Implication of Climate Variability for Latex Exudates F Rubber Tree (Hevea Brasilliensis) in the Humid Tropics of South Eastern Nigeria.

Imoh J. Ekpoh and Francis I. Okpiliya
University of Calabar,
Calabar – Nigeria

And

Pius B. Utang
Cross River University of Technology
Calabar – Nigeria.

Abstract
The study aimed at: assessing the relationship between latex exudates and climate variability; identifying the most critical climate element(s) in the yield variability of rubber; and examining the predictability of rubber yield based on climate variability. Fifteen years data was collected from documented, but unpublished, sources and analyzed using multiple step-wise regressions. Two models were developed and all suggested that variable rubber yield was significantly related to the joint influence of climate elements. The most significant variables identified however were rainfall, temperature and sunshine hours. These three elements had significantly negative effects on rubber yield. Analysis of residual and standard error however suggested that these models did not provide good and reliable prediction hence the data generated may have been by chance occurrence. This was suggested to be possible at the intra-annual scale because of multicollinearity that existed between the independent variables. It was therefore recommended that further studies be conducted with a more robust model be developed to incorporate as many independent variables as possible and factor analysis carried out as a reduction tool. Finally, that agro forestry planner should also consider the implications of climate variability for other tree crops.

Key words: Latex exudates, climate variability, yield variability, critical climate element(s), statistical models.

1. Introduction and background

The productive capacity of crops is influenced by an array of environmental and socio-economic factors. Within the physical environment, climate is considered more influential as it either impacts directly or accentuates the impact of other factors.

Climate is considered as the average condition of the weather elements but one of its characteristics is the variation in space-time dimension. Variation in crop productivity which is largely under the dictate of the climate system therefore depends on the nature of variation in the climate and the crop type. For most crops generally the choice of growth hinges on the long-term average conditions, hence crops in the humid tropics vary from those in the semi-arid regions. Even within these regions the local climate varies and so local crop types and nature of yield.

In the humid tropics, variability is an integral part of the climate system. In this environment, the short-term climate fluctuations and deviation from the mean condition which are eminent do significantly influence crop yield. This ordinarily should be applicable to tree crops such as rubber, but the rooting system may be assumed to be more adept to short-term variations. On the basis of this adaptation, yield variations may not be very significant at the short-term in relation to climate variation, except in cases of extreme and severe climate events such as drought.

Rubber yield in the form of latex exudates in Odukpani has over the years been variable both within and between successive years. This could be related to climate variability and other continuously variable factors. What implications of climate variability for the variable yield form the main thrust of this study.

The reason for this is on the premise that climate is the key factor on yield variation. Planning agro-ventures therefore requires an understanding of the impact of different climate elements on crop productivity. The specific objectives of the study were therefore to: assess the relationship between latex exudates, as collected and measured (weighed) monthly and yearly, on the one hand and four climatic elements-rainfall, temperature, sunshine hours and evaporation on the other hand; identify which of these elements are more critical in explaining the yield variation over a 15 year period; and project future yield trends using models developed for this study.

2. Changing latex exudates in Odukpani

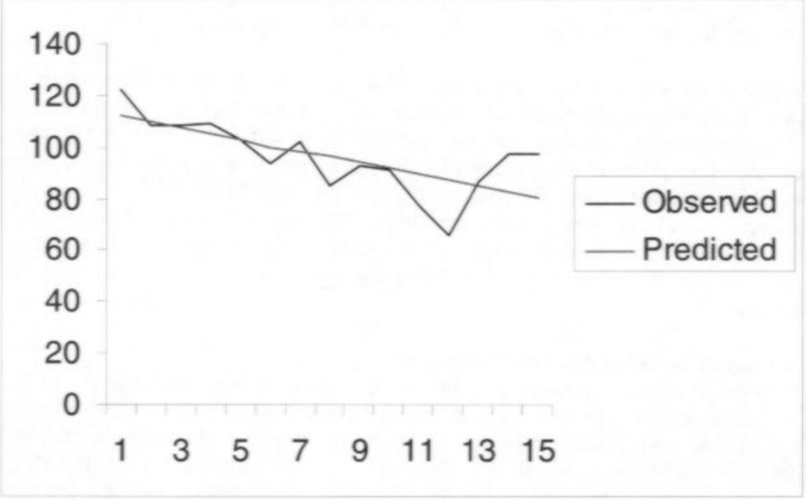
The socio-economic relevance of rubber crop cannot be over emphasized. In the Cross River region, rubber is an export earner and a source of raw material for the local rubber and plastic industries. A major exporter of rubber is Dunlop international and an estimated 25 percent of her export comes from PAMOL Nig. Ltd in Odukpani. This company is involved in cultivation, processing latex into either crumb sheet or latex concentrate and operates a plastic factory. These employ quite a substantial number of people, estimated to be above 4,000.

