International Journal of Sustainable Applied Sciences (IJSAS)
Vol.2, No.8, 2024: 805-820

Climate Variability and the Resilience of Smallholder Tea Production in the East Usambara Mountain Farming System, Tanzania

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ARTICLEINFO

Keywords: Climate Variability, Climate Change, Tea, Agrifood Systems, Resilience, Usambara, Smallholder Farmers, Tanzania

Received : 05, July
Revised : 18, July
Accepted: 23, August

ABSTRACT

The complexities of climate change are well-known, and it has immediate and long-term consequences on the environment and natural resources. This global concern adversely affects sustainable development sectors and economic systems including the agricultural sector. The tea sector is among the largest export crops contributing to earnings and revenues. Its production has been declining, and the reasons behind this decline remain unclear. This study proposed to explore the influences of climate variability on the current productivity trend of smallholder tea farmers in Tanzania. The study involves quantitative data analysis, collected from 1990 to 2020 including monthly precipitation, temperature statistics, and Greenleaf production gathered as secondary data from the Tea Research Institute of Tanzania and the Tea Board of Tanzania. The study found that rainfall and temperature change significantly influence smallholder farmers' tea production in the East Usambara Mountains. The optimal climate elements (temperature and precipitation) positively improve smallholder farmers' tea production. In contrast, extreme climate variability triggers negative effects on tea production when precautions and adaptation measures are not considered. To summarize, it is recommended that farmers engage in different programs and training sessions to enhance their perception and adaptability to climate change.

INTRODUCTION

Climate change and variability are recognized as a complex phenomenon characterized by diverse weather conditions (Thornton et al., 2014) that have short-, medium, and long-term effects on ecosystems and natural resources (Kahimba et al, 2015; Kalkuhl and Wenz, 2020); these are global threats that have negative impacts on sustainable development sectors and economic systems. Tanzania is among the vulnerable countries in Africa, with a population that has minimum protection from the impacts of climate change (Mkumbukiy, 2022). However, this country is highly dependent on the natural resources efficiency to maximize production through rainfed agriculture for the food security and sustainable livelihoods of its citizens (Kahimba et al, 2015; Oestigaard, 2016). For instance, the drought that occurred in 2000-2002 affected more than 50 million Tanzanians, while in 2004-2005 low farm returns frustrated efforts to alleviate poverty and food security (URT, UNEP&GCF., 2007).

Furthermore, agriculture is a powerful sector of the Tanzanian economy. According to the World Bank (2002), it generated about 45.1% of GDP in 2000 concerning 80% of the citizens who are directly or indirectly dependent on agricultural activities for their livelihoods. Tanzania's agriculture farming system is divided into large-scale and small-scale production. The smallholder growing system was presented in the early 1960s under the Ministry of Agriculture in various crops including tea. In addition, the land in the small-scale farming system is divided into small plots of various produce owned by individual households. Smallholder agriculture is the predominant livelihood (75-80%) in Tanzania; it tends to depend highly on the availability of rainfall and operates on an average area of 0.2 to 2 ha. Moreover, it is dominated by the participation of women (URT 2011c; and ACRP, 2014). Smallholder farmers contribute about half of the total Greenleaf produced in Tanzania.

Tea crops are an important component in the various national incomes as tea products (dry leaf) are exported while earning foreign currency. Consequently, as in other crops, climate events can also destroy the growth and development of tea plants. According to Ochieng et al. (2016) described that tea is highly sensitive to changing climate and its related weather conditions. Moreover, rising temperatures and extreme weather events are creating a serious challenge to the tea agrifood system sustainability (Wenyan et al.,2018; Sharma and Gunasekare, 2018). Despite the importance of the tea industry (Loconto, 2010) in building Tanzania's economy and community livelihood, efforts to enhance smallholder tea farmers' resilience to climate change and variability are still in their infancy, particularly in East Usambara. It is well known that tea is among perennial cash crops by which minimal changes in climate variables alter Greenleaf quantity and quality. Munishi et al (2017) reported that Tea production has been declining, and the reasons behind this decline remain unclear. However, most of the researchers in Tanzania trying to find the possible reason for this declining trend of production. Whereby, some of them mentioned several factors as the major source of poor production, which are Biophysical factors, Environmental factors, and socioeconomic factors compared to other crops produced in Tanzania, the present assessment does not indicate to what extent the environmental factors such as climate change impacts affect smallholder tea production as well as their revenues, and what adaptation measures are taken to combat the effects. This implies that there is a great need to assess the contributions of climate variability and socioeconomic drivers to the resilience of the tea smallholder farmers in Tanzania. Findings from this study will help the government of Tanzania and other tea-growing countries to improve their efforts in supporting the agricultural sector and its subsectors, on the urgent implementation of climate change risk assessment and management policy for timely combatting climate change and variability effects on the development sectors for better country's economy and community livelihoods.

