Global Scientific JOURNALS

GSJ: Volume 10, Issue 5, May 2022, Online: ISSN 2320-9186

www.globalscientificjournal.com

Impact of Climate Variability on Tea Production in Rwanda

Frank Celestin Dushimimana[1] and Lamek Nahayo[1]

[1]Faculty of Environmental Studies, University of Lay Adventists of Kigali, and P.O.Box: 6392, Kigali, Rwanda

Abstract: The goal of this study was to determine the impact of climate variability on tea production. The study considered Mulindi Factory Company (MFC) located in the Northern Rwanda within 11 years (2010-2021). Secondary data on rainfall and temperature variability and tea production were collected from the factory and neighboring meteorological stations. Microsoft Excel and Pearson Correlation of Statistical Package for Social Sciences (SPSS) software analyzed the relationship between temperature and rainfall variations and tea production. The results indicated that 2014 and 2020 years recorded high rainfall of 105.5 and 126.2 mm, respectively while temperature was quite stabilized and/or constant. The tea production increased from 8,383.41 Kg/Ha in 2010 to 10,131.40Kg/Ha in 2021. A statistically significant (positive) relationship between rainfall variation with tea production (r1= 0.990) and between temperature variations and tea production (r_2=0.993) was obtained. Regardless of the fact that tea production recorded increasing production, it is good to recognize the fact that fertilizers also were increasing, which likely contributed to the production. Whereas if only rainfall and temperature were considered as major contributing factors to tea production, there would be decreasing trend of tea production. This calls for further studies on the impact of unstated factors like soil, tea varieties in tea production and adapting climate resilient methods.

Keywords: Climate variability, Mulindi Factory Company, Rainfall, Tea production, Temperature, Rwanda

1. Introduction

Global warming is generating climate change, which has been acknowledged as a key challenge around the world (IPCC, 2014). In this context, the entire globe has seen a dramatic increase in altering climate, which is expected to continue at a rapid rate in the future, with catastrophic consequences for agriculture, including tea. Climate change is described as an alteration in the statistical features of the climate system, such as averages, variability, and extremes, that lasts several decades or longer (NASA, 2022). The future climate variability will have more negative consequences all throughout the world. By 2100, global average temperatures are expected to have changed by 1.1 to 5.4 degrees Celsius. The volume and severity of precipitation will vary greatly by region, with some parts experiencing an exponential surge and others experiencing a fall (Robinson, 2020).

Rwandan tea is planted on hillsides at high altitude between 1,900 and 2,500 m, and on well-drained marshes at an altitude of between 1,550 and 1,800 m, with precipitation ranging between 1200 mm to 1400mm per annum. Temperatures for tea production range from 21°C to 29°C, with 16°C being the minimum permitted temperature (NAEB, 2012). Tea and coffee are by far the most important export commodities in Rwanda, accounting for more than 90% of total earnings. And tea alone, accounts 30% of the country's foreign exchange earnings (NISR, 2018) (Bizoza, 2014).

In Rwanda, Tea cultivation is a vital source of livelihood for most rural people, contributing significantly to poverty alleviation, job development, and foreign exchange profits (Dutta & R, 2014). However, climate change is unmistakably becoming a serious global concern for agricultural systems, including tea production (Ahmed, et al., 2019) (Chang & Brattlof, 2015). After water, tea is the second most popular beverage (Paiva, 2020). However, the rising air temperatures and change in seasonal precipitation have a harmful effect on tea production (Dutta & R, 2014). In order to improve production in the face of climate change, it is critical to examine the effects of climate change on yield of important food crops farmed primarily for human consumption. Unfortunately, there are certain gaps in research or studies that highlight the influence of climate change on important agricultural yields (Cheserek & al., 2015).

Several repercussions have been observed at both the farm and national levels since the emergence of extreme climate events (Bore JK & Nyabundi, 2016). To the best of the researcher's knowledge, there is no research conducted on how climate variability affects tea production in Rwanda. Therefore this study aims to analyze the impacts of climate variability on tea production, with the Case of Mulindi Factory Company in Gicumbi district of Rwanda. The results of this study will be beneficial to policymakers in domains such as agriculture and environmental conservation. The study also may add knowledge about the consequences of climate variability on tea production and provide information to other interested researchers and academicians.

2. Methods and Materials

2.1 Description of study area

Gicumbi district is located in Rwanda's Northern province and shares borders with Uganda to the north, Kigali to the south, Nyagatare and Gatsibo Districts to the east, and Rulindo and Burera Districts to the west. Gicumbi District has a population of 424,112 people, with 231,429 women and 211,073 men. It has an area of 829 km^2 and has a population density of 534 people per km^2. The district is divided into 21 sectors, 109 cells, and 199 planned settlements (MINAGRI, 2013).

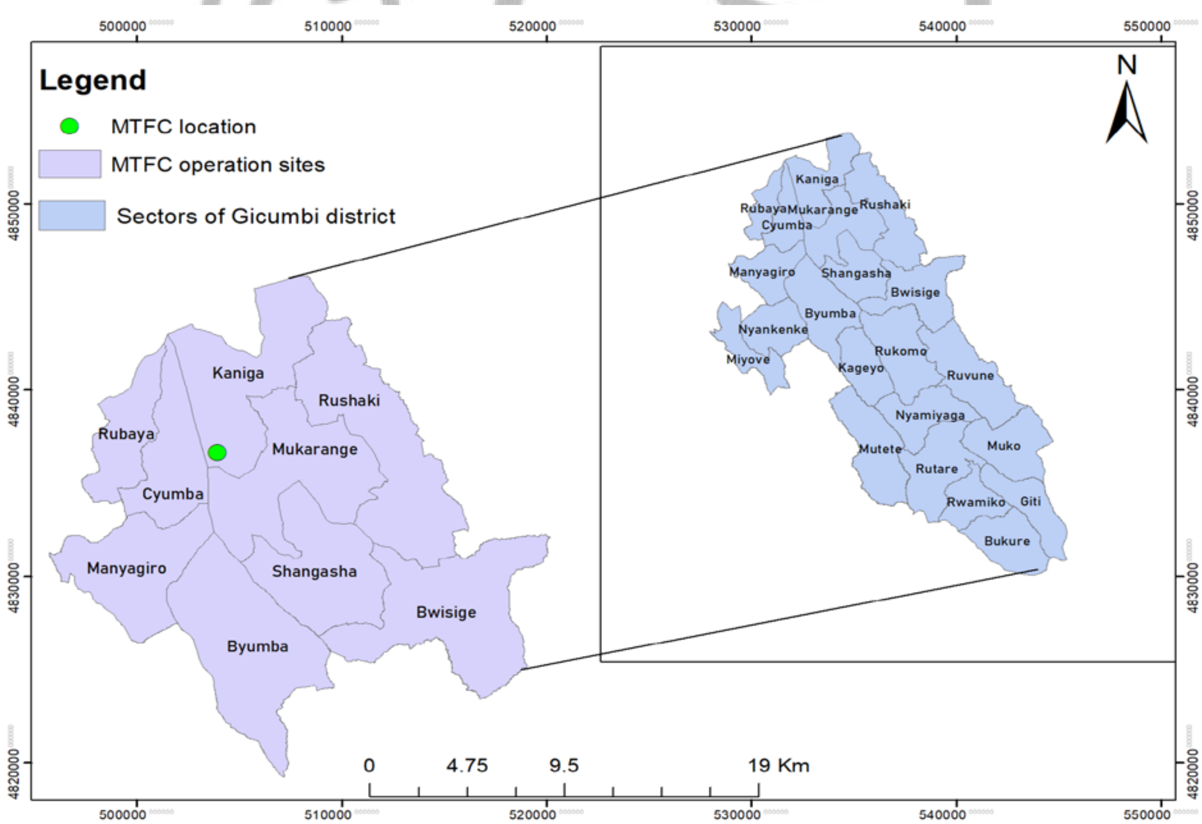

Figure 1: Map of Tea Plantation Sectors, Location of MFC in Gicumbi District.

Mountains with an altitude of 1,200-1,500 meters characterize the Gicumbi district. The average temperature is between 15 and 16 degrees Celsius (NAEB, 2022). Because of its topography, the district is especially subject to landslides and soil erosion (REMA, 2013). As a result, the government and other international organizations have set up programs to assist farmers in preventing landslides and soil erosion. The district's total land protected from soil erosion amounts for 89.8% of the total land, while irrigated land accounts for 1% of the entire land (NISR, 2012a).

Tea plantations are found in eleven of Gicumbi's twenty-one administrative sectors. Mulindi factory company (MFC) is located in Kaniga Sector, 14 kilometers from the Gatuna border, an hour's drive from Kigali, and 5 kilometers from the Kigali-Gatuna route (GoR&SSEE, 2011). The factory is the largest in terms of production, but it relies on 2 cooperatives, COOPTHÉ and Village's Tea, which is known as COOTHEVM, for its green leaf supply because it does not have its own plantations (NAEB, 2012). COOPTHÉ accounts for 35% of the total, with 585 ha exploited, while Villagers' Tea accounts for 55%, with 1150 ha. There are only 174.4045 hectares in the industrial block, for a total of 1909.4045 hectares (REMA, 2013). All of these tea plantations are spread throughout ten different agricultural sectors (MINECOFIN, 2013). About 90% of this land is in a valley or wetland, with the remaining 10% on mountain sides. The factory, which has a capacity of 3200 tons, was erected in 1962. Following the conflict, the factory and tea plantations were rebuilt between 1994 and 1996 (NAEB, 2022).

2.2 Data collection and analysis

Different types of data were used in this study. Over the last 11 years (2010-2021), time series data (secondary data) on tea production, area harvested, and fertilizers application were collected from Mulindi Factory Company (MFC), climate variables (rainfall and temperatures) were collected from the factory. The data were analyzed by using Microsoft Excel and were presented into charts and Tables. Thereafter, the Pearson correlation of SPSS analyzed how rainfall and temperature variability affected tea production. Finally, based on the fact that the study used two variables namely independent (climate variability) and dependent (crop production) variables, the authors applied the Pearson Correlation detailed in Table 1 below.

Table 1: Pearson Correlation analysis

	Coefficient, *r*	
Strength of Association	**Positive**	**Negative**
Small	.1 to .3	-0.1 to -0.3
Medium	.3 to .5	-0.3 to -0.5
Large	.5 to 1.0	-0.5 to -1.0

In order to successfully perform the Pearson Correlation analysis, the authors based on the Pearson Correlation analysis guideline (Table1) expressing the fact that a p-value smaller than 0.05 indicated a statistically significant association (at 5 % level) and a p-value larger than 0.05 reveals no statistically significant association between two variables tested.

3. Results

The results in Figure 2 showed that precipitation around Mulindi Factory Company (MFC) has been fluctuating over the years. Between the year 2010, 2011, 2012 and 2013 rainfall around MFC was ranging from 79mm to 89 mm per year. However, in 2014 precipitation increased to 105.5 mm. While in 2018, the precipitation increased respectively every year from 91.1mm to 95.7mm in 2019, which increased to 126.2 mm in 2020 and decreased to 117.9mm in 2021. This means that the amount of rain (precipitation) around MFC has been increasing over time.

