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Impact of climatic variables on rubber (*Hevea brasiliensis*) yield in humid lowland of southwest Nigeria

Ugwa IK, Mesike CS[☼], Ubani SE

Rubber Research Institute of Nigeria, P.M.B. 1049, Benin City

[☼]Corresponding Author:
Rubber Research Institute of Nigeria, P.M.B. 1049, Benin City, Nigeria; Email:- sammesike@gmail.com

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ABSTRACT
The study was aimed at determining impact of some climatic variables with rubber yield in humid lowland of southwest Nigeria. Monthly rubber yield and climatic data from 2006 to 2012 were collected from Rubber Research Institute of Nigeria main station, Iyanomo near Benin City. Data collected were analyzed using catographic techniques correlation and regression. The results show

that there were high variability of climatic factors and rubber yield. Few climatic variables were significantly correlated with rubber yield. The minimum temperature, maximum temperature and maximum relative humidity were negatively correlated. Simple and multiple regressions relationships of the significantly correlated variables with yield contributed 31 percent to 57 percent of rubber yield. Effective adaptation strategies such as the use of improved and wind resistance clones, access to credit loan. Soil management strategies, rubber based cropping systems and field hygiene are suggested as ways to mitigate against negative effect of climate change and therefore improve rubber yield in the study area.

Key words: Climatic factor, Rubber yield, latex, variability, Nigeria.

1. INTRODUCTION

Rubber (*Hevea brasiliensis* Willd ex Adr. De Juss. Arg. Muell.) is a quick growing tree whose bark is tapped for latex. Rubber, also known as rubber tree or Para rubber, grows up to 40m in height but in some plantations may not exceed 28 m due to growth retardation occasioned by tapping. When the rubber trees are about 4-5 years of age they became subjected to wintering (Tappan, 1969), an annual shedding of the senescent leaves that often render the trees leafless for a short period. The climatic conditions necessary for optimum rubber growth include annual rainfall between 1750 – 2000 mm evenly distributed and within 125 – 150 rainy days per annum, maximum temperature of about 23 – 33ºC, moderate wind and relative humidity of about 80%.

Rubber grows in the humid lowland rainforest agro ecological zone of Nigeria known as the Rubber Belt of Nigeria (RBN) which consists of about 7.6 million hectares extending from Ogun to Akwa Ibom states in southern Nigeria. The area underlie in soils of mainly coastal plain sands and the southern fringes of the basement complex (Ojanuga *et al.* 1981). The soils have been reported to be derived from unconsolidated sedimentary deposits of the Miocene Pleistocene periods whose deposits comprise of old alluvial sediments and are highly leached, low in soil nutrients and susceptible to erosion. The predominantly sandy texture and low total porosity have made some authors doubt the ability of the soils to retain water and nutrients (Babalola and Obi, 1991; Ugwa *et al*., 2006). In spite of this doubt, the soils are known to have immense potentials to support tree crop husbandry.

Climate and soils are the main environmental factors that determine crop yields. Climate determines the suitability of a given crop while the soil provides the crops nutrients. There have been changes in our climate with consequent erosion, erratic storms and crop failures. About 80% of the variability in agriculture is due to weather vagaries (Anuforum, 2015; Mesike and Agbonaye, 2016).

Rubber in Nigeria is poised to take its pride of place as cash spinning crop. However, the only threat is the climate variability especially rainfall and temperature. The southern Nigeria according to Ibe (2015), is warming and inducing serious changes in our climate. Carbon dioxide is the principal gas that is causing the warming as a result of its emission through fossil fuel burning, intensive agriculture and the manufacturing industries (Anufuro, 2015).

The response of rubber to the environment may be accessed through the yield of its latex. Understanding the weather at a particular site is useful to rubber farmers in knowing the effect of climate variables on the growth and development of the crop (Mesike et al. 2015). Rao *et al*. (1998), investigated the relationship between yield and meteorological parameters on clone RRII 105 in India and observed significant positive association between rainfall and the latex yield. Mesike *et al.* (2007) reported that both temperature and evaporation influenced latex yield while wind velocities were negatively correlated with dry rubber under the condition found in India. The impact of climate on latex yield have been neglected in Nigeria or not well studied. Only few papers have been published on the effect of climate on rubber yield especially on polyclonal rubber plantation. Therefore, the objectives of this paper are to find the impact of climate factors and rubber yield under humid lowland situation, estimate rubber yield under a given climate condition of an area as well as look at some mitigation and adaptation strategies to addressing the impact of climate on yield.

2. MATERIALS AND METHODS

2.1. Study area

The study area is at Rubber Research Institute of Nigeria (RRIN) Iyanomo, near Benin City. It is located between latitude 6º 08' and 6º 11'N and longitude 5º 34' and 5º 38'E and occupies an area of 2078 ha. The area is characterised by hot humid climate. The total amount of rainfall is between 2000 mm-2500 mm annually and is fairly distributed from March to November. The total annual rainy days is over 110 and could reach up to 140 in some years. July and August is regarded as part of the rainfall anomaly of southern Nigeria because it is a gradual break on the rainy season when the atmosphere water vapour is ever at its highest. In local palace it is called the August break or the little dry season. The mean minimum temperature in the study area is 22°C while the mean maximum temperature is 32°C.

RRIN is in the humid lowland region of southwestern Nigeria, is dominated by thickets along the wild groves. Wire grass (*Eleusine indica)* spear grass (*Imperata cylindrica*) and other grasses are found in the rubber plantation and often pose fire danger during the harmattan period. However, Orimoloye and Akinbola (2013) observed that the geology of the area is underlain by the southern Nigeria sedimentary basin and this is within the area Ojanuga *et al*. (1981) describe as the acid sands of the southern Nigeria which is of sandstone deposits. It consists of yellow and white sand sometimes containing a cross bedding. The soils of this area have been characterised as Ultisol and Inceptisol (Ugwa et al. 2006; Nwacholor and Orimoloye 2012). They observed that the organic carbon is moderate and available P, K and Mg in the subsoil were low. The micronutrients are adequate and they increase along the soil profile.

2.2. Collection of latex and data

The plantation is of polyclones made up of RRIN developed clones, exotic clones and wild grooves. They have been planted at various times from 1970 to 2010. The system of tapping was 1/2S. d/2 nil stm(half-spiral cut of the bark with alternate daily harvest with no stimulation). Tapping usually begins at 0600hr and harvested about 1030hr GMT on all tapping days. Rubber yield was collected in bulk latex to determine the dry rubber content (DRC)

The yield is expressed in kg dry rubber calculated as follows:

DRY = 0.976LD + c/2 .... (1)

where,

DRY = dry rubber yield (kg)

0.976 = specific gravity of the latex

L = Latex collected

D = Dry rubber content as determined by metrolac (%)

C = latex drippings of latex that have coagulated.

In brief the yield of a plantation is expressed as

Yield = Kg/ha/yr .... (2)

where, Kg = dry (kg), ha = hectare, and yr = year.

Monthly rubber yield and climate data from 2006 to 2012 were obtained from RRIN. Climate variables such as rainfall amount (R_{mm}), minimum temperature (T_{min}), maximum temperature (T_{max}), and minimum relative humidity (RH_{min}), and maximum relative humidity (RH_{max}), wind velocity were obtained from Automatic Weather Station (AWS) while rubber yield was obtained from RRIN tapping unit of Agronomy Department. Data were analysed using catographic techniques, descriptive statistics, correlation and regression analyses.

3. RESULTS AND DISCUSSION

3.1. Characterization of climate conditions at the study area

In the study area, the mean annual rainfall of 2554 mm, spread between 125 to 140 days is optimum for rubber growth and development. Opeke (1986) and Ugwa *et al* (2005) have proposed a total annual rainfall ranges between 2000 and 2500mm over 125 to 150 rainy days. Figure 1 shows the rainfall distribution for RRIN which indicates variability in the distribution of rainfall. The lowest amount of rainfall in 2009 was 1582mm while 2557mm was the highest total amount of rainfall in 2012. It was also observed that the months of July and September gave the highest rainfall figures of over 350 mm with a drop of 284 mm in August (Table 1). This might be due to the August break when there is increase in rainfall anomaly resulting to little dry season. It is expected that the months of December, January and February will show low amount of monthly rainfall that registered not more than 50 mm. This is the harmattan period which is the dry and dusty North east trade wind that blows from the Sahara desert to the Gulf of Guinea.

The temperature of the location is usually high. RRIN recorded 22 and 31°C for mean T_{min} and mean T_{max} annual respectively. January recorded the lowest T_{min} while December had the highest monthly T_{max} (Table 1). The location is not affected by low temperature. Vijayakunic *et al.* (2008) reported that in China growth of rubber was recorded in winter. The thermal state encountered in the study area is above 26 ^{0}C (Figure 2). The difference between T_{max} and T_{min} will result in increased evaporation. Rubber often respond to heat stress that may affect physiological development. Tillekeratne (2010) attributes this high variation to the rising CO_2 concentration in the atmosphere. The rainfall and temperature ranges and variation of the area are typical of the humid lowland of southwest Nigeria (Ojo-Atere *et at.* 2011).

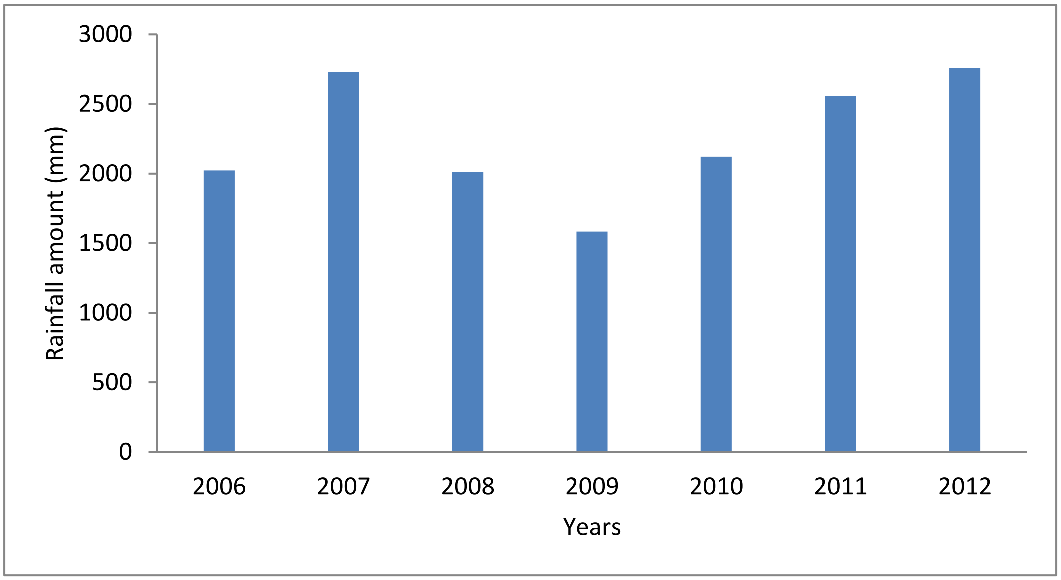

Figure 1 Mean annual rainfall for RRIN
(Source: RRIN Meteorological Station, Iyanomo)

Table 1 Mean monthly weather report (2006-2012)

Month	Rainfall	Tmin C	Tmax	T mean
Jan	12.09	23.60	28.84	26.22
Feb	48.23	25.57	31.07	28.32
Mar	80.80	26.37	30.97	28.67
Apr	226.91	25.94	30.31	28.13
May	238.37	25.71	28.71	27.21
Jun	299.11	25.41	27.54	26.48
Jul	378.61	25.13	26.56	25.85
Aug	284.30	24.81	25.9	25.36
Sep	368.20	24.96	27.41	26.19
Oct	220.79	24.73	28.64	26.69
Nov	91.11	25.23	30.49	27.86
Dec	6.00	24.04	31.24	27.64