LITERATURE REVIEW

Climate Change and Variability in Tanzania

According to URT (2013), Tanzania is divided into seven important climatological zones to assess baseline climatology, observed trends, and climate change, Lake Victoria Basin (Northern regions), Northeastern highlands zone/regions, Northern coast zone/regions, Southern coast zone, Southern western highland zone, central zone, and western zone. VPO through its National Climate Change Strategies of Tanzania (2012) reported that the general trends of the climate change variables were examined from 1960 to date, whereas from 1961 to 2013 an increase of 1.0oC of the average annual temperature has been observed more during nighttime. Furthermore, for certain decades a decrease of 2.8 mm per month of annual rainfall has been recorded in Tanzania, this situation influences the existence of droughts for a long period destroying water sources, wetlands, ecosystems, and biodiversity. Moreover, it is projected that in the future temperature will increase by 1.0 to 2.7oC, and more warming is expected in the western side of the country whereby a temperature increase up to 3.4OC is projected by 2100 (URT,2015). Consequently, some of the regions in Tanzania will experience increased rainfall that will come as heavy events than in the current. Whereby, increased temperature and rainfall will also increase the number of diseases like malaria and cholera, some of the highly productive areas will also be affected by declining rainfall, and droughts that will influence decreased agricultural productivity (URT, 2012).

In addition to that, increased concentrations of Greenhouse Gases in the atmosphere (Choudhary et al, 2015) are the major factor in changing climate due to increased global warming. Most of the developing countries are affected by climate change (Urban, 2019) due to their least adaptive capacities. Tanzania is one of the developing countries that are emitting a negligible amount of greenhouse gases but it's experiencing the great impacts of climate change caused by other developing countries through its development sectors. From 1990 to 2005 different National Inventory series of the Greenhouse Gas emissions were conducted in Tanzania. In 2014 a total of 286.49 million metric tons of Carbon dioxide were emitted in Tanzania (WRI CAIT, 2018) from different sustainable development activities such as agricultural production, manufacturing, Land use, and waste sector. The VPO's Second National Communication (2014) reported an increased greenhouse gas emissions trend from the energy utilization, industries operation, product consumption, and waste. The increase in emissions trend is due to increasing population (estimated 60 million) and economic activities.

Vulnerability of Tanzania's Smallholder Farmers to Climate Variability

In Tanzania, approximately 4 million people are small-scale farmers managing less than 2 hectares of agricultural land. However, Smallholder farmers are among the most vulnerable even small variations in the climate bring impacts to food security as well as livelihoods. These farmers grow cereals and other cash crops for their livelihoods. According to Tanzania URT (2019), yields of key cereal crops are likely to decrease due to temperature rise and decreased water availability with significant implications for commercial investment, smallholder farmers, and food security. During dry season, approximately 25% of the processed tea was lost due to prolonged drought in the Southern Highlands of Tanzania (Carr, 2012; Msomba et al, 2018). Due to climate change's adverse impacts that resulted in the unusual distribution of rainfall (Floods), prolonged drought, pests, diseases, and noxious weeds infestations, most large-scale and small-scale farmers in Tanzania experiencing decreased yields (Kangalawe et al, 2009; Munishi et al, 2010). The increased rainfall causes loss of soil nutrients and other important microbial agents in different ways such as leaching, runoffs and waterlogging that impacts growth and development of the plant. This situation would cause increased uses of agrochemicals and pest and disease-resistant cultivars which also increases the cost of production to smallholder farmers. The long-term changing climate will impact the future growth and development of Tanzania's agriculture sector. Also, severe drought has exerted pressure on biodiversity and ecosystems (URT, 2014; Irish Aid, 2016).

METHODOLOGY

The study involves quantitative data analysis, collected from 1990 to 2020 including monthly precipitation, temperature records, and Greenleaf production gathered as secondary data from different government and private tea authorities in Tanzania. Data about Greenleaf production were accessed from the East Usambara Tea Company (EUTCo) and Tea Board of Tanzania (TBT) platforms. The intended component of exploration was smallholder farmers who were selling green leaves to tea companies allocated in the East Usambara Mountains.

