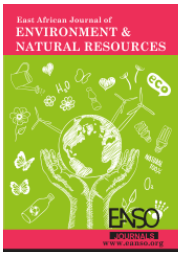

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Original Article

Impact of Rainfall Variability on Rural Tea Roads in Kericho, Kenya

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Climate Change, Rainfall Variability, Repairs and Maintenance, Rural Tea Roads, Kericho County.

ABSTRACT

Climate variability is a global phenomenon that is posing a threat to the infrastructure and agricultural sector. Intense precipitation often results in the deterioration of rural road infrastructure resulting in inaccessibility. Rainfall and temperature data from 1989 to 2019 was obtained from Kenya Meteorological Department. Data on Greenleaf and cost of repairs and maintenances are from selected tea factories managed by Kenya Tea Development Agency. Data on perception is based on a questionnaire survey of 398 randomly selected tea farmers. Results show that climate variability is experienced in Kericho ($p <$ 0.005). There is a varsity variation in mean maximum temperatures $F_{(0.05,\ 29)} =$ 5.564 (p = 0.009) and mean minimum temperature $F_{(29)}$ =8.503 (p = 0.000). However, the linear regression analysis shows that rainfall has decreased (y = 2.5476x - 40.778) while the temperature has increased (y = 0.028x - 0.4473). There is a significant positive correlation between the amount of rainfall and cost of repairs and maintenances for five factories (r = 0.122, r = 0.046, r = 0.029, r = 0.255) except one (r = -.261, p = .466). Therefore, the climate has significantly varied from 1989-2019 and heavy rains occur periodically that damage rural tea roads, thus impacting negatively on tea transportation. There is a need, therefore, for heavy investment of emergency funds for repair and maintenance of rural tea roads based on rainfall variability and heavy rain return period pattern.

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INTRODUCTION

Climate variability (in)directly impact road infrastructure by damaging the roads (Solomon, 2007; Lobell *et al.*, 2011; Wheeler & Von Braun, 2013; Le Roux *et al.,* 2019), with deteriorated road infrastructure leading to delay in transportation of goods, time loss and road accidents (Nkomo *et al.*, 2019). Rural roads play significant roles in reducing poverty and boosting rural income (Le Roux *et al.*, 2016). Road network is not only vital for interconnection but also essential for sustainable industrial development and the economy (Luo and Xu, 2018).

The majority of rural household's sources of income are tied to the success of rain-fed agricultural production (Bakhsh and Kamran, 2019). Climate change and variability have been observed to adversely affect the agricultural industry, with the situation expected to get worse in the future (Ochieng *et al.,* 2016). It may also lead to devastating societal and economic assets, relatively destroying the essential infrastructure like roads (Hirsch and Archfield, 2015; Molua *et al.*, 2020). Tea is one of the most important cash crops worldwide, playing a significant role in rural development and poverty reduction in developing countries (ITC, 2016) and contributes 20% of the national foreign exchange in Kenya (Azapagic *et al.*, 2016).

Rainfall in Kenya has become irregular and unpredictable while temperature variation shows an increasing trend (Mwangi *et al.,* 2014). Kericho is not an exception since it is manifested by a decrease in rainfall in terms of amount, intensity, distribution, and the temperatures are showing an upward warming trend of 0.2 °C per decade (Omumbo *et al.*, 2011). Predictions for future effects of climate change and variability show that agriculture may severely be affected, especially the tea sector (Ochieng *et al*., 2016). Tea production is influenced strongly by rainfall and temperature- higher rainfall leads to higher production (Nijamdeen *et al*., 2018), but excessive rainfall and high temperature can cause the low productivity and low quality of the tea (Nianthi, 2018). Tea requires temperatures of 19-29 ºC, which implies that temperatures below 19 ºC and above 29 ºC have a detrimental effect on tea production (Leshamta, 2017), whereas the requires rainfall ranges between 1500 mm and 2500 mm (Bett, 2018).

