the livelihoods of populations in the research region, according to the conclusions of this study, which were backed up by field data and a literature review. Households have created a number of adaptation tactics in order to survive in a changing climate as a result of the effects. As a result, a wide range of technology and inventions are available to help the region adapt to the effects of climate change and fluctuation. Smallholder farmers, for example, should be educated on when to plant and what crop varieties to sow during long and short rains. To prevent climate change, only particular crop kinds can be grown during long seasons (MAM) rainfall, whereas drought-resistant crops should be planted during short rain (OND). Given future weather estimates, this is an innovation that will undoubtedly address long-term rainfall and temperature changes. Farmers should be given the opportunity to acquire climatic information so that they can plan ahead in order to achieve this innovation. Farmers will also use long-term climatic information to invest in livestock production.

Because of the uncertain nature of climate change, financial institutions should be prepared to lend to farmers for agricultural projects once long-term weather projections have been confirmed. Both the national and local governments can assist in the development of new policies and a strategy for achieving food security. This can help communities adapt to the effects of climate change by sustaining livelihoods through sustainable resource management. Adaptive strategies based on scientific and indigenous knowledge are crucial in the development of adaptive policies to help communities adjust to the consequences of climate change in the region. Indigenous knowledge may be effectively merged with scientific information to improve climate change mitigation and adaptation methods, as it is based on years of observations, perceptions, and experiences. Cost efficiency, co-benefits, trade-offs, and feasibility are further techniques to consider when designing adaptive technology. New transformative technologies are intended to improve climate change resistance while simultaneously aiding adaptation efforts to improve livelihoods. According to scientific transformation knowledge, new technologies may be inefficient or even harmful if they are not suitable for future climate conditions.

The study's participants' behavior has changed as a result of the effects of climate change. Some of the changes have a positive impact on people's lives and should be emulated in other areas. Respondents to the focus groups and key informant interviews (FGDs and KIIs) agreed that climate change and variability have an impact on regional livelihoods. As a result, communities must improve their coping mechanisms in light of the effects of climate change on livelihoods in order to perform better in the future. This will aid communities in becoming more resilient to climate change and fluctuation. Water harvesting, soil erosion prevention, crop diversification, natural resource protection, promotion of sustainable agriculture, early warning systems, investing in wood-lots, and effective natural resource management will all help communities cope with the effects of climate change. Policymakers and governments should be required to establish institutions to educate communities on the effects of climate change on people's livelihoods. As a result, we urge that further research be done to help communities understand how climate change and fluctuation affect people's livelihoods. When it comes to communication resources such as radios, television stations, and mobile phones, it is critical that communication systems are in place to ensure that women, men, and children have equitable access to climate information. Changes in weather patterns appear to have the potential to cause significant changes in water supply, agriculture, grazing land, and natural hazards.

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Ensayo en macetas

Inóculo bacteriano. Las cepas bacterianas fueron crecidas en caldo Luria Bertani (LB) a 30°C, durante 48 h a 80 rpm, posteriormente se centrifugaron a 8000 rpm y resuspendieron en buffer de fosfatos 0.1M pH 7.4 para obtener una absorbancia de 0.5, que corresponde aproximadamente a $1x10^9$ UFC/mL.

Preparación de las macetas. Las semillas de plantas de frijol *(Phaseolusvulgaris)*, fueron sembradas en macetas conteniendo 250 g de sustrato Miracle Gro® sin esterilizar. Fue usado un diseño experimental al azar, esto para evaluar el efecto del crecimiento de las bacterias promotoras de crecimiento vegetal (BPCV), donde el factor de tratamiento fue la inoculación bacteriana (4 tratamientos correspondientes al número de cepas utilizadas). Un tratamiento adicional correspondiente al testigo, el cual consistió en agregar sustrato sin inocular a cada unidad experimental. Cada tratamiento se realizó por quintuplicado.

