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Development of a Multiple Linear Regression Model for Rainfall Distribution on Other Meteorological Parameters: A Case Study of Idofian, Kwara State, Nigeria.

By

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Abstract

This research work presents the development of a multiple linear regression model for rainfall distribution using other meteorological parameter a case study of Idofian. The required data were obtained from the meteorological section of the National Centre for Agricultural Mechanization (NCAM). The variables were subjected to multiple linear regressions, measures of central tendency and dispersion. The result of the analysis shows that meteorological parameters at the location revealed fluctuation of different patterns. Relative humidity, minimum temperature and evaporation depict downward trend while wind speed and maximum temperature depict upward trend at the study area confirming the continual reduction in rainfall at the location over the years, which will eventually affect availability of water for agricultural production and other uses.

Key words: Climate variability, rainfall, Idofian, multiple linear regression

1.0 Introduction

Accurate information on all-weather variables such as precipitation, wind, evaporation, relative humidity, minimum temperature, maximum temperature and radiation is essential for proper agricultural planning in Nigeria. In addition, daily weather data has contributed immensely as a source for many agricultural models in recent times. There is hardly another branch of human activity that is as dependent on the weather and climate as agriculture, despite the notable advances in agricultural technology over the last fifty years. More than ever, agro-meteorological services are important, owing to the challenges posed by increasing climate variability, associated extreme events and climate change. These challenges have impact in terms of socio-economic conditions in general, especially in developing countries.

(Sharply and Williams, 1990) reported that studies have revealed the climatic change impact effect on some agricultural management models like Erosion/Productivity Impact Calculator (EPIC) therefore there is need to mitigate climate change impact on agriculture. This model was developed to assess both the effectiveness of erosion minimization techniques and the impact of soil loss, since erosion has long been recognized as a problem of land use. This model has become a comprehensive model with nine interactive components; one of them is weather generator (WXGEN) that stimulates daily weather from an input climatic data. (Robertson and Foong,1977) and (Foong,1981) also predicted that a yield of crop is based on climatic factors using mathematical modeling to predicted result. Factors including rainfall, solar radiation, maximum and minimum temperatures which play a vital role at floral initiation were taken into consideration to construct these models. Also considering the use of meteorological data in modeling (Ong,1982) discovered a high correlation between yield of oil palm, rainfall and dry spells as also temperature and sunshine using a step-wise regression approach. (Chow, 1991) constructed a statistical model for predicting crude palm oil production with trend, season, rainfall, etc. in Southern Malaysia.

A change in climate affects the usual timing and intensity of precipitation and temperatures, which in turn affects all other means of livelihood such as agriculture. (Salami et al., 2011) carried out a study on impact of global warming on rainfall and temperature for some selected cities in the Niger Delta region of Nigeria using nonparametric Man-Kendall test to identify monotonic trend and the Sen's slope estimator to develop models for the variables. The study revealed that there is evidence of global warming in Owerri and rainfall has significantly increased in Calabar over the years. The trends in rainfall of Owerri and Port-Harcourt were not significant. Also, plots of the developed model revealed a positive trend in the rainfall at the station. The objectives of this study is to develop a multiple linear regression model that will show the trend in the rainfall distribution area as well as to assess its impact on other meteorological variables. The lack of proper knowledge of climatic variability in Nigeria has resulted to poor agricultural planning in the area of planting date of food crops. This could be as a result of changes in weather condition during the season which has resulted to indeterminate planting date of food crops. There is an urgent need to develop a multiple linear regression model for use in Nigerian agriculture in addressing this problem such that it will adopt a more flexible approach of modeling the non-rain variables responsible for these problems. This model when developed will form an input for climatic data that would be suitable for agriculture which will help to assess the impact of rainfall distribution on crop production and the possible changes in weather condition.

2.0 Research Methods

2.1 Description of the Study Area

Idofian is located in Ifelodun local government area of Kwara State and it lies between Latitude $8^o26'$ N and Longitudes $4^o30'$ East (Ahaneku, 1997).Its climate is being dominated by Inter-tropical Convergence Zone (ITCZ), which has resulted into two seasons which are: wet and dry seasons. The on-set of the rainy season is usually in the month of April and cessation is usually in the month of October. The rainfall season is always at its peak within the month of June to

September. The dry season also commence from the month of November and ends in March. The mean annual rainfall of Idofian is 1700mm, while the mean monthly maximum and minimum temperatures in the basin are 31°C and 29°C, respectively, with the highest temperatures recorded in the months of February through April(Meteorology Report, 2009).