Most of the workers employed by Pamol are housed in rent free accommodation in the plantation where free electricity, pipe borne water, recreational facilities and medical care are provided. The implication for revenue, income and other social problems due to any downward trend in yield could be colossal.

Over the years the latex yield has been subject to many fluctuations. The factory appears to be producing below the capacity needs of the local plastic industries and a major interest appears to be export oriented. Naturally the yield of rubber in Odukpani, as elsewhere in the humid tropics is subject to daily, monthly and even yearly variations. But it appears the product is becoming more inconsistent and unreliable in yield.

Preliminary examination of the nature of variation based on measure of dispersion and time series analysis of available data, for the past 15 years suggests some variation and a downward trend. The result shows that only a small variation in yield occurred at both intra-annual with 28.28 percent coefficient of variation and inter-annual scale, with 16.58 percent coefficient of variation. These variations though small could be statistically significant and could impinge on the socio-economic fabric of the society. The downward trend as graphically shown in Fig. 1 ascertains some negative socio-economic impact.

FIG. 1:Observed an estimated values of rubber yield based on time series analysis



Source: ***Fieldwork, 2007***.

The regression equation is given as: $y = 111.96-2.23X$, where X represents time shows a negative impact of changing times on yield. As previously noted, the variation in yield could be determined by an array of factors, most notably climate perturbations. Several climate parameters can either in combination or singly influence latex yield. The involvement of these climatic parameters, either jointly or separately, in the observed variability and trend of Para-rubber yield in Odukpani forms the major problem addressed by this study.

Many studies have addressed the issue of climatic variability and crop yield. These have however concentrated more in the field of food crops in the high latitudes. In the low latitude areas of the tropics, much has been done in the semi-arid region. In the humid tropics not much has been done for food crops not to talk of tree crops.

Studies related to food crops such as those of Hellewell (1998); ; Easterling (1997); Ekpoh (1999); Qui (1995); Sionit (1987); and so on, have used statistical tools of correlation, especially regression, either with historical data or cross-sectional data to provide explanation. Statistical models developed have been used to provide prediction of yield and for sensitivity analysis. In terms of rubber yield (a tree crop) much literature has been descriptive with little empirical justification of yield variation vis-à-vis climate variability. Scholars such as Webster and Baulkwill (1989); Anochili and Tindal (1986); McDonald and Low (1984), Pusparajah (1983) and Opeke (1972) have provided expositions of the climate conditions adequate for enhanced rubber yield arid growth. As pointed out by Webster and Baulkwill (1989) and McDonald (1984), rubber is sensitive to both extreme of the weather, while Anochili and Tindal (1986) note that rubber requires an average of between 24^{O}C and 29^{O}C for efficient growth, Opeke (1972) is of the view that rubber is sensitive to diurnal variations of rainfall with yield reduced under deficit rainfall.

In terms of longitudinal analysis of yield variation and meteorological parameters of rubber based on historical data, studies have concentrated more in Asia and South America. One of such is that by Sanjeeva et al (1998) in India. These studies made use of field data at different temporal resolutions and correlated these with meteorological parameters such as maximum and minimum temperature, sunshine hours, rainfall, vapour pressure and evaporation. These studies show significant relationship with many of the climatic parameters. In Odukpani, not much has been done in terms of multivariate analysis, which aims at identifying the most critical factors, which could assist in the development of valid predictive models.

3. Study area

Study aims at examining the role of climatic variability in the changing yield of para-rubber in Odukpani, in south eastern Nigeria. By rubber yield emphasis is placed on latex exudates from the tree that is tapped, collected and weighed in kilogram per hectare. By climate variability is meant changes (deviation) in the average conditions of climate parameters from the determined temporal mean from year to year and month to month (Barrow and Lee, 2001, IPCC, 2001; Pary and Carter, 1998, Schneider and Londer, 1984).

The areas where data for this study is generated from are Odukpani Local Government of Cross River and part of Calabar municipality, located on 4^{O}00 and 5^{O}00'N and 8^{O}00' and 8^{O}31'E. Odukpani has its south eastern flank widely cultivated with rubber in plantations and this extends to part of Calabar municipality. The plantations occupy about 2,286 hectares, with 2, 072 hectares under PAMOL holding. These plantations are divided into 5 divisions comprising of Adiabo, Ikot Ansa, Odukpani main, Akim-Akim and Ikot Omin.