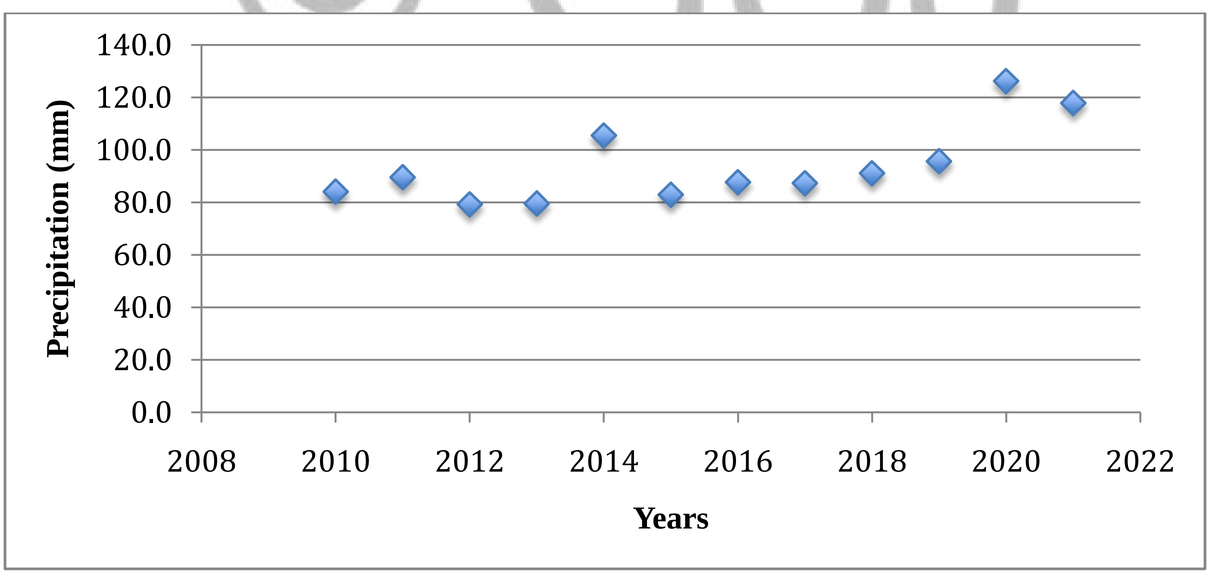

Figure 2: Variation of Precipitation

Source: Research data (2022)

According to the results in Figure 3, the minimum temperature ranged between 12.9 and 16.7°C from 2010 to 2021. Furthermore, apart from 2013 and 2014 where the temperature were 21.4 and

22.6 °C, generally the maximum temperature around MFC was around 25°C, with an average temperature between 19°C and 20°C. This indicates that the temperature around MFC remained constant from 2010 to 2021.

