# An Analysis of Mean Monthly Soil Temperature Fluctuation at Different depths at Compton Experimental Site, West Midlands, (UK), Between 1975 - 2008

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## ABSTRACT

The study analyzed mean monthly soil temperature fluctuation at different depths at Compton research site over the period (1975-2008), West Midlands; (UK) based on the statistical analysis of the data base of (12,045) days of individual soil temperature measurements in sandy-loam of the salwick series soils. It was found that the mean monthly soil temperature at all depths significantly increased from 4.80C, although a dramatic fluctuation at 5 cm depth was evident. The soil temperature decreased to around mid-April and then increased steadily, where it attained the maximum in August. However, it has also been observed that soil temperatures fluctuated at 5 and 10 cm depths. The temperature range at 5 cm depth was 16.50C and 10.50C at 10 cm depth. The study concludes that variation occurs at different soil depths and the pattern of fluctuation was in response to periodic shifts in meteorological variables acting on the soil system.
**Keywords:** soil temperature, temperature fluctuation, diurnal temperature variation, seasonal trend

## I. INTRODUCTION

Bai *et al.* (2010), Soil temperature is a very significant environmental factor that control the exchange of heat energy between the land surface and atmosphere. The speed of biological, physical and chemical response in soils have powerful controls on plant growth and soil formation.

Wu and Subbaru (2008) argued that sub soil temperatures are influenced by meteorological conditions and agricultural practices. Diurnal variations in soil temperature occur especially in the sub soil, and frequently soil moisture fluctuates. Similarly,Tang *et. al.* (2011) observed that the pattern of soil temperature fluctuations with depths and time are the result of heat transfer processes functioning in the soil system.
In soil classification, soil temperature is an important factor for consideration (Soil Survey Staff, 1999; cited in Bai *et al.* 2010). It is integrated into soil taxonomy through the soil temperature system, such as the variation between mean summer temperature and mean winter soil temperature, as well the mean annual soil temperature.

Over the years, scientists for example, Lambert *et al*. (2005), Martinez *et. al.* (2008), Ghahreman *et al.* (2010) and Tang *et al*. (2010) described the patterns of soil temperature variations at different depths, and seasonal trends, with the emerging view that soil temperatures fluctuates dramatically.

Hu and Feng (2003) argued that fluctuation in soil temperature and moisture change the pattern of heat transfer from the surface and influence atmospheric boundary layer processes and regional circulation (Pan and Mahrt 1987; Peters-Lidard *et al*. 1998; cited in Hu and Feng 2003). Soil temperature fluctuation results mostly from shallow radiation and latent heat exchange and vertical heat transfer in soils with diverse thermal properties. Thus, soil temperatures at different depths are exceptional parameters that are valuable to demonstrate surface energy regional environmental processes and the state of climate.

Ghahreman *et al.* (2010) demonstrated that soil temperatures fluctuate as a function of the occurrence of solar radiation, rainfall, local vegetation cover, soil properties, soil depth and seasonal movement in overlying air temperature. Variation in soil temperature occurs both daily and yearly and those changes are most apparent at or very close to the surface, where sunlight has most influence.

Lascalar and Pereira (2003) observed that solar radiation is a vital process governing the diurnal increase in soil temperature and water evaporation, regulating the rate of soil $C0_2$ production and $C0_2$ emission from soil to the atmosphere.

Lu and Cheng (2009) reported that soil $C0_2$ emission is determined by complex interfaces of temperature, soil properties, decomposition of organic substrates and moisture. During winter, global climate change have minute influences on soil $C0_2$ emissions, but during summer periods $C0_2$ emission increased considerably. Despite the variation in air temperature during winter, soil temperature declined as a result of snow and soil frost.

Zhang *et al*. (2005) argued that changes in soil temperature for lengthy periods may fluctuate from that of air temperature. These are due to the fact that modification of climatic variables, snow, vegetation and soil moisture (humidity, solar radiation and precipitation) generally control water and energy fluxes on the surface and within the soil. Hence, these processes transformed the connection between soil and air temperatures. Similarly, changes in precipitation and snow intensity are of much significance as changes in air temperature in assessing soil temperature changes.

