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ANALYSIS OF MICRO CLIMATIC VARIATIONS IN JIMETA-YOLA, NIGERIA

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ABSTRACT

This study investigates the micro climatic variations in Jimeta-Yola in northern Nigeria. Ten stations were established in various locations within the town for the measurement of temperature and relative humidity. The measurement exercises were conducted in three phases in February, April and September of the year 2001 representing harmattan, dry and wet seasons respectively. Each phase of the observation was conducted simultaneously with that of Federal University of Technology, Yola (FUTY) weather station which formed the rural control site. Analysis of variance technique (ANOVA) was used to assess the variation of temperature within the city. Student t test was employed to assess the difference between the city and rural temperatures while Correlation analysis was used to examine the relationship between temperature, micro relief and population density of the city. ANOVA results indicate that there is significant variation in temperature within the city in all the seasons. The results of correlation analysis revealed that relief does not have significant influence on the micro climate of the area. On the other hand, population density was found to be the major factor responsible for variations in micro climate. Comparison of the rural and urban temperatures shows that temperature in the city is higher in February and April indicating an urban heat island effect of 3^0 C and 6^0 C respectively. The difference in September (a wet-month) is however, not significant because of the greater amount of cloud cover over the city. Consistent higher temperatures and lower relative humidity values in the city centre are attributed to greater heat absorption and storage capacity of the city structures.

Key Words: micro climate, urban heat island, temperature, humidity, Urban climate.

INTRODUCTION

The most spectacular way in which man modifies local climate is by the construction of large cities. Inside every city, there is a mass of buildings and pavements with a variety of shapes and orientations that profoundly transform the natural landscape into a city scape (Ojo, 1977). These buildings and pavements are composed mostly of rocky, steel, tarmac and brick materials with characteristically large thermal conductivities and heat capacities than most materials of the natural environments.

Faniran and Ojo (1980) have noted that the walls, roads and streets of cities do not only serve as reflectors but absorb parts of the energy received. These elements as well, direct parts of the solar energy to other absorbing surfaces within the city. Thus, almost every available surface within the city absorbs and stores parts of the energy available, only to release it to the environment whenever there is a deficit. On the other hand, outside the city, because there is a relatively greater cover of vegetation as well as greater areas of wet soils, much of the energy there is used for evaporation and evapotranspiration, which creates a cooler climate than those in the cities.

The activities of man also influence the microclimate of a city to a greater extent. For instance, cooking, heat and smokes from factories, vehicles and air conditioners make the city a generator of heat (Ayoade, 1983). This situation is compounded by the use of refrigerators as well as the greenhouse effects due to re-radiation of solar energy from the concrete and asphalt into a polluted atmosphere.

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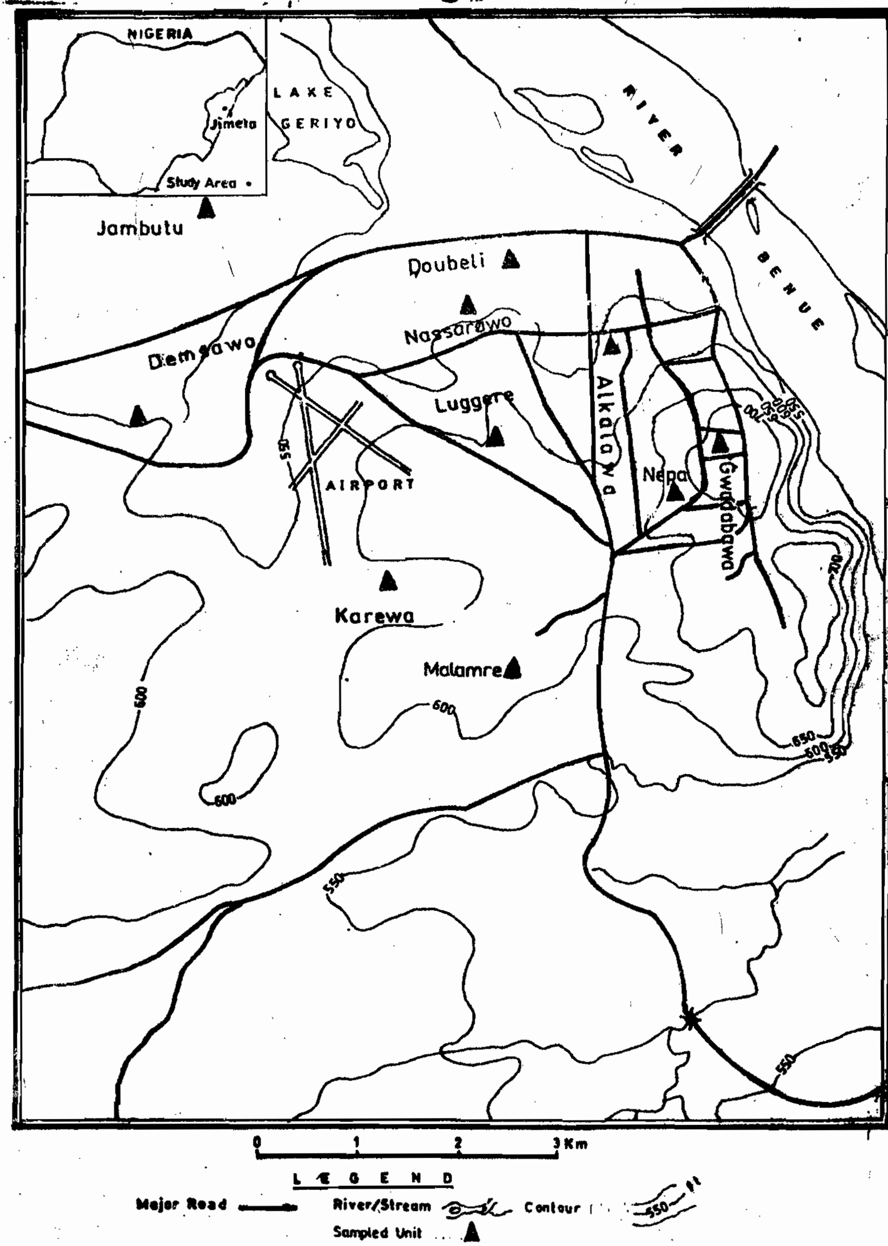

FIG. 1 : JIMETA, SHOWING ALTITUDE AND MEASUREMENT SITES
(SOURCE:- GREATER YOLA MASTER PLAN)

Oguntoyinbo (1978) has observed that precise data on the elements of climate in cities and their surrounding areas are fundamental to the study of urban heat inlands. However, the lack of observed data, especially in Nigeria because of the absence of remotely - sensed data, is a major limiting factor. Particularly, this limitation causes the inability to describe quantitatively the areal extent and exact distribution of variations in micro-climates. Hence, studies on the city climates are very few in the tropical world generally and Nigeria in particular. The only known studies in Nigeria are in Ibadan, southern Nigeria, by Oguntoyinbo (1978) and Adebayo (1985). It is against this background that this study is designed to examine the characteristics and variations of micro climate in Jimeta-Yola, a typical city in northern Nigeria. The study focuses attention on temperature and relative humidity variations within the city and between it and its rural environments.

THE STUDY AREA

Jimeta-Yola is located on latitude 9^0 14' and longitude 12^0 38'. The town lies within the Benue trough, at an approximate altitude of 189m above sea level (Figure 1). Jimeta - Yola falls within the tropical savannah climate with distinct wet and dry seasons. Dry season spans from November to April, while wet season lasts from May to October. The mean values for some climatic elements for twenty

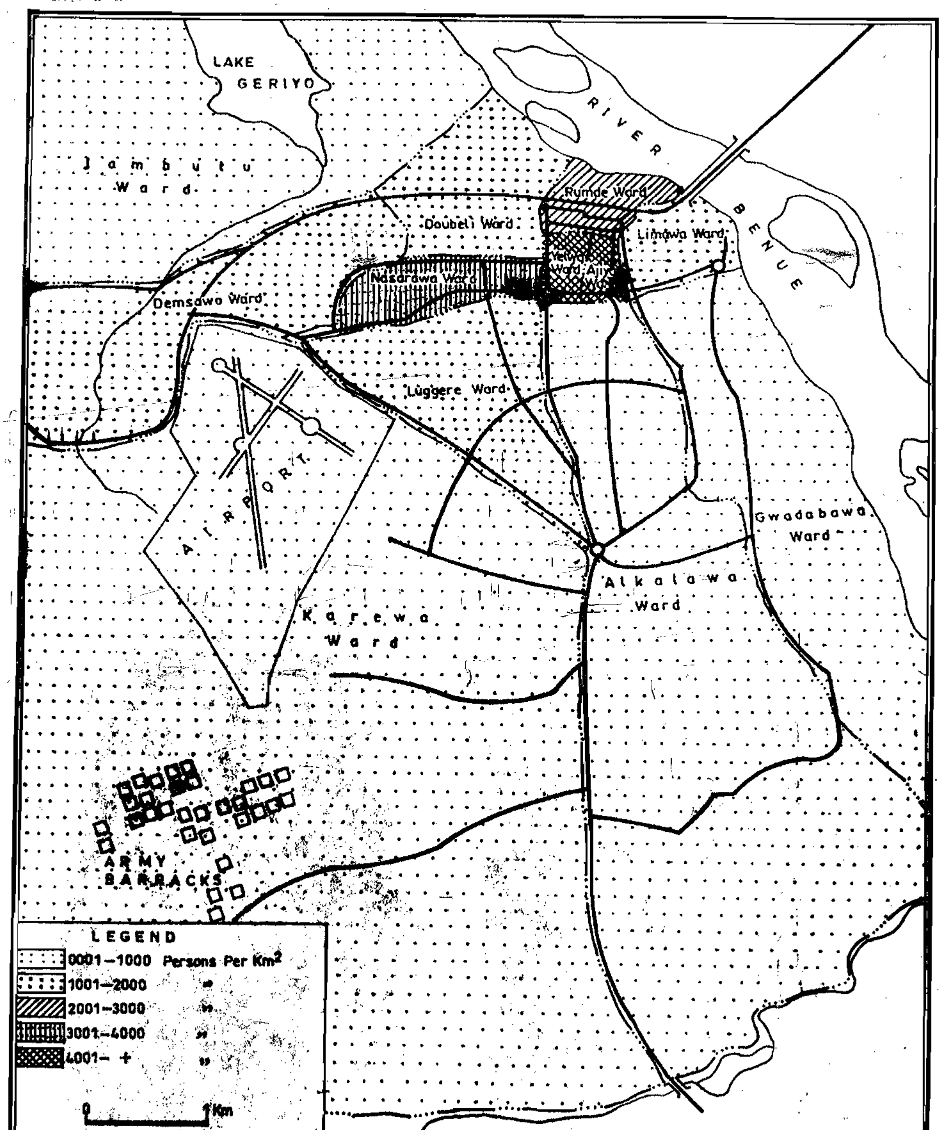

FIG. 2 : POPULATION DENSITY OF WARDS IN JIMETA
SOURCE : Raw data from National Population Commission, Yola.

years (1981-2000) are presented in table 1.

Temperature in Jimeta - Yola-Yola is generally high throughout the year, but there is usually a seasonal change. There is a gradual increase in temperature from January to April. The seasonal maxima usually occur in March or April. There is a distinct drop in temperature at the onset of rains. A slight increase after the cessation of rains (October-November) is common before the onset of harmattan in December when the temperature drops further. Between January and March, relative humidity is extremely low (25-34%) in Jimeta-Yola. It starts increasing as from April and reaches the peak (about 80%) in August. This is due to the influence of the humid maritime airmass which covers the whole area during this period. Relative humidity starts to decline again from October following the cessation of rains (Adebayo, 2001).

METHODS OF STUDY

Detailed micro climatic measurements of temperature and relative humidity were conducted in the 10 stations established in various wards within Jimeta - Yola town. The stations include Karewa, Demsawo, Doubeli, Nasarawo, Luggere, Jambutu, Alkalawa, Gwadabawa, Malamre and NEPA. The measurements were taken with the use of dry and wet bulb thermometers placed at the veranda, to get a required air temperature rather than sun's temperature. Federal University of Technology, Yola (FUTY) weather station located 9km from the city, was used as a control rural site. Observations and recordings of information from each of the ten established stations in the town were done by trained observers under the supervision of the researchers. In order to determine the peak periods of urban heat island effects, readings were taken at the various stations

Table 1: Mean Climatic Conditions of Jimeta-Yola (1981 - 2000)

Month	Rainfall (mm)	Temperature		Relative Humidity %
		Max. °C	Min. °C	
January	0.0	34.4	17.5	26
February	0.0	36.9	20.4	26
March	5.9	39.8	24.5	34
April	53.7	39.5	26.3	44
May	105.3	36.1	25.2	58
June	126.8	33.6	23.7	68
July	189.3	31.5	23.2	80
August	208.7	30.8	22.8	81
September	164.3	31.5	22.9	75
October	56.0	35.0	22.9	76
November	0.3	35.8	18.8	46
December	0.0	34.6	16.6	35

Source: Nigeria Meteorological Service, Yola, Nigeria (including the rural control site) simultaneously on hourly basis. Such observations lasted from 6am to 11pm daily for seven days. The experiment was done in three phases thus : February 5th to 11th representing conditions during harmattan periods ; April 11th to 16th representing dry season and September 11th to 16th representing wet season conditions. All these readings were taken in the year 2001. In order to establish the altitudes and geo-coordinates of each of the measurement sites, a GARMIN 12 hand held global positioning system (GPS) was used.

Both descriptive and inferential statistics were used in analyzing the data. The Inferential statistical techniques used in data analysis include correlation analysis to examine the relationship between temperature, altitude and population density; analysis of variance to assess the variation in temperature within the city and Student t-test to examine the difference between urban and rural temperatures.

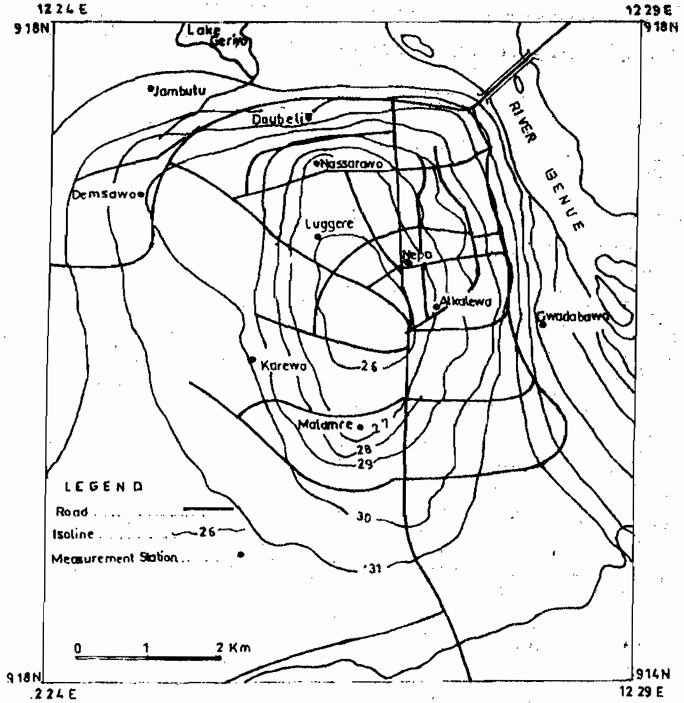

Fig. 4 Relative Humidity(%) Variations within Jimeta (Feb.,2001)

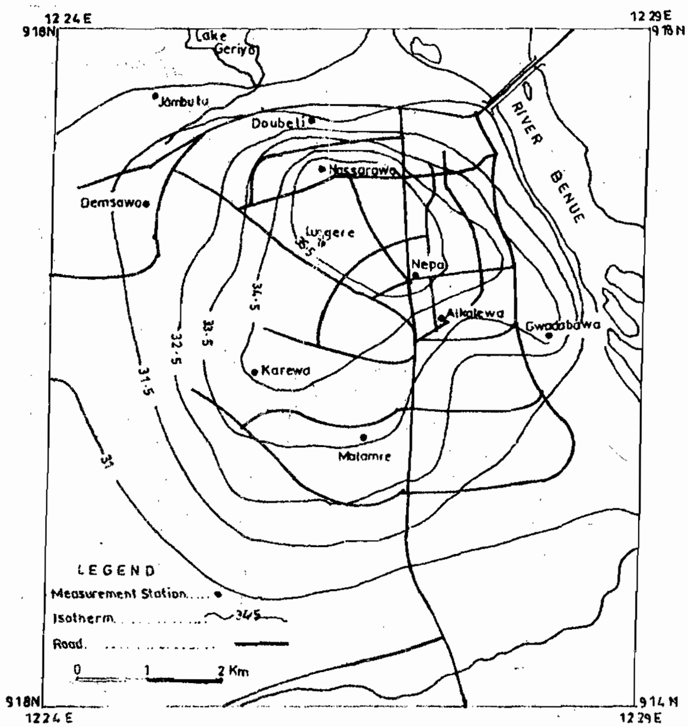

Fig. 3 Temperature (°C) Variations within Jimeta (Feb.,2001).

RESULTS AND DISCUSSIONS

General Physical Characteristics of Jimeta - Yola

The river Benue is the most conspicuous physical feature around Jimeta - Yola. Being situated very close to the river bank, the city lies on the flood plain with a gentle undulating topography (Fig. 1). Jimeta - Yola city exhibits the characteristics of a typical African city with cleared vegetation, reclaimed swampy areas, buildings of various sizes and orientations, criss-cross of road networks and concrete surfaces as well as open spaces like parks. Human activities from homes, small scale industries, transportation, etc serve as sources of pollution and heat generation in the city. With a projected population of 206,921 people, from 1991 census figure, Jimeta - Yola has eleven political wards. The wards include Karewa, Demsawo, Doubeli, Nasarawo, Luggere, Jambutu, Alkalawa, Gwadabawa, Malamre, Ajiya and Limawa.

Of these wards, Nasarawo, Luggere, Doubeli, and NEPA (Alkalawa) constitute the high density

Table 2: Mean Temperature and Relative Humidity Values in Jimeta - Yola (2001)

Station	AK	DB	DS	GD	JB	KR	LG	ML	NP	NS	Mean
TEMP Feb.	32.6	31.5	31.9	33.9	31.0	34.6	35.7	33.6	35.7	35.7	**33.6**
Apr.	40.8	38.2	42.2	44.2	40.6	40.5	46.8	40.6	43.2	45.3	**42.2**
Sep.	32.7	32.9	31.3	32.0	32.9	32.1	32.8	32.3	32.5	34.7	**32.6**
Mean	**35.4**	**34.2**	**35.1**	**36.7**	**34.8**	**35.7**	**38.4**	**35.5**	**37.1**	**38.6**	**36.1**
R/H Feb.	27.0	33.0	30.2	34.9	32.9	30.0	26.1	26.5	26.4	26.8	**29.4**
Apr.	40.2	56.0	49.6	62.6	58.1	47.7	44.6	44.1	43.1	43.0	**48.9**
Sep.	77.6	83.9	82.2	84.2	81.2	82.4	78.4	80.8	81.6	80.0	**81.1**
Mean	**48.3**	**57.6**	**54.0**	**60.0**	**57.4**	**53.4**	**49.7**	**50.5**	**50.4**	**50.0**	**53.1**

Source: Field work, 2001

Key

AK = Alkalawa, JB = Jambutu, ML = Malamre
DB = Doubeli, KR = Karewa, NP = NEPA
DS = Demsawo, LG = Luggere, NS = Nasarawo
GD = Gwadabawa,

areas. Most of the streets here are narrow. The houses are closely packed and are mostly of traditional types, owned by low income earners. In addition, most of the rooms are poorly ventilated without ceilings, air conditioners or fans. Moreover, there are frequent movements of cars and motor cycles. Heat generating activities like grinding machines, bread baking, local brewing and cooking with firewood are very common in these wards. Alkalawa, Demsawo and Gwadabawa are the medium density wards while Malamre, Karewa and Jambutu can be classified as the low density parts of Jimeta - Yola town (Fig.2).

Micro-Climatic Variations Within Jimeta - Yola

A. Seasonal Variations:

Table 2 shows the pattern of mean temperature and relative humidity for each observation sites in the three seasons in 2001. Generally, an appreciable variations in temperature and relative humidity can be clearly observed between the three seasons. February and September temperatures depict similar distributional pattern between the stations. The least mean temperature was recorded at Jambutu, Doubeli and Demsawo in February, April and September respectively. This is because, apart from the fact that these wards have low population density, they are also situated at the outskirts of the town very close to the Benue valley particularly Jambutu and Doubeli. However, Luggere, Nasarawo and NEPA, being high density wards located in the city centre, have consistently higher temperatures in all the seasons. Gwadabawa exhibits higher temperature of 44.2^{0} C in April which could be attributed to the thermal conductivity and heat capacity of the structures in the area. In April, the lowest temperature recorded (38.2^{0} C) in the city is more than the highest mean temperature recorded in February and September.

Variations in relative humidity are much more pronounced on seasonal basis. The values recorded in September are generally much higher than those of February and April. The prevailing humid maritime airmass during this period is responsible for this. The low values of relative humidity recorded in February are attributed to the effect of dry and dusty continental airmass (harmattan) during the period.

Table 3:Summary of ANOVA Results for the variation in February, April and September Temperature within Jimeta - Yola Town

Variation Tested	F-value	P	Test Result
Feb. Temp.	25.54	0.000	Significant at 1%.
April Temp.	6.58	0.000	Significant at 1%
Sept. Temp.	1.73	0.010	Significant at 10%

Table 4: Summary of Correlation Analysis Between Altitude,Temperature and Population Density and Temperature

Variation Tested	r	P	Test Result
Temperature and Attitude	-0.112	1.81	Not Significant
Temperature and Population Density	0.562	0.10	Significant at 10%

Table 5:Summary of T-Test of Difference Between Urban and Rural Temperature

Variable Tested	t-value	P	Test Result
Feb. Temp.	5.35	0.000	Significant at 1%
April Temp.	2.09	0.047	Significant at 5%
Sept. Temp.	1.45	0.016	Not Significant

B. Spatial Variation: Variations in micro-climate in the area were not only noticeable on seasonal basis but also spatially on daily basis according to the city's stratification(Figures 3 - 8). The maps shows that Nasarawo, Luggere and NEPA areas have consistently higher temperatures whereas places like Jambutu and Doubeli also have lower temperatures in all the seasons. This is because the former have high population densities whereas the latter are low density areas. On the other hand, temperatures at Karewa, Gwadabawa, Malamre, Demsawo and Alkalawa vary with seasons. For instance, whereas Karewa and Malamre fall under areas with higher temperatures in February, in September and April, they are among the areas with low temperature.

Significant spatial variation also occurred in relative humidity in Jimeta - Yola. However, variations in mean relative humidity are almost a reverse pattern of that of temperature. Generally, locations within the core of the city exhibit lower relative humidity values than those at the outskirt. For instance, NEPA, Alkalwa, Nasarawo and Malamre areas have consistently lower relative humidity values whereas places like Doubeli, Demsawo, Karewa etc have higher relative humidity. The areas with low relative humidity fall within the high density residential areas with narrow streets and congested buildings that tend to restrict wind flow, while places with high values are relatively low density areas which experience free flow of humid air from the rural environments.

In order to assess the variations in temperature within the town, analysis of variance (ANOVA) statistical technique was used. The result (Table 3) has shown that the null hypothesis had to be rejected in favour of the alternative hypothesis. This implies that there are significant variations in micro-

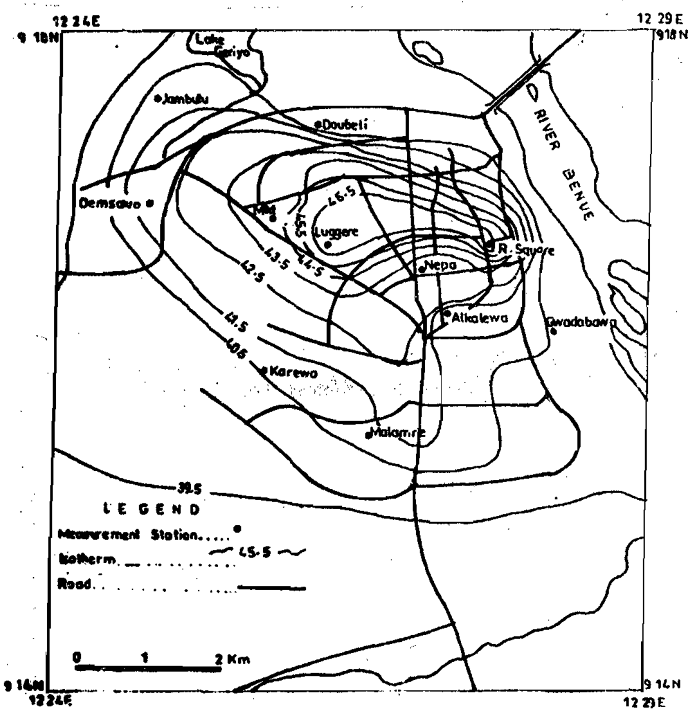

Fig. 5 Temperature(°C) Variations within Jimeta (April,2001).

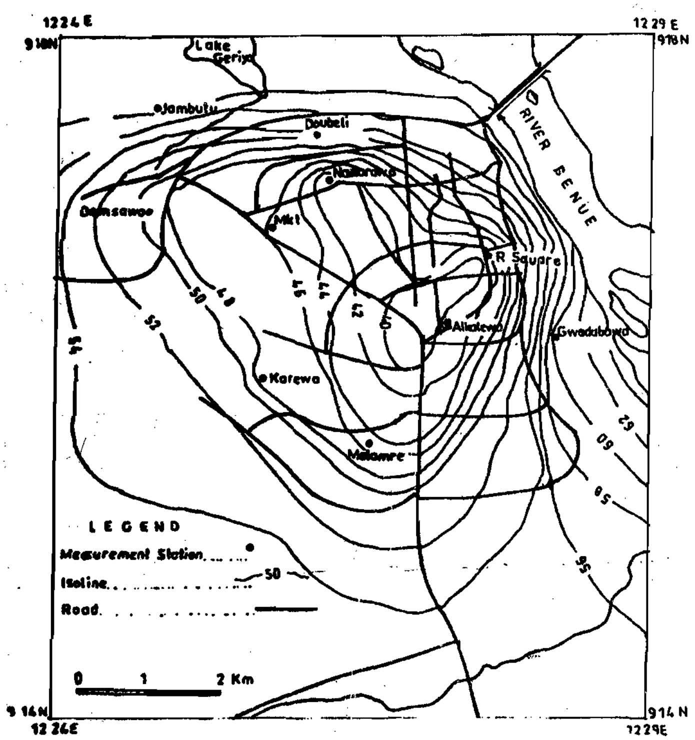

Fig. 6 Relative Humidity(%) Variations within Jimeta (April,2001).

climatic conditions within the town. The variation mostly occurs in February and April when it proved to be significant at 1% whereas the value of the level of significance at which this variation occurs in September is 10%.

Factors Influencing Micro-Climate in Jimeta - Yola

Several factors such as relief, vegetation, anthropogenic activities e.t.c influence the micro-climate of a given area. However, in this study, only the influence of relief and population density were examined. Correlation analysis was used to assess the relationship between temperature and these two factors. The results (Table4) show that there is no significant relationship between temperature and altitude of the stations. In other words, altitude does not play a significant role in temperature variation in the city. On the other hand, the result indicates that temperature is positively correlated with population density at 10% level of significance. This means that population density is a significant factor affecting temperature variation in the city. This is because areas with high population are always associated with numerous anthropogenic activities such as generations from home cooking, air pollution, traffic activities etc.

Occurrence of Urban Heat Island in Jimeta - Yola

Figures 3,5,&7 reveal a rapid increase in temperature from the outskirts to the city centre. In February, when the harmattan effect is being felt, the highest value of 35.7°C was recorded in the heavily built-up areas of Nasarawo, Luggere and NEPA compared to the rural site with only 30.4° C. This is a reflection of the high density of buildings and population in these areas which are also characterised by narrow streets and absence of open spaces between buildings. The heat island effect, therefore, accounted for a temperature difference of about 3°C in February.

Observations during the hot period in April showed that the city exerts much influence on the temperature. During this period, the temperature in the city centre was found to be 6°C higher than in the rural areas. The effect is higher than that obtained by Oguntoyimbo(1978) (4°C) in Ibadan and Botkin and Keller(1995) (2°C) in New York,U.S.A. but lower than that obtained by Lee(1992) (15°C) in Seoul city and Hanwell (8°C) in London. The marked increase in the heat during this period is attributable to clear and cloudless skies characteristic of the season. Under this condition, rapid increase of heat occurs because of the direct solar radiations and greenhouse effect provided by the pollutants as well as the thermal characteristics of the city structures.

In September, the heat island effect was lower than those of February and April. The highest heat island effect of 1.1°C was observed at Nasarawo.

The marked decrease in the heat island effect during this period is attributable to the greenhouse effect of clouds.

In order to assess the difference in temperature between the city centre and rural site, Student t-test was employed. The result indicated that at 1% and 5% levels of significance in respect of February and April observations respectively, a null hypothesis had to be rejected. However, a null hypothesis, at 5% level of significance, was accepted in the case of September temperature (Table 5). This means that there is significant difference in temperatures between the city centre and the rural site in February and April, whereas no significant difference occurred in September. Lack of significant difference in rural-urban temperature in September, can be attributed to the effect of cloud cover.

CONCLUSION

The result of this study has shown that urban morphology and residential stratification account for the temperature and humidity variations within the city. The high density city centre exhibits a typical heat island effect of 3° C and 6° C in February and April respectively. The higher temperature and lower humidity in the city centre are due to greater heat absorption and storage capacity of the city structures. In addition, other anthropogenic activities and the general lack of town planning which resulted to closely packed buildings without well laid out streets also contributed to the occurrence urban heat island in Jimeta - Yola.

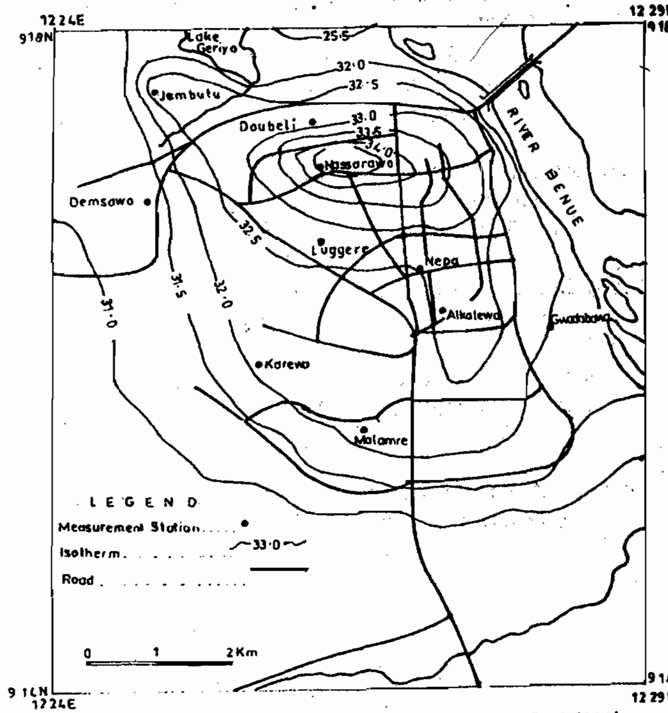

Fig. 7 Temperature (°C) Variations within Jimeta (Sept,2001).

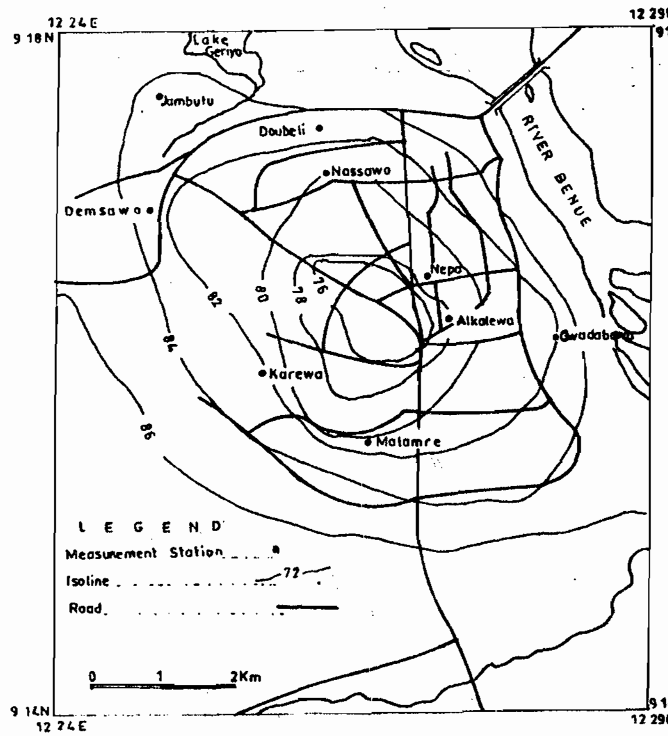

Fig. 8 Relative Humidity(%) Variations within Jimeta (Sept.,2001)

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