Climate-related events damage feeder roads, culverts and bridges (Wang *et al.,* 2019). Improved rural accessibility leads to reduced cost of travel and time, promotes sustainable utilization of resources and growth of businesses in rural areas (Cook *et al.*, 2015). High rainfall areas are likely to experience increased flooding and a reduction in water quality (Mujere and Moyce, 2018). Rainfall variability is commonly associated with an increase and decrease in the amount of rainfall received, which in return, is associated with excessive floods, droughts and famines, energy shortages, destruction of property and even death (Omeny *et al.,* 2008). Therefore, climate-resilient road infrastructure in rural areas is critical for improving quality of life (Le Roux *et al.*, 2019). However, the relationship between rainfall variability and rural tea roads has not been fully understood, which this paper focuses on.

METHODOLOGY

The paper is based on a study conducted in Kericho, Kenya located in longitude 35º3´0´´ E, 35º41´30´´E to latitude 0º1´3´´N, and 0º37´30´´S (*Figure 1*). It is characterized by undulating topography with

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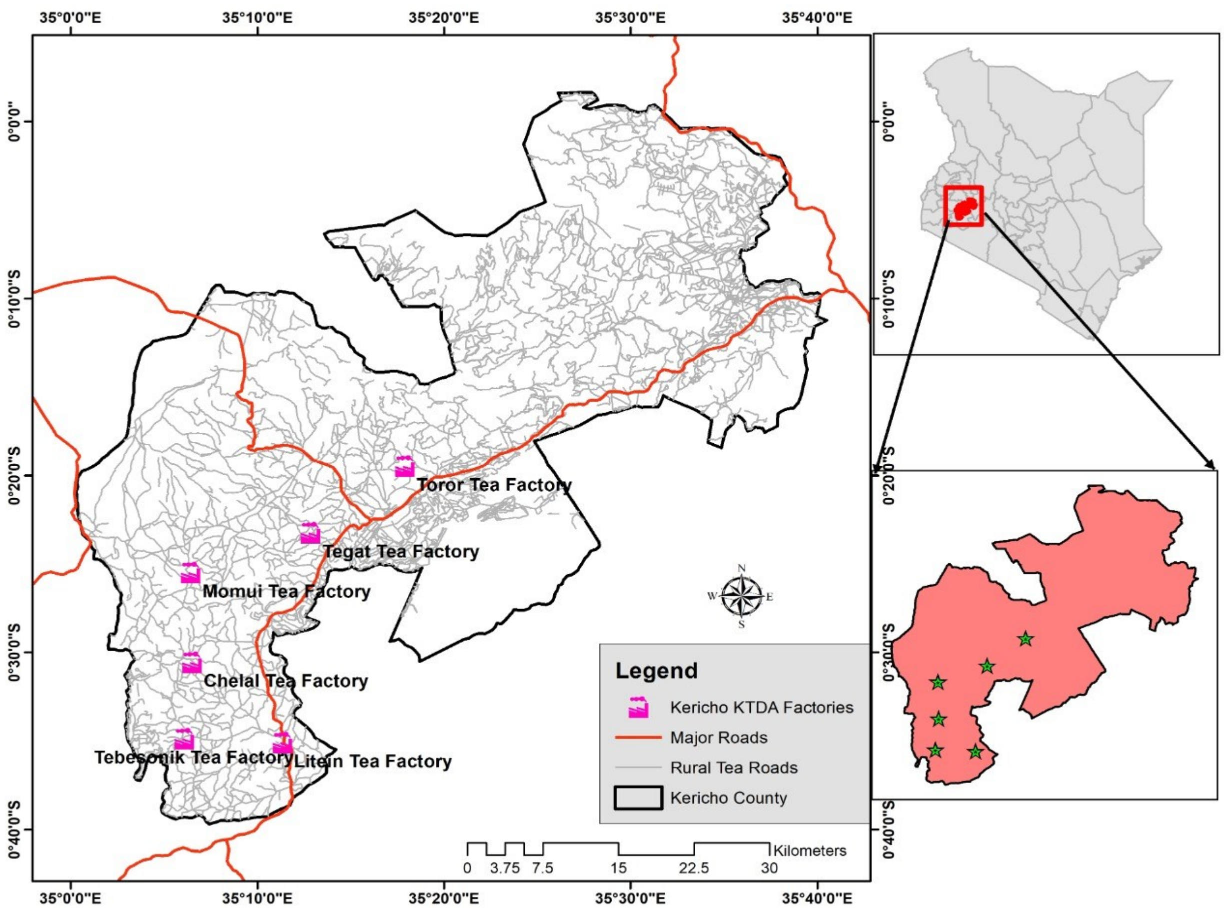
altitudes ranging from 1800-3000 m above sea level, temperatures from 10-29 °C (GoK, 2017). The long rains occur in the months of April to June, while short rains in the months of October to December. Kericho also experiences dry seasons from January to March. The two major rivers are Chemosit and Kipsonoi (Ng'etich *et al.*, 1995) and flow towards Lake Victoria. Tea is the major cash crop in the county (GoK, 2017). There are seven factories managed by Kenya Tea Development Agency (KTDA) in Kericho that six were randomly selected, but excludes the private and multinational tea companies.

Figure 1: Rural tea roads and KTDA factories in Kericho



Historical climate data was obtained from Kenya Meteorological Department from 1989 to 2019 so as to determine climate variability trends using rainfall and temperature as indicators and analysed through simple linear regression analysis. To established how rainfall has affected rural tea roads, historical records on rural road repairs and maintenances overtime was obtained from individual sampled factories managed by KTDA in Kericho and Pearson product-moment correlation used to observe their relationship. Structured questionnaires were administered to 398 farmers based on Yamane, (1967) formula to obtain their perception of climate variability and its impacts on rural tea roads in Kericho. Six statements were sampled and their perception on rainfall and temperature variability influence on rural roads was determined on a five-point Likert scale. One–way Analysis of Variance and T-test was carried out on perception to determine their statistical significance.

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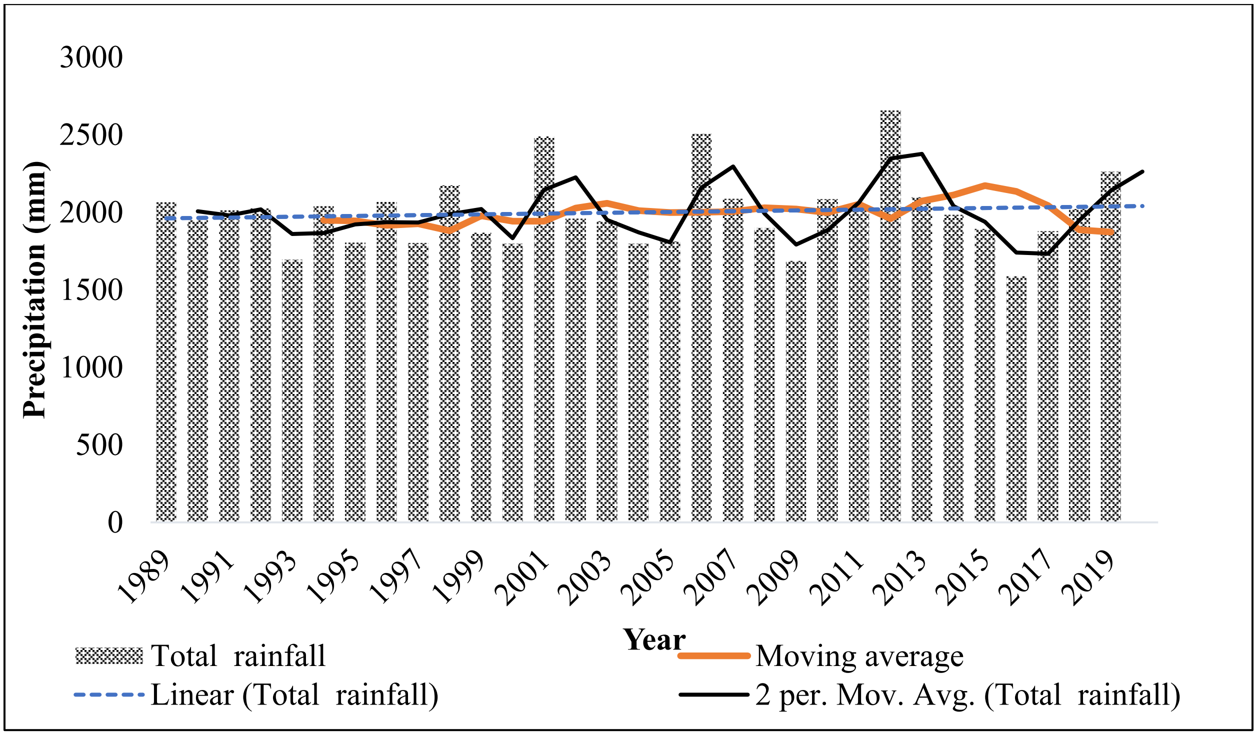
RESULTS AND DISCUSSION

Rainfall and Temperature Variability in Kericho

Figure 2 shows changes in precipitation from 1989 to 2019 with a 5-year moving average. Rainfall tends to rise and then drop after one year as observed from 1992 to 1998. There is a precipitation rise in 1998 then drops for 2 years and rises again in 2001 followed by a significant drop of 4 years. Precipitation rises again in 2006 followed by a significant drop for 5 years then rises again in 2012 followed by a drop for 6 years. The reason for these swings is due to climate variability in Kericho. There is an emerging pattern where rainfall has been declining from the noticeable trend of 1, 2, 4, 5, 6 declines. Therefore, rainfall has been declining in Kericho and there is a likelihood that there will be a 7-year decline of rainfall from 2020.

Figure 2: Rainfall linear trend and 5 years moving average for the period 1989 to 2019



The mean annual rainfall for Kericho is 1999.73 mm with a standard deviation of 236.9 mm (*Figure 3*), with rainfall anomalies ranging from 654 to -416. The year 2012 recorded the highest positive variation followed by 2006 and 2002 respectively. On the contrary, the year 2017 recorded a significant negative variation followed 2007 and 1994 respectively. The amounts of rainfall recorded from 1989-2019 are split into ten-year intervals (decadal), whereby the means and standard deviations are compared (*Figure 3*). The result shows that the mean rainfall for the second ten years is significantly higher (2016.5 mm) than the first 10 years (1963.6 mm) and the last 10 years (1992.7 mm). The t-test results ($t = 0.119$, $df = 29$) show that rainfall has been decreasing significantly ($p = 0.889$) in Kericho, which can be attributed to climate variability.

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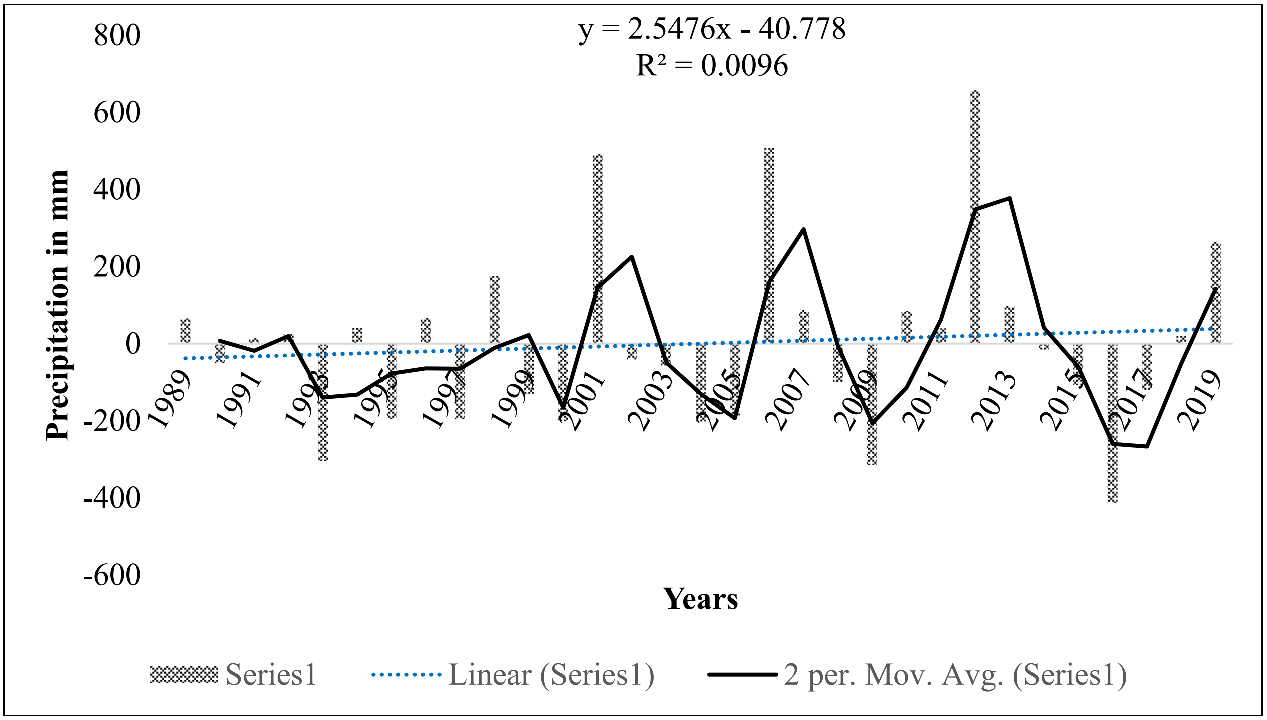
Figure 3: Annual precipitation variance in Kericho