In a review, Uvarov *et al*. (2011) observed that an array of temperature dynamics in soil considerably go beyond the changes predicted for future decades. Similarly, global warming not only means levels but also series of temperature variations are likely to change. For instance, soil winter temperatures rapidly increased more than the mean temperature over recent years. Furthermore, Tang *et al*. (2010), argued that pattern of disparity in soil temperature with depth and time give insights into heat transfer development processes in soil. By nature, variation in soil temperature is constantly in reaction to the increasing shift in the meteorological regime acting on the soil-atmosphere boundary.

Lambert *et al*. (2005) noted that soil temperature frequently fluctuate. Yearly and diurnal soil temperature dynamics influenced many biotic and abiotic processes in soil systems. Lavigne *et al*. (2004) observed that soil temperature increased significantly from April and mid-June and then was comparatively stable between late June until late August. Thereafter, temperature decreased gradually from September and December. However, differences from the overall pattern caused yearly climatic data to fluctuate among the years. Small diurnal or weekly differences in soil temperature often occurred. Minimal diurnal and weekly temperature fluctuations occurred in winter, when snow cover was intact. Thus, notable diurnal and weekly differences of temperature occur intermittently between May and November.

Sierra *et al*. (2010) reported that many scholars demonstrated that seasonal fluctuation in soil temperature encouraged changes in the arrangement of microbial community related to soil organic carbon (SOC) turnover, (Fenner *et al*. 2005; cited in Sierra *et al.* 2010) noted that advanced thermal adaptation of soil micro-organisms can play a significant role in abating the positive response between the soil C cycle and warming climates.

Many researchers have explored the pattern of soil temperature fluctuation using different criteria. Correspondingly, an array of related studies were conducted for example Mila and Yang (2008), Wang *et. al.* (2011), Gutknecht *et. al.* (2012), and Schindlbacher *et. al.* (2014) their contribution showed great extent of interest and knowledge in soil temperature regime.

There has not been any research on soil temperature fluctuation at Compton. Based on this background therefore, the aim of the study is to examine the mean monthly soil temperature fluctuation at the research site with a view to ascertain the typical behavior of this particular soil thermal environment at different depths. This will create awareness interest and knowledge on secular trends.

**Site Description**

The current study was carried out at Compton Campus (University of Wolverhampton), West Midlands (UK). It is roughly 2.39 km from the University of Wolverhampton, City Campus, and is located at 52.58717$^0$E and 2.163483$^0$S, (URL:itouch map). The research site was established in 1970, also measurement of soil temperatures began in 1975 and has over the years been used for studies on soil temperature, soil conservation, plant experiment and meteorology. The meteorological station at the upper flat section has a short grass cover and elephant plant (Miscanthus) as part of long term meteorological observations.

Brandsma (1997) reported that the nature of the soil is sandy-loam of the Salwick series with a dark topsoil of 32 cm deep and a sandstone rock underneath. The texture of the soil consists of sandy silt loam 41.4% (2000-60 µm), silt 51.3% (60-2 µm), clay 7.3% (< 2 µm) and soil organic matter content is 2.7% by weight. The pH level is 6.5 as (Vaz, 2001) demonstrated.

## II. METHODS AND MATERIAL

The materials for temperature measurement at Compton research site include: Slab minimum thermometer, The bare earth minimum thermometer, which is used to measure the temperature in open air on short grass, 60 cm deep thermometer, and rain gauge which is used to measure the amount of precipitation received (mm), a Stephenson's Screen (maximum and minimum wet and dry bulb) which is used to measure air temperature and relative humidity, the soil thermometer at depths of 5, 10, 20 and 30 cm. An anemometer is used to measure wind direction and velocity.

Data for the present study was collected from Compton meteorological station. These soil temperature data were measured at different soil depths based on 37 years of observation 1975-2012. This study analyses the soil temperature data recorded between 1975-2008. Results are analyzed using statistical methods (Excel package). The statistical analysis involves descriptive statistics (mean, median, minimum and maximum temperature). Correlation and regression analysis were used to identify temporal trends in soil temperature.

