Effect of rainfall variability on tea growing in Kyamuhunga tea estate. A cross-sectional study.

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Abstract
Background
Water availability is the most important factor for crop productivity in rain-fed agriculture. This study examines how changes in rainfall affect tea growing.
Methods
This study adopts a cross-sectional research design to gather data. It employed quantitative approaches to provide a comprehensive understanding of the research topic. The research design includes surveys, interviews, and observations to collect primary data, as well as the review of existing literature to supplement the findings.
Results
The key findings reveal that rainfall variability had a significant positive influence on tea growing since the p-value is less than 0.05. The Pearson correlation coefficient (r=.566) shows a positive, moderately significant influence of rainfall variability on tea growing. This implies that any positive changes in rainfall variability led to a positive change in tea growing in the Kyamuhunga Tea estate. The results also indicate that a unit increase in rainfall variability will result in a 0.321 increase in tea growing (B=.321, p=0.000 < 0.05).
Conclusions
Rainfall variability had a significant positive influence on tea growing, and there was a moderate, significant influence of rainfall variability on tea growing. This implies that any positive changes in rainfall variability led to a positive change in tea growing in the Kyamuhunga Tea estate.
Recommendation
The study recommends that, for tea farmers, considering implementing irrigation systems to supplement water during periods of low rainfall. Tea growers should collaborate with researchers and institutions to stay updated on the latest techniques and practices.

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Introduction

Water availability stands as the most crucial factor in maintaining crop productivity in rain-fed agriculture. Even if drought-tolerant traits are introduced, without water in the soil, crops cannot thrive. Rainfall variability, which varies from season to season, has a significant impact on soil water availability for crops and, consequently, poses risks to crop growth. Nevertheless, there doesn't appear to be a definitive upper limit for the amount of rainfall needed to sustain robust tea growth. For example, in Sri Lanka, certain regions receive as much as 5100 mm of rainfall, and tea thrives under these conditions. On the other hand, it's believed that rainfall below 1300 mm annually has an adverse effect on tea growth, but various studies have reported differing effects of rainfall on tea cultivation.

In Bangladesh, Ali et al. (2014) conducted a study to assess the impact of rainfall variability on tea leaf growth in different tea estates. Their research revealed that tea yields are significantly influenced by microclimatic parameters, particularly rainfall, temperature, humidity, and light duration. Inadequate rainfall results in irreplaceable losses since irrigation is seldom employed on tea plantations. Conversely, heavy rainfall can lead to topsoil erosion and the leaching of fertilizers and chemicals. Their analysis of field experiments and weather data indicated that the highest tea leaf growth per hectare occurred in regions receiving between 4000 mm and 4600 mm of rainfall. Tea growth

showed a slight increase with rising total annual rainfall.

In Japan, Ndamani and Watanabe (2015) conducted a study examining the influence of rainfall on crop growth, including tea, and suggested adaptation strategies. They observed moderate seasonal and irregular annual rainfall patterns. Rainfall in their study area typically commenced in May, with the number of rainy days and rainfall volume (mm) declining in June before peaking in July and August. Across all crops studied, including tea, sorghum, millet, and groundnut, there was a negative correlation between annual rainfall and crop growth.

However, it's important to note that Ndamani and Watanabe (2015) might have presented a different perspective if their study had focused solely on tea cultivation. They might argue that while other crops exhibited a negative correlation between rainfall and growth, tea cultivation could respond differently. They could present contrasting evidence or suggest that tea plants may have specific adaptations to rainfall patterns.

In Pakistan, Ahmed et al. (2014) conducted research on the effects of water availability and pest pressures on tea (Camellia sinensis) growth and quality. They found that higher water availability and jasmonic acid (JA) treatments significantly increased the growth of new tea leaves. The impact of water availability and JA on tea quality varied among individual secondary metabolites. Higher water availability increased total methyl xanthine concentrations but had no significant effect on epigallocatechin 3-gallate concentrations. Water availability, JA treatments, and their interaction did not affect epicatechin 3-gallate concentrations. These findings highlight the complex interactions between climate change effects, precipitation, and pest pressures within agro-ecosystems, emphasizing the need for future climate studies to consider both biotic and abiotic factors.

Hossain et al. (2015) conducted a study on the effect of rainfall on tea yield and crop distribution, indicating that tea leaf growth slightly increased in various tea estates in the Sylhet district due to increased rainfall. The results suggested that tea cultivation thrives when there is abundant rainfall with a high number of rainy days.

In rural Malawi, Moylan (2021) investigated the impact of rainfall variability on agricultural growth and household welfare. Their findings revealed that households experiencing severe negative rainfall shocks during the wettest quarters of agricultural seasons had significantly lower crop yields, agricultural output values, total per capita consumption expenditures, food expenditures, and dietary diversity.

A study focused on Kenya's tea sector and climate change by Elbehri (2015) identified a weak negative relationship between tea yields and rainfall at Timbilil Tea Estate. This was attributed to low temperatures during the rainy season, which depressed crop yields. In contrast, at Magura Tea Estate, a weak positive relationship between yields and rainfall was observed due to the warmer regional temperatures. Frostbite had the potential to reduce tea yields by up to 30 percent for three consecutive months, with areas like Kericho, Sotik, and Nandi Hills experiencing a net loss of green tea leaves due to hail estimated at 2.7 million kg per annum.

Additionally, Juma (2014) conducted research on the effects of rainfall variability on tea cultivation in Muranga County, Kenya. Their study, based on tea yield data from 2015 to 2021, indicated a positive relationship between rainfall variability and tea cultivation in the county.

It's important to note that studies conducted in Uganda on rainfall variability were limited to specific regions and counties, and their findings may not be applicable to other parts of the country. Additionally, these studies focused on different time periods that experienced varying climatic changes. For example, Mwaura and Okoboi (2014) studied the period from 2021 to 2016, and their findings may not be representative of conditions after 2016. This study examines the effect of rainfall variability on tea growing in the Kyamuhunga Tea estate.

Methodology

Research Design

The study utilized a cross-sectional research approach to examine participant groups with diverse interests yet similar characteristics. This approach provided a snapshot of the population's characteristics, behaviors, attitudes, or conditions at a specific moment, allowing for an understanding of the current status and identification of prevalent issues.

Reconnaissance survey

A reconnaissance survey on the effects of rainfall and temperature variability on tea growing at the Kyamuhunga Tea Estate in Bushenyi District was a valuable study, especially considering the important role climate variables play in agricultural production, particularly for crops like tea. A reconnaissance survey is a preliminary study

conducted to understand the broader context, which would help identify critical variables, assess potential challenges, and guide more in-depth research. The data was collected using interviews with local farmers, estate managers, and agricultural experts to gather anecdotal and experiential data about the effects of climate variability. The researcher visited the tea fields and observed any visible signs of stress on the plants due to extreme weather conditions. The data was also collected on weather Stations on rainfall and temperature data from weather stations in and around the estate, or install temporary weather stations to monitor climate conditions.

Target population

The study population included tea farmers including the Farmers. In August 2021, the national population census put the population of Bushenyi at 251400, and according to the district growing report (2021), Kyamuhunga sub-county had an estimated population of 22,400, of which 66% are believed to be tea farmers.

Inclusion and exclusion criteria

People included in the study were both men and women aged 18 years and above, and of sound mind, who were directly or indirectly participating in Tea growing at or around Kyamuhunga Estates in Bushenyi District, with the relevant information. People who are below the age of 18 and are participating in Tea growing were not qualified to participate in the study.

Sample size and determination

A sample of 136 respondents was selected using the single population proportion formula with 95% level of confidence and 5% margin of error. These were 123 tea-growing farmers, 6 local leaders, 5 agriculture service providers, and 2 weather station managers. The sample size for the study was determined using the Krejcie and Morgan Table (1978)

Table 1 Category and target sample

Category	Target population	Sample Size	Sampling Techniques
Farmers	180	123	Simple Random Sampling
Local leaders	6	6	Purposive sampling
Agriculture service providers	5	5	Purposive sampling
Weather station managers	2	2	Purposive sampling
Total	**193**	**136**	

Source; (Kyamuhunga sub-county **Annual report of (2023)**

Sampling strategy

The sampling frame for this study comprised all households engaged in tea cultivation within the research area. According to the 2019 district records, Bushenyi District is divided into 11 sub-counties, 76 parishes, and 647 villages. To select tea farmers in Kyamuhunga Sub-County, a simple random sampling method was employed. Initially, purposive sampling was utilized to identify and select proficient local leaders and agricultural service providers in the sub-county as part of the first stage.

Simple Random Sampling

Simple random sampling was employed to farmers because it ensures that each member of the target population has an equal and independent chance of being included. The researcher gave a random number to every object or member of the accessible population placing the number in the container and then pick any number at random; the subject corresponding to the picked number was included in the sample. If the number was picked the second time was ignored. This technique was used to select the farmers.

Purposive Sampling

Purposive sampling is a technique in which the required information is gathered from special or specific targets or groups of people on some rational basis. The researcher chooses the participants as per his/her own judgment, keeping in mind the purpose of the study. This technique was employed to select Local leaders, agriculture service providers, and weather station managers. These individuals were identified within the Bushenyi district as key informants expected to provide detailed and insightful information crucial to the study.

Sources of Data

Primary Data

The researcher acquired both qualitative and quantitative data on the study variables by using questionnaires and conducting interviews with chosen participants from Kyamuhunga Tea Estate. This thorough approach is designed to effectively capture the perspectives of the respondents. Primary data refers to information in its original, unaltered state, directly obtained from the original sources. The collection of primary data enhances the research's reliability since it is conducted by the researcher conducting the study.

Secondary Data

Secondary data sources encompass information gathered by other researchers or individuals that were not originally collected for the current study but are pertinent to the research problem. These sources consist of handbooks, annual reports, performance records, employment policies, relevant content from the organization's website, blogs, journals, newsletters, and various documented materials. The secondary data went through a rigorous assessment for reliability, validity, sufficiency, and appropriateness in addressing the research inquiries. The utilization of numerous independent data sources is intended to verify the authenticity and precision of any assertion, thereby bolstering the study's reliability and validity.

Data collection methods

Primary data was collected using questionnaires, Focus group discussions, the interview method, and the observation method. Other supportive methods of data collection on climate change were used to estimate rainfall and temperature variability and tea behavior during specific climatic conditions. These methods may include:

Historical Climate Data: Gather historical climate data from meteorological stations or relevant sources to analyze long-term rainfall and temperature trends in the study area.

Questionnaires

Questionnaires were formulated to collect data from tea farmers, agricultural experts, and other pertinent stakeholders. These questionnaires encompassed inquiries regarding climate patterns, variations in rainfall, fluctuations in temperature, and how these factors were perceived to affect tea cultivation and the quality of tea produced. Additionally, the questionnaires delved into specific indicators of tea quality, such as flavor, aroma, appearance, and market value.

The selection of the questionnaire method assumed that respondents possessed the ability to read and write, facilitating their ability to answer the study's questions independently. The questionnaire method allowed a coverage of a wide geographical area within a relatively short timeframe. Furthermore, it empowered respondents to provide candid and straightforward responses to the questions. The questionnaire method was chosen for its simplicity of administration, enabling respondents to complete it at their convenience. This approach also granted respondents ample time to contemplate their responses, reducing the likelihood of hasty answers and thereby enhancing the accuracy of the responses (Saunders et al., 2017). To structure the questionnaires, a 5-point rating scale was employed, utilizing a 5-point Likert scale ranging from 1 - Strongly Disagree (SD), 2 - Disagree (D), 3 - Neutral (N), 4 - Agree (A), and 5 - Strongly Agree (SA). This scale was selected for its robust characteristics and was expected to facilitate cost and time efficiency while encouraging a higher rate of response.

Interviewing Method

An interview was a direct, in-person conversation between two individuals conducted with the primary objective of gathering pertinent information to fulfill a research purpose. This method involved a series of key questions that encompassed the areas to be explored. It afforded the researcher some flexibility to delve into the subject matter. The interview guide, comprising a set of questions, was introduced and explained by the researcher to the interviewees before they responded. During the interviews, the researcher filled out the interview guide based on the responses provided by the interviewees.