The planting density at RRIN is 450 trees/ha. However, there are few vacancies occasioned by diseases and pests, stem snap or root lodging. The wind speed in the location is between 2.18 to 2.36 km/h. This do not pose serious damage to the trees (Zongdao and Xueqin, 1983), although, factors which dispose rubber trees to wind damage have been reported by Omokhafe and Akpobome (2007). These include rubber height, heavy canopy structure, plant vacancies and high wind velocity. There is therefore likelihood of wind damage as a result of the mixed clone nature of the plantations. Omokhafe and Akpobome (2007) indicated that GTI and NIG 904 are the most wind tolerant clones in the area when compared with PR 107 and RRIN develop clones which do not show likeliness to tolerate high wind velocity.

The RH_{min} varies from 50 to 62%, the RH_{max} is between 66 and 99% while the RH_{mean} is 70% The low RH_{min} reflects the high radiation of the study area at that particular period. The lower the relative humidity at a particular temperature, the more atmospheric air takes up water through transpiration and evaporation from both the plant and the soil surface. The state of low RH_{min} is observed at RRIN to be during the dry period of December to March when the radiation is high. Low yield of latex during the hot period is related to increase loss of water due to resultant drop in pressure and this observation is supported by (Watson 1989 and Mesike *et al* 2007). Tapping in the location is often done early in the morning, 0600 to 1000hrs and latex yield proves to be high. This is due to high pressure potentials in the outflow area which Simonds (1969) defined as part of the bark from which latex flows during tapping.