The area falls within the humid tropics, which coincides with Koppen's AM, Thornthwaite's and Budyko's forest climate (Ojo, 1978). The climate is characterized by high mean monthly temperature of 27^{O}C, a small annual range (2^{O}C) and generally high temperature throughout the year, annual ranfall exceeds

1500mm, it is double maxima and only 2-5 months are without appreciable rainfall during the year. This condition as defined by Webster and Baulkwill (1989) favour rubber cultivation.

Humidity is constantly high, usually over 90 percent in early morning and 60 to 80 percent at mid day and approaching 100 percent at night. Insolation is constantly high, with not less than 40 hours of sunshine a month, most of it lost by reflection and absorption by cloud cover. Evaporation is equally high throughout the year.
The climate regime favours tree crops and this is what gives the area its rich and luxuriant/evergreen vegetation. The predominant vegetation type is that of rainforest. Freshwater swamps are also common along the flood plains of the Cross River and Calabar River.

Although food crops are widely grown and form the mainstay of the local economy, tree crops are also common. These include rubber and oil palm. Except for the wild species and few individual holdings, these crops are owned by PAMOL Nig. Ltd.

4. Materials and methods

Yield data used for the study was average quantity of latex exudates in kilogram per hectare, summarized on monthly and yearly basis for 15 years. Four climatic parameters-rainfall (mm) temperature (^{O}C) sunshine (hours) and evaporation (ml) were used to represent climate variability. They were collected for the same temporal span with yield.

Whereas data on yield was collected from the records of Pamol Nig. Ltd, climate data was collected from the Nigerian Meteorological Agency (NIMET) station at the Margaret Ekpo International Airport. Rubber is widely grown in other parts of Cross River State, such as Akamkpa, Biase, Akpabuyo, Yakurr and Ikom. The choice of Pamol plantations found in Odukpani and parts of Calabar municipality was because of the proximity to reliable meteorological station and the organized nature of the establishment, which appears to be the only one that keeps up to date data on production. All the data were therefore collected from unpublished documented sources.

Multiple step-wise regression analysis was used to provide explanation of the relationship between observed yield and climatic parameters. The generalized multiple regression model adopted was of the form:

$$Y = a X b_1X_1 X b_2X_2 + b_3X_3 X b_4X_4 + e$$

Where:

Y = yield in kg/ha; X = rainfall (mm); X2 = temperature (^{O}C), X3 = Sunshine (hours) and X4 = evaporation (ml); a = constant or intercept on y axis, b = regressor of dependent variable on independent variable; e = error term.

The analysis was carried out in two phases one using mean monthly data values and the other using mean annual data values.

4. Results and discussions

4.1 Mean monthly relationships

Analysis result of the relationship between mean monthly latex yield and climate parameters confirms a strong and significant correlation given the joint influence of the 4 independent variables. This is because the calculated F- value is higher than tabulated value at 0.05 alpha level. This result is presented in table 1. Here, the high correlation coefficient and coefficient of determination indicate that 84.1 percent of the mean monthly variation in yield is explained by the joint contributions of the climatic parameters.

Table 1: Showing regression analysis results

Corr. Coeff (R)	=	0.92
Coeff. of determination (R^2)	=	0.841
F value calculated	=	9.23
P value	=	0.06
df		11

A multiple regression equation developed from the analysis was of the form:

Y	=	$950 - 0.045X_1 - 34.5X_2 - 0.860X_3 - 0.075X_4$
t	=	561 – 2.14 – 4.75 3.94 -0.28
p	=	0.00 0.070 0.000 0.006 0.786
SE	=	8.44

The equation indicates that of all the climate parameters, rainfall, temperature and sunshine were more significant predictors of the variation in yield, given the higher calculated t values than the p values. Generally the equation shows that during the year on the average for the 15 years of record, increase deviation of the climatic parameters resulted in decreased yield, with temperature influence having more negative impact. The high standard error of estimate (SE = 8.84) implies that the model was not a good fit for the prediction of rubber yield and so the model was not a good and reliable predictor of the variable rubber yield. This suggests that other variables could have equally contributed to the yield variation.

Multiple correlation analysis result as presented in table 2 confirms that a higher negative correlation existed between temperature and rubber yield. The table also shows that multicollinearity existed between most of the climatic parameters. This suggests that the values of the regression coefficient were unstable and less useful for prediction, thus confirming the non-reliability of he model prediction. The relationship between the independent variables individually was generally low and negative. Given the high correlation based on joint effects, it is therefore not possible to attribute the variable yield to a specific climatic parameter at the intra-annual scale since most of them correlate with one another.