## III. RESULT AND DISCUSSION

The findings of the study demonstrate that soil temperature at all depths increased considerably, although a dramatic fluctuation at 5 cm depth was apparent. The soil temperature decreased to around mid-April and then increased steadily, where it attained the maximum in August (Figure 1). Mean monthly soil temperature at all depths increased from 4.8$^0$C, but soil temperature at 5 cm depth was relatively lower during this period. However, soil temperature at 30 cm was colder at the beginning of summer, compared to soil temperatures at 5, 10 and 20 cm depths and at 10 cm soil temperature was greater and increased continuously until October.

Uvarov *et al*. (2006) observed that variation in both seasonal and diurnal temperature significantly influenced the growth and population of earthworm species and dynamics of earthworm communities at different times. These variations in temperature also affect soil respiration, biomass and overall activity of soil micro-organisms. In general, decreased diurnal temperature variations resulted to an increase in $C0_2$ production. Temperature variation with season considerably alter the dynamics of carbon loss from the soil, as compared with consistent temperature systems.

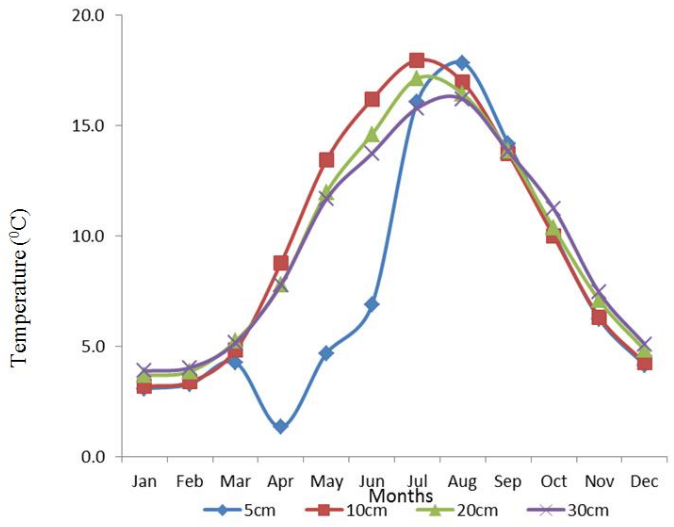


**Figure 1:** Mean monthly soil temperature at different depths at Compton (1975-2008)

A periodic tendency of increased soil temperature at 10 cm depth revealed the distinctive attribute of this particular soil thermal environment, which indicates the degree of soil warming during summer (Table 1). Soil temperatures fluctuated at 5 and 10 cm depths. The temperature range at 5 cm depth was 16.5$^0$C and 10.5$^0$C at 10 cm depth. Tang *et al.* (2011) argued that variations in soil temperature occur at different soil depths and its importance at any given period and the pattern of fluctuations depend greatly on space and time.

**Table 1:** Descriptive statistics of mean monthly soil temperature at different depths at Compton (1975-2008).

| Depths (cm) | Mean (°C) | Minimum (°C) | Maximu m (°C) | Range (°C) | Standard Deviation | SE Mean | No. Measurements (months) |
|---|---|---|---|---|---|---|---|
| 5 | 7.7 | 1.3 | 17.8 | 16.5 | 5.5 | 0.3 | 254 |
| 10 | 9.9 | 3.2 | 13.7 | 10.5 | 5.6 | 0.4 | 327 |
| 20 | 9.7 | 3.7 | 17.1 | 13.4 | 5.0 | 0.3 | 320 |
| 30 | 9.7 | 3.9 | 16.2 | 12.3 | 4.6 | 0.3 | 320 |

### Seasonal Trends

Soil temperature at 10 cm, was greater during the summer period and drastically declined with increased depth (Table 1). At 5 cm depth soil temperature was moderate and gradually decreased with increased depth. Uvarov *et. al.* (2011) noted that recurring temperature variations considerably alter the dynamics of carbon loss from the soil system as in contrast with stable temperature system.

## IