Relationships between Climate Parameters and Forest Vegetation At and Near Digya National Park, Ghana

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Research Article

ABSTRACT

This paper evaluates the effect of three climate parameters on forest cover in Ghana and the normalized difference vegetation index (NDVI) at Digya National Park derived from Landsat image data. Climate data (temperature, humidity, dewpoint, rainfall) are assembled from statistics provided by Ghana's Meteorological Agency. The study introduces a weighted averaging method by computing weather information from neighbouring stations. Also, this research introduces a model of dewpoints, enabling the direct calculation of dewpoints from temperature and humidity data. The major finding is that while temperature significantly affects forest cover and Park vegetation, dew-points and rainfall do not. The paper suggests where future research may be more fruitful in analyzing the effects of climate on vegetation.

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1. INTRODUCTION

Climate study literature for Africa and Europe tends to be biased excessively toward the analysis of rainfall (Hess et al., 1995; Rodo et al., 1997; Corte-Real et al., 1998; Esteban-Parra et al., 1998; Agnew and Chappell 1999; Shinoda et al., 1999; Graef and Haigis, 2001; Lucero et al., 2002; Twumasi et al., 2005a; Simms 2006; Conway et al., 2009; Salack et al., 2011; Goula Bi et al., 2011). When Belda and Melia (2000) investigated climatic parameters affecting forest vegetation in Spain, their focus was almost entirely devoted to rainfall. Oduro-Afriyie (1996) discussed Ghana; but again the issue was erosion due to rainfall. Although Paturel et al. (1997) also investigate climatic variability along the coast of the Gulf of Guinea, their article clearly was focused almost entirely on rainfall. When Jury and Gwazantini (2002) analyzed climate variability and the prediction of lake levels in Malawi, the issue was again rainfall.

Gyau-Boakye (2001) and Gyau-Boakye and Tumbulto (2000) analyzed declining rainfall in the upper White and Oti Volta basins and the effect of the Akosombo Dam on Volta Lake levels. But they also took into account the mean monthly variation in air temperature as measured at Tamale in the North end of Ghana. The comment was that there had been 1 degree Celsius rise from 1945 to 1993 and that there was an increase in evaporation for this rise in temperature (Gyau-Boakye and Tumbulto, 2000). These researchers, however, did not analyse the effects of temperature rises on forest cover or vegetation.

Recent work of Ephrath et al. (1996) in Israel and several other countries noted a daily variation in air temperature and wind speed. Their study was oriented to the consideration of daily fluctuation statistics rather than year-over-year variations. Koranteng and McGlade (2001), however, analysed climatic trends in waters off Ghana in the Gulf of Guinea, showing interesting findings about the coastal water temperature. Over the period 1963 to 1992, they reported surface temperatures averaging 26 degrees Celsius, but with no significant trend over the period. The problem was that they did not discuss Ghana per se.

In Ghana, it is widely understood (Dickson and Benneh, 1990) that Ghana's weather depends to a large extent on the position of the Inter-Tropical Convergence Zone (ITCZ) between Tropical Continental (CT) air mass and the Tropical Maritime (MT) air mass. This Zone shifts from the coastal plain to areas well north of Ghana during the annual weather cycle of dry and wet seasons. Since vegetation requires moisture, rain, and the right range of temperatures there is the expectation that vegetation may be a function of the air masses which characterise Ghana's weather.

The significance of climate data is found in its effects on vegetation, which may be measured either by ground-truth survey or remotely by satellite measures of NDVI. Many studies of the recent past suggest that NDVI measures are reliable enough to warrant direct application. Rasmussen (1998a, 1998b) applied the NDVI measure using AVHRR data to net primary agricultural production and crop yield assessment, evaluating each against ground-truth data from several sources with significant results in nearly all cases. Eklundh (1998) used an AVHRR NDVI measure to estimate rainfall in East Africa with some success. Geoghegan et al. (2001) looked the question whether there were any relationship between NDVI and other

remotely sensed information and household survey data about the description of the land in the Yucatan Peninsula, and again with considerable success. Other studies (Duncan et al. 1993; Shippert et al., 1995; Kammerud, 1996; Teillet et al., 1997; Goetz, 1997; Lambin and Ehrlich, 1997; Ehrlich et al., 1997; Twumasi, 2004) show that NDVI measures are well correlated with ground-truth information about vegetation.

In all, recent literature has shown that there has been very little analytical interest in the possible effects of dewpoints and temperature on vegetation. Filling this gap was the primary reason for this research. Thus, the purpose here is to evaluate the effect of climate on forest cover in Ghana and vegetation at Digya National Park using climatic and remotely-sensed data.

2. MATERIALS AND METHODS

2.1 Study Area

Digya National Park Reserve is located 300 km inland and North northwest of Accra, the capital of Ghana. Its geographical coordinates are 7 degrees 5 minutes North latitude and 0 degrees 45 minutes West longitude. The Park occupies 347,830 hectares of land area (WCMC, 1997). See Figures 1 and 2. This park is the second largest in Ghana. Digya was recognised as a national park in 1971 under the Wildlife Regulations Act. The geological formation of the reserve is of the Obosum and Oti Beds type, consisting of shale and mudstone. Generally, the soils of the area belong to the forest ochrosol and oxysol groups (Brammer, 1962, Benneh and Dickson, 1990). Forested areas of Digya National Park are mostly pure evergreen and mixed deciduous. The elevation of Park lies between 841 meters (Volta Lake level) and 1192m above sea level with the highest peak in the West-central area. The most intense rainfall generally occurs during the summer months, while the dry season peaks in December--January.

2.2 Methodology

As stated above, the purpose of this study is to investigate what aspects of the climate in the area of Digya National Park, Ghana, affect its vegetation. There are two dependent variables to consider-- forest cover and the normalized difference vegetation index (NDVI) measured by Landsat MSS for 1978, Landsat 4 and 5 for 1985 and 1991 and Landsat ETM+ for the year 2000 at Digya National Park. These satellite data were obtained from the United States Geological Survey (USGS) Department. A number of images were assembled for each year under investigation especially during June and July when vegetation tends to be at maximum, and a selection for the image describing the whole year was based on minimum interference from cloud cover during these months. The image acquisition dates for the selected images were June 15, 1978, July 1st, 1985, July 5th, 1991 and June 27th, 2000 (Twumasi, 2004).

