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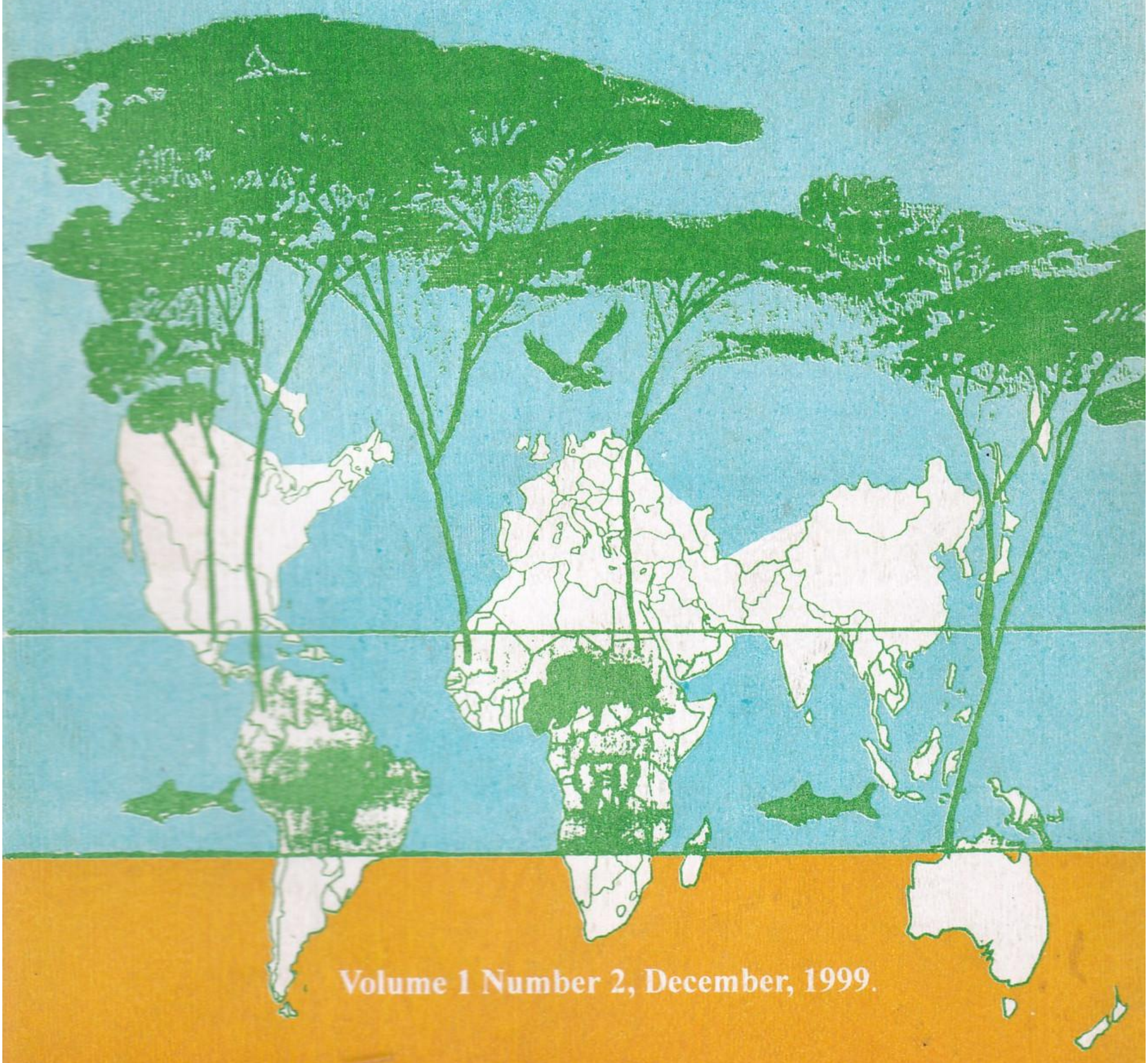

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# Radiation flux over bare soil in humid tropical environment

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**ABSTRACT** - Radiation fluxes over the bare ground within the urban centre of Aba was measured using both the solari-albedometer and net radiometers. This was done to determine the magnitudes of the global radiation, the albedo, the net long wave radiation and the net radiation. This is believed to be relevant in producing the energetic regimes of the bare soil surface. Results show that global radiation varied from 0.423gcal/cm$^2$/min (0.29$^5$ Ikg M-$^2$S$^{-1}$) to 0.671gcal/cm$^2$/min (0.468Ikg m-2S-1). The daily pattern was that of increase from early morning till late afternoon and thereafter a decrease in the pattern. The seasonal pattern showed an increase from wet season. The net long wave dry season values increase from morning to afternoon and decrease thereafter. For the wet season the net long wave reduced from morning to afternoon. The net radiation over the bare ground exhibited minimum values during the rainy season. It is pertinent to note that though the global radiation over the bare ground surface may not differ from those of other surface within any given time (Ekanem, 1997) but the albedo factor, and the net radiation show marked variation from other surfaces (Ekanem, 1999). This has implications for the overall energy regime of the urban centre.

**Keywords:** Radiation, Flux, Soil, Aba, Albedo.

## INTRODUCTION

The direct measurement of radiation fluxes over any kind of surface in a tropical environment are few (Oguntoyingbo, 1971). Estimation of the radiation flux in the tropics has been the most frequently used method to obtain the radiation values. Results from extrapolation and empirical formulae from extratropical areas are generally unsatisfactory (Ayoade, 1980). This work is an attempt at measuring the radiation balance over the bare ground in the urban environment of Aba. This paper summarises the results of the measurement and compares these with those derived from empirical formulae.

## AIMS AND OBJECTIVES

The main aim of this study was to determine the character of the radiation fluxes over the bare ground soils in Aba urban. The detailed objectives of the study then were to:

1. Determine the magnitude of global radiation over the bare ground.
2. Determine the values of the albedo over the same surface.
3. Examine the magnitude of the long wave radiation over the bare soil surface.
4. Determine the values of the net radiation over the bare ground.

It is believed that the data generated and the analysis will be of use in the prediction of the energetic regimes over the bare soil surface within the urban environment.

## STUDY AREA

Thid study was conducted in a humid tropical city of Aba. The choice of Aba was because it is a medium size city being that most other studies were done in large urban centres like Lagos and Ibadan (Ojo, 1988; Adebayo, 1985).

Aba is located in the eastern part of the country with a purely continental environment. It lies at about $5^0$.06'N and $7^0$.21'E(Fig. 1). Aba is generally less than 100 meters above sea level (Ofomota, 1975), with a diameter of about 12 kilometers. It can be classed as a tropical rainy - hot climate with high temperatures, high rainfall and high relative humidities.

## MATERIALS AND METHODS

Measurements of global radiation, albedo and net radiation were done over a bare ground surface in an urban environment of Aba. The measurements were done for twelve calendar months of the year (May - June). The instruments used for the measurements were:

a. Solari-albedo meter used for measurement of the global radiation and the reflectivity coefficient.
b. Type S-1 radiometer-net radiation.
c. Thornthwaite Model 603 net radiometer-net radiation.

To obtain the diurnal pattern, five consecutive measurements were taken at (07.00 hour, 10.00 hour, 13.00 hour, 16.00 hour and 18.00 hour) within the chosen day. However, the mean monthly values were used for the analysis.

The instruments were used to obtain the global radiation albedo and the net radiation of the surface. The long wave radiation was computed from the other three parameters.

## RESULTS AND DISCUSSION

Three parameters were measured, namely the global radiation (Q + q); albedo 9); net radiation (Rn). The long wave parameter (L*) was computed from the other three, using the equation (Q + q) (1 - ) + L* = RN.

## GLOBAL RADIATION (Q + q)

The values of the global radiation over the bare ground surface varied from 0.388gcal/$cm^2$ /min (0.271skg $m_{;}^{-2}$ $S^{-1}$ ) to 0.502gcal/$cm^2$ /min (0.350skg $m^{-2}$-$^{-1}$5 ) during the early morning (0.700 hour). The monthly average for this early morning stood at about 0.423gcal/cm/min (0.295Skg $m^{-2}$ $5^1$).

For the early morning period the seasonal variation showed a decline from the late dry season through the wet season with a minimum in August. Thereafter there was a steady increase. However, there was some some rapid increase during the transition months of October and November.

***Radiation flux***

By late morning (10.00 hour) there was an increase in the monthly average values of the global radiation. The least value recorded during this period was 0.486gcal/cm²/min (0.399Skg m⁻² 5⁻¹ ) which was observed in August while the maximum value of 0.560gcal/cm²/ min (0.391Jkg m⁻² 5-1) was recorded in March. The afternoon (13.00 hour) and late after (16.00 hour periods recorded the highest values of 0.672gcal/cm²/min (0.469 and 0.476Ikg m-2 s -1) respectfully which were observed in March. The least values of these periods were recorded in the month of August(0.608gcal/cm²/min (0.424Skg m⁻² s⁻¹) and 0.624gcal/cm²/min (0.435jkg m⁻² s⁻¹) respectively. The average values for the periods were 0.643gcal/cm²/min (o.449kg m⁻² s⁻¹) and 0.654gcal/cm²/min (0,456Jkg m⁻² s⁻¹) respectively. The evening values showed a substantial decrease from those of the afternooon and late afternoon. The minimum value was still recorded in August as 0.420gcal/cm2/min (0.293Jkg m⁻² s²) while the maximum value of 0.472gcal/cm²/min (0.329Jkg m⁻² s⁻¹) was obtaind iin march in March.

The average for this period was about 0.446gcal/cm²/min (0.311jkg m-2 s-1). Generally, therefore, the diurnal pattern showed a trend of increase from morning till late afternoon. Thereafter it began to decrease. On monthly basis, the pattern exhibited a trend of decrease with the rains and thereafter it picked up gradually and began to increase during the dry season until it reached the peak within the months of February/March. Thereafter, there was a rather sharp decline in the value of global radiation with the onset of the rains. (Table 1 and Figs. 2 and 3).

## ALBEDO

The reflection coefficient (albedo) of the bare ground surface exhibited a unique pattern. The early morning values and the evening values were higher than those of the afternoon. However it is worth noting that the variation between those of the morning and evening on the one handand those of the early and late afternoon on the other was not much. The average morning value was 15.5% while that of the late morning was 13.14%. Afternoon recorded 9.47%, late afternoon9.46% while the evening was 12.89%. The variation in the value of albedo being as much as 6.11%. The all time monthly average albedo was 11.40% over the bare ground. This was lower than that of the grass surface which recorded a monthly all time over average of 12.53% while that of water was 14.11%. This is only true for polluted water (Ekanem, 1997). It is significant that the monthly pattern of the albedo over the bare ground is more predictable and shows a more bare ground surface,. there was an increase of albedo with increase global radiation. High values were recorded at the onset of the rains, but this pattern changed to low values at the peak of the rains in August/September. Thereafter there was an increase of the albedo values until another peak was reached in February, the peak of the dry season. Thereafter it began to decrease gradually again.

The dry season averages were higher than the wet season values at all times. This could be because during the dry season the rays of the sun are more oblique for the location of Aba (where the measurements were taken) than during the wet season and oblique rays suffer greater reflection than direct rays (Ekanem, 1997; Seller and Robinson, 1986). Also contamination in the air is more in the dry season, as a result of dust. Table 2 and Figs. 4 and 5 show the pattern of this variable decreasing from morning till late afternoon and increasing thereafter.

## LONG WAVE RADIATION

The long wave radiation over the bare ground seemed to exhibit more positive pattern than other surfaces like water and grass (Ekanem, 1997). The positive values were dominant in the rainy months with the negative values being dominant in the dry season months of December to February. Thereafter, it began to increase again. This pattern could be as a result of the increased cloudiness during the rainy season. Cloudiness and atmospheric pollutants like dust, smoke are known to increase counter radiation and reduce the escape of terrertial radiation. The average monthly values of the long wave for the surface was 0.012gcal/cm$^2$/min (0.008Jkg m$^{-2}$ S$^{-1}$).

However, there seemed to be some marked disparities between the diurnal and seasonal patterns. The early mornings and evenings seemed to have higher values than the mid-days. This must have been due to the near clear atmosphere of the afternoon which allows for increased escape of the long wave radiation. This was also applicable to the dry season period whose values ran in the negative pattern. It meant that this period had higher outgoing long wave values to the point that the terrertial radiation became higher than what was returned as counter or re-radiation. While the dry season increased from morning to afternoon and late afternoon, the least values were in the morning and the evenings. It meant that counter radiation were lower in the afternoon than in the mornings and evenings. This could be as a result of clearer skies experienced during the day in addition to increased insulation. However it is worth noting that the values of mornings were higher than those of the evenings over the bare ground. This could be ascribed to the reduced global radiation for this period. The wet season pattern, however, showed the reverse, which was on the positive side as against the dry season which was on the negative. Here, the net outgoing long wave decreased from morning towards the afternoon. There was, however, an indication of an increase in the terrestial radiation escaping into space from morning (1-1). In other words, during the rainy season, the terrertial radiation is not enough to meet the counter radiation (1-1), and there is an increase in the amount of the outgoing terrertial radiation into space (1 ) towards the afternoon. Table 3 and Figs. 6 and 7 show the trends of long wave radiation over the bare ground surface.

## NET RADIATION

Over the bare ground surface, the net radiation pattern exhibited the minimum values during the rains (June) with a value of about 0.297gcal/cm$^2$/min (0.207Jkg m$^{-2}$ s$^{-1}$) in the morning. Thereafter it began to increase until it reached the peak at the height of the dry season (February) with 0.413gcal/cm$^2$/min (0.288Jkg m$^{2}$ s$^{-}$ )

showing about 40% increase from that of the wet season. There was an increase in the net radiation in the late morning. This was as a result of an increase in the total morning global radiation. The minium value occured in the middle of the rains (June) (0.408gcal/cm$^2$/min 0.284Jkg m-$^2$ s -1, while the maximum occured in February, the climax of the dry season (0.477gcal/cm$^2$/min) ( 0.333Jkg m$^2$ s$^1$ ). The overall monthly average for this period was 0.431gcal/cm$^2$/min (0.301Jkg m-$^2$ s $^{-1}$).

The early afternoon and late afternoon had the highest values of net radiation over the bare ground. The afternoon minium, 0.531gcal/cm$^2$/min (0.370Jkg m$^{-2}$ s $^{-1}$) occured in June while the maximum value of this time was recdorded in January and February (0.616gcal/cm2/min) (0.430Ikg m$^{-2}$ s $^{-1}$). The overall monthly average value at this time was 0.575gcal/cm2/min (0.40Jkg m$^{-2}$ s -1). The overall average of late afternoon was 0.546gcal/cm$^2$/min (0.405Jkg m-$^2$ s $^{-1}$) while the minimum of 0.546gcal/cm$^2$/min (0.38Jkg m$^{-2}$ s$^{-1}$) was observed in June and the maximum value of 0.607gcal/cm$^2$/min (0.424IJkg m$^{-2}$ -s $^{-1}$) was observed in February . The pattern was that of a steady increase from the middle of the rains until the maximum was recorded at the climax of the dry season. This pattern could be attributed to the steady departure or gradual cessation of the rains. By evening the values of the net radiation decreased to 0.348gcal/cm$^2$/min (0.243Jkg m$^2$ $^{-1}$s ) in June (minimum) and 0.415gcal/cm$^2$/min (0.280Jkg m$^{-2}$ s $^{-1}$) (maximum) in February. The general monthly average was 0.379gcal /cm$^2$/min (0.264Jkg m$^{-2}$ s $^{-1}$).

It is worth mentioning here that while there was a steady increase of the net radiation from the middle of the rains towards the dry season, there was a sharp drop of the net radiation values as soon as the rains started in earnest in the months of April. For instance, in the evening there was a recorded 10% drop in the value of the net radiation between the months of April and March. The diurnal pattern of net radiation exhibited a markedly higher values in the afternoons and evenings than in the mornings. The general overall monthly average values of net radiation over bare ground was 0.462gcal/cm$^2$/min (0.322Jkg m-$^2$ s-$^1$).

The monthly average and the wet season average show the peak in the late afternoon while the dry season average shows the peak in the early afternoon. This is an evidence that, on the average the late afternoon period has the highest net radiation. Table 4 and Figs. 8 and 9 show the pattern of net radiation over bare ground surface.

## CONCLUSION

It is apparent from the results that the global radiation over the bare ground surface may not be different from to her surfaces within any given time (Ekanem, 1997) but the albedo factor and the net radiation components show marked variation from the other surfaces as the bare ground values of net radiation are lower than those of other urban surfaces (Ekanem, 1999). The main contributing factor to this is the character of the bare ground, which has a higher albedo. This has a significant role in the reduction of the overall energetics of the urban environment. There is therefore the need to leave some of the areas of the urban centre as bare ground as it will also supplement the "green areas" in reducing the surplus energy experienced in the urban areas.