2.2 Data Collection

The data required for this study are meteorological data spanning for the period of 10 years (2010 – 2020) which includes precipitation, maximum and minimum temperature, wind speed, relative humidity and evaporation. The required data were obtained from Nigeria Meteorological Agency (NIMET), Oshodi, Lagos together with data obtained from the meteorological section of the National Centre for Agricultural Mechanization (NCAM).

2.3 Data Analysis

The data were analyzed using measures of central tendency and dispersion such as: minimum, maximum, mean, median and standard deviation. Also, multiple linear regression model was adopted to develop a linear regression model in the study.

2.3.1 Multiple regression models

Multiple regression model is a statistical tool for modeling variables with one dependent and two or more independent variables. It can be used to develop a linear regression model. Ojoye (2012) used the regression model to assess the overall impact of meteorological parameters such as precipitation, temperature, evaporation on the run off in some selected locations in Sudano-Sahelian ecological zone of Nigeria. The multiple linear regression model that was adopted in this study is presented in Equation 1.

$$Y = a_1X_1 + a_2X_2 + a_3X_3 + a_4X_4 + a_5X_5 + b$$

$$Y = 0.16\,X_1 + 2.23\,X_2 + 0.937\,X_3 + 2.078\,X_4 + 0.703\,X_5 - 153.27$$

where:

Y= Rainfall (mm)

X_1=Relative humidity (%)
X_2= Minimum Temperature (^oC)
X_3=Maximum Temperature (^oC)
X_4= Wind (m/s)
X_5= Evaporation (mm)
a_1, a_1, a_2, a_3, a_4, a_5 = constants

3.0 Results and Discussion

The results obtained for the descriptive statistical analyses of the meteorological data are presented in Tables 1 to 6.

Table 1: Statistical Analysis of Rainfall

MONTH	JAN	FEB.	MAR	APR.	MAY	JUNE.	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
MIN.	0	0	0	19.6	42.3	12.6	63.5	24.1	62.3	9.2	0	0
MAX	127	176	167.9	223.9	355.7	370.8	325.9	338.3	1188	292.1	152.9	148
MEAN	9.4	13	46.2	97.2	162.3	180.1	154.1	142	241.1	134.6	15.3	8.9
MEDIAN	0	1.2	33	88.3	152.9	177.2	148.6	131.4	238.6	126	2.9	0
STDEVA	24.6	31.1	35	52.4	69.2	65.9	71.4	82.5	169	74.4	29.2	28.1

The above table shows the statistical analysis of rainfall in Idofian, Kwara State, Nigeria

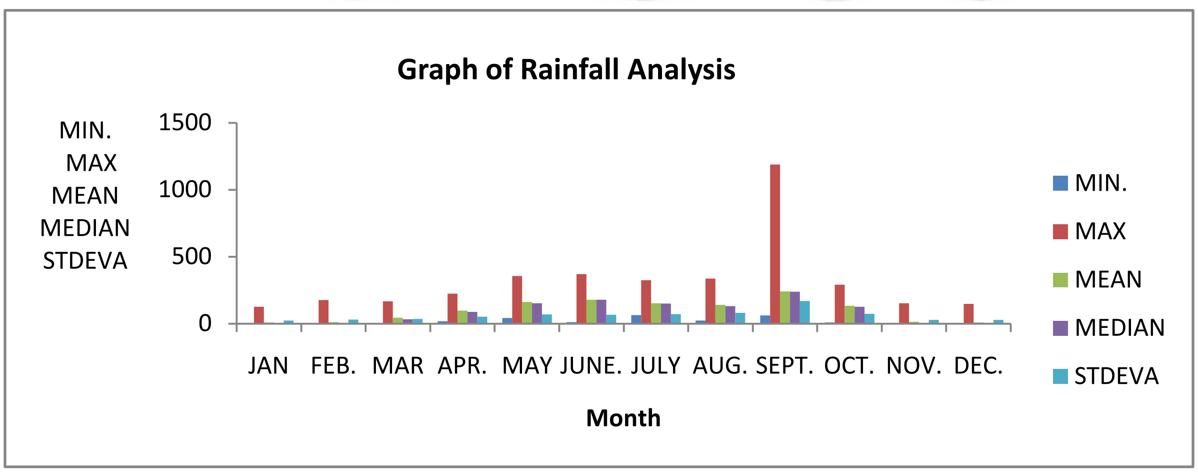

Figure1: Graph of Rainfall Analysis

The above Figure shows the statistical graph of rainfall in Idofian, Kwara State, Nigeria

Table 2: Statistical Analysis of Minimum Temperature

MONTH	JAN	FEB.	MAR	APR.	MAY	JUNE.	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
MIN.	14.4	19.1	20.2	21.6	21	21	20.7	18.3	17.7	20.7	16.6	16
MAX	23.2	24.2	26.8	26.2	25.9	25.8	22.6	22.4	22.5	23.6	24.9	22.2
MEAN	19.8	22.1	23.49	23.4	22.73	21.9	26.11	21.17	21.1	21.52	20.88	19.28
MEDIAN	20.1	22.3	23.5	23.3	22.6	21.8	21.4	21.3	21	21.6	21.2	19.2
STDEVA	1.94	1.29	0.98	1.02	0.89	0.75	29.86	0.75	0.75	0.54	1.58	1.65

The above table shows the statistical analysis of Minimum Temperature in Idofian, Kwara State,

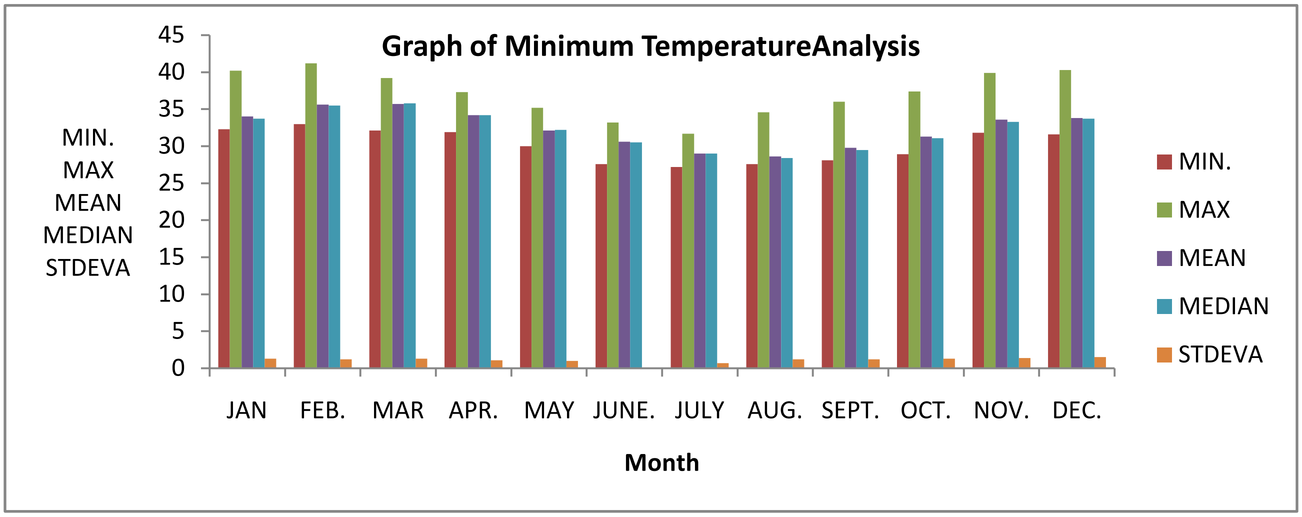

Figure 2: Graph of Minimum Temperature Analysis

The above Figure shows the statistical graph of Minimum Temperature in Idofian, Kwara State, Nigeria

Table 3: Statistical Analysis of Maximum Temperature

MONTH	JAN	FEB.	MAR	APR.	MAY	JUNE.	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
MIN.	32.3	33	32.1	31.9	30	27.6	27.2	27.6	28.1	28.9	31.8	31.6
MAX	40.2	41.2	39.2	37.3	35.2	33.2	31.7	34.6	36	37.4	39.9	40.3
MEAN	34	35.6	35.7	34.2	32.1	30.6	29	28.6	29.8	31.3	33.6	33.8
MEDIAN	33.7	35.5	35.8	34.2	32.2	30.5	29	28.4	29.5	31.1	33.3	33.7
STDEVA	1.3	1.2	1.3	1.1	1	0,9	0.7	1.2	1.2	1.3	1.4	1.5

The above table shows the statistical analysis of Maximum Temperature in Idofian, Kwara State, Nigeria

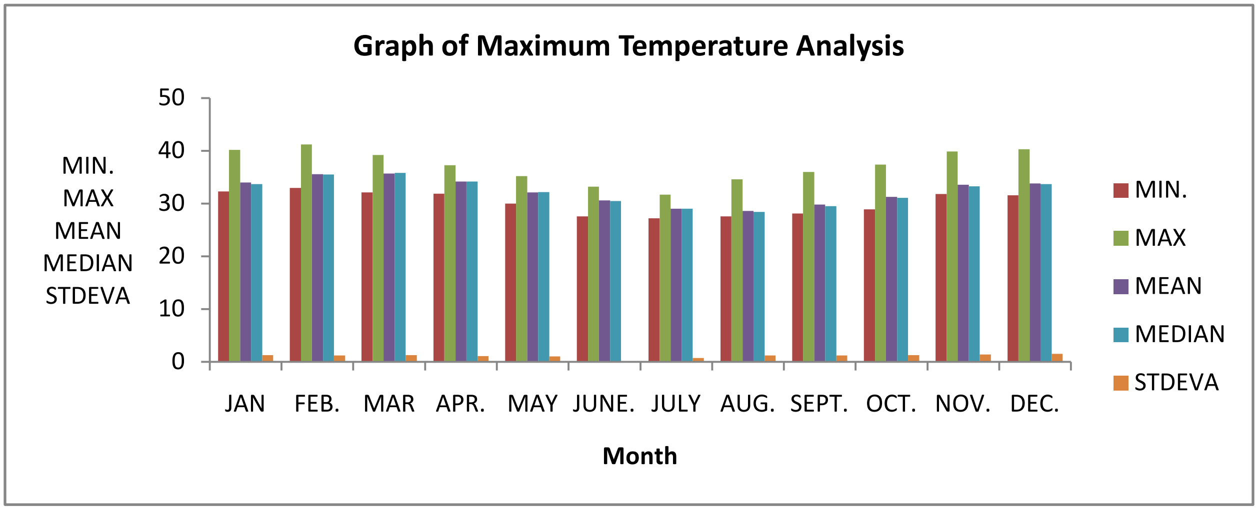

Figure 3: Graph of Maximum Temperature Analysis

The above Figure shows the statistical graph of Maximum Temperature in Idofian, Kwara State, Nigeria

Table 4: Statistical Analysis of Relative Humidity

MONTH	JAN	FEB.	MAR	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
MIN.	22	30	44	67	71	75	73	75	76.2	50	50	32
MAX	80	76	75	80	84	89	92	92	89	88	84	76
MEAN	53.2	60.1	67	74	78.8	82.2	84.4	85.5	84.9	81	70.4	58.3
MEDIAN	56	63	69	74	79	83	85	86	85	83	72	58
STDEVA	14.2	12.5	7.4	3.2	2.8	2.8	3.4	3.4	2.9	5.7	7.7	10.7

The above table shows the statistical analysis of Relative Humidity in Idofian, Kwara State, Nigeria

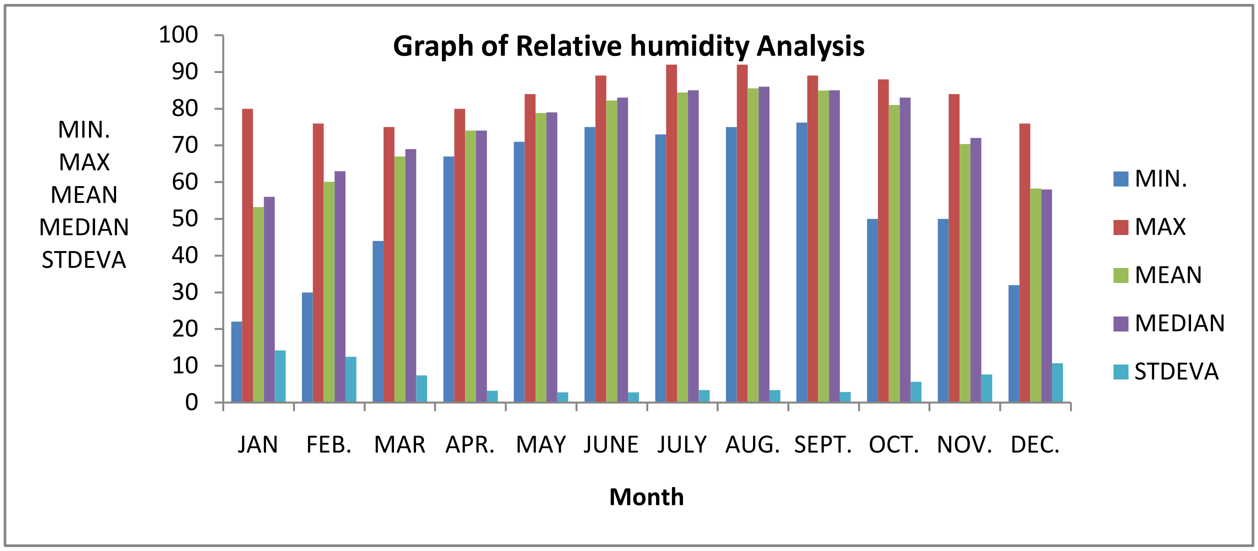

Figure 4: Graph of Relative Humidity Analysis

The above Figure shows the statistical graph of Relative Humidity in Idofian, Kwara State, Nigeria