Table 2: Zero-Order Correlation Matrix based on mean monthly data analysis

	Y	X_1	X_2	X_3	X_4

Y	1.00	-0.009	-0.505	-0.069	-0,370
X_1		1.00	-0.654	-0.619	-0.737
X_2			1.00	0.847	0.811
X_3				10	0.659
X_4					1.00

The estimated values of the yield based on joint effects from the regression analysis are as shown in Table 3 and Fig. 3. The table shows that jointly, the yield was over predicted in 7 months by about 1.72kg/ha. This low over-estimation suggests that the model provided a good estimate of the yield. However the high standard error of estimate as already noted confirms that the regression model was not a good fit for predicting yield of rubber within the year and so should not be relied on. Therefore, though linear relationships existed between the climatic parameters and latex yield, multincollnearity implies instability of the variables in predicting the yields, hence the model developed could have occurred by chance.

Table 3: Observed and predicted monthly yield (kg/ha) based on joint effects of climate parameter (Jan-Dec. 1992-2006)

Observed	Predicted
115.18	111.18
77.14	67.15
55.54	70.06
78.27	80.81
95.59	97.93
105.22	110.69
101.69	95.63
107.94	116.53
99.26	101.04
114.77	111.3
131.38	113.99
128.33	136.02

Source: PAMOL, 2007, Fieldwork, :

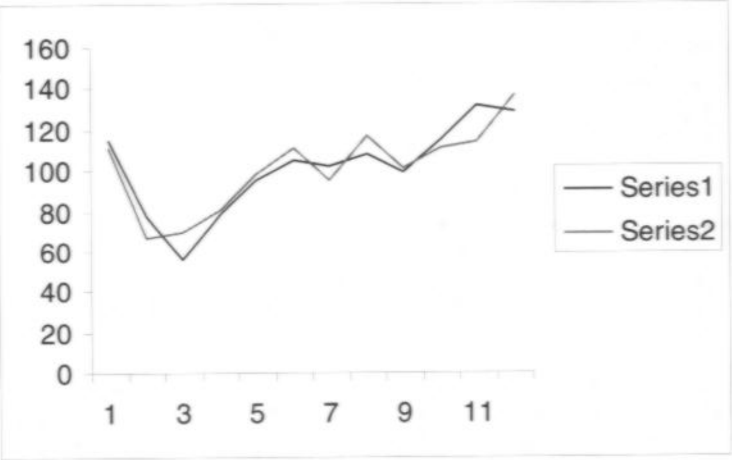


FIG. 3: Observed and predicted values based on mean monthly climate variables

This makes the result at variance with those of Sanjeev et al (1998) where rainfall beyond a month period showed significant positive correlation with yield. The other correlations however are in consonance with Sanjeeva et al (1998) except for evaporation, that temperature, evaporation and sunshine show significant negative correlation with rubber yield, irrespective of the time period considered. Generally, the results of this study are in conformity with Thompson (1970) and 1969) who noted that no single weather variable can best explain yield variation.

4.2 Mean annual rubber yield and climate

It is already established that a downward trend existed in the latex yield during the 15 years of available data. Examining the implications of climate variability for this trend, multiple regression analysis was carried out.

The result as presented in Table 4 shows that a high and significant relationship existed between the variable yield and the climatic parameters jointly, hence higher calculated F- value than P- value at 0.05 alpha level. From Table 4, 49.4 percent of the variation in average yearly yield was explained by the joint effects of the climatic parameters. This implies that more than 50 percent of the yield variation was accounted for by other climate and non-climate variables not included in the model, such as soil moisture, humidity, vapour pressure, technology and farm management practices.

Table 4: Results of multiple regression analysis

Corr. Coeff (R)	=	0.702
Coeff. Of determination (R^2)	=	0.494
F value calculated	=	2.44
P value at 0.05	=	0.115
df		14

The regression analysis provided a model of the form;

Y	=	$290 - 0.280X_1 - 4.02X_2 - 0.140X_3 - 0.147X_4$				
t	=	$2.43 - 2.41$	-1.00	1.69	-0.31	
p	=	0.035	0.037	0.341	0.123	0.765
SE	=	9.96				

This result also confirms that a unit deviation in temperature accounted for the highest negative yield than all the other variables. The result also confirms that evaporation did not have significant influence on the yield. The high standard error of estimate (SE = 9.96) also suggests that the model was not a good and reliable predictor of the yield and so the observed result occurred by chance.