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***Radiation flux***

**Table 1: Global radiation over bare ground surface at Aba (gcal/cm²/min) (*Jkg m⁻² s⁻¹)**

| Time Hours | Monthly Average | | Dry Season Average | | Wet Season Average | | Global Radiation Range | |
|---|---|---|---|---|---|---|---|---|
| 7.00am 07.00 | 0.423 | 0.295 | 0.453 | 0.316 | 0.408 | 0.285 | 0.388-0.502 | 0.271-0.350 |
| 10.00am 10.00 | 0.511 | 0.357 | 0.539 | 0.376 | 0.498 | 0.347 | 0.084-0.560 | 0.339-0.391 |
| 1.00pm 13.00 | 0.643 | 0.449 | 0.673 | 0.469 | 0.629 | 0.438 | 0.606-0.672 | 0.424-0.469 |
| 4.00pm 16.00 | 0.654 | 0.456 | 0.671 | 0.468 | 0.647 | 0.451 | 0.624-0.882 | 0.435-0.476 |
| 6.00pm 18.00 | 0.446 | 0.311 | 0.478 | 0.328 | 0.434 | 0.303 | 0.420-0.472 | 0.293-0.329 |
| MEAN | 0.535 | 0.374 | 0.501 | 0.406 | 0.523 | 0.365 | 0.505-0.578 | 0.352-0.403 |

Source: Field Data

**Table 2: Albedo over bare ground surface at Aba (%)**

| Time Hour | Monthly Average | Dry Season Average | Wet Season Average | Albedo Range |
|---|---|---|---|---|
| 07.00 7.00am | 15.57 | 17.78 | 14.46 | 12.00-18.20 |
| 10.00 10.00am | 13.14 | 15.73 | 11.85 | 10.60-16.20 |
| 13.00 1.00pm | 9.47 | 11.23 | 8.58 | 7.00-12.00 |
| 16.00 4.00pm | 9.46 | 11.10 | 8.64 | 7.00-11.80 |
| 18.00 6.00pm | 12.89 | 15.53 | 11.58 | 10.40-16.00 |
| MEAN | 12.11 | 14.27 | 11.02 | 9.40-14.84 |

Table 3: Average long wave radiation over bare ground surface at Aba (gcal/cm²/min) (*Jkg $m^{-2}$ $s^{-1}$)

| Time | Hour | Monthly average | | Dry season average | | Wet season average | | Long wave radiation range | |
|---|---|---|---|---|---|---|---|---|---|
| 0700 | 7.00am | 0.016 | 0.011* | -0.007 | 0.005* | 0.24 | 0.017* | -0.001-0.034 | -0.00-10.024* |
| 1000 | 10.00am | 0.013 | 0.009 | -0.008 | -0.006 | 0.020 | 0.014 | -0.009-0.030 | -0.006-0.021 |
| 1300 | 1.00pm | 0.007 | 0.005 | -0.012 | -0.008 | 0.016 | 0.011 | -0.02-0.028 | -0.014-0.019 |
| 1600 | 4.00pm | 0.008 | 0.006 | -0.009 | -0.006 | 0.020 | 0.014 | -0.012-0.030 | -0.088-0.006 |
| 1800 | 6.00pm | 0.010 | 0.007 | -0.004 | -0.003 | 0.017 | 0.012 | -0.016-0.027 | -0.011-0,019 |
| Mean | | 0.011 | 0.008 | -0.008 | -0.006 | 0.019 | 0.014 | -0.012-0.030 | -0.008-0.018 |

Source: Derived from field data.

**Table 4: Average net radiation over bare ground surfaces at Aba (gcal/cm²/min) (*Jkg m-² s-¹)**

| Time | Hour | Monthly average | | Dry season average | | Wet season average | | Long wave radiation range | |
|---|---|---|---|---|---|---|---|---|---|
| 0700 | 7.00am | 0.341 | 0.238* | 0.374 | 0.261* | 0.325 | 0.227* | 0.297-0.413 | 0.207- 0.288* |
| 1000 | 10.00am | 0.431 | 0.301 | 0.456 | 0.318 | 0.418 | 0.292 | 0.408-0.477 | 0.284-0.333 |
| 1300 | 1.00pm | 0.575 | 0.401 | 0.610 | 0.426 | 0.558 | 0.389 | 0.531-0.616 | 0.370-0.430 |
| 1600 | 4.00pm | 0.581 | 0.401 | 0.602 | 0.420 | 0.570 | 0.398 | 0.456-0.607 | 0.381-0.424 |
| 1800 | 6.00pm | 0.379 | 0.264 | 0.401 | 0.280 | 0.367 | 0.256 | 0.348-0.415 | 0.243-0.290 |
| Mean | | 0.461 | 0.322 | 0.489 | 0.341 | 0.448 | 0.312 | 0.426-0.506 | 0.297-0.353 |

Source: Derived from field data.

***Radiation flux***


Fig 1a: Abia state showing the location of Aba(study area)

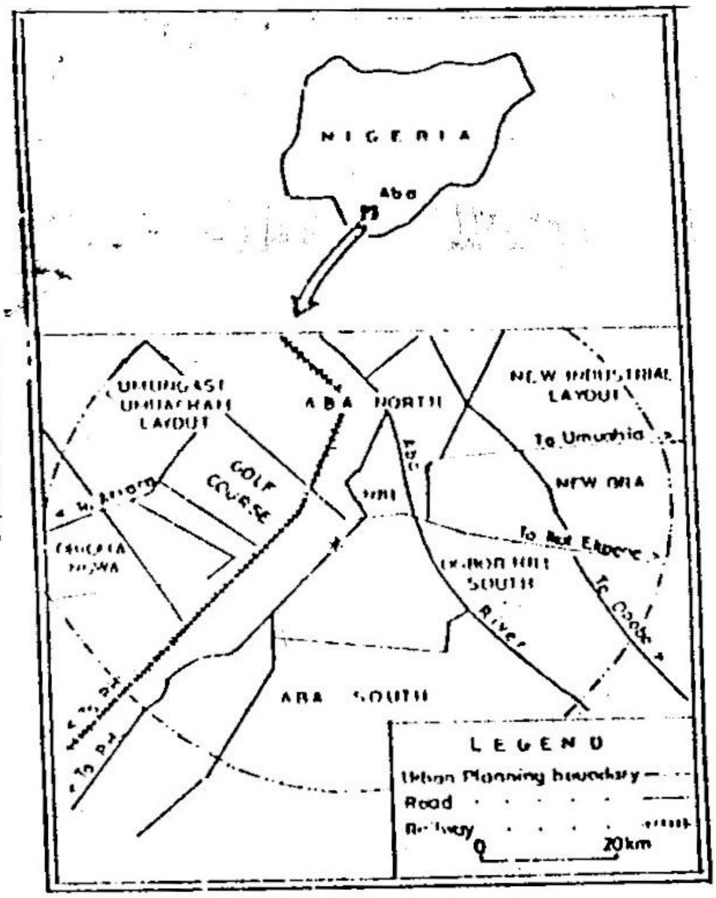


Fig.1b Point of measurement ; *

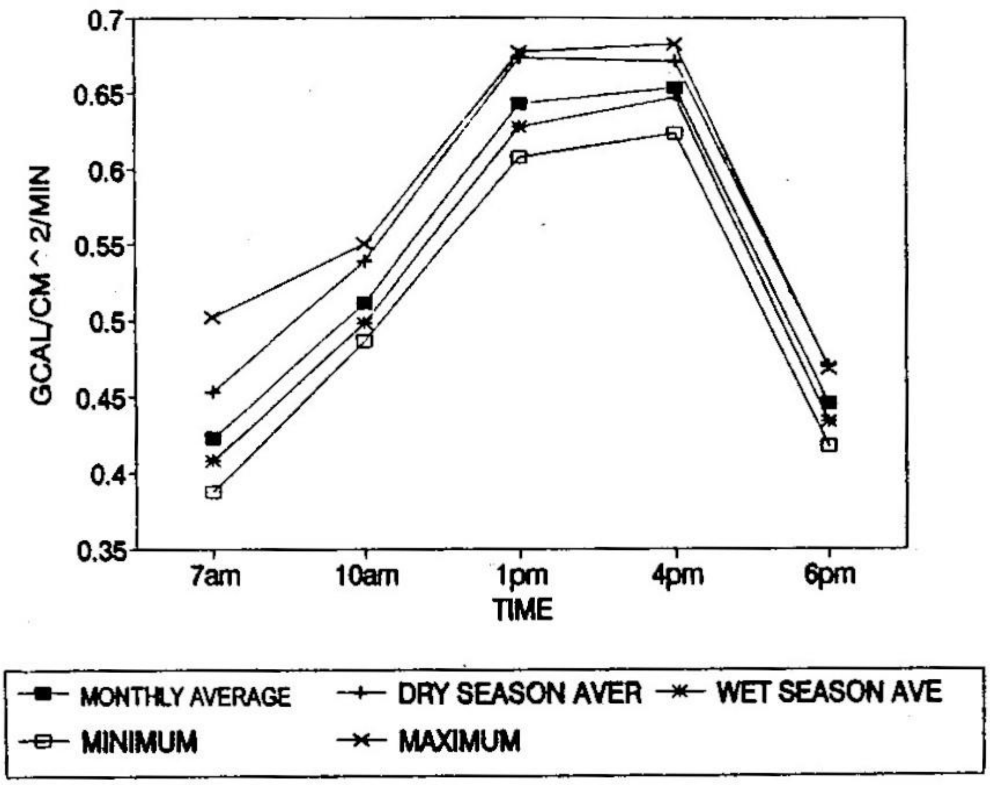


**Fig. 2 Average global radiation over bare ground surface**

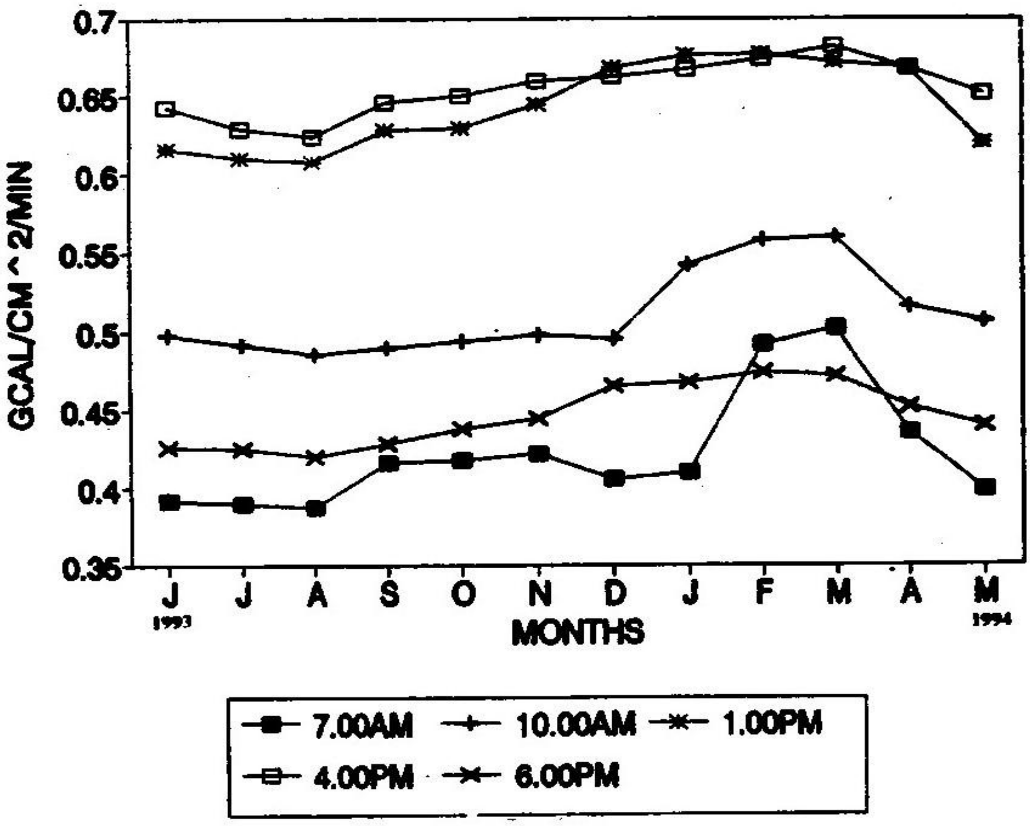


Fig. 3 Monthly average global radiation over bare ground surface

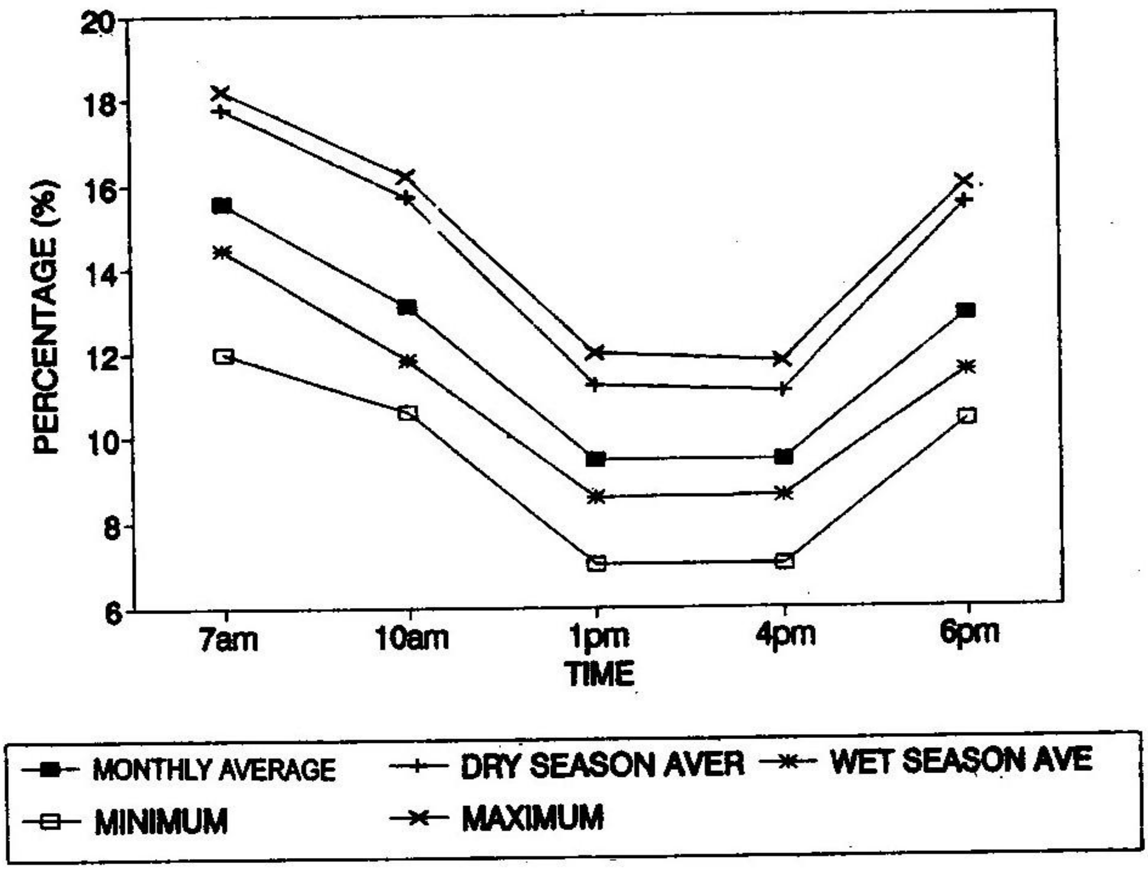


Fig. 4 Average albedo over bare ground surface

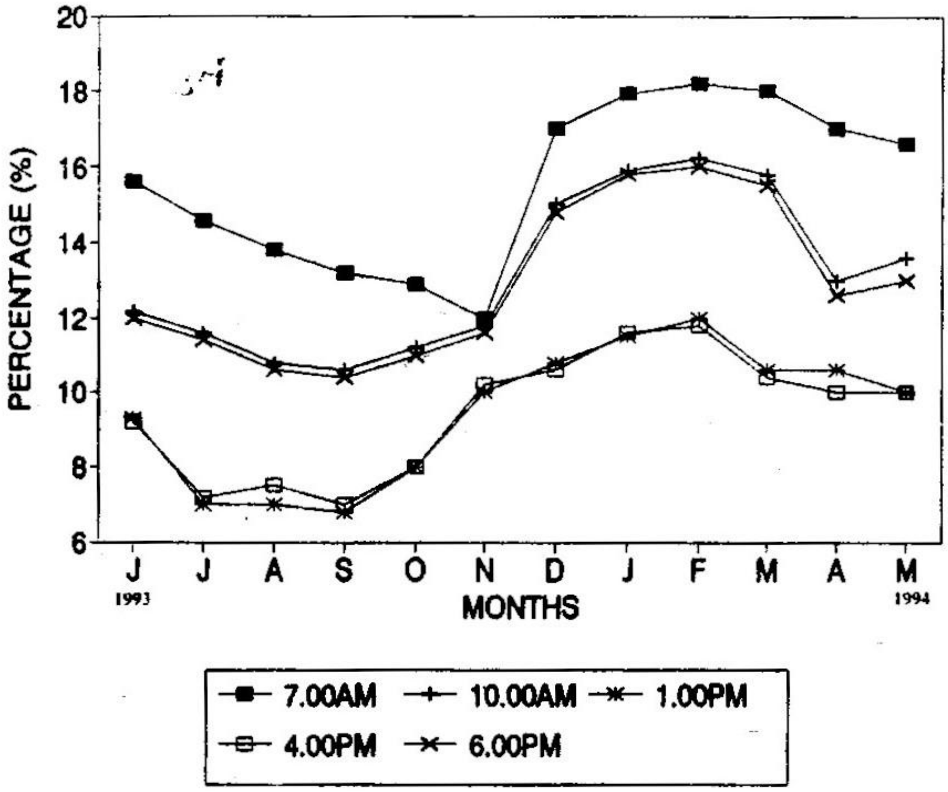