To gather in-depth qualitative data, the researcher created and employed a semi-structured interview guide when interviewing respondents from Kyamuhunga Tea Estate. These interviews were chosen because they enabled the researcher to probe for additional information, seek clarification, and observe the facial expressions of the interviewees. This method was selected because it was expected to yield comprehensive insights into a research issue or question. The interview guide was preferred because it facilitated a thorough understanding of individuals' perspectives or experiences and allowed for further exploration of their responses compared to questionnaires. Interviews had the advantage of eliciting more information through probing, as well as enabling

clarification and the observation of interviewees' facial expressions.

Observation Method

Observation, as a research method, entailed a systematic process of selecting, closely examining, listening to, reading, touching, and recording the behaviors and characteristics of living entities, objects, or phenomena. Observations could take the form of overt, where everyone involved was aware of being observed, or covert, where those being observed were unaware, and the observer remained concealed. Direct Observation and Indirect Observation methods were used to collect the following data;

Remote Sensing: Utilize remote sensing techniques and satellite imagery to assess vegetation health, land cover changes, and to estimate rainfall patterns over a larger area.

Weather Station Data: Collect data from weather stations within or near the study area to obtain specific rainfall and temperature measurements during the study period.

Laboratory Analysis: Conduct laboratory analysis of tea samples to assess tea quality parameters such as chemical composition, flavor profiles, and sensory attributes. This can involve using equipment and techniques to quantify and compare tea quality levels.

Research instruments

Questionnaire

Closed-ended questions were preferred in the interview guide because they were straightforward and easy for respondents to answer. They allowed for the collection of quantifiable and measurable data and helped filter out irrelevant responses. To ensure clarity and understanding, the interview guide was translated into local languages, particularly for farmers who might not be proficient in English. Farmers were the appropriate target audience for this guide, as they could provide valuable insights into tea cultivation trends and responses to climate change. The researcher personally administered the interview guide to minimize potential bias.

Interview Method

A structured interview guide containing closed-ended questions was employed to collect information from household heads. This guide covered various aspects, including respondent demographics, tea cultivation practices, and yields, and the strategies employed to adapt to fluctuations in rainfall and temperature.

Data Quality Control and Management

Content Validity

To ensure the content validity of the research instruments, the researcher sought input and feedback from experienced researchers, including the supervisors. Following this, a questionnaire underwent a pilot test to assess its validity before full administration. The validity of the questionnaires was evaluated through a pre-testing process, involving the distribution of questionnaires to ten (10) individuals from the study population who were not part of the sample. Data collected from this pre-test were analyzed to identify any shortcomings in the instruments and make necessary adjustments if required.

Content Reliability

Reliability was assured by pre-testing the instrument and computation of the Cronbach Alpha coefficient, which was between 0.94 and 0.89 (Hof 2021).

The data collected was entered into Microsoft Excel version 2019 for ease of data entry and cleaning, after which it was transferred to the Statistical Package for Social Scientists (SPSS) version 26 for further data management and analysis. Descriptive and inferential statistics were used to interpret the study findings. Results were presented in tables, bar graphs, and pie charts.

Quantitative Data Analysis

The data analysis process was conducted in three stages: Univariate analysis, bivariate analysis, and multivariate analysis.

Univariate Analysis: Continuous data were summarized using statistical measures such as mean, variance, and standard deviation. Categorical variables were presented using frequencies and percentages.

Bivariate Analysis

Pearson's chi-square test was employed to explore potential associations between each independent variable (rainfall and temperature variability/climate change) and the dependent variable (tea growing). Statistical significance for

these relationships was determined using Pearson's chi-square test with a significance level set at $p<=0.05$. Variables found to be significant at this stage were further considered in the multivariate analysis.

Multivariate Analysis

T-tests were utilized to examine which factors had a more significant impact on tea growing compared to others. Given that the dependent variable is continuous in nature, the chosen statistical model for this analysis was the linear regression model.

Data Collection Procedure

The researcher was given an introductory letter from the Directorate of Graduate Studies, Research, and Innovations at Bishop Stuart University to allow the researcher to carry out the study. This letter gave respondents confidence to provide relevant information after the purpose of the study was revealed to them. The letter of introduction assisted the researcher in obtaining authorization from the administration of Kyamuhunga Tea Estates in Bushenyi District. After receiving permission, consent was sought from the participants. Subsequently, questionnaires were handed out, and respondents were given a designated period to return the fully completed questionnaires. Dates were scheduled for interviews with key informants. Once responses were collected, they were reviewed, organized, and coded for analysis.

Ethical Considerations

According to Johnson (2018), ethics are principles and guidelines that serve to protect our cherished values. In order to conduct the study in Bushenyi District, the researcher obtained an introductory letter from the Directorate of Graduate Studies, Research, and Innovation of Bishop Stuart University. Bishop Stuart University's Research Ethics Committee provided ethical approval for the study.

Additionally, permissions were sought from agricultural service providers and local leaders, who facilitated introductions to the weather station managers. Further authorization was requested from the weather station managers to access data on temperature and rainfall variability recordings.

Permissions were sought from local leaders in the selected villages where data were collected. These leaders then introduced the researcher to the farmers. Verbal consent was obtained from the participants after explaining the study's purpose and significance. They were assured that the research was solely for academic purposes and would not cause any harm to them. All participant names and family information were kept strictly confidential. During interviews, research assistants and the researcher provided interpretations of the interview guides to the respondents. Participants also had the option to ask questions and withdraw from the study at any point, even in the middle of data collection. The value and impact of this research hinged not only on its ethical integrity but also on the originality of its discoveries (Walliman, 2020).

The main ethical principles in this research included issues such as no harm to respondents, informed consent, privacy and confidentiality, cooperation, competence of researchers, and publication of findings. The researcher applied all these ethical principles.

Results

Response rate

Response rate shows the percentage of respondents who were able to participate in the study and give their views out of those sampled. The study was interested in the response rate in order to measure data quality, determine the validity of estimates, analysis, and inference of the findings. The response rate is detailed in Table 2.

Table 2: Respondents' response rates

Category of respondents	Target sample size	Responses	Percent
Farmers	123	117	95.1
Local leaders	6	6	100
Agriculture service providers	5	5	100
Weather station managers	2	2	100
Total	**136**	**130**	**95.6%**

Source: Field data (2025)

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Table 2 presents the response rate of the questionnaires distributed for the study on the effects of rainfall and temperature variability on tea growing in the Kyamuhunga Tea Estate, Bushenyi District. Out of the 123 questionnaires distributed, 117 were returned, accounting for 95.1% of the total. The overall response rate is 95.6% which indicates a successful data collection effort, suggesting strong participant engagement and minimizing non-response bias. According to Amin (2005), a response rate of 70% and higher is enough for a credible study. Mugenda (1999) noted that's response rate of 50% is good, a response rate of 60% is better and a response rate of 70% is best for further analysis.

Table 3 Demographic background of the respondents

Variable	Category of respondents	Frequency	Percentage
Gender	Female	56	52.1
	Male	61	47.9
Age	20-30 years	18	15.4
	31-40 years	30	25.6
	41-50 years	47	40.2
	Above 50 years	22	18.8
Education Level	Diploma	61	52.1
	Bachelor's degree	43	36.8
	Certificate	12	10.3
	Post graduate level	1	0.9
Main activity	Crop growing	81	69.2
	Livestock Growing	21	17.9
	Others	15	12.8
Mode of land acquisition	Purchase	25	21.4
	Inherited	44	37.6
	Rented	43	36.8
	Others	5	4.4

Source: Field data (2025)

Table 3 reveals that 61(47.9%) of the respondents were males and 56 (52.1%) were female. This showed how gender was to determine the effects of rainfall and temperature variability on tea growing in Bushenyi District, South Western Uganda. The identical values in the Percent indicate that all responses were valid, and confirm the total respondent pool. This balanced yet slightly male-skewed representation provides a comprehensive demographic context, which is essential for interpreting the study's findings on environmental impacts on tea cultivation.