The temperature trend shows that the highest mean temperature peak is observed in 2016 with 18.4 ºC, with inter-annual variability and increase from 2002 to 2019, although in 2008 and 2013 it is below the long term mean. Therefore the seasons are getting warmer and the mean global surface air temperature is getting warmer (Elizbarashvili *et al.,* 2013). The mean, maximum and mean minimum temperature for the first 10 years is compared to the second and last 10 years. The maximum temperatures for the last 10 years are significantly higher than the first and second 10 years $\{F_{(0.05,\ 29)} = 5.564, p = 0.009\}$. On the contrary, the recorded minimum temperature for the last 10 years is higher than the first and second 10 years, which is a significant variation in temperature $\{F_{(29)} = 8.503, p < 0.001\}$.

Figure 4: Mean annual temperature in Kericho

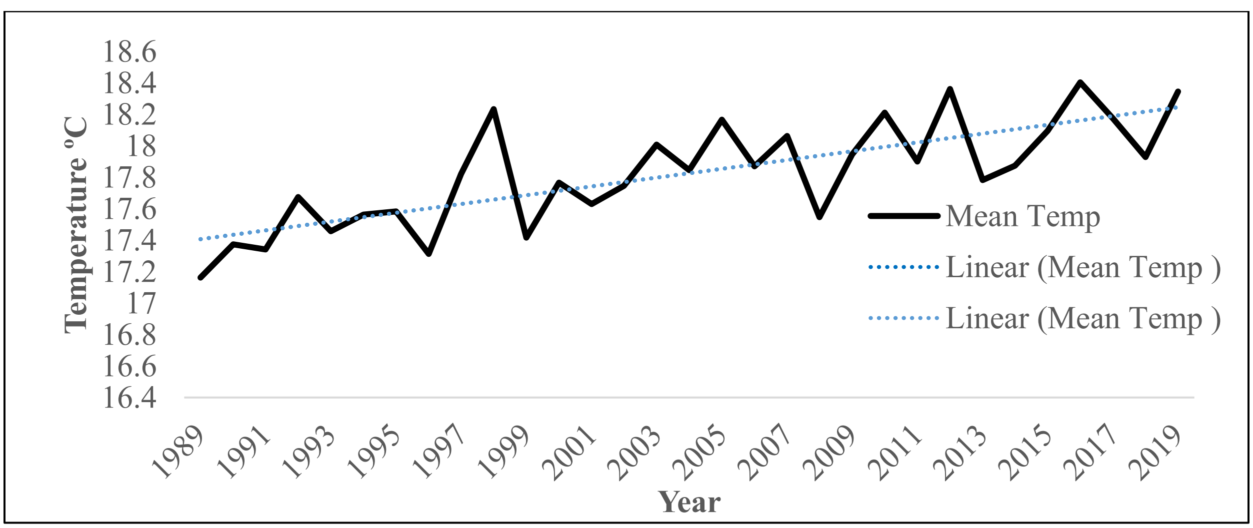


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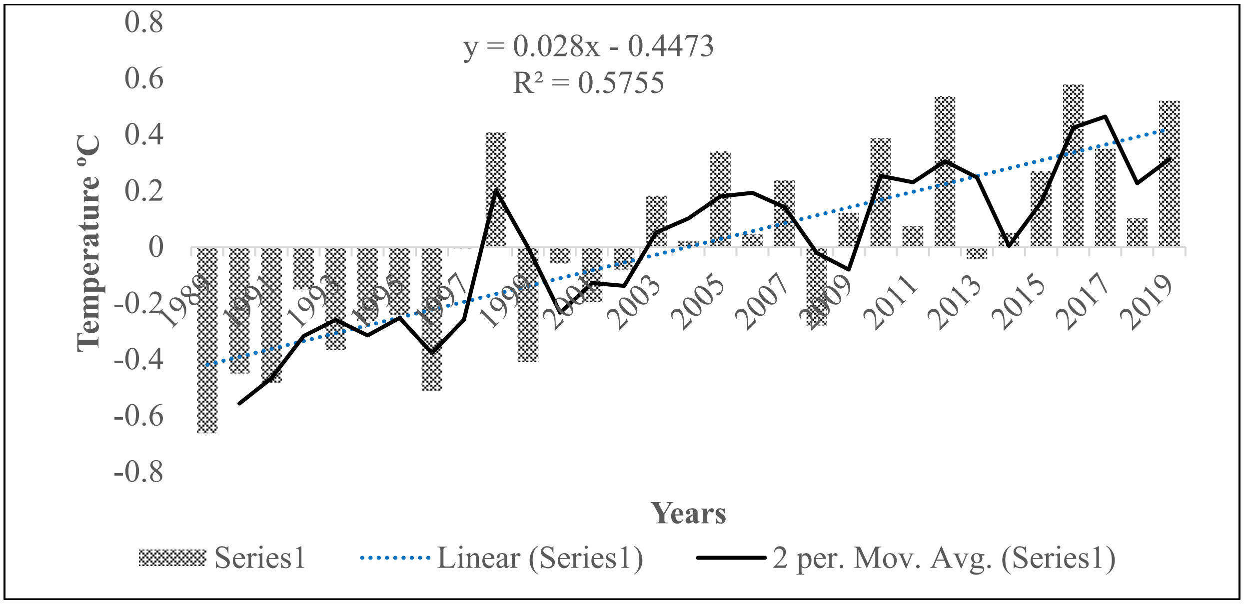
Figure 5 shows inter-annual variability in temperature. The trend indicates that the temperature has been increasing from 2002 to 2019, except in 2008 and 2013, where the temperature is below the long-term mean.

Figure 5: Variance of temperatures from long term mean in Kericho



Green Leaf Supply to Factories in Kericho

There is a general increasing trend in the supply of green leaf to the factories over time (*Figure 6*). The year 2012 received the highest amount of rainfall recorded (2657.1 mm), but when compared to green leaf supply, all factories recorded a lower amount. This might be due to the effect of heavy rainfall on rural roads serving the tea factories. Heavy rainfall delays the general movement of green leaf to collection points and to processing factories. The supply of green leaf in the year 2013 spiked up (27,145,952 kgs) and the rainfall amount (2097.1 mm) recorded that year is lower than in 2012. On the contrary, 2016 recorded the lowest amount of rainfall with a total of 1586.9 mm, but when compared to green leaf supply, it is higher (29,715,311 kgs). The trend also shows a general increased total weight of green leaf over time., which can be attributed to an increase in acreage under tea since more people are planting tea because it is the main source of income in Kericho.