Fig. 5 Monthly average albedo over bare ground surface

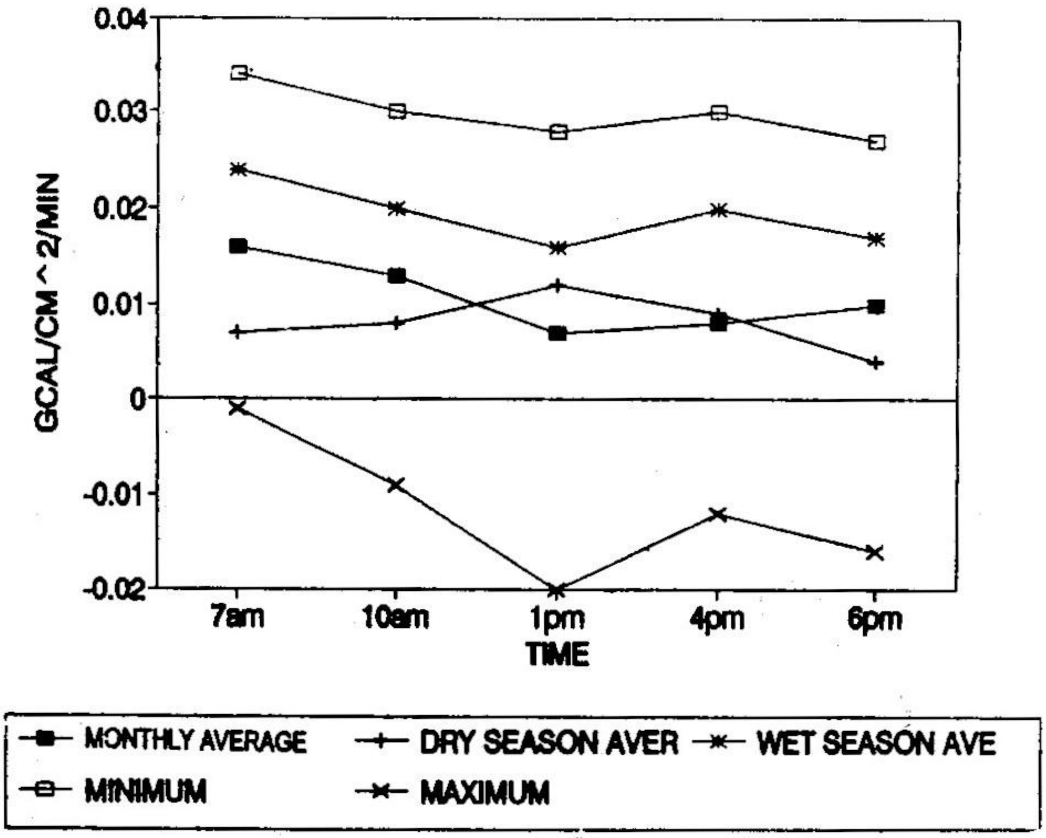


Fig. 6 Average long wave radiation over bare ground surface

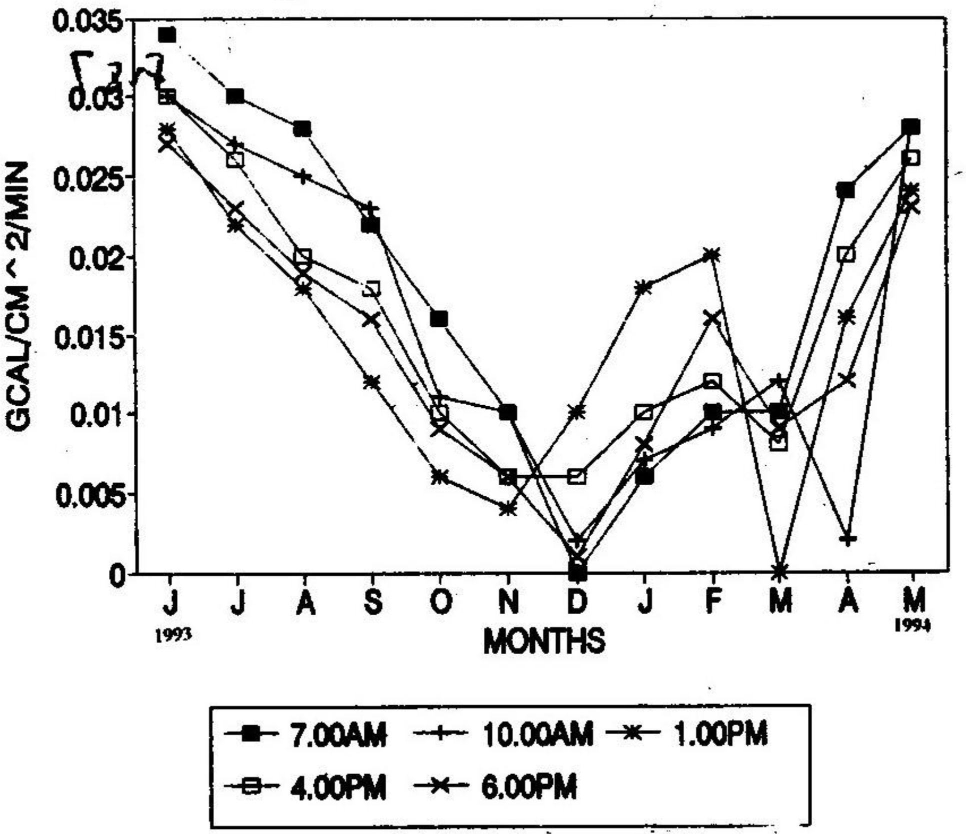


Fig. 7 Monthly average long wave radiation over bare ground surface

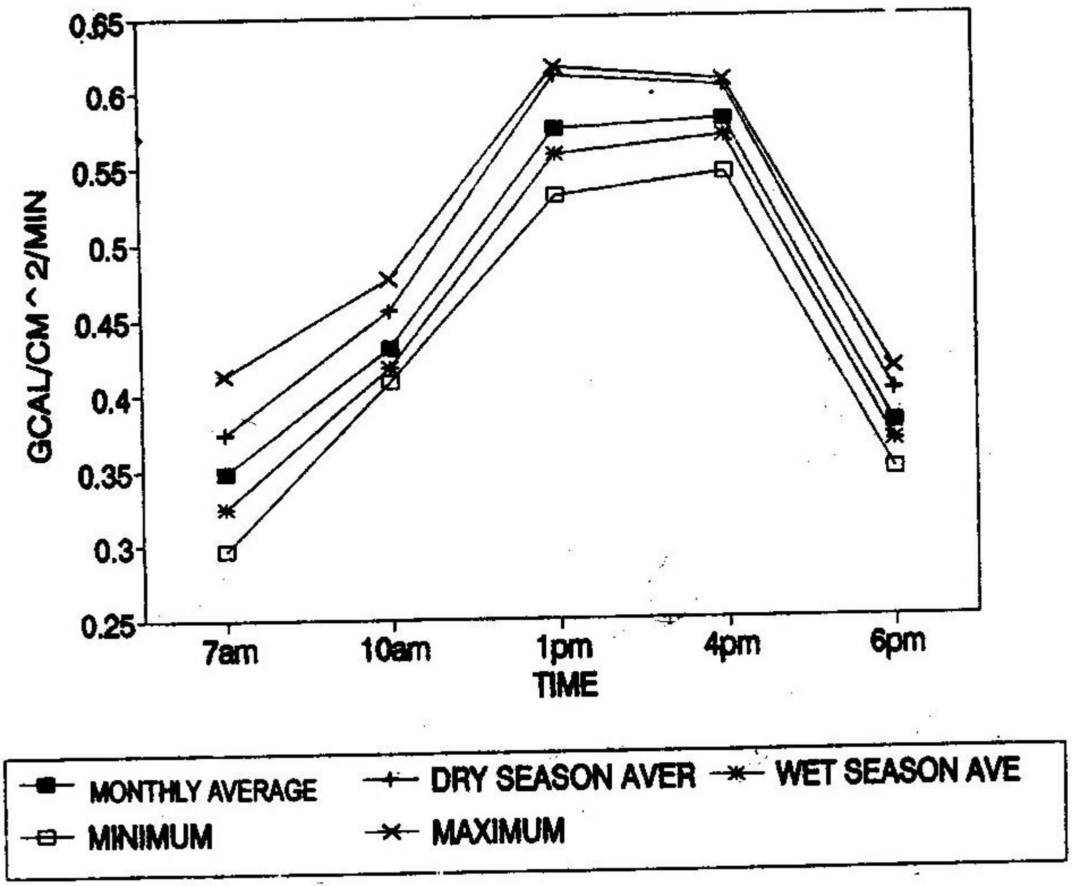


Fig. 8 Average net radiation over bare ground surface

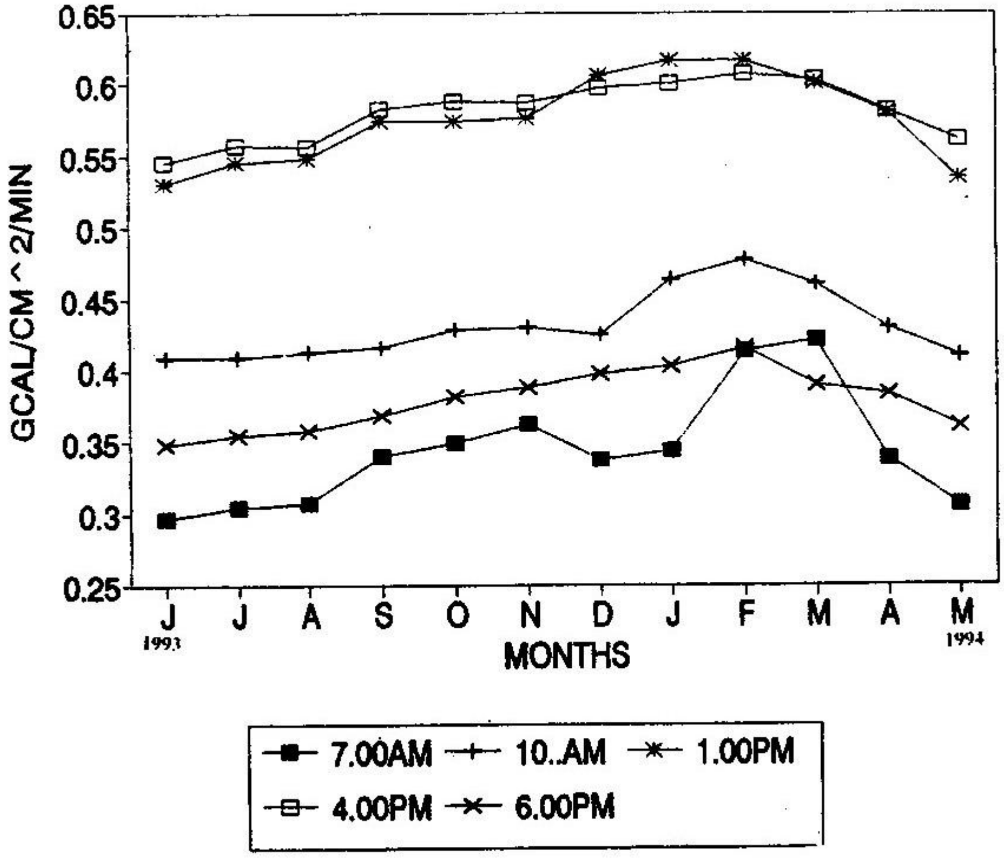


**Fig. 9 Monthly average net radiation over bare ground surface**