Table 3 further shows that the majority 47 (40.2%) of respondents fall in the age bracket of 41-50 years; followed by 30 (25.6%) in the age bracket of 31-40 years of age; 22 (18.8%) were in above 50 years while the least 18 (15.4%) were 20-30 years of age. The Majority of the respondents being in age bracket of 41-50 years implying that the respondents are still in productive age and experienced thus understanding how to determine the effects of rainfall and temperature variability on tea growing in Bushenyi District, South Western Uganda. Understanding this demographic spread is crucial for interpreting the respondents' perspectives and experiences related to environmental impacts on tea cultivation

The education levels of respondents' shows that majority 61(52.1%) were diploma, 43(36.8%) were bachelor's degree, 12 (10.3%) were certificates and 1 (0.9%) had post graduate level. This implies that majority of the respondents had diploma hence the study was informative in nature.

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The educational profile of the respondents implies that the study must focus on providing practical, accessible, and actionable information to a community that is mostly educated at the diploma and bachelor's degree levels. The findings consider the need for clear explanations of complex climate-related concepts and focus on equipping farmers with skills that is directly applied to their agricultural practices.

Table 3 shows that the majority, 81(69.2%) of the respondents engage mainly in crop growing, 21(17.9%) engage in livestock growing and 15(12.8%) are in other activities. The majority of households are engaged in crop growing, followed by livestock growing, with a smallpercentage involved in both activities and other unspecified activities. This distribution provides valuable context for understanding the primary economic activities of the respondents, which is essential for assessing how rainfall and temperature variability might impact their livelihoods related to tea cultivation.

Regarding the mode of land acquisition, 44(37.6%) inherited the land, 43(36.8%) rented, 25(21.4%) purchased and 5(4.4%) from other modes. This implies that the fact that nearly 75% of the land is inherited or rented indicates that a significant portion of tea farmers may not feel the same long-term security or financial stability that comes with land ownership. This potentially limit the adoption of climate-resilient agricultural practices, such as the implementation of water management systems or the purchase of climate-resistant tea varieties.

Rainfall Variability on tea growing in Kyamuhunga Tea estate.

The study sought to examine the effect of rainfall variability on tea growing in Kyamuhunga Tea estate. The question items on the same were measured using the scale where 1 = Strongly Disagree (SD), 2 = Disagree (D), 3 = Neutral (N), 4 = Agree (A), and 5 = Strongly Agree (SA). In this study, analysis was done cumulatively with "strongly Agree" and "Agree" were aggregated to mean agreement, Neutral remained the same, "Strongly disagree" and "disagree" were aggregated to indicate disagreement. Means were also used to analyse the data with a mean above 3 indicates an agreement of respondents, a mean of 3 shows un decided and a mean below 3 shows disagreement by respondents. The standard deviation (Std) of close to 1 show agreement, while the standard deviation of close to Zero show the disagreement of the respondents as per Table 4.

Demographic Characteristics of the Respondents

To understand the data characteristics and ensure that the sample covered the different dimensions of the study, the researcher explored the background information of the respondents. The background characteristics helped to know that the information given is credible, dependable, truthful, reliable, transferable, and conformable by respondents who participated in the study. In this section, respondents provided information on their age, gender, marital status, occupation, education level, and working experience. The results about the background of the respondents are presented in Table 3 using frequencies and percentages.