The zero-order correlation matrix in Table 5 shows that rainfall correlated more negatively with yield than other variables. However the generally low, negative relationship between yield and the climatic parameters suggests that variables other than those used in the model could have contributed more to the variation of average yield on a yearly basis. This also implies that though yield varied, climate was rather more reliable and stable during the period under study.

Table 5: Zero-Order Correlation Matrix

	Y	X_1	X_2	X_3	X_4
Y	1.00	-0.569	-0.005	-0.200	-0.309
X_1		1.00	0.261	-0.055	-0.639
X_2			1.00	-0.197	0.289
X_3				1.00	-0.046
X_4					1.00

The estimated values of the yield based on the model developed as shown in Table 6 and Fig 4 indicate that the yield was generally under-estimated by about 3.7kg/ha. Though this low value suggests a good estimate, the high standard error already shows that the model was not reliable and so this good estimate could have occurred by chance. This implies that climate alone did not account for the variability in yield and so other variables need to be explored.

Table 6: Observed and predicted average yearly yield (kg/ha) based on joint effects of climate variables (1992-2006).

Observed	Predicted
122.23	105
107.96	121.43
108.19	106.82
109.13	95.92
108.13	112.57
93.31	92.79
102.07	91.70
85.31	90.27
93.03	92.08
91.45	86.13
97.48	77.87
66.00	92.29
86.28	91.95
97.19	101.90
97.17	89.21

Source: PAMOL, 2007; Model prediction, 2007

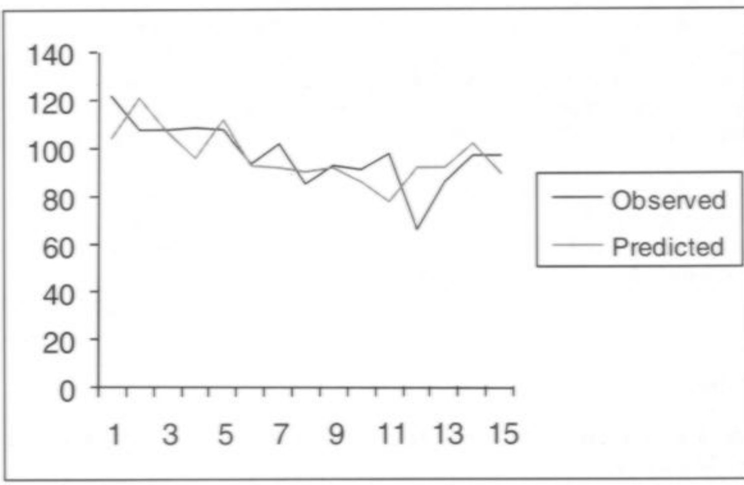


FIG. 4: Graphical illustration of observed and predicted mean annual rubber yield (1992-2006)

Source: Fieldwork, 2007

The generally low correlation between the individual climatic parameter with yield suggests as Viglizo (1995) points out, that impact of any climatic variable on yield should incorporate other climatic as well as land use and management practices. This helps to indicate how crop type and technology should be adopted to overcome problems. The low percentage explanation also confirms the above assertion and affirms that management practices are the real impact when it comes to adverse effects (Viglizo, 1995). The variation between the result of intra-annual and inter-annual variability also confirms what Hadjichristoloudou (1982) asserts that, though annual rainfall accounts for variation in yield over time, highest variation is accounted for by seasonal distribution.

5. Conclusion

The effect of climate variability on the latex yield of rubber cannot be over-emphasized. This has been ascertained in this study. However the results further confirm that rubber yield cannot be predicted by a single climatic element. At the same time, the applicability of the statistical crop weather models developed in this study has been observed to have limitation for the assessment of rubber yield. These models are observed to lack goodness of fit and reliability for estimating rubber yield. Several other factors therefore could have contributed, in addition to climate variability, to the variable latex exudates and the downward trend observed.

It is therefore necessary to consider these other variables in the yield assessment of rubber by developing a more robust model, which would consider all the factors, as well as applying more rigorous statistical analysis such as factor analysis and further step-wise regression. Such variables that need to be taken into consideration are; possibility of severe intervening weather, soil moisture indices, managerial problems such as inability to harvest at the right time, poor techniques of tapping, diseases of the plants, diversion of product by tapers and other detrimental practices. All these may have contributed to the lack of reliability of estimate based on climate alone.

Despite the above short-comings, this study however provides additional impetus for the understanding of the interaction of rubber yield with climate. The study adds pep to Simane and Struik's (1993) assertion that agro-climatic analysis is a valuable tool for planning sustainable crop production.

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