Table 5: Statistical Analysis of Evaporation

MONTH	JAN	FEB.	MAR	APR.	MAY	JUNE.	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
MIN.	3.5	1.4	5.1	2.9	2.4	2	1.5	1.4	1.6	1.1	2.9	1.8
MAX	13.5	13.8	13.6	7.9	6.1	4.3	3.8	3.7	4.4	4.2	8	10.6
MEAN	8.6	9.4	7.9	5.7	3.9	3	2.6	2.5	2.4	3	5.9	7.2
MEDIAN	8.2	9.5	7.9	5.7	4	3	2.7	2.6	2.4	2.9	5.7	7.4
STDEVA	2.3	2.5	1.7	1.1	0.8	0.5	0.6	0.5	0.5	0.7	1.2	2

The above table shows the statistical analysis of Evaporation in Idofian, Kwara State, Nigeria

Table 5: Statistical Analysis of Evaporation

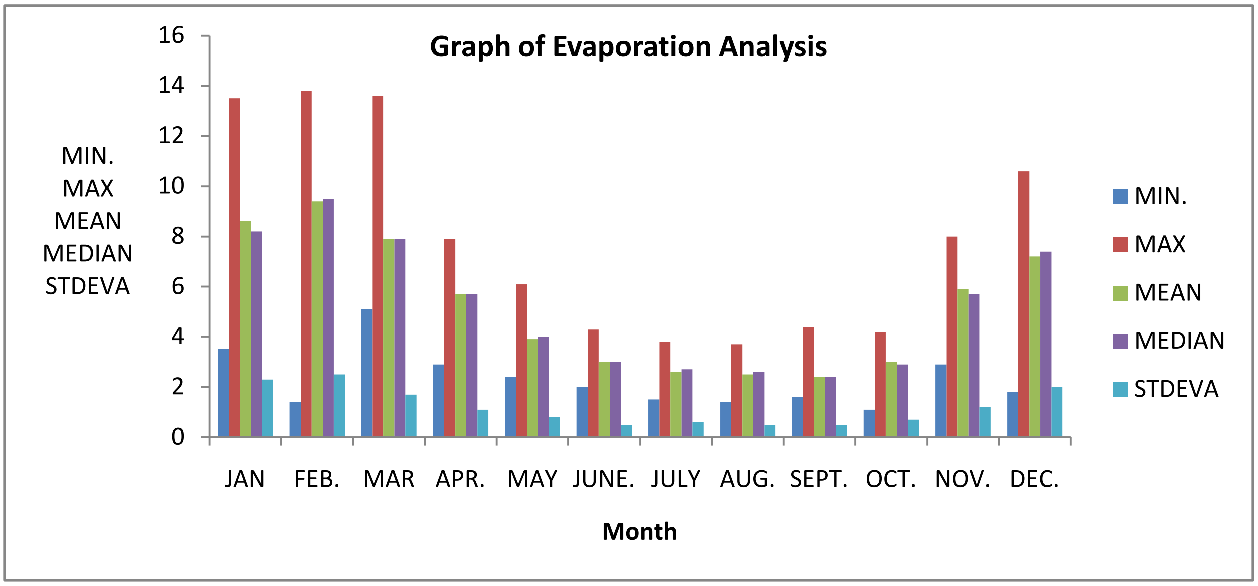

Figure 5: statistical graph of Evaporation

The above Figure shows the statistical graph of Evaporation in Idofian, Kwara State, Nigeria

Table 6: Statistical Analysis of Wind

MONTH	JAN	FEB.	MAR	APR.	MAY	JUNE.	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
MIN.	1.5	1.4	2.1	1.8	1.3	1.7	2	2.3	1.1	1.5	1	1
MAX	8	6.5	7.3	8.1	8.6	7.2	7	7.4	6.8	5.5	5.7	6
MEAN	4.2	4.5	5.4	5.6	5.2	4.8	5.1	5.2	4	3.8	3.5	3.7
MEDIAN	4.2	4.6	5.7	6	5	4.9	5.3	5	4	4	3.5	3.5
STDEVA	1.4	1.1	1.1	1.6	1.6	1.2	1.3	1.4	1.2	1.1	1.2	1.2