Table 4 Descriptive statistics for rainfall Variability

RAINFALL VARIABILITY ON TEA GROWING	SD	D	NS	A	SA	Mean	Std. Deviation
Variability in rainfall affects soil-water availability to tea crops	5 (4.3%)	11 (9.4%)	1 (0.9%)	62 (53%)	38 (32.5%)	4.09	.915
Heavy rainfall destroys tea plantation	5 (4.3%)	0 (0%)	3 (2.6%)	60 (51.3%)	49 (41.9%)	4.26	.875
Scanty rainfall causes irreparable losses to tea plantations	3 (2.6%)	0 (0%)	5 (4.3%)	68 (58.1%)	41 (35%)	4.23	.759
Heavy rains lead to erosion of top soil and wash away available fertilizers and other chemicals	6 (5.1%)	3 (2.6%)	0 (0%)	75 (64.1%)	33 (28.2%)	4.08	.921
Frost bite significantly reduces tea growing and yields	5 (4.3%)	0 (0%)	6 (5.1%)	76 (65%)	30 (25.6%)	4.08	.832
Rainfall determines how fast a tea crop will grow from seed, including when it will be ready for harvesting.	34 (29.1%)	7 (6%)	5 (4.3%)	49 (41.9%)	22 (18.8%)	3.15	1.546

Source: Field data (2025)

The study established that 5 (4.3%) strongly disagreed, 11 (9.4%) disagreed, 1 (0.9%) not sure, 62 (53%) agreed, and 38 (32.5%) strongly agreed that variability in rainfall affects soil-water availability to tea crops. This implies that the majority of the respondents agreed with a mean of 4.09 and a standard deviation of 0.915.

It was also established that 5 (4.3%) strongly disagreed, 3 (2.6%) were not sure, 60 (51.3%) agreed, and 49 (41.9%) strongly agreed that heavy rainfall destroys tea plantations. This implies that the majority of the respondents agreed with a mean of 4.26 and a standard deviation of 0.875.

Table 4 further shows that 3 (2.6%) strongly disagreed, 5 (4.3%) were not sure, 68 (58.1%) agreed, and 41 (35%) strongly agreed that scanty rainfall causes irreparable losses to tea plantations. This indicates that the majority of the respondents agreed with a mean of 4.23 and a standard deviation of 0.759.

Table 4 indicates that 6 (5.1%) strongly disagreed, 3 (2.6%) disagreed, 75 (64.1%) agreed, and 33 (28.2%) strongly agreed that heavy rains lead to erosion of top soil and wash away available fertilizers and other chemicals. This indicates that the majority of the respondents agreed with a mean of 4.08 and a standard deviation of 0.921.

It was established that 5 (4.3%) strongly disagreed, 6 (5.1%) neutral, 76 (65%) agreed, and 30 (25.6%) strongly agreed that frostbite significantly reduces tea growing and yields.

This indicates that the majority of the respondents agreed with a mean of 4.08 and a standard deviation of 0.832.

Finally, it was established that 34 (29.1%) strongly disagreed, 7 (6%) disagreed, 5 (4.3%) were neutral, 49 (41.9%) agreed, and 22 (18.8%) strongly agreed that rainfall determines how fast a tea crop will grow from seed, including when it will be ready for harvesting. This indicates that the majority of the respondents agreed with a mean of 3.15 and a standard deviation of 1.546.

Qualitatively;

It was revealed by Key Informant B that;

"Most farmers revealed that there is an increased tea growth rate that increased their tea harvests during the longer daily rains compared to the longer dry season, with reduced tea growth that reduced their harvests."

Key Informant D noted that;

Climate variability, particularly fluctuations in rainfall and extreme weather events, has a significant impact on tea production. Respondents consistently observed that irregular rainfall patterns reduce soil-water availability, directly affecting the growth and productivity of tea crops. Heavy rainfall was reported to cause physical damage to tea plantations, including soil erosion, nutrient loss, and the washing away of fertilizers and agrochemicals, thereby lowering yields.

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Key Informant C pointed out that;

Scanty rainfall was described as causing severe water stress and irreparable losses to tea plants. Additionally, frost bites were identified as a major climatic hazard that considerably reduces tea growth and yield quality.

This implies that the findings underscore that tea farmers perceive climatic variability as a major constraint to sustainable tea production, requiring adaptive management practices to mitigate its adverse effects.

Discussion

The study shows rainfall variability had a significant positive influence on tea growing since the p-value is less than 0.05. The Pearson correlation coefficient (r=.566) shows that there is a positive, moderately significant influence of rainfall variability on tea growing. This implies that any positive changes in rainfall variability lead to a positive change in tea growing in the Kyamuhunga Tea estate. The results also indicate a unit increase in rainfall variability will result in a 0.321 in rainfall variability to the Tea growing (B=.321, p=0.000<.05) increase in rainfall variability to the Tea growing.