Se sembraron 3 semillas las cuales fueron inoculadas con 25 mL de la suspensión bacteriana. Al tratamiento testigo se le agregó 25 mL de buffer de fosfatos 0.1M pH 7.4. Se evaluó el número de días de germinación, porcentaje de germinación. Posteriormente se mantuvieron en invernadero durante 21 días, regándolas diariamente con 30 mL de agua destilada. Durante el experimento se midió la altura de las plantas, número de hojas, número de flores, número de vainas, peso de las semillas.

Evaluación de crecimiento. Al final del ensayo, se evalúo el crecimiento del tallo y de la raíz de las plantas mediante, procesadas mediante el software ImageTool 3.0.

Determinación de nutrientes en las plantas. Los nutrientes en el fruto fueron determinados mediante Absorción Atómica usando el método EPA 3052(EPA, 1996).

Análisis estadístico. Se realizó un análisis de varianza a los datos obtenidos experimentalmente, para determinar las diferencias entre los tratamientos, mediante la comparación de las medias usando HSD de Tukey con un nivel de significancia del 95% (α = 0.05). Los análisis fueron determinados mediante el software SPSS versión 15.

RESULTADOS

En el análisis del porcentaje de germinación de las semillas de *Phaseolus vulgaris* inoculadas con las BPCV *Serratia k120, Serratia Mc119, Pantoea 113, Pantoea 134*, se encontró que disminuyen significativamente los días de germinación y se incrementa de manera significativa el porcentaje de germinación de las semillas inoculadas con BPCV, con respecto al testigo como se puede ver en la tabla 1.

Phaseolusvulgaris		
Tratamiento	Días de Germinación o emergencia	Porcentaje de germinación
Control	8	62 5 ± 2.5
Serratia k120	5 [a]	95.6 ± 3.2 [a]
Serratia Mc119	6 [a]	94.3 ± 2.8 [a]
Pantoea 113	5 [a]	93.6±3.1 [a]
Pantoea 133	5 [a]	94.8±2.8 [a]
[a] Muestras con diferencia significativa $p<0.05$		

Tabla1. Porcentaje de germinación de semillas de *Phaseolus vulgaris* inoculadas con bacterias promotoras de crecimiento vegetal

Los cambios en la fenología y la biomasa de las semillas de *Phaseolus vulgaris* en las plantas inoculadas con las bacterias promotoras del crecimiento vegetal fueron significativamente mayores en todas las cepas probadas en los parámetros de la longitud de la raíz, la altura de la planta, el número de hojas, el número de flores, el número de vainas y el peso seco de las semillas, lo que indica que las BPCV ya sea de manera directa o indirecta están promoviendo el crecimiento vegetal y la captación de nutrientes favoreciendo a las plantas y a la producción de semillas como se puede observar en la tabla 2.

Phaseolus vulgaris						
Tratamiento	**Longitud Raíz (cm)**	**Altura de la planta (cm)**	**Número de hojas**	**Número de flores**	**Número de vainas**	**Peso semillas (g)**
Control	16.45 ±1.36	18.67 ± 1.26	8 ± 2.12	8 ± 1.23	5 ± 1.35	0.07
Serratia k120	35.56±2.14 [a]	25.83 ± 1.58 [a]	14 ± 3.25 [a]	12 ±1.05 [a]	11 ± 1.28 [a]	0.12 [a]
Serratia Mc119	34.21±1.45 [a]	24.35 ± 1.45 [a]	12 ± 1.25 [a]	11 ± 1.14 [a]	10 ± 1.32 [a]	0.11 [a]
Pantoea 113	31.45±2.68 [a]	19.56 ± 1.56	13 ± 1.26 [a]	12 ± 1.28 [a]	9 ± 1.26 [a]	0.10 [a]
Pantoea 133	33.89±3.12 [a]	26.24 ± 2.14 [a]	14 ± 2.35 [a]	11 ± 1.24 [a]	10 ± 1.18 [a]	0.09 [a]
[a] Muestras con diferencia significativa $p<0.05$						

Tabla2. Efecto en las plantas de *Phaseolus vulgaris* inoculadas con bacterias promotoras de crecimiento vegetal

El análisis de algunos nutrientes esenciales en las semillas de *Phaseolus vulgaris* indican que hay una diferencia significativa($p<0.05$) en el Ca, P, Fe, Zn y proteínas en las plantas inoculadas con la BPCV mientras que en el Mg no se presentó ninguna diferencia significativa, lo que establece que las semillas con las plantas inoculadas tienen un valor nutritivo más elevado con respecto al control como se muestra en la tabla 3.

