Soil Temperature Profile at Uturu, Nigeria.

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ABSTRACT

A soil mercury-in-glass thermometer was used to measure the bare soil temperature profile at Uturu (Lat. 05.33^0N, 06.03^0N and Long. 07.10^0E, 07.29^0E) at 5cm, 10cm, 20cm, 30cm, and 50cm depths. Four readings were taken per day at 3 hours interval starting from 7am to 4pm and the daily mean temperatures were calculated based upon which the monthly mean temperatures were calculated. The period of study lasted for five months, starting from December, 2007 to April, 2008 representing the Harmattan, dry, and wet seasons. The monthly mean soil temperature profile obtained for the period of study are 31.5^0C, 28.2^0C, 32.0^0C, 34.2^0C, and 32.4^0C at 5cm depth for the various respective months, 30.3^0C, 26.8^0C, 31.1^0C, 31.8^0C, and 31.3^0C at 10cm depth, respectively, 30.4^0C, 26.9^0C, 31.0^0C, 31.6^0C and 31.3^0C at 20cm depth, respectively, 30.6^0C, 27.2^0C, 30.9^0C, 31.9^0C, and $31.^0$C at 30cm depth, respectively while at 50cm depth the measured temperature values are 30.7^0C, 27.3^0C, 30.8^0C, 32.0^0C, and 31.5^0C, respectively.

The temperature values measured at all depths studied for the period of study represents the monthly mean soil temperature at Uturu during the Harmattan while the temperature readings obtained in March represents the mean soil temperature during the dry season, and those measured in April represents the mean temperature value during wet season.

(Keywords: bare soil, temperature, soil profile, mercury-in-glass thermometer)

INTRODUCTION

Frank (1998) noted that geologists reserve the term soil for the topmost layers which contain organic matter and can support plant life. Charles (1987) observed that the soil is formed when rocks are continuously broken down by weathering. The Earth absorbs sun's energy which reaches it in the form of ultraviolet rays, and changes this into heat. Later this energy is radiated back from the earth to the atmosphere in the form of infrared rays, felt as heat. Heat is energy in the process of transfer from the region of higher temperature to the region of lower temperature. Hugh (2004) stated that temperature is a quantitative description of a body's hotness or coldness.

Takeuchi (1967) observed that daily experience shows that the temperature at the earth's surface fluctuates constantly, it is high during the day and low at night; it varies within the season and with depth. These meteorological temperature changes mainly depend on the heat from the sun. Baver (1972) noted that some physical factors such as latitude, exposure, distribution of land and water, and vegetation can affect radiation distribution over soil surface which greatly determine the soil temperature.

The soil temperature is generally expressed as thermal regime of soils, which usually includes heat flux into the soil, the thermal characteristics of the soil and heat exchange between soil and air. Soil temperature is a basic property required to evaluate most biological and physical processes in the soil-animal ecosystem (Allmaras, 1964).

FAO (1993) observed that soil temperature influences the absorption of water and nutrients by plants, seed germination and root development, as well as soil microbial activity and crusting and hardening of the soil. Hickin (2009) stated that such factors as air temperature, solar radiation, precipitation, soil temperature and wind all have an effect on the environment sensed by the plant, and thus may influence the rate of the development. Willis (1957) reported that the most favorable soil temperature at 10cm depth for maize growth in a temperate environment is 24^0C while in the tropics, the optimal soil temperature range for maize growth was reported to lie between 25 to 34^{0}C (Lal, 1974). Generally, crop yield rises with increase in soil temperature to a point and decreases with further increase in soil temperature. Soil temperature at each depth changes periodical with the periodical changes of ambient temperature and solar radiation.

Landsberg (1958) noted that the range of soil temperature at various depths, and the diffusivity of soil are related to values of density, conductivity, and specific heat of soils which are themselves not as neatly determined for soil in practice as it can be done for metal block, since their values may vary from day to day or even from hour to hour in nature depending on soil's states as influenced by weather, cultivation, and covering vegetations. The values also vary with depths, as different soil horizons may possess considerably different characteristics. Though, this inconsistency gives some problems, it shows that one need to measure temperature at two or more depths to determine the vertical profile temperature conditions. The measurement of soil temperature profile at Uturu for 5cm, 10cm, 20cm, 30cm, and 50cm is of interest from the stand point of environmental impacts.

MATERIALS AND METHODS

A mercury-in-glass soil thermometer (Casella-London immersion) was used to measure the bare soil temperature profile at Abia State University meteorological station. The mercury-in-glass thermometer has calibrated marks which allow the temperature to be read by the length of the mercury within the tube, which varies according to the amount of heat given to it. When the soil temperature rises, the mercury in the bulb expands and rises up the tube. When the soil temperature falls, the mercury contracts and falls down the tube. Five holes were dug and the soil mercury-in-glass thermometer supported by a stand were firmly installed into these holes to ensure good contact with the soil at 5cm, 10cm 20cm, 30cm, and 50cm depths.

The thermometers were spaced 65cm apart and arranged in an orderly manner to make for easy reading of the soil temperature. Four readings were taken at 3 hours intervals per day starting from 7am to 4pm. The measurements were made at 7am, 10am, 1pm, and 4pm, daily for the five consecutive months starting from December, 2007 to April, 2008. The period December to February represents the Harmattan (Cold North East Trade Winds locally called Harmattan) while March represents the dry season and April the wet season. The mean daily temperature for each day was calculated based on which the monthly mean temperature which represents the soil temperature for the month was calculated.

BASIC THEORY

Baver (1972) observed that net radiation represents the difference between the total downward and upward radiation flux. It is a measure of the energy available at the soil surface. The parameters of net radiation include albedo, evapotranspiration, heat fluxes to soil and air, and long wave radiation. Geiger (1965) expressed net radiations, S, as:

$$S = I+H+G-\delta\, T^4-R \qquad \textbf{(1)}$$

Where I+H+G is the global radiation, G is the counter radiation, δT^4 is the radiation emitted by the soil surface, and R is the albedo (percentage reflection). At night, I+H and R are zero and net radiation becomes negative.

Thermal radiation from the sun, vegetation, mulches, shade and instillation, heat capacity, thermal conductivity and diffusivity of the soil, latitude, net radiation and heat balance are some of the soil factors that affect soil temperature.

Idris (1981) observed the variation in soil temperature with depths of 5cm, 10cm, 20cm, and 30cm for bare and mulched soils carried out at Samaru-Zaria, in Kaduna State. The result showed that for the early part of the day to about 11.00am, temperature increases down the soil profile and is reversed in the afternoon. The temperature also reverses between 6.00pm and 8.00am the next day. At 5cm depth, the soil temperature at 18.1^{0}C at 8.00am use to its maximum of about 32.2^{0}C for bare soil at 4.00pm while that of mulched soil rose from 20.8^{0}C to 29.8^{0}C at the same time intervals. At 10cm depth, it rose from about 29.1^{0}C and 21.7^{0}C at 8.00pm to its maximum of about 29.1^{0}C and 27.9^{0}C at 5.00pm for bare and mulched soil respectively and then started falling. At 20cm depth, soil temperature fell to its minimum of about 22.7^{0}C and 23.5^{0}C at 10.00am and rose to about 26.9^{0}C and 26.2^{0}C for bare and mulched soils respectively at 6.00pm. At 30cm depth, soil temperature almost constant, fell to about 24.1^{0}C and 24.3^{0}C at noon (12.00pm) and rose to about 25.1^{0}C and 24.9^{0}C for bare and mulched soils respectively at 6.00pm. The minimum was always higher for the mulched soil while the maximum was higher for the bare soil.

RESULTS AND DISCUSSION

The monthly mean variations in soil temperature for the various depths, 5cm, 10cm, 20cm, 30cm and 50cm is as shown in Table 1.

Table 1: Monthly Mean Soil Temperature at Uturu.

Months	Monthly Mean Soil Temperature (^{0}C)				
	5cm depth	10cm depth	20cm depth	30cm depth	50cm depth
Dec	31.5	30.3	30.4	30.6	30.7
Jan	28.2	26.8	26.9	27.2	27.3
Feb	32.0	31.1	31.0	30.9	31.2
March	34.2	31.8	31.6	31.9	32.3
April	32.4	31.3	31.3	31.0	31.5

Table 1 shows that at 5cm depth, the monthly mean soil temperature obtained range from a minimum of 28.2^{0}C in January to maximum 34.2^{0}C in March. At 10cm depth, the monthly mean soil temperature obtained range from a minimum of 26.8^{0}C in January to a maximum of 31.8^{0}C in March. At 20cm depth, the minimum and maximum monthly mean soil temperature range of 26.9^{0}C-31.6^{0}C was obtained in the months of January and March, respectively. The same trend is applicable for the 30cm and 50cm depths in that the months of January and March recorded the lowest and highest temperatures, respectively (Table 1).