This is in agreement with Ali et al. (2014), who conducted a study to assess the impact of rainfall variability on tea leaf growth in different tea estates. Their research revealed that tea yields are significantly influenced by microclimatic parameters, particularly rainfall, temperature, humidity, and light duration. Inadequate rainfall results in irreplaceable losses since irrigation is seldom employed on tea plantations. Conversely, heavy rainfall can lead to topsoil erosion and the leaching of fertilizers and chemicals. Their analysis of field experiments and weather data indicated that the highest tea leaf growth per hectare occurred in regions receiving between 4000 mm and 4600 mm of rainfall. Tea growth showed a slight increase with rising total annual rainfall.

This is in agreement with Ndamani and Watanabe (2015), who conducted a study examining the influence of rainfall on crop growth, including tea, and suggested adaptation strategies. They observed moderate seasonal and irregular annual rainfall patterns. However, Ndamani and Watanabe (2015) presented a different perspective if their study had focused solely on tea cultivation. They might argue that while other crops exhibited a negative correlation between rainfall and growth, tea cultivation could respond differently. They could present contrasting evidence or suggest that tea plants may have specific adaptations to

rainfall patterns.

This is in agreement with Ahmed et al. (2014), who conducted research on the effects of water availability and pest pressures on tea (Camellia sinensis) growth and quality. They found that higher water availability and jasmonic acid (JA) treatments significantly increased the growth of new tea leaves. The impact of water availability and JA on tea quality varied among individual secondary metabolites.

The results are also in line with Hossain et al. (2015), who conducted a study on the effect of rainfall on tea yield and crop distribution, indicating that tea leaf growth slightly increased in various tea estates in the Sylhet district due to increased rainfall. The results suggested that tea cultivation thrives when there is abundant rainfall with a high number of rainy days. Moylan (2021) investigated the impact of rainfall variability on agricultural growth and household welfare. Their findings revealed that households experiencing severe negative rainfall shocks during the wettest quarters of agricultural seasons had significantly lower crop yields, agricultural output values, total per capita consumption expenditures, food expenditures, and dietary diversity.

Conclusion

The study concluded that rainfall variability had a significant positive influence on tea growing since the p-value is less than 0.05. The Pearson correlation coefficient (r=.566) shows that there is a positive, moderately significant influence of rainfall variability on tea growing. This implies that any positive changes in rainfall variability lead to a positive change in tea growing in the Kyamuhunga Tea estate. The results also indicate a unit increase in rainfall variability will result in a 0.321 in rainfall variability to the Tea growing (B=.321, p=0.000<.05) increase in rainfall variability to the Tea growing.

Recommendations

To mitigate the negative effects of rainfall variability, tea farmers should consider implementing irrigation systems to supplement water during periods of low rainfall. This can help ensure adequate soil moisture and promote optimal tea growth.

It is crucial for tea farmers to closely monitor weather patterns and anticipate changes in rainfall and temperature. By staying informed, they can adjust their farming practices accordingly and minimize the impact of climatic fluctuations on tea cultivation.

Continued research and development in the field of tea cultivation can provide valuable insights and innovative solutions to mitigate the effects of climatic variability. Tea growers should collaborate with researchers and institutions to stay updated on the latest techniques and practices.

List of Abbreviations

AOGCM:	Atmosphere-Ocean General Circulation Model
FAO:	Food and Agriculture Organization
IPCC:	Intergovernmental Panel on Climate Change
SPSS:	Statistical Package for the Social Sciences
UN:	United Nations
ASALs:	Arid and Semi-Arid Lands
CCKP:	Climate Change Knowledge Portal
GoU:	Government of Uganda
MAAIF:	Ministry of Agriculture, Animal industry and Fisheries
NAADS:	National Agricultural Advisory Services
MOALF:	Ministry of Agriculture and Livestock and Fisheries

Data availability

Data is available up on request

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PUBLISHER DETAILS