The variation of forest cover in million hectares for the whole of Ghana was assembled from data found in Fairhead and Leach (1998), Leach and Fairhead (2000), WCMC (1992) and other sources which suggested that while Ghana's forest cover in 1900 was about 9.3 million hectares (ha), it had declined to 4.2 million ha by 1950, 1.8 by 1980, 1.7 in 1985, and 1.5 in 1992. The figures for the years 1978, 1990, 1991, and 2000 were found by linear interpolation (Twumasi 2004 and 2005; Twumasi et al., 2005b). Results are found in Table 7.
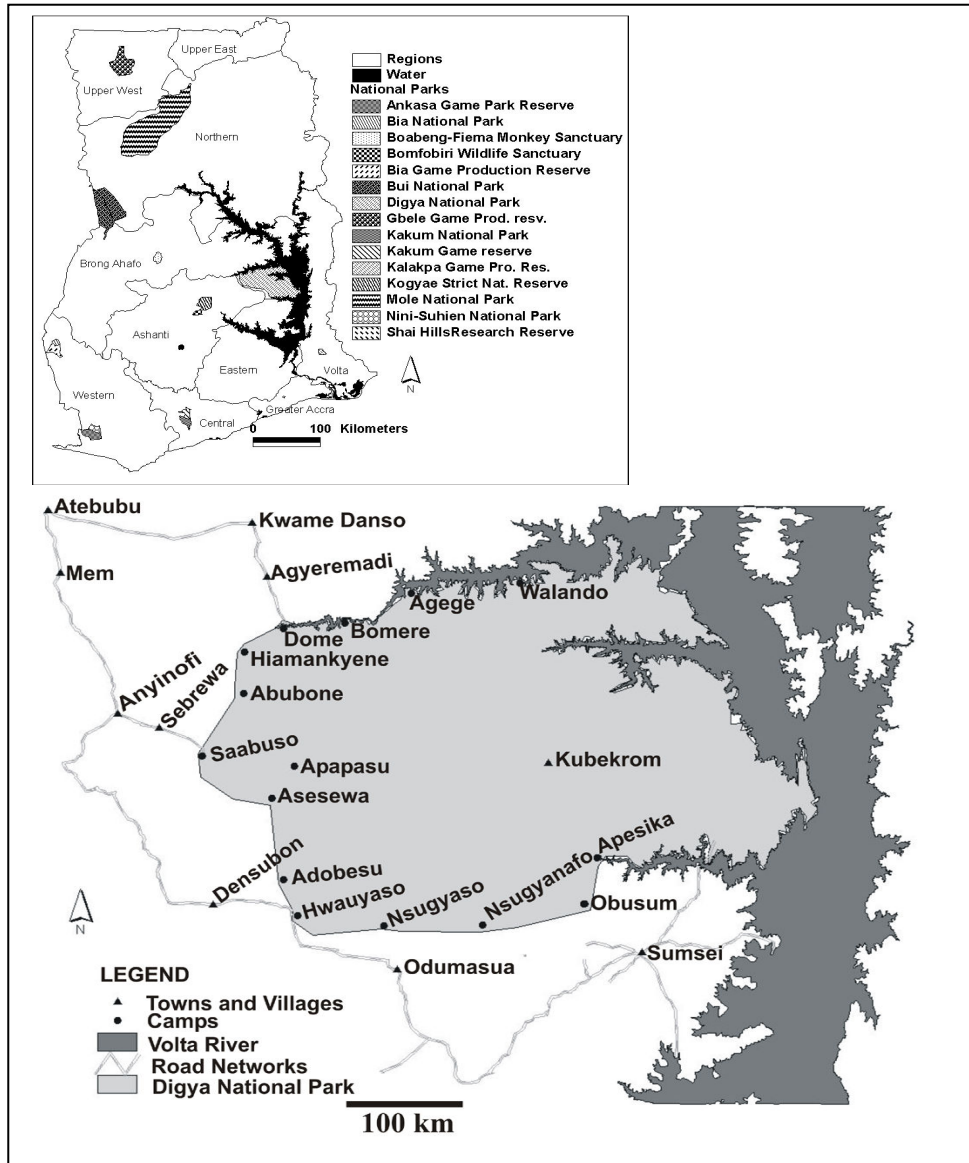
Fig. 1. Study area. The map shows Digya National Park with surrounding villages and camps. Insert shows the position of Digya in Ghana

The mean values for NDVI within Digya National Park were computed using the red and near-infrared bands of Landsat detectors. Results are found in Table 7. NDVI is generally defined as a ratio of the difference to the sum of the intensities of radiation at near-infrared and red wavelengths by a satellite sensor, as shown below:

$$NDVI = \frac{(NearIR - Red)}{(NearIR + Red)} \qquad (1)$$

The independent variables - mean annual temperature, mean annual dewpoint and mean annual rainfall were obtained from the record published by the Ghana Meteorological Agency (Government of Ghana, 2003). The data are distributed by the Department explicitly listing for each month of each year between 1978 and 2000 the mean daily maximum temperature, the mean daily minimum temperature, the monthly rainfall in millimetres, the mean daily relative humidity at 0600 hours, the mean daily relative humidity at 1500 hours, the mean daily duration of bright sunshine in hours, and the total number of rain days.

There are at least three shortcomings in the Agency's compilation of this information. First, it does not show annual averages or averages of monthly data over all measuring stations. The Agency lists parameters, for instance, at Kete-Krachi measuring station, for February 1978, but does not compile the mean values of these parameters for February 1978 for all 22 measuring stations. Nor does it compute their average values for the whole year at Kete-Krachi and each other measuring station. This means that the analyst, interested in the values of these parameters for the whole country, and for the whole year at a specific measuring station, is compelled to compute these averages himself. Secondly, the Agency does not have a weather station at Digya National Park. The observations found in the Agency's publication are from 22 national stations within the country, but not at the Park. Finally, the Agency's publication does not show dewpoint information.
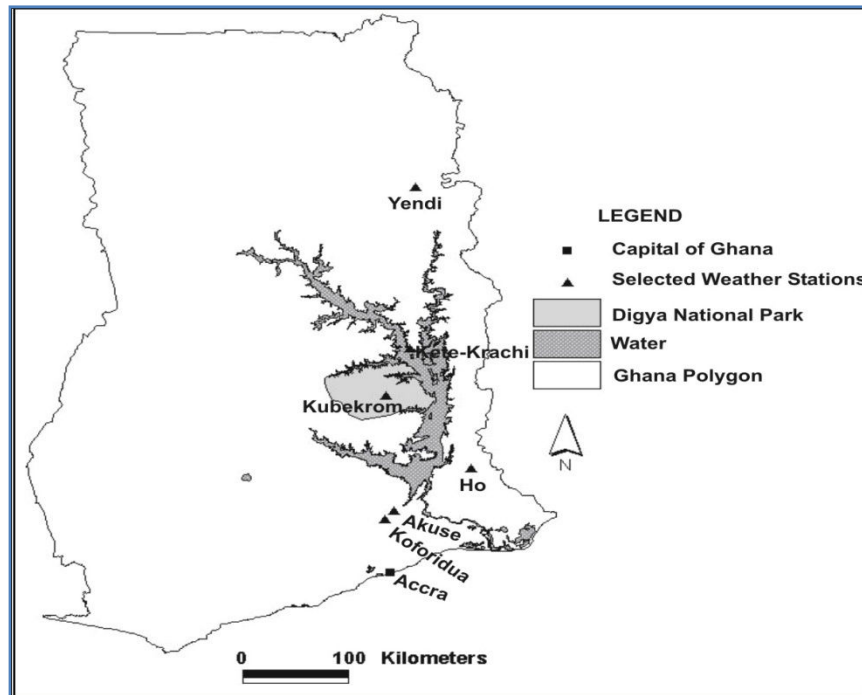
Fig. 2: Locations of the selected weather stations

The first problem was addressed by calculating the annual averages from the monthly statistics actually listed. This is a straight-forward arithmetic exercise and was applied to the temperature, humidity and rainfall data, selected results of which are seen in Tables 2-4 below. The second shortcoming, as mentioned above, was that there was no weather station at Digya National Park. This problem was solved by identifying several weather stations

nearest the Park and by weighting each parameter in inverse proportion to the distance between the weather station and Kubekrom, a village located in the approximate centre of the Park (Figure 2). The percentage weights to apply to each station's statistics assume that the effect of climate at Kubekrom is inversely proportional to the distance to the weather station. For example the weight for Ho station is found to be 20%, as seen in Table 1 (see also Twumasi, 2004 and 2005).

Table 1: Distance weights to apply to five meteorological stations whose data are used to estimate temperature parameters at Kubekrom in Digya National Park

Station Name	Location		Distance to Kubekrom	Weight (100/Distance)	
	Latitude (degrees)	Longitude (degrees)			
(Kubekrom)	7.34N	0.24W	-	-	-
Ho	6.67	-0.50	111km	0.901	20%
Kete-Krachi	7.83	0	60	1.667	38
Koforidua	6.08	0.25	140	0.714	16
Akuse	6.17	-0.17	137	0.730	16
Yendi	9.42	0	232	0.431	10
				4.443	

Table 1 shows the results of applying the weighting scheme, showing how the temperature numbers for these selected weather stations determine the temperature estimate for Kubekrom. A sample calculation runs as follows in the station order given here:

$$0.20 \times 27.1 + 0.38 \times 27.6 + 0.16 \times 26.6 + 0.16 \times 27.7 + 0.10 \times 27.3 \qquad (2)$$

the result of which is 27.3 degrees Celsius for Kubekrom (estimate).

Table 2: Temperature (degrees Celcius) estimated at Kubekrom using Table 1 weights.

Year	Ho	Kete-Krachi	Koforidua	Akuse	Yendi	Kubekrom (estimate)
1978	27.1	27.6	26.6	27.7	27.3	27.3
1980	27.0	27.8	26.5	27.8	28.1	27.5
1985	27.3	27.8	26.8	27.5	27.6	27.5
1990	27.7	28.0	27.0	28.1	28.5	27.8
1991	27.3	27.7	26.7	27.8	27.8	27.5
1992	27.5	27.7	26.7	28.0	27.7	27.5
2000	27.8	28.1	27.2	28.5	28.1	28.0

All of the Kubekrom estimate (est) figures in Tables 2-4 were compiled in the same manner using the same weights.

The rainfall estimate for Kubekrom in Digya National Park is computed the same way as the estimates of temperature and humidity - that is, using the same weighting scheme identified in Table 1 above. The weighting scheme applied in Tables 2-4 raises an issue about the reliability of such estimates. This issue may be clarified by applying the weighting scheme to the data series from an actual station and then comparing the estimates from the weighting

scheme to the actual statistics reported by that station. This procedure shows that while the weighting scheme may lead to over or under-estimates of temperature by as much as 1 degree Celsius, it is also very well correlated with observation, so that the observations track the estimates very closely, within less than 0.2 degrees.

Table 3: Dewpoints estimated at Kubekrom using Table 1 weights

Year	Ho	Kete-Krachi	Koforidua	Akuse	Yendi	Kubekrom (estimate)
1978	22.5	22.0	23.0	22.9	20.1	22.2
1980	22.4	22.3	23.1	22.9	20.2	22.3
1985	22.2	21.1	22.6	22.7	19.4	21.6
1990	22.6	22.2	22.4	22.8	20.1	22.2
1991	22.7	22.7	22.6	23.0	20.3	22.5
1992	21.9	21.7	22.0	22.7	18.7	21.6
2000	22.5	22.1	22.8	23.6	19.5	22.3

Table 4: Mean annual monthly rainfall (millimetres) and Kubekrom estimates for certain years

Year	Ho	Kete-Krachi	Koforidua	Akuse	Yendi	Kubekrom (estimate)
1978	101	96	107	98	111	101
1980	119	113	128	96	83	111
1985	112	111	127	91	103	110
1990	97	111	109	76	78	99
1991	118	203	138	98	124	151
1992	67	88	86	65	77	79
2000	102	115	102	92	105	106
						108/20

The third and last shortcoming is more difficult to solve than the others because dewpoint data are often used to find relative humidity, and such information may be expected to be important in climate studies as it is a general property of an air mass as a whole apart from fluctuations in actual temperature. The reason for suspecting the dewpoint is a general property of an air mass comes from the familiar experience of everyone in widely divergent climates that the humidity tends to maximise near dawn when the temperature is low then fall to a relative minimum in the mid to late afternoon when the temperature is relatively high. The explanation is that the dewpoint is roughly the same at both times and is thus is a general property of the air. This is especially relevant in view of the widely shared belief that Ghana's climate is the result of the shifting convergence of two major air masses, one which forms over the Sahara Desert and the other which comes from the tropical Atlantic trade winds.

In the absence of dewpoint information from Ghana's Meteorological Agency, a mathematical dewpoint model was developed from Tennent (1971) standard data about the vapour pressure of air. Table 5 shows the data from Tennent (1971) between 0 and 50 Celsius, the range of chief interest in weather studies:

Table 5: Vapour pressure of air versus temperature and pressure estimation models

Temperature (Celsius)	Saturated Vapour Pressure (kilopascals)	Linear Log Model	Error	With Normal Boost	Error
0	0.6107	0.6107	0	0.617	0
5	0.8719	0.8249	-0.047	0.8678	-0.004
10	1.227	1.114	-0.113	1.219	-0.008
15	1.704	1.505	-0.199	1.694	-0.010
20	2.337	2.032	-0.305	2.327	-0.010
25	3.166	2.745	-0.421	3.161	-0.005
30	4.242	3.708	-0.534	4.245	0.003
40	7.375	6.764	-0.611	7.403	0.028
50	12.34	12.34	0	12.34	0

The model columns show how well the model of this study fits published physics data on the water saturation properties of air. It was found that the best type of function to use is one which correlates the Log of the pressure with the temperature. Linear/Linear and Log/Log models are less well correlated. But even with the Linear/Log approach, the predictions tend to fall below the empirical pressure figures in the middle of the temperature range. It was found that this prediction sag can be almost completely eliminated by multiplying the model by a Normal curve. The constraints determining the constants to use in defining the Normal curve are that the overall predicted values must be exactly correct for 0 and 50 degrees Celsius and also that prediction error should be a relative minimum for other temperatures between 0 and 50. The two simple model constants are K and L, while the Normal correction constants are C, V and M, as follows:

The simple Linear/Log model was found to be

$$\text{Log } P = -0.21417 + 0.02611 \text{x} T \tag{3}$$

With Normal correction (boost), this relation becomes

$$\text{Log } (P/1.151507) = -0.21417 + 0.02611 \text{x} T - ((T - 25)/101)^2 \tag{4}$$

Since this is quadratic in T due to the effect of the Normal correction term, solving for T (finding the inverse) involves solving a quadratic equation, with the following result:

$$T = 0.5 \, [LV+2C - \text{SQRT} \, ([LV+2C]^2 - 4[C^2 + V\text{Log}(P/M) - VK])] \tag{5}$$

where L=0.02611, K=-0.21417, C=25, V=10201 and M=1.151507.

The significance of this finding on the vapour pressure is as follows:

The relative humidity, by definition, is the ratio, expressed as a percentage, of the vapour pressure of air at its dewpoint to the vapour pressure of the air at its actual temperature. The dewpoint is experimentally found by lowering the temperature of a given air mass to the point at which droplets of water begin to form on a smooth glass slide. By definition, the relative humidity is exactly 100% for any temperature identical to the dewpoint. For example, using Table 5, if the current temperature is 30 Celsius and the dewpoint is 20 Celsius, then

the relative humidity is 100x2.337/4.242 or 55%. Using the corrected model, the vapour pressures are 4.245 and 2.327 respectively; so the calculated relative humidity would be 54.8%. Going the other way, of course, the dewpoint may be found from the corresponding vapour pressure. For instance, if the temperature is 30 Celsius and the humidity is 54.8% then the dewpoint vapour pressure is 4.245x54.8/100 or 2.335 kilopascals. Use of relation (5) then gives 20.0 as the dewpoint temperature.

Tables 1-5 present the results of using these two relations in calculating the dewpoint, as seen in the third column in each group of temperature data. Relations (4) and (5) may be illustrated by showing how to find the dewpoint for the 1978 mean temperature maximum (humidity minimum - at mid-afternoon) at the Ho weather station (Table 1). The annual temperature maximum on average, is 31.9 Celsius and the minimum humidity (at roughly 1500 hours) was 61%.

From relation (4) above, Log (P/1.151507) is

$$-0.21417 + 0.02611 \times 31.9 - ((31.9 - 25)/101)^2 \tag{6}$$

or 0.61407. It follows that

$$P/1.151507 = 10^{0.61407} = 4.1122 \tag{7}$$

Hence,

P = 4.7352 kilopascals

Since the listed humidity is 61%, it follows that the vapour pressure at the dewpoint is 4.7352 x 61/100 or 2.8885 kilopascals. To make effective use of relation (5) in finding the dewpoint temperature from the dewpoint vapour pressure, it is convenient to run a preliminary calculation evaluating the quantity LV+2C,
which appears twice in relation (5). This quantity is

$$0.02611 \times 10201 + 2 \times 25 = 316.348. \tag{8}$$

Hence, the dewpoint temperature is

$$0.5 \times [316.348 - \text{SQRT} ([316.348]^2 - 4[25^2 + 10201 \times \text{Log}(2.8885/1.151507) - 10201 \times 0.21417])] \tag{9}$$

or 23.5 Celsius, exactly the same answer found in Table 6 for the 1978 dewpoint under Temperature maxima. This is the temperature of a glass slide which, when suddenly exposed to air at 31.9 C and relative humidity 61%, would condense droplets of water out of that air mass.

3. RESULTS AND DISCUSSION

As noted above, familiar evidence of temperature and humidity variation during the day suggests that the dewpoints of air are relatively constant, thus permitting the mean dewpoint to be considered as a general property of an air mass. The data assembled in this paper at Tables 2-4 provide the confirmation of this view. Table 6 shows the mean temperature and dewpoint maxima and minima for each of the weather stations used to generate estimates at

Kubekrom in Digya National Park. The Range difference is the average of the maxima minus the average of the minima for each variable at each station.

Table 6: Average temperature and dewpoint maxima and minima at the five stations used to derive estimates at Kubekrom in the period 1978-2000

Station	Temperature maxima		Temperature minima		Range difference	
	T	**Dewpoint**	**T**	**Dewpoint**	**T**	**Dewpoint**
Ho	32.2	23.5	22.8	21.6	9.4	1.9
Kete-Krachi	32.6	22.4	23.3	21.4	9.3	1.0
Koforidua	31.8	24.3	21.9	21.1	9.9	3.2
Akuse	33.0	24.5	23.0	21.6	10.0	2.9
Yendi	33.8	20.9	22.2	18.1	11.6	2.8

T = Temperature

Two important facts are shown by Table 6. First, while the temperature variation at each station averages about 10 degrees, the dewpoint temperature variation averages only about 2 degrees. Secondly, the first four stations show very similar dewpoints on average, while Yendi station shows dewpoints significantly lower than those for the first four.

The location data of Table 1 suggest the reason for this latter contrast: Yendi, at 9.42 degrees North latitude, is located in the northern half of Ghana, and more than 230 kilometres North of Digya National Park (Figure 2). The northern portion of the country is plainly more influenced by air masses blowing into Ghana from the Sahara Desert than by air masses blowing into Ghana from the tropical maritime trade winds. The weather at Yendi is dominated by a different kind of air than that found in the southern half of the country, where the other stations are located. It is generally hotter at Yendi, and the humidity tends to be much lower, reflecting the drier air from the Sahara.

The main issue, however, is whether the climate variables influence forest cover and vegetation. Table 7 shows the data considered in the evaluation of the results of this paper. The T or temperature variable was selected from Table 2 Kubekrom estimates; the D or dewpoint variable was selected from Table 3 Kubekrom estimates; and the R or mean rainfall variable was obtained from the Kubekrom estimates in Table 2.

Table 7: Relationship between forest cover in Ghana and vegetation in Digya National Park and climate parameters

Year	Mean Temperature (Celsius)	Mean Dewpoint (Celcius)	Mean Rainfall (mm)	Forest Cover (million hectares)	Vegetation
Y	T	D	R	FC	NDVI
1978	27.3	22.2	101	1.90	0.411
1980	27.5	22.3	111	1.80	-
1985	27.5	21.6	110	1.70	0.301
1990	27.8	22.2	99	1.55	-
1991	27.5	22.5	151	1.53	0.219
1992	27.5	21.6	79	1.50	-
2000	28.0	22.3	106	1.31	0.103

The relationships between the independent climate variables and the dependent forest cover (FC) and vegetation (NDVI) variables are evaluated as shown in Tables 8-10. Table 8 gives the results of linear regression on the variables as shown in the Function column of this table. The probability of the null hypothesis (that is, the hypothesis that there is no difference between the value of r and zero) is listed in the p(Ho) column and was computed by finding the integral of the small-sample Student t Distribution between t and infinity for the t-score defined by

$$ t = \frac{r \times SQRT\ (DF)}{SQRT\ (1 - r^2)} \tag{10}$$

where DF is the number of degrees of freedom. The number of degrees of freedom in correlation studies is always equal to the number of observations minus the number of variables including the dependent variable in the regression analysis. In the Eval column of Table 8, S means statistically significant at least at the 95% level of confidence; NS means not statistically significant.

Table 8: Linear regression analysis of Table 7 data, using the same parameter labels

Function	Equation	r	DF	T	P(Ho)	Eval
FC on T	FC=20.73-0.693T	0.81	5	3.09	0.014	S
FC on D	FC=2.22-0.0276D	0.05	5	0.11	0.458	NS
FC on R	FC=1.63-0.0001R	0.02	5	0.03	0.489	NS
FC on T,D and R	FC=19.079-0.797T+0.220D-0.0033R	0.867	3	3.01	0.029	S
NDVI on T	NDVI=11.417-0.405T	0.93	2	3.54	0.036	S
NDVI on D	NDVI=2.862-0.118D	0.35	2	0.53	0.325	NS
NDVI on R	NDVI=0.434-0.0015R	0.26	2	0.39	0.367	NS
NDVI on T and R	NDVI=12.166-0.423T-0.00211R	0.9998	1	49.99	0.006	S

Table 9 shows how well the regression equation estimates the forest cover dependent variable. The actual statistics are from Fairhead and Leach and other sources as described above, and the estimates measures are calculated results from the relations found in Table 8. The Error results are merely the differences between the calculated estimates and the actual figures.

Table 9: Actual and estimated forest cover measures as found in Tables 7 and 8

Year	Actual	FC on T	Error	FC on T, D & R	Error
1978	1.90	1.81	-0.09	1.87	-0.03
1980	1.80	1.67	-0.13	1.70	-0.10
1985	1.70	1.67	-0.03	1.55	-0.15
1990	1.55	1.46	-0.09	1.48	-0.07
1991	1.53	1.67	0.14	1.61	0.08
1992	1.50	1.67	0.17	1.65	0.15
2000	1.31	1.33	0.02	1.32	0.01
			-0.00		**-0.02**

Table 10 shows how well the regression estimates for NDVI match the actual numbers found from satellite image data. Once again, the Errors are just the differences between the estimated figures and the actuals.

Table 10: Actual and estimated vegetation measures as found in Table 7

Year	Actual	NDVI on T	Error	NDVI on T & R	Error
1978	0.411	0.361	-0.050	0.406	-0.005
1985	0.301	0.280	-0.021	0.303	0.002
1991	0.219	0.280	0.061	0.216	-0.003
2000	0.103	0.077	-0.026	0.099	-0.004
			-0.009		**-0.003**

As shown in Table 8, both Ghanaian forest cover and vegetation at Digya National Park are both significantly affected by temperature. Further, both FC and NDVI are shown on an individual basis to be not significantly related to dewpoint and rainfall.

However, the multiple regressions of FC on T, D and R and of NDVI on T and R are significant. Further, the direction of the influence of rainfall on forest cover and NDVI is the same: negative. Both rainfall terms are found to have negative coefficients, each similar to the other. It is therefore suspected that some of the deforestation in Ghana and the loss of vegetation at Digya National Park are due to excessive flooding. This could be due to the accumulation of water backed up behind the Akosombo dam project. See Figure 1. To assess this suspicion more research will be required.

4. CONCLUSION

This paper found that the climate parameter, the dewpoint, does in fact behave the way temperature and humidity variations suggest, namely, it varies very little. This fact suggests that it is the type of climate variable descriptive of general air masses. It was found that the Northern part of the country, as measured at Yendi, is dominated by a different air mass than the Southern portion as measured by dewpoint data.

In addition, this paper found that both forest cover and vegetation are significantly related to temperature and that these two variables are not individually related either to the dewpoint or rainfall aspects of the climate. The specific nature of these relationships shows further that the direction of influence is the same: Forest cover declines with increasing temperature, and so does NDVI. In view of the facts that Ghana has suffered deforestation over the last century and that Digya National Park has shown loss of vegetation during the last two decades, the year-over-year average temperature increase must be part of the explanation for these losses. There are other factors, as well, such as logging, flooding, the search for fuelwood at a time of rising petrol prices; but the research above shows that no comprehensive report on deforestation and vegetation loss can be complete without considering the influence of the long-range increase in the temperature.

This research also shows, perhaps for the first time, that the dewpoint and rainfall aspects of climate are not significantly related to forest cover and vegetation, except by way of multiple regression analysis which suggests the possibility that rainfall in Ghana may at times be excessive, causing loss of vegetation. While this conclusion is inter-confirmed by the

analysis of both forest cover and vegetation (NDVI), it is suggestive only of the need to pursue further research.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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