Study Area Profile

The study is carried out within East Usambara Mountain in Amani, Muheza district at Tanga Region Tanzania. This is a territory of low mountains adjacent to the coast and then southward from Mt. Kilimanjaro in the north-eastern corner of Tanzania. They occupy a total area of 1300 km2 which covers 40km long and 10km wide between 4o 48′ and 05o 13′S and 38o 32′ and 38o

48′E, whereby about 83.8 km2 is covered by forest reserve (Hamilton,1989). Furthermore, its altitude ranges from 900 to 1506 meters above sea level. From its Eastern edge, they are only 40km from the Indian Ocean. The East Usambara Mountain governmentally falls into two districts, Muheza and Korogwe, both part of the Tanga region.

Climatic Characteristics

East Usambara Mountains experience a monsoonal climate with a bimodal rainfall pattern. It has two types of rain season, which are short rain season ('Vuli') in October to December characterized by wet and warm conditions, and long rain ('Masika') in March to May (Magang et al, 2014). The Long driest season in East Usambara is experienced from July-September while another dry season is between January to February before the long rain. The mean annual rainfall is 1800mm, with the recorded mean minimum and maximum daily temperatures of 16.3o C and 24.9o C respectively. Furthermore, the mean annual humidity is 87% and 77% in the morning and at midday, respectively. Generally, in East Usambara, frosts occur during July, which is the driest season.

Analytical Data Test (Data Clearance)

Autocorrelation Test

The study reveals 2.035 from the Durbin-Watson readings which signifies lack of autocorrelation in the collected information. This is the rule of thumb of autocorrelation of the Durbin-Watson reading which is not less than 1.5 and not greater than 2.5 (1.5< X <2.5) reflects lack of autocorrelation of the retrieved information of the variables (Blundell et al, 2001; Bett, 2018; Doryab and Salehi, 2018).

Table 1. Autocorrelation Test

Model	Durbin Watson
1	2.035

- Predictors: (Constant), Temperature (Celsius), Rainfall (mm)
- Dependent Variable: Tea Production (Kg/ha)

Test of Normality

From the findings of this study, the p-values for tea Greenleaf output, temperature and rainfall were 0.256, 0.225 and 0.152, respectively. The calculated p value indicates normal distribution of the data are normally distributed since the values are higher than the 0.05 significance level.

Table 2. Tests of Normality

	Shapiro-Wilk		
	Statistic	df	Sig.
Tea Production (Kg)	.958	31	.256
Rainfall(mm)	.950	31	.152
Temperature (Celsius)	.956	31	.225
- Lilliefors Significance Correction			

Multicollinearity Test

This study finds that all values of independent variables lie below 10, whereby rainfall (VIF=1.387), Temperature (VIF=1.286), and Socioeconomic factors (VIF=1.426). This suggests each independent variable in this study is not predicted or explained by another variable from the same case.

Table 3. Multicollinearity

Model		Collinearity Statistics	
		Tolerance	VIF
1	(Constant)		
	Rainfall(mm)	.721	1.387
	Temperature (Celsius)	.777	1.286
- Dependent Variable: Tea Production (Kg/ha)			

Data Processing and Analysis

Moreover, data processing and analysis was conducted by using Statistical Package for Social Science and Excel. Through the collected information from the respondents, interlinkage and interdependence of the independent and dependent were correlated and analyzed using multiple regression methods. Also, these models were used to test the proposed hypotheses as well as how the weather elements explain the variability of tea production. The testing of the study's six research assumptions was considered as guidance reaching to decisions and policy recommendations. of the study as a basis for deriving relevant conclusions.

The regression model was:

$$Y = \beta 0 + \beta 1\, X1 + \beta 2\, X2 + \varepsilon$$

Whereby:

Whereby:	Y	= Tea Greenleaf Yield
	X1	= Precipitation
	X2	= Temperature
	ε	= Error term
	β0	= Constant term
	β1, and β2	= Co-efficient

RESULTS

Trends of Precipitation and Tea Production

According to the results in Figure 1, precipitation in the East Usambara Mountains has been changing over the years. Between the years 1990 and 2020, rainfall in East Usambara Mountains ranged from 1100mm to 2500mm per year. Nevertheless, in some of the years, an abrupt decrease and increase in precipitation have been experienced. In the years 1996 and 2019, precipitation was 1031mm and 2804mm as the lowest and highest record, respectively, which is against the normal range of precipitation distribution in this location.