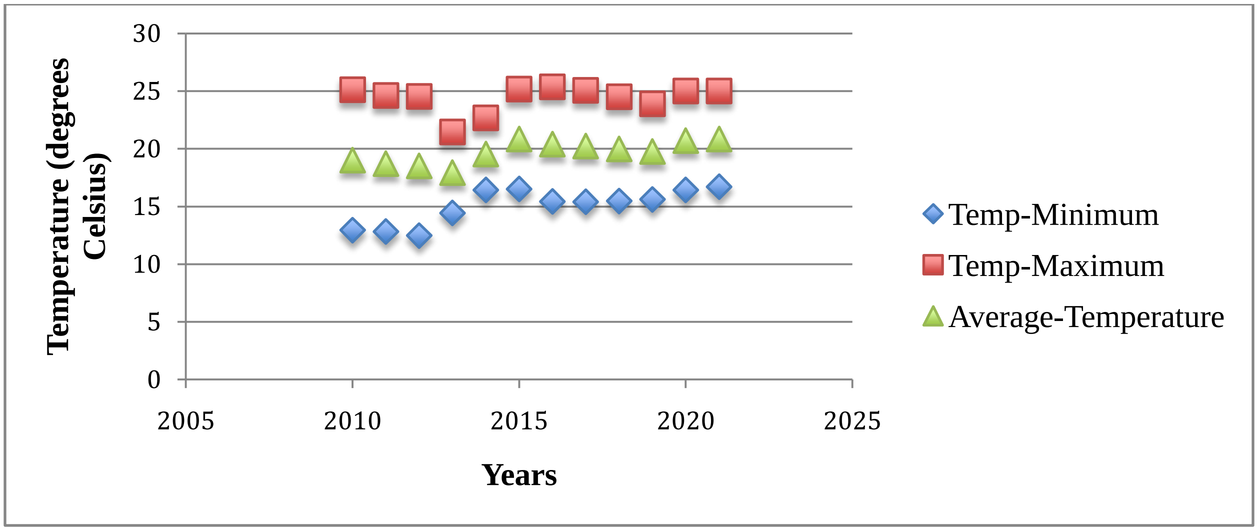

Figure 3: Variation of Temperature

Source: Research data (2022)

The results in Figure 4, the application of NPK fertilizer has been increasing from 339,080Kg in 2010 to 345,467Kg in 2011, and 330,943Kg in 2012, before increasing to 352Kg in 2013. The application of fertilizer kept increasing in 2014 from 389,239Kg to 396,451Kg in 2015. In 2016, the use of fertilizer decreased considerably to 316,319Kg, in the following years the application of NPK slightly to reach 363,300Kg in 2020 and increased greatly in 2021 to 455,043Kg.

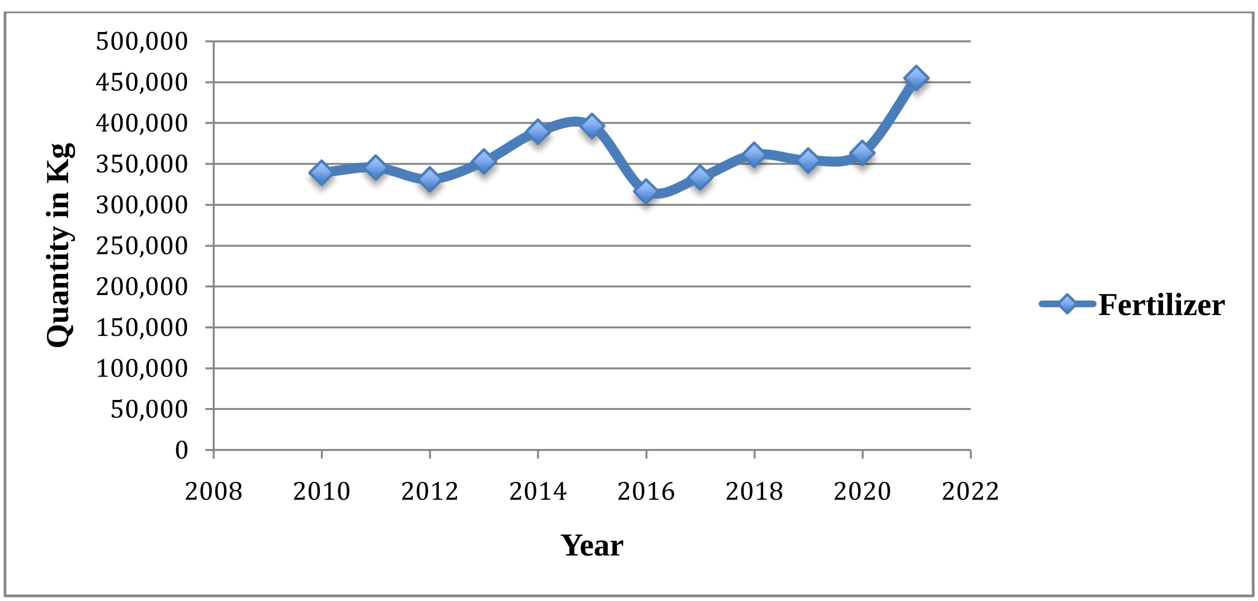

Figure 4: Variations of fertilizer applications

Source: Research data (2022)