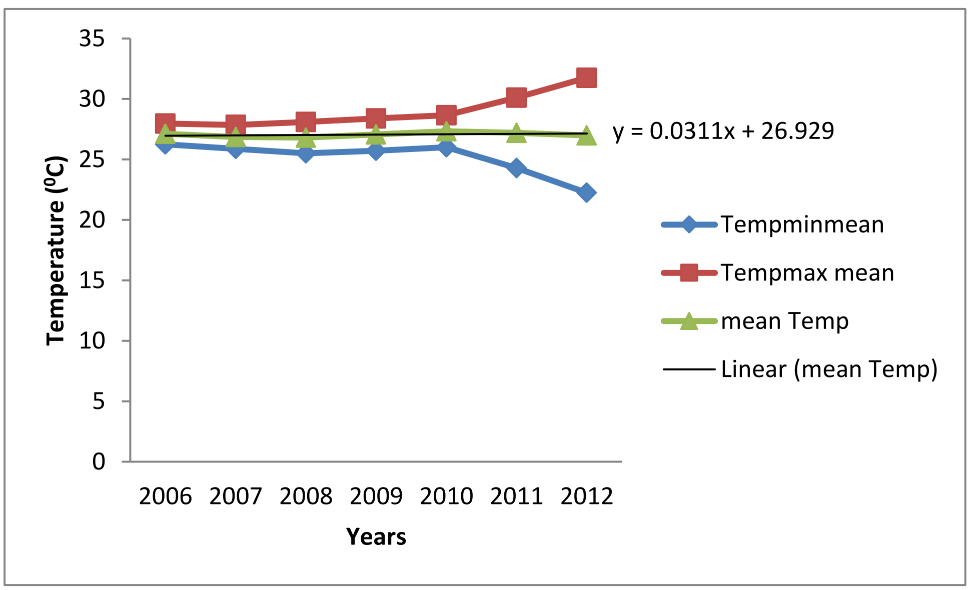

Figure 2 Mean annual temperature for RRIN

3.2. Yield characteristics of the study area

Figure 3 shows that there is high variation of rubber yield during the period under investigation. The lowest yield of rubber was recorded in the month of July 2006. The rainfalls intensity and the rainy days might have affected tapping activities during this period thereby reducing the yield. Beside, faulty tapping might have damaged some of the cambium where the latex vessels are closely together. According to Simmonds (1989) yield is determined by the initial flow rate and the turgor pressure which is controlled by temperature and tapping system. When compared with soil properties of the area, Orimoloye and Akinbola (2013) found that the yield pattern was not consistent with the pedological properties. Probably it might be due to the carbon positive production caused by the cumulative emission of fossil fuels, use of herbicides and fertilizers as well as uncontrolled burning. The excessive CO_2 in the atmosphere traps heat close to the surface of the earth giving rise to atmospheric warming. This might affect the yield. Also, the fluctuation of yield might not be due to soil moisture deficiency since the area is adequately supplied with water from rainfall. The pattern of rainfall has an effect on the latex harvest. Ikpe *et al* (2015), has observed that erratic rain has a negative effect on crop yield.