Phaseolusvulgaris						
Tratamiento	**Ca**	**Mg**	**P**	**Fe**	**Zn**	**Proteína**
Control	267.5 ± 15.65	162.7 ± 25.45	10200 ± 78.89	39.9 ± 2.14	24.4± 1.25	36
Serratia k120	580.3 ± 14.32 [a]	182.8 ± 21.48	35700 ± 98.56 [a]	75.8 ± 3.15 [a]	33.1 ± 2.08 [a]	55 [a]
Serratia Mc119	628.6 ± 21.56 [a]	181.1 ± 14.89	40800 ± 89.45 [a]	61.6 ± 2.48 [a]	36.2 ± 1.09 [a]	52 [a]
Pantoea 113	635.8 ± 18.89 [a]	181.2 ± 18.89	38250 ± 78.45 [a]	53.4 ± 3.14 [a]	31.8 ± 2.18 [a]	51 [a]
Pantoea 133	687.9 ± 24.78 [a]	182.7 ± 21.48	45900 ± 67.48 [a]	56.4 ± 2.98 [a]	19.4 ± 1.78 [a]	56 [a]
[a] Muestras con diferencia significativa $p<0.05$						

Tabla 3. Calidad nutricional de las semillas de *Phaseolus vulgaris* inoculadas con bacterias promotoras de crecimiento vegetal

En las plantas de *Phaseolus vulgaris* el comportamiento del Mn indica que se presentó una diferencia significativa ($p<0.05$) en las plantas inoculadas con las bacterias *Serratia k120, Serratia Mc119 y Pantoea 133,* con respecto al control, mientras que las inoculadas con la bacteria *Pantoea113*no se encontró diferencia significativa. En el Cu se obtuvo una diferencia significativa ($p<0.05$) en todas las plantas inoculadas con las BPCV usadas con respecto al control; sin embargo, en el Ni no se presentó ninguna diferencia significativa en las plantas inoculadas con las cepas bacterianas con respecto al control. Para el Zn solamente se presentó una diferencia significativa ($p<0.05$) entre las plantas inoculadas con las bacterias del género *Pantoea 133* con respecto al testigo. En el caso del Fe todas las plantas inoculadas con diferentes cepas de BPCV presentaron una diferencia significativa ($p<0.05$) con respecto al testigo. Pare el Na y K no se presentaron diferencias significativas entre las plantas inoculadas con las BPCV y el control y finalmente el P presentó una diferencia significativa ($p<0.05$) entre las plantas inoculadas con las BPCV con respecto al control como se muestra en la tabla 4.

Phaseolus vulgaris								
Bacteria	**Mn**	**Cu**	**Ni**	**Zn**	**Fe**	**Na**	**K**	**P**
Control	48.01 ± 3.73	8.90 ±3.79	19.31 ±3.12	45.19±3.02	218.11 ± 3.20	1,078.42 ±3.11	247.27 ±3.23	35,244.89 ± 112.00
Serratia k120	97.31 ±2.77[a]	24.35 ±3.89 [a]	21.39 ±2.56	51.00 ±2.50	374.17 ±6.28 [a]	1,126.16 ±2.35	289.79 ±3.63	65,322.88 ± 118.00 [a]
Serratia Mc119	67.66 ±2.24[a]	32.46 ±2.98 [a]	19.74 ±3.25	49.44 ±3.36	368.89±4.41 [a]	1,178.28 ±2.80	258.79 ±4.60	72,871.57 ± 125.00 [a]
Pantoea 113	56.57 ± 4.56	38.57 ±2.97 [a]	22.62 ±3.69	44.61 ±2.82	384.38 ±2.99 [a]	1,370.42 ±4.55	279.04 ±5.85	78,461.74 ±191.00 [a]
Pantoea 133	82.15 ±4.15[a]	58.35 ±4.12 [a]	21.70 ±3.04	64.18 ±3.50 [a]	369.45±4.10 [a]	1,379.98 ±2.98	276.40 ±3.23	118,624.25±217.00 [a]
[a] Muestras con diferencia significativa $p<0.05$								