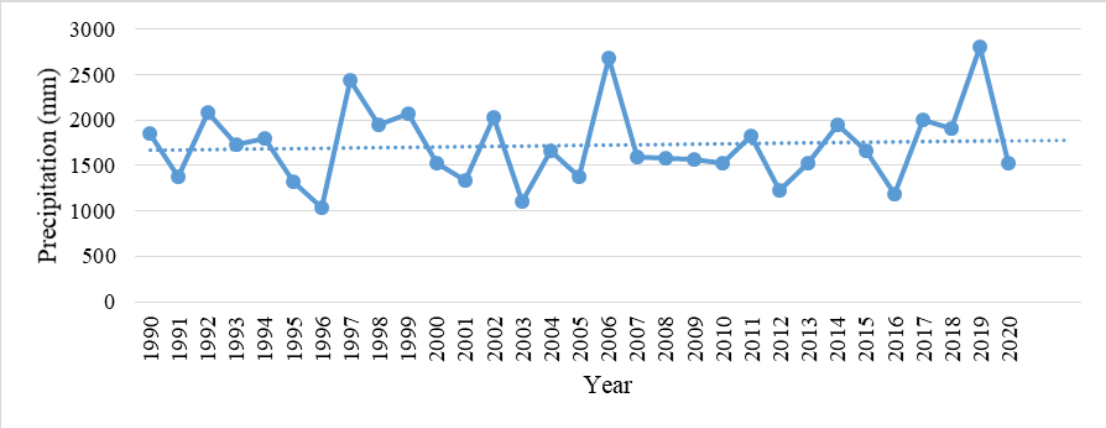

Figure 1: Rainfall trend in East Usambara Mountain from 1990-2020(mm)

The results from Figure 2, show that between the years 1990 to 1993 tea yield was 596144kg, 556,324kg, 615,799kg, and 562,233kg, respectively. Then, an unexpected fall in Greenleaf production in 1994 was noticed by a yield of 365214kg. The trend of rising and falling tea Greenleaf yield experienced in the following years up to 2020. However, while the precipitation significantly increased in some of the years 2006 and 2019 total tea Greenleaf harvest does not change in relation to rainfall.

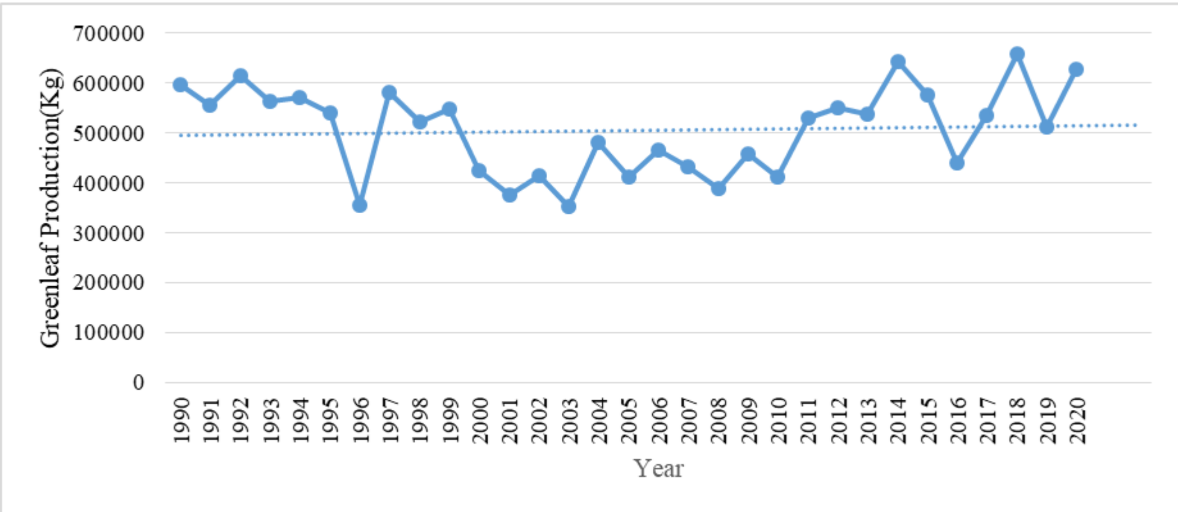

Figure 2: Tea Production Trend of Smallholder Farmers from 1990-2020(Kg/ha)

Correlation Analysis for Precipitation and Tea Production

The Pearson correlation coefficient was employed to explore the relationship between precipitation and tea Greenleaf produced by smallholder farmers in East Usambara Mountain. There is a substantial relationship involving the precipitation and productivity trend of the tea rainfall in East Usambara (r=0.396, p-value =0.027). This indicates that any changes in precipitation influences tea production in East Usambara.