Furthermore, the authors analyzed the recorded tea production under the above factors (rainfall, temperature and fertilizers). Therefore, as illustrated in Figure 5, it was noticed that the production of tea recorded the fluctuating production. For example, in 2010, the production increased from 8,383.41 Kg/Ha to 9,161.36 Kg/Ha in 2011. The two following year MFC has seen a decrease in production from 7,474.21Kg/Ha of 2012 and 7,419.39Kg/Ha of 2013. In 2014, the production increased considerably to 9,498.28Kg/Ha and to 9,554.08Kg/Ha in 2015. The same Figure 5 showed that in 2016, the tea production decreased to 8,607.44Kg/Ha before increasing slightly from 9,209.42Kg/Ha in 2017 to 9,785.97Kg/Ha. A small decrease in production was observed from 9,283.27Kg/Ha in 2019 to 9,046.90Kg/Ha in 2020. In 2021 the production increased considerably to reach 10,131.40Kg/Ha.

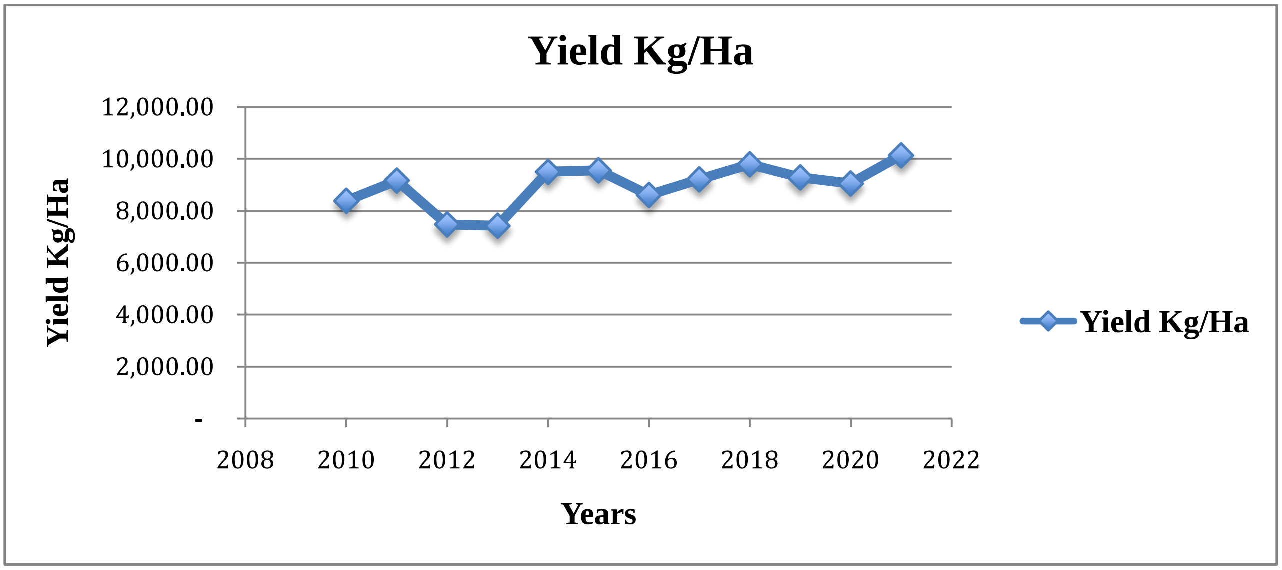

Figure 5: Variations of tea production

Source: Research data (2022)

The generated and combined Pearson correlation analysis between variations on rainfall and temperature and fertilizer application with tea production at Mulindi Factory Company was indicated in Table 2. The analysis shows a statistically significant (positive) relationship between rainfall variation and tea production with the correlation r1= 0.990. The same Table 2 showed a statistically significant (positive) relationship between temperature and tea prediction with the correlation r_2=0.993. In addition, the analysis generated a statistically significant (positive) relationship between fertilizer application and tea production with the correlation r3= 0.593.