Tabla 4. Calidad nutricional de las plantas de *Phaseolusvulgaris*inoculadas con bacterias promotoras de crecimiento vegetal

DISCUSIÓN

El crecimiento poblacional actual implica que se estudie la manera de llegar a una agricultura sustentable, considerando que esta debe ser un sistema integrado de producción para satisfacer las demandas del ser humano abarcando las dimensiones social, económica y ambiental (Osorio 2008; Salgado 2014). Para lograr la agricultura sustentable es necesario pensar en la aplicación de tecnologías que sean amigables con el ser humano y con el medio ambiente por lo que uno de estos sistemas comprende el uso de BPCV entre las que se encuentran los géneros *Pseudomonas*, *Klebsiella*, *Rhizobium*, *Enterobacter*, *Acinetobacter*, *Bradyrhizobium*, *Serratia*, *Escherichia, Azotobacter*, *Beijerinckia*, *Derxia*, *Azospirillum* y *Stenotrophomonas*(Cota O., 2012;Vargas *et al*., 2001; Martínez *et. al.,* 2020).

La inoculación de las BPCV a las plantas de *Phaseolus vulgaris* favoreció la germinación, esto sugiere que las bacterias se pudieron adherir al endospermo de la semilla y aceleraron su emergencia (Romero-García *et. al.,* 2016). Por otra parte, las bacterias de *Serratia y Pantoea* contribuyeron significativamente al aumento de la longitud de la raíz lo que favorecería un incremento en la nutrición de la planta (Marquez-Benavides *et.al*., 2017; Lara-Capistran *et. al*., 2019; Romero-García *et. al.,* 2016), la altura de la planta y el número de hojas que podría mejorar el proceso de fotosíntesis (Lastochkina*et. al.,* 2021), así como el incremento en el número de flores por ende en la proliferación del número de vainas y el peso de las semillas, lo que establece un incremento en la capacidad de producción de *Phaseolusvulgaris* (Tamayo-Aguilar *et. al.,* 2020; El attar*et. al.,* 2021; AdelAlAli*et al.,* 2021).

Los macro y micronutrientes se incrementaron considerablemente en las plantas que se inocularon con las BPCV, mejorando de esta manera la calidad de las plantas y lo que pudiera favorecer la producción de las semillas por las plantas concordando con lo reportado por Márquez-Benavides *et. al.,* 2017; Ruíz-Santiago *et al.,* 2020; Moreno *et. al.,* 2018; Lastochkina*et al.,* 2021.

En cuanto al análisis de la calidad nutricional de las semillas de *Phaseolus vulgaris* encontramos que las BPCV favorecen significativamente el incremento de Ca, Mg, P, Fe, Zn y proteína comparado con el control sin inocular lo que coincide con lo reportados por Fiori et. al 2021; Kumar *et. al*., 2016; Fernandezy Sánchez. 2017; El Attar*et. al.,* 2019.

Las BPCV usadas ayudarían a mejorar la producción de las semillas de *Phaseolus vulgaris* con una mejor calidad nutricional lo que establece su posible uso en campo como biofertilizantes y de esta manera ayudar a disminuir la presencia de plagas que afectan considerablemente la producción y calidad nutricional de las semillas, así como también modificar el uso de fertilizantes químicos que alteran las características fisicoquímicas del suelo y la biodiversidad microbiana de éste, lo que también puede llegar a modificar el medio ambiente.

CONCLUSIÓN

Las BPCV *Serratia k120, Serratia Mc119, Pantoea 113, Pantoea 133*, mejoran la producción, y la calidad nutricional de las semillas de *Phaseolus vulgaris* por lo que pueden ser usadas como biofertilizantes en los cultivos de esta planta y contribuir a la mejora en la producción de estas.

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