Table 4. Correlations Coefficient

		Tea Production (Kg/ha)	Rainfall(mm)
Tea Production (Kg)	Pearson Correlation	1	.396*
	Sig. (2-tailed)		.027
Rainfall(mm)	Pearson Correlation	.396*	1
	Sig. (2-tailed)		.027

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

Regression Analysis for Precipitation and Tea Production

Furthermore, the study proposed to explore the interdependence of the precipitation variability and tea Greenleaf yield in the East Usambara Mountains. The proposed default hypothesis was:

H0: Precipitation trend in the East Usambara Mountains does not significantly affect the tea production of smallholder farmers.

The r-squared for the relationship between two variables namely, precipitation variability and tea Greenleaf yield in the East Usambara mountains was 0.157. This means that precipitation changes in the East Usambara Mountains can explain 15.7% of the smallholder tea production.

Table 5. Model Summary for Rainfall and Tea Production

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
	.396	.157	.1128	81776.695

Predictors: (Constant), Rainfall (mm)

Referring to Table 6, the p-value (0.027) was determined to be less compared to the indicated significance level, which was 0.05, whereas the calculated F (5.389) was greater than critical than the F (4.17). This implies that the default assumption (Ho) of the study is rejected, and vice versa. This situation implies that the regression model is the perfect approach to explain the relationship of precipitation with tea Greenleaf yield in East Usambara Mountain.

Table 6. Anova for Rainfall and Tea Production

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	36040827329.282	1	36040827329.282	5.389	.027b
	Residual	193935407637.493	29	6687427849.569		
	Total	229976234966.774	30			

- Dependent Variable: Tea Production (Kg/ha)
- Predictors: (Constant), Rainfall (mm)

Moreover, the study results for regression coefficient for precipitation and Greenleaf yield was 81.792, which reflects that precipitation in East Usambara Mountains has a considerable impact on smallholder farmers' tea Greenleaf harvest. This indicates that a minor change in precipitation and soil moisture availability would lead to 81.792% change in Greenleaf yield in the East Usambara Mountains. Therefore, through the results from the study, the default hypothesis was rejected that precipitation in East Usambara does not significantly impact the tea production of smallholder farmers.

Table 7. Coefficient for Rainfall and Tea Production

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	365084.738	62342.344		5.856	.000
	Rainfall(mm)	81.792	35.232	.396	2.321	.027

- Dependent Variable: Tea Production (Kg)

Trends of Temperature Change and Tea Production

Figure 3, showed the minimum temperature ranged from 16 oC to 18oC range from 1990 to 2020. Moreover, the maximum temperature ranged from 24 oC to 26 oC and the average temperature was between 18 oC to 21 oC. This implies that the temperature does not changed much in the East Usambara Mountains for the period ranging from 1988 to 2017.

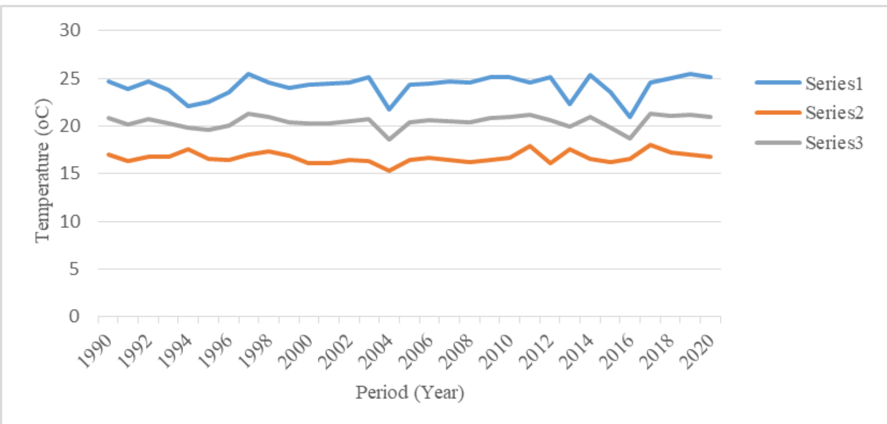

Figure 3: Temperature Variation in East Usambara from 1990-2020 (oC)

Key: Series 1 = Maximum temperature, series 2= Minimum temperature, and seies3= Mean temperature

Correlation Analysis for Temperature and Tea Production

The Pearson correlation coefficient was used to evaluate the relationship of temperature change (independent variable) with the tea Greenleaf produced (Dependent variable) by smallholder farmers in East Usambara Mountain. There is a considerable positive relationship between temperature change and tea production trend in East Usambara (r=0.411, p-value =0.022). This indicates that temperature variability influences tea production in East Usambara.

Table 8. Correlations Coefficient

		Tea Production (Kg/ha)	Temperature (Celsius)
Tea Production (Kg)	Pearson Correlation	1	.411*
	Sig. (2-tailed)		.022
Temperature (Celsius)	Pearson Correlation	.411	1
	Sig. (2-tailed)	.022	

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

Regression Analysis for Temperature and Tea Production

The study aims to test the relationship between temperature changes in the East Usambara Mountains with tea Greenleaf yield. The null hypothesis was:

H0: Temperature variability in the East Usambara Mountains does not signifi cantly affect the tea production of smallholder farmers

From the results shown in Table 9, the r-squared for the relationship between two variables which are temperature variability and tea Greenleaf yield in the East Usambara Mountains was 0.169. This shows that temperature variability in the East Usambara Mountains can explain 16.9% of the smallholder tea production.

Table 9. Model Summary for Temperature Change and Tea Production

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.411[a]	.169	.140	81178.937

Predictors: (Constant), Temperature (Celsius)

Referring to Table 10, the was p-value (0.022) which considered to be smaller than the proposed significance level 0.05, the F-calculated (5.898) was more than the F-Critical (4.17). This situation suggests that the regression model fit to forecast the impact of temperature on tea green leaf yield in East Usambara Mountain.

Table 10. ANOVA Table for Temperature and Tea Production

Model	Sum of Squares	df	Mean Square	F	Sig.
1Regression	38865660945.645	1	38865660945.645	5.898	.022[b]

Residual	191110574021.129	29	6590019793.832
Total	229976234966.774	30	

- Dependent Variable: Tea Production (Kg/ha)
- Predictors: (Constant), Tea Production

Moreover, Table 11 results show that temperature variability in the East Usambara Mountains has a significant influence on smallholder farmers' tea Greenleaf production. It was indicated through 62565.501 value of the regression slope. The study indicates that a minimal change in temperature facilitates changes in tea Greenleaf yield in the East Usambara Mountains. Therefore, the result rejects the proposed null hypothesis, smallholder farmers tea Greenleaf yield in East Usambara are not significantly affected by the temperature.

Table 11. Coefficient for Temperature and Tea Production

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-539771.572	430762.009		-1.253	.220
	Temperature	62565.501	25762.930	.411	2.429	.022

- Dependent Variable: Tea Production (Kg/ha)

DISCUSSION

The Effects of Rainfall on Tea Production

The study established that change in precipitation can significantly and positive pose effects on the smallholder farmers productivity in the East Usambara Mountains. These findings directly harmonize with the various scholars, that the tea harvest is significantly forced with the weather parameters including precipitation, moisture, sunlight duration and atmospheric temperature (Ali et al, 2015). Moreover, not only smallholder farmers' tea production is affected by rainfall variability but also large-scale growers. During dry season, approximately 25% of the processed tea was lost due to prolonged drought in the Southern Highlands of Tanzania (Carr, 2012; Msomba et al, 2018). The study also concurs with Cheresek, Elbehri, and Bore (2015) in Kenya that precipitation patterns has a significant consequence on tea yield. Moreover, Precipitation variability has direct positive impacts not only on tea production but also on Greenleaf tea quality, it was confirmed that unpredictable precipitation arrangements have impacted quantity and wealth of the tea Greenleaf by influencing existence of invasive pests and weeds in and in the tea farming system (Ahmed et al, 2014).

However, optimal precipitation facilitates increase in yields of tea Greenleaf, but excess precipitation (greater than 2500mm) can have negative impacts on produced tea, even as more unpredictability in precipitation leads to more tea being produced (Bett, 2018). The study noticed that variability in rainfall has detrimental effects on tea bushes as well as plant-soil water availability. Moreover, observed changes in precipitation in all climatic spells significantly impact the water security that pose an additional challenge to the tea plant growth and hence it poses a great risk to farm productivity (Ali et al, 2014). A study by Msomba et al (2018) testified that tea plant development and production can also be determined by the availability of irrigation water. In addition, the study established that prolonged and heavy precipitation is detrimental to tea bushes which concurs with Kipngeno (2018) that a suitable amount of precipitation is significant to tea Greenleaf yields. The study revealed that unpredicted and partial precipitation triggers permanent failures of the tea farms and estates.

Effects of Temperature Variation on Tea Production

The study acknowledged that changes in temperature have substantial influence on smallholder farmers' tea yields in the East Usambara Mountains. These findings concur with the study of Wijeratne (2014) tea production in low and mid-elevations is highly affected by climate change, where rises tea crops in low elevation impacted more than higher elevation due to variation of weather conditions, that in low elevation experiencing high temperature, and reduced availability of crop water. A monthly mean temperature higher than 22 °C is assumed to diminish tea farm output. However, a study by Ali et al (2015) reported that the yield of tea is significantly forced by microclimatic factors of a region especially rainfall, temperature, humidity, and duration of light. The study agrees with Duncan et al (2016) who described that tea yield has deteriorated severely as the climate has warmed, principally when the monthly temperature exceeds 27 °C. Moreover, in a similar study performed in China by Boehm et al (2016); results allegedly showed that monsoon dynamics affected plucking timing assessments and shortened tea yields by 0.5% for a 1% upsurge in the monsoon season evacuation date.

The study observed that temperatures play a crucial role in the modification rate of evapotranspiration of the plant and soil, optimal temperature influences all plant metabolisms that ensure sustainable plant growth and development. Extreme temperature rises or falls tend to cause higher evapotranspiration or chilling injury of the plant, respectively. These findings relate to Leshanta (2014) that extreme cold conditions are detrimental to tea production due to frost conditions which damages tea leaves, and roots and reduces the efficiency of laborers in charge of tea leaf harvesting (Kipngeno, 2018).

CONLUSION

The study findings indicated that optimal climate elements (temperature and precipitation) have a positive effect that improves smallholder farmers' tea production in the East Usambara Mountains farming system. In contrast, extreme changes of climate parameters have substantial effects on tea Greenleaf production when precautions and adaptation options are not taken into consideration. Consequently, more prevalent, and excessive weather factors like an upsurge in temperature and prolonged heavy rainfalls can cause environmental complications that are directly related to the negative consequences on tea farm productivity. Furthermore, the study concludes that precipitation is among the influential factors that determine tea plant productivity in the East Usambara Mountains. Indeed, optimal distribution of rainfall controls sufficient nutrient uptake from the soil to the plant through roots to the leaves. Whereas prolonged heavy rainfalls are linked to the leaching of nutrients from the soil, soil erosion, and washout of topsoil which acts as a repository of nutrients, and habitat of beneficial microorganisms. Indeed, the study determines that exceptional precipitation below 1400mm and above 2500mm can detrimentally affect smallholder tea production in the East Usambara Mountains. Undersupply of rainfall leads to soil drought which directly destroys the tea plant. Therefore, an adequate water supply on the tea farm is highly recommended as an important factor to consider before establishing the production site. To conclude, since both extremely high and low precipitations affect smallholder farmers' tea production, farmers are encouraged to participate in various programs and training that will increase their level of perception and management skills. Also, farmers are advised to apply knowledge of climate change adaptation and mitigation measures to increase their production.

Regarding the consequences of temperature on smallholder tea Greenleaf production, the study concludes that its variation has a explicit and considerable influence on tea Greenleaf production in the East Usambara Mountains. ideal temperature ensures satisfactory tea plant physiological and biochemical processes like photosynthesis, cell membrane fluidity, and plant water absorption which ensures its water potential and vice versa. Extreme temperature variations below 15oC and above 30oC have negative repercussions on tea Greenleaf production. Further, extremely low temperatures below 15oC are injurious to tea Greenleaf production through the chilling injury problem and reduced efficiency of tea Greenleaf puckers. In addition, exceedingly hot temperature conditions can cause heat stress to tea leaves, disease prevalence, and pest infestations that reduce the quality and quantity of tea leaves.

FURTHER STUDY

This research still has limitations so further research is still needed on the topic “Climate Variability and the Resilience of Smallholder Tea Production.”

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