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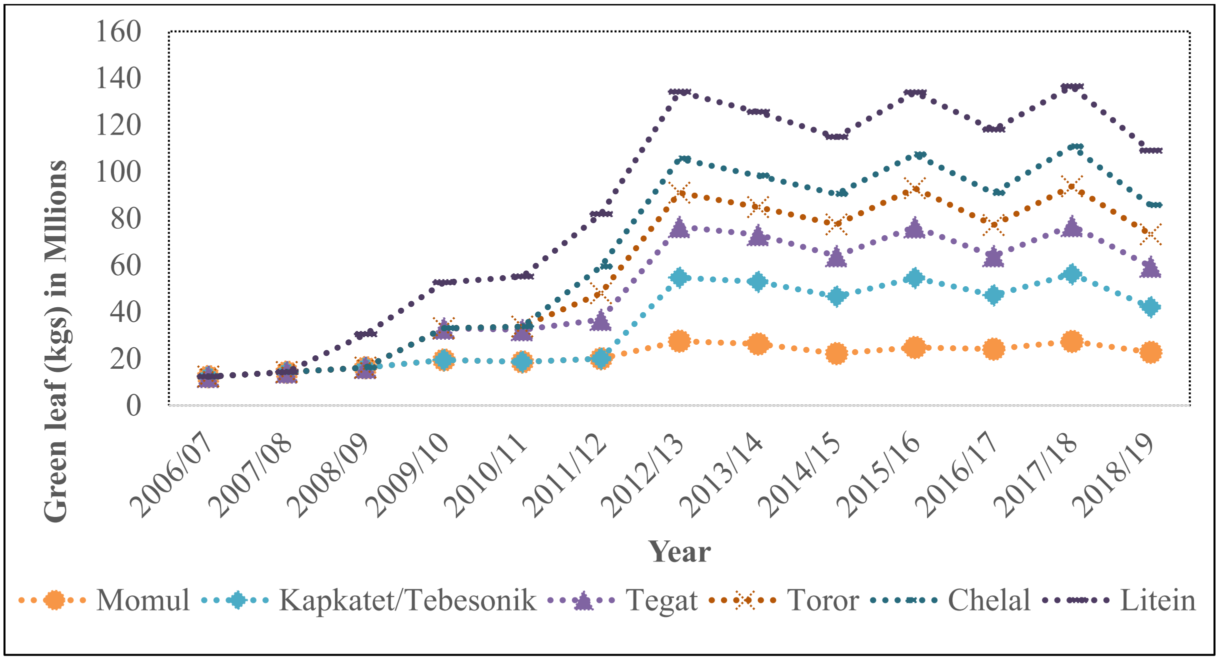
Figure 6: Green leaf supply in Kericho



Rural Tea Roads Repairs and Maintenance in Kericho

The rural environment is often the growth engine of a country for food supply and other produce from rural areas. Roads in rural areas have a short life due to erosion and wear and maintaining these roads to a suitable standard is increasingly becoming a difficult task due to cycles of deterioration and the need for repairs. Kenya Tea Development Agency (KTDA) used to deduct some amount of money (Cess) from farmers specifically for rural tea road maintenances but was abolished in the year 2013 under the Tea Act Chapter 343-part VI. The abolition of cess has led to the loss of a dedicated maintenance budget of roads serving tea farmers. This has led to delays in delivery of green leaf tea hence losses incurred in total net weight. Rural roads are under Class E and since devolution, they are in a better condition than before, but low in maintenance. A certain percentage of money (22%) of the Roads Maintenance Levy Fund (RMLF) through the Kenya Rural Roads Authority (KeRRA) is allocated for the maintenance of rural roads, which tea roads fall within. KeRRA also has dedicated funds for emergency operation and maintenance.

Figure 2 shows that there are recurrent spikes of heavy rains and drought, yet operation and maintenance budgets are based on the routine financial year. Product moment of correlation between the amount of rainfall (mm) recorded overtime and the amount of money spent on rural road repairs and maintenances show that Litein tea factory has a greater positive correlation since its inception compared to the others where they have a heavy investment on roads relative to green leaf, followed by Momul tea factory (r = 0.122), Tegat tea factory of (r = 0.029), with least being Kapkatet/Tebesonik tea factory (r = 0.046). Toror tea factory had a negative correlation because its operations and maintenances began way later in the financial year 2013/2014 and were inconsistent, unlike the rest of the tea factories (r = -2.61).

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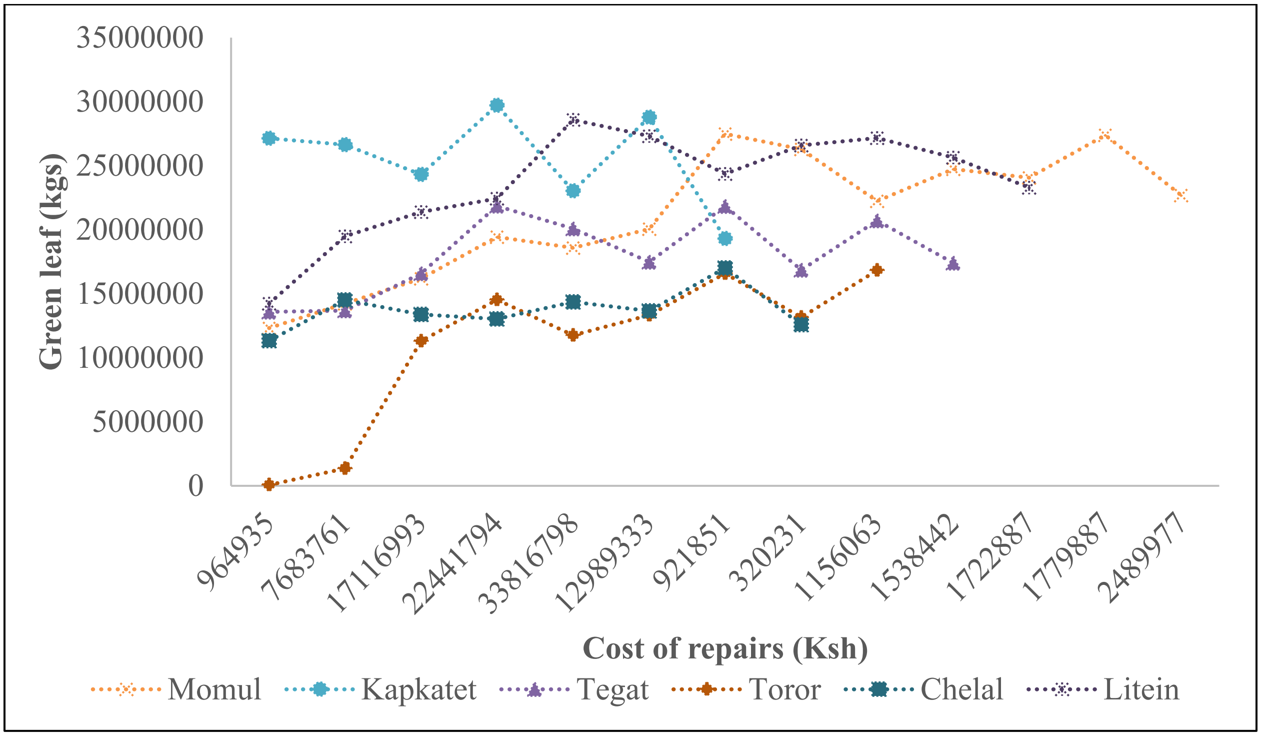
Figure 7: Green leaf supply and cost of repairs in Kericho tea factories



Perception of Farmers on the Influence of Rainfall on Rural Tea Roads

The sample respondents were (42.7%) female and (57.3%) were male. The majority of the farmers (60%) perceive heavy rainfall as affecting transportation of green leaf to factories, whereas 65% perceive it positively affecting tea yield by increasing the quantity. However, 92% perceive heavy rainfall leads to damage of rural tea roads and affects accessibility and supply of green leaf to factories. The significant variations on the influence of rainfall on rural tea roads tested at 0.05 significance level show that there is no significant variation in their understanding and responses {t = 195.05, df = 397, p = 0.000)}.

One of the underlying factors that influence farmer's perception is gender. Most households in Kericho tea farms are headed by men. The significance level of tea farmers' responses and gender tested at 0.05 significance level show that there is no significant difference between gender (male and female) in their opinions (F = 0.066, df = 1, p = 0.797); thus their opinions have a positive association. 98% of tea farmers perceive increasing frequencies of weather extremes (hailstones) as reducing tea quality and quantity. 94% of tea farmers noted that continuous repair and maintenance of unpaved rural roads ensures accessibility and movement during the rainy season.

The temperature has significant effects on tea production. Tea farmers perceive climatic stressors to have considerably contributed to reduced yields. The majority of sampled tea farmers (96%) perceive extreme hot conditions heat stresses tea leaves compared to 83% who perceive that extreme cold conditions affect tea production. 72% of tea farmers perceive temperature do not affect tea transportation, while 70 % perceive that temperature variability to be affecting tea production. Influence of temperature on rural tea roads is tested at 0.05 level of significance result shows that there are no significant differences (t = -0.560, df = 396 p = 0.576). Similarly, with regards to the influence of gender on respondents' opinions (p > 0.05), results show that gender is not statistically influencing responses.

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CONCLUSIONS

Kericho has experienced climate variability over the last three decades where rainfall has been decreasing while temperature increasing, but characterised by increased variability and anomalies. Higher rainfall swings are more damaging on rural tea roads. Abolition of rural tea roads cess levies has led to delays in road repairs after heavy rains, which hinders collection and transportation of green leaf to factories. Tea farmers perceive high rainfall affects tea yields positively but affect rural tea roads and green leaf supply to factories negatively due to poor accessibility.

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