For the five depths studied, the lowest recorded temperature was obtained in January while the highest recorded temperature was obtained in March. This is as a result of the fact that the cold North East Trade Winds locally called Harmattan was at its peak in January while the global solar radiation was at its maximum in March. The monthly mean soil temperature at Uturu for the period studied therefore ranges from 26.8^{0}C in January to 34.2^{0}C in March. In general, for the five months studied, the 5cm depth was found to be warmer than the other depths because the highest recorded temperature was obtained at this depth for each of the month studied. The reason is obvious, the intensity of the incoming solar radiation is always higher at shallow soils (depths) than at deeper soils since the solar radiation gets to the 5cm depths first and heats it up before getting to the deeper layers. This is in agreement with that reported by Idris (1981).

A comparison of the seasonal variations in soil temperatures reported by Idris (1981), and that obtained at Uturu showed that the monthly mean soil temperature at Uturu was lowest in January and highest in March while that obtained in Samaru-Zaria was lowest in January and highest in April. Samaru-Zaria in the Northern part of Nigeria experienced her peak global solar radiation in April while Uturu in the East experienced hers in March. This may be as a result of the latitudinal differences in both locations.

Figures 1-5 are the graphs of monthly mean soil temperature variations at 5cm, 10cm, 20cm, 30cm, and 50cm depths respectively against months of measurements. The figures showed that the lowest temperature was recorded in January while the highest were in March. Lal (1974) reported that optimal soil temperature range for maize growth in tropics lie between 25-34^{0}C while monthly mean soil temperature obtained at Uturu for the period of study lies between 26.8^{0}C-34.2^{0}C which is in agreement with that reported by Lal. The bare soil temperature at Uturu is therefore favorable for maize growth.

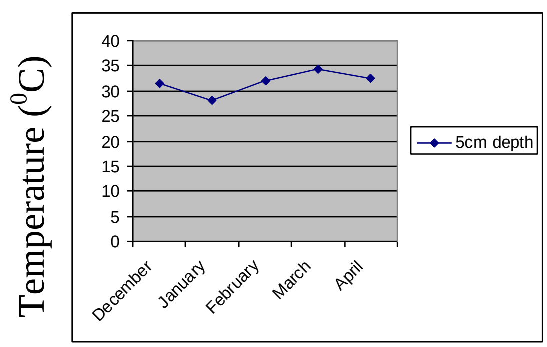

Figure 1: Monthly Mean Soil Temperature Variations against Months of Measurement for 5cm Depth at Uturu.

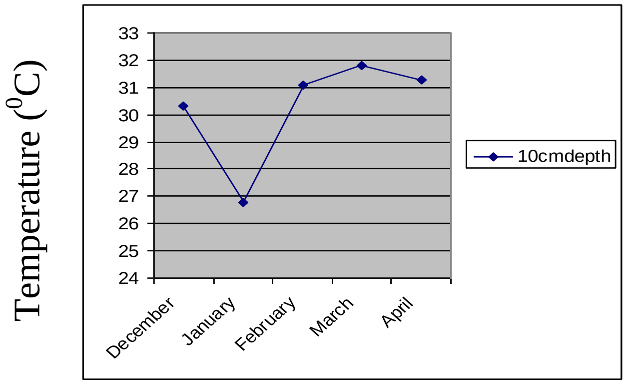

Figure 2: Monthly Mean Soil Temperature Variations against Months of Measurement for 10cm Depth at Uturu.

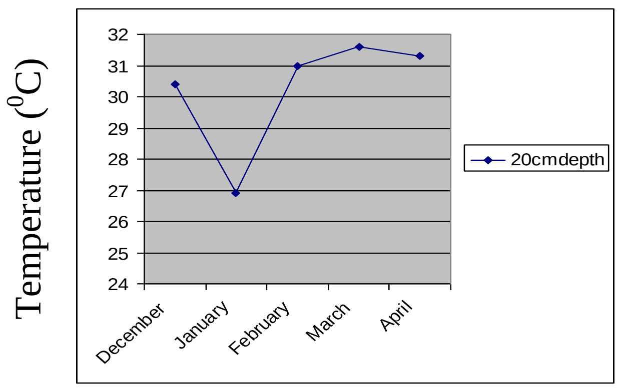

Figure 3: Monthly Mean Soil Temperature Variations against Months of Measurement for 20cm Depth at Uturu.