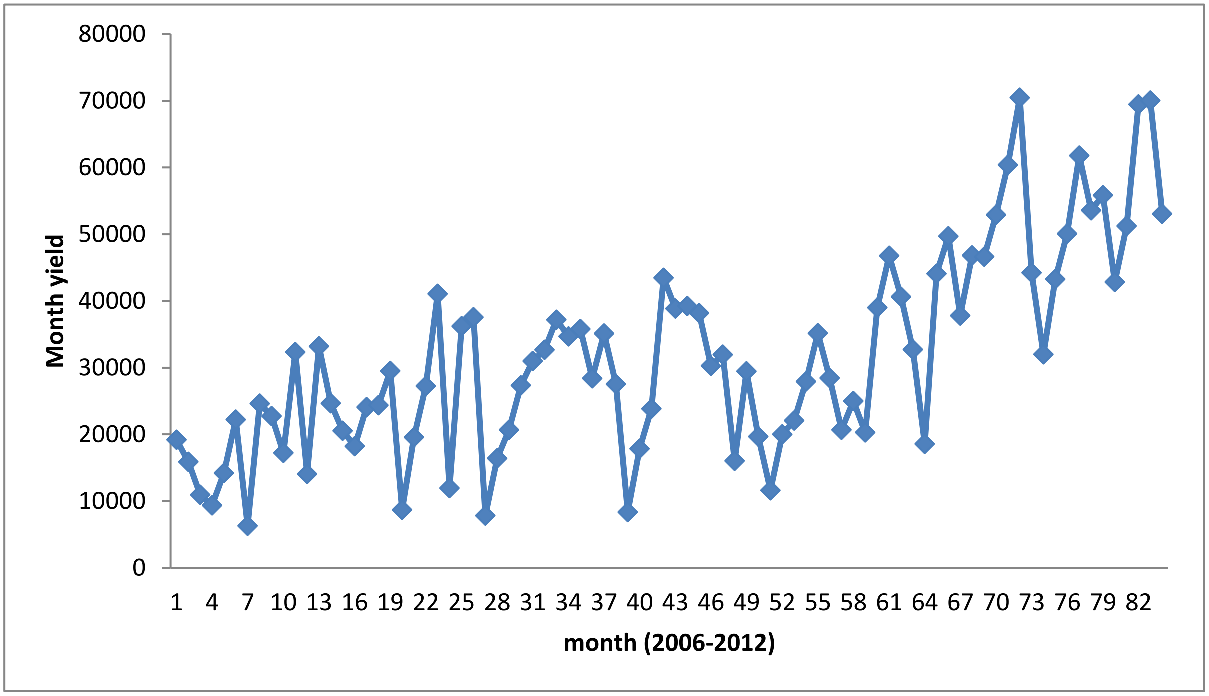

Figure 3 Trend of rubber yield

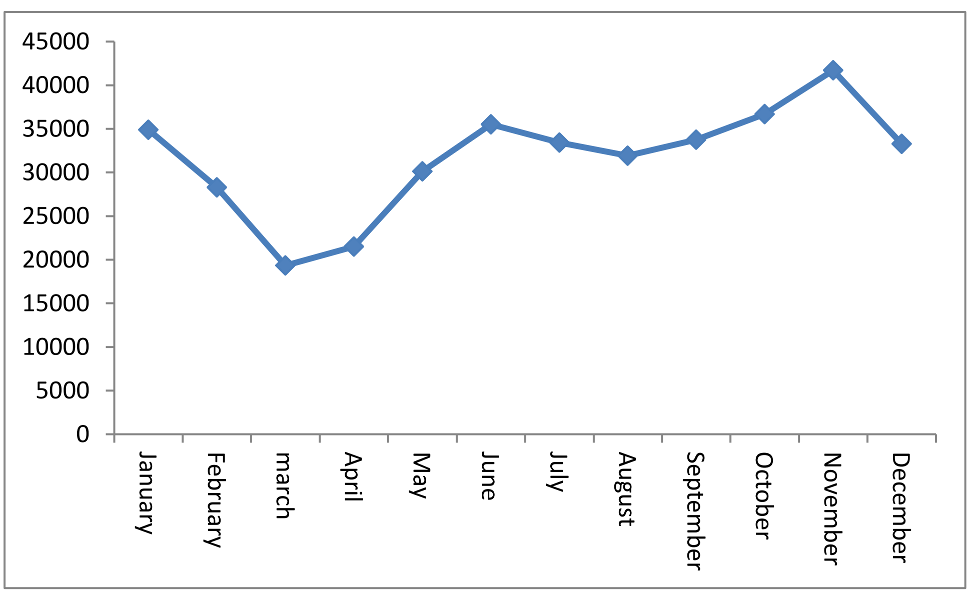

Figure 4 Mean monthly yield of rubber (2006 – 2012)

The mean monthly yield of rubber is shown in Figure 4. The months of February to May depict low yield of which March is the lowest. The yield picks up in the month of June and drops during the small dry season (July and August). The highest yield was in the dry season when the Dry Rubber Content (DRC) is high. There was an observable increase in the volume of latex after rain in the rainy season and also, the latex was diluted such that the DRC when measured was low. High amount of soil moisture may also lead to dilution of latex (Rao *et al* 1989). All these conditions indicate monthly variability in yield. Since the number of tapping days is higher during the dry season. There is dilution of the latex during the rainy season which increases the volume of latex but lowers the DRC.

3.3. Variability of climatic factors and latex yield

The coefficients of variability were calculated to evaluate the variability of climate factors and rubber yield (Table 2). The yield, R_{mm}, RH_{max}, RH_{mean} and rainfall distribution (rain days) were highly variable factors (CV > 35) while the wind velocity, T_{min}, T_{max}, T_{mean} and RH_{min} were slightly variable factor (CV ≤ 15). Changes have been observed in the rainfall amount and distribution as well as in temperature (Annforum, 2015).

Table 2 Variability of climatic factors and latex yield

	Mean	SD	CV	Max	Min
Yield	31713.16	15111.54	47.6507	70464.6	6287.8
R_{mm}	184.8786	156.2229	84.5003	644.4000	0.000000
wind	2.240476	0.283744	12.6645	3	1.7
T_{min}	25.12619	1.708457	6.79951	27.8	20.9
T_{max}	29.20119	2.911113	9.96916	38.00000	24.20000
T_{mean}	27.16369	1.424577	5.24442	32.25	22.55
RH_{min}	58.26310	3.691794	6.33642	62.60000	50.80000
RH_{max}	82.27024	82.45	100.219	99.9	66.3
RH_{mean}	70.26667	70.1	99.7628	80.75	59.35
Rainday	10.77381	10	92.8177	27	0

R_{mm} = rainfall amount
ETP = evaporation
T_{min} = minimum temperature
T_{max} = maximum temperature
T_{mean} = mean temperature
RH_{min} = minimum relative humidity
RH_{max} = maximum relative humidity
RH_{mean} = mean relative humidity