The above table shows the statistical analysis of Wind in Idofian, Kwara State, Nigeria

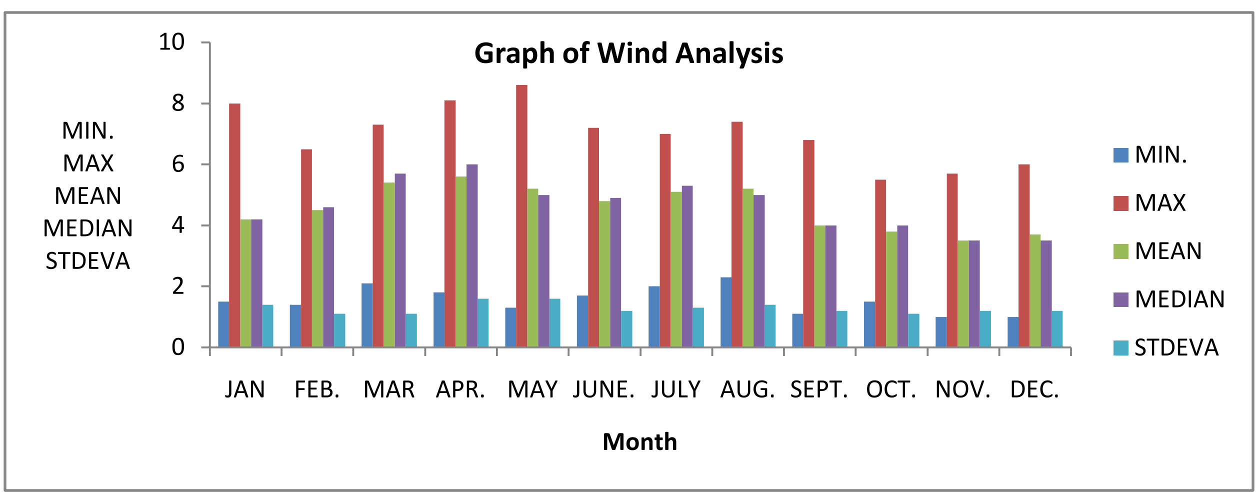

Figure7: Figure shows the statistical graph of Wind

The above Figure shows the statistical graph of Wind in Idofian, Kwara State, Nigeria

3.1 Results of Multiple Linear Regression Model

The multiple linear regression model obtained from the analysis is presented in Equation 2. Summary of the linear regression model that was generated from the analysis of the meteorological data were presented in Table 7. Also Table 8 presented the summary of the analysis of variance (ANOVA) obtained from the analysis.

Table 7: Summary of Result for Multiple Regression Model

	Value
Included Observation	493
R-Square	0.1958
R-Square (Adjusted)	0.1876

Table 8: Regression Summary of ANOVA Result

	Sum of Squares	Df	Mean Square	F	Sq
Regression	1757113.1734	5	351422.66347	23.7160	NAN
Residual	7216339.5999	487	14817.9458		
Total	8973452.7733	492			

The multiple regression models indicate that the average rainfall received over the year is 398.59mm. The coefficient of relative humidity is -0.264 showing that rainfall will decrease on the average by 0.264mm per month for every $1^0/_0$ decrease in relative humidity. The coefficient of minimum temperature is -8.963 which implies that rainfall will decrease by 8.963mm per month for every 1°C decrease in minimum temperature. The coefficient of maximum temperature is 0.662 which implies that rainfall will increase by 0.662mm per month for every

1°C increase in maximum temperature. The coefficient of wind is 2.863 showing that rainfall will increase by 2.863mm per month for every 1m/s of wind. Finally, for every 1mm decrease in evaporation it will cause a reduction in rainfall by 11.744mm per month.

4.0 Conclusion

The meteorological parameters within of the study area were analyzed. The parameters were subjected to multiple linear regression analysis and measures of central tendency and dispersion. Relative humidity, minimum temperature and evaporation shows a decreasing trend in Idofian. While wind and maximum temperature shows an increasing trend at the study area. In conclusion, the upward trends in maximum temperature and wind speed can cause a continual reduction in rainfall and may eventually affect availability of water for agricultural production in this location.

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