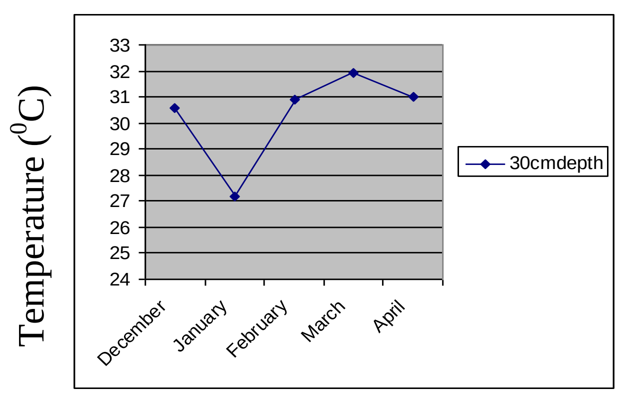

Figure 4: Monthly mean soil temperature variations against months of measurement for 30cm depth at Uturu.

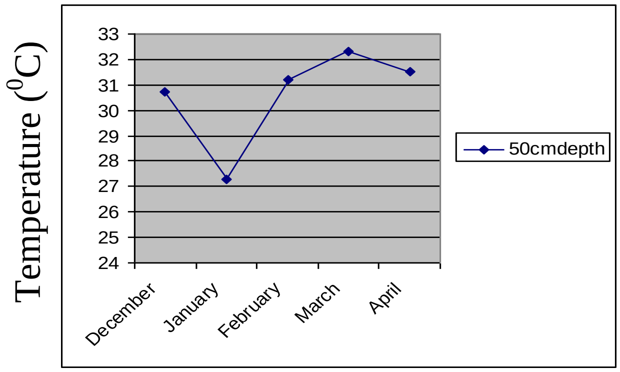

Figure 5: Monthly Mean Soil Temperature Variations against Months of Measurement for 50cm Depth at Uturu.

CONCLUSION

A soil mercury-in-glass thermometer was used to measure the bare soil temperature profile at Uturu (Lat. 05.33^{0}N, 06.03^{0}N and Long. 07.10^{0}E, 07.29^{0}E) at 5cm, 10cm, 20cm, 30cm, and 50cm depths. Four readings were taken per day at 3 hours interval starting from 7am to 4pm and the daily mean temperatures were calculated based upon which the monthly mean temperatures were calculated.

The period of study lasted for five months, starting from December, 2007 to April, 2008 representing the Harmattan, dry and wet seasons. The monthly mean soil temperature profile obtained for the period of study are 31.5^{0}C, 28.2^{0}C, 32.0^{0}C, 34.2^{0}C, and 32.4^{0}C at 5cm depth for the various respective months, 30.3^{0}C, 26.8^{0}C, 31.1^{0}C, 31.8^{0}C, and 31.3^{0}C at 10cm depth, respectively, 30.4^{0}C, 26.9^{0}C, 31.0^{0}C, 31.6^{0}C and 31.3^{0}C at 20cm depth, respectively, 30.6^{0}C, 27.2^{0}C, 30.9^{0}C, 31.9^{0}C, and 31.^{0}C at 30cm depth, respectively, while at 50cm depth the measured temperature values are 30.7^{0}C, 27.3^{0}C, 30.8^{0}C, 32.0^{0}C, and 31.5^{0}C, respectively.

The temperature values measured at all depths studied for the period of study represents the monthly mean soil temperature at Uturu during the Harmattan while the temperature readings obtained in March represents the mean soil temperature during the dry season and that measured in April represents the mean temperature value during wet season. The low mean monthly temperature values obtained in January at all depths was as a result of the fact that the Harmattan was at its peak unlike in

March when the global solar radiation reaches its peak and the intensity of the sun's rays reaching the soil was high and this accounts for the high values of mean monthly soil temperature values obtained in March at all depths. The 5cm depth is closer to the Earth's surface, and the solar radiation reaches it before other layers coupled with the fact that the near ground temperature increases as solar radiation increases accounts for the highest mean monthly soil temperature value obtained at 5cm depths.

ACKNOWLEDGEMENT

The author is grateful to Mr. Azubuike Kingsley Eze, Egeruo Chika, Uzoukwu Victor Chidi, Anumoke Kyrian Chigozie, and Ukaegbu Chidiebere Fortune for their assistance in this work.

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SUGGESTED CITATION

Chiemeka, I.U. 2010. "Soil Temperature Profile at Uturu, Nigeria". *Pacific Journal of Science and Technology*. 11(1):478-482.

Pacific Journal of Science and Technology