Table 3 shows the results of the correlation analysis. Three climatic variables were significantly correlated with rubber yield. T_{min} and T_{max} were negatively correlated ($p<0.01$). The negative effect of temperature on yield was also evaluated by Mesike *et al.*(2007). There were more temperature variation in November and December but less in July and August (Figure 2). RH_{max} was negatively and significantly correlated with the yield ($p<0.05$). The negative significance of RH_{max} could be explained by the fact that high relative humidity favours fungal attacks. According to Rao (1975) and Orumwense *et al.* (2013) high relative humidity favours proliferation of pathogenic agents and also the development of phytophthora, Odium and corynespora leaf fall diseases which are detrimental to a good evolution of rubber plantation. The negative significance of the temperature indicates that increase temperature has a tendency to increase the dryness of the tapping notch and as a result decrease yield in rubber. There was no significance difference in the effect of wind velocity. Omokhafe and Akpobome (2007) had reported that wind velocity between 1.9m/s has no effect on rubber trees and that at 2.0 to 2.9m/s both growth and latex flow are highly affected.

Table 3 correlation analysis of climatic factors with rubber yield

		yield	rainfall amount	wind	T_{min}	T_{max}	T_{mean}	RH_{min}	RH_{max}	RH_{mean}	Rain day
yield	Pearson Correlation	1	0.088	-0.165	-0.738**	-0.412**	-0.021	0.127	-0.078*	-0.009	0.047
	Sig. (2-tailed)		0.428	0.135	0.000	0.000	0.846	0.250	0.043	0.933	0.671
	N	84	84	84	84	84	84	84	84	84	84

** Significant at 1%

* Significant at 5%

The analysis of single linear regression relationship (Y= aX+b) was carried out only for yearly climatic variables, X significantly correlated ($p<0.01$) with Y. Valid regression equations that were calculated are summarized in Table 4. The result shows that T_{min} contributed 51 per cent of rubber yield at 1 per cent significant level using the prediction equation 3. This has implication on recommendation on tapping time. Lower temperatures are observed more in the early hours of the day. The tugor pressure responsible for latex yield is higher in lower temperatures.

$$Y=53242.31 - 661.843T_{min} \quad (3)$$

Similarly, T_{max} and RH_{max} contributed 38% and 31% of rubber yield respectively at 5% significant level using the prediction equation

$$Y= 45527.88 - 448.316T_{max} \quad (4)$$

and equation (3) $Y= 56067.92 - 64.5863RH_{max}$ (5)

When the significantly correlated climatic variables were pooled for regression, T_{min}, T_{max} and RH_{max} contributed 57% of rubber yield at 1% significant level using the prediction equation

$$Y= 56010.41 - 6383.218T_{min} + 3614.429T_{max} + 75.371RH_{max} \quad (6)$$

Table 4 Prediction equation of rubber yield

Regression equations	R^2	P
$Y=53242.31 - 661.843T_{min}$	0.513	0.001
$Y= 45527.88 - 448.316T_{max}$	0.381	0.044
$Y= 56067.92 - 64.5863RH_{max}$	0.313	0.031
$Y= 56010.41 - 6383.218T_{min} + 3614.429T_{max} + 75.371RH_{max}$	0.571	0.001

4. CONCLUSION

The results obtained showed gradual increase in temperature and fluctuation in rainfall amount, rainy days and relative humidity influence rubber yield. There was high variation of rubber yield, rainfall amount, Relative Humidity maximum, Relative Humidity mean and rainfall distribution during the period under investigation.

Correlation analyses have shown that only a few climatic variables (Tmin, Tmax and RH_{min}) were significantly correlated during the period observed. Significant simple or multiple linear regression relationships between dry rubber annual tonnage and a few yearly climatic variables were established; they contributed to explain yield variations in the range of 31.3 to 57.1%. Other mathematical relationships for more accurate predictions must be built, as for example curvilinear regressions; for linear regressions may not be sufficient to explain yield variations in their completeness.

To mitigate the above changes, effective adaptation strategies aimed at influencing decisions irrespective of climate variability should be put in place. The use of improved clones, improved rubber operations, soil management strategies, rubber based cropping systems and field hygiene are some of the methods that may be put in place.

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