Table 2: Summary of correlation between independent and dependent variables

		Rainfall	Temperature	Fertilizer
Tea production	Pearson Correlation	.990	.993	. 593
	Sig. (2-tailed)	.041	.043	.029
	N	3	3	3

*. Correlation is significant at the 0.05 level (2-tailed).

Source: Primary data, 2022

4. Discussion

Global warming has a direct effect on crops, food chains and production cycles in terms of marked changes on growth and yield processes. The reports of the intergovernmental Panel on Climate change (IPCC) indicate that the rise in temperature since 1980 led to reduction in yields of staple crops offsetting gains even from improved farm practices, which has several implications for agriculture, crop yields and patterns in the long run (IPCC, 2001). In Rwanda, changing climate started to manifest its impact on agricultural production many years ago. For example, in 2015, the dry season started early than expected, and this greatly led to reduction of agricultural production mainly in the Eastern province (Lamek. N., 2018).

For this study, it was noticed that both 2014 and 2020 years recorded high rainfall of 105.5 and 126.2 mm, respectively. For the temperature variation, the record was quite stabilized and/or constant compared to the rainfall. With regard to fertilizers, since 2010 to 20921, the record kept on increasing in terms of application. The tea production revealed a growing trend from 8,383.41 Kg/Ha in 2010 to 10,131.40Kg/Ha in 2021.

Recent studies (FAO, 2014; Dutta & R, 2014 & Lamek et al., 2018) on the impact of climate variability confirmed the fact that under climate change, the agricultural production will likely decrease or be damaged. This results from the fact that tea production depends on the local weather but also other factors like soil properties, fertilizer application, types of tea varieties, etc., might contribute to its production variation. This agree with the current research, as shown in Figures 2,3 and 4, rainfall, temperature and fertilizers varied over time and the tea production recorded varying production over years. This expresses that rainfall, temperature or fertilizer affected the production by either increasing or decreasing its production.

In addition, as previously reported, climate variability affects agricultural production in Sub-Saharan Africa because the sector accounts near 96% of rain-fed agriculture compared to overall production (FAO, 2014). This expresses that rainfall and temperature variability greatly affects these countries' agriculture since the sector is rain-fed. This is due to the reason that irrigation is not developed in these areas (FAO, 2017). This also confirms with the results of this study in Table 2 where the Pearson Correlation between rainfall and temperature variations generate a positive relationship with coffee production compared to that of fertilizer and tea production (Table 4.4).

Hence, the results of this study confirm the fact that climate variability is impacting on tea production at some extent and that potential impacts on human, environmental and economic systems require a cost that can, to some extent, be avoided by taking appropriate actions to adapt to the changes in temperature and rainfall.

5. Conclusion

The study employed secondary data on rainfall, temperature variations, fertilizers application along with tea production recorded between 2010 and 2021 at Mulindi Factory Company in the Northern Rwanda. The Microsoft Excel and SPSS software enabled the researcher to analyze the collected data. The results indicate that both 2014 and 2020 years recorded high rainfall of 105.5 and 126.2 mm, respectively. For the temperature variation, the record was quite stabilized and/or constant compared to the rainfall. With regard to fertilizers, since 2010 to 2021, the record kept on increasing in terms of application. The tea production also revealed a growing trend from 8,383.41 Kg/Ha in 2010 to 10,131.40Kg/Ha in 2021. For the relationship between rainfall and temperature variations with tea production, a statistically significant (positive) relationship (r1= 0.990) and (r_2=0.993) was estimated, respectively. This confirmed that p*recipitation and temperature variability significantly impact tea production*. Policy maker can base on the findings of this study to implement climate resilient agriculture.

Acknowledgements

The authors thank Mulindi Factory Company that provided the data and facilitated the completion of this research.

References

Ahmed, S., Griffin, T., Kraner, D., Schaffner, M., Sharma, D., Hazel, M. (2019). *Environmental Factors Variably Impact Tea Secondary Metabolites in the Context of Climate Change: A Systematic Review*. *Front. Plant. Sci. 10, 939*. Frontiers in Plant Science.

Bizoza. (2014). Population Growth and Land Scarcity in Rwanda : the other side of the Coin.

Bore JK & Nyabundi. (2016). *Impact of climate change on tea and adaptation strategies (Kenya) Report of the Working Group on Climate Change of the FAO Intergovernmental Group on Tea.* Food and Agriculture Organization of the United Nations, Rome.

Chang, K., & Brattlof, M. (2015). *Socio-Economic Implications of Climate Change for Tea Producing Countries* . Rome, Italy.: FAO.

Cheserek, B. E., & al., e. (2015). Analysis of Links between Climate Variables and Tea Production in the Recent Past in Kenya. 5-17.

Dutta, & R. (2014). Climate change and its impact on tea in Northeast India. *Journal of water and climate change* , 625-632.

FAO. (2017). *The Future Of Food And Agriculture – Trends and Challenges.* Rome: FAO.

GoR&SSEE. (2011).*"Green Growth and Climate Resilience: National Strategy for Climate Change and Low Carbon Development Development."* Kigali/Rwanda.

IPCC. (2001). *Climate Change 2001: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change*, pp. 981–996. J.J. McCarthy, O.F. Canziani, N.A. Leary, D.J. Dokken & K.S. White, eds. Cambridge, UK and New York, USA, Cambridge University Press.

IPCC. (2014). *“Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to theFifth Assessment Report of the International Panel of Climate Change.”*

Lamek. N., et al, (2018). *Rainfall variability and its impact on rainfed crop production in Rwanda.* American Journal of social Sciences research vol4, No 1,2018. Pp.9-15

NAEB. (2022, February 3). *NAEB.* (N. A. Board, Producer) Retrieved January 27, 2022, from www.naeb.gov.rw: https://www.naeb.gov.rw

NAEB. (2012). *Rwanda Tea Section: Tea production in Rwanda . Strategies for Tea Sector Development.* . National Agricultural Export Development Board. Kigali: National Agricultural Export Development Board.

NASA. (2022). *NASA Global Climate Change. Global Surface Temperature: Vital Signs of the Planet. 2020. Available online: https://climate. nasa.gov/vital-signs/global-temperature/ (accessed on 26 January 2022).* Retrieved January 22, 2022, from www.nasa.gov: https://climate. nasa.gov/vital-signs/global-temperature/.

NISR. (2012a). *Integrated Household Living Conditions Survey (EICV3).* Kigali, Rwanda.

NISR. (2018). *Seasonal Agriculture Survey 2018 anual report.* Kigali: National Institute of Statistics of Rwanda.

MINAGRI. (2013). *Plan for the Transformation of Agriculture in Rwanda – Phase III.”*. Kigali, Rwanda. : Ministry of Agriculture and Animal Resources.

MINECOFIN. 2013. “*Economic Development and Poverty Reduction Strategy (2013-2018): Shaping Our Development*.” Ministry of Finance and Economic Planning. Kigali, Rwanda.

Paiva, L. L. (2020). *Current Research in Food Science Variability of antioxidant properties , catechins , caffeine , L-theanine and other amino acids in different plant parts of Azorean Camellia sinensis.*, Azore/Portugal.

REMA. (2013). *"The Assessment of Economic Impacts of the 2012 Wet Season Flooding in Rwanda."* . Rwanda Environmental Management Authority. Kigali, Rwanda.

REMA. (2015). *Rwanda state of envornment and outlook Report.* Kigali, Rwanda.

Robinson, S. (2020). *Climate change adaptation in SIDS: A systematic review of the literature pre and post the IPCC Fifth Assessment Report*. Wiley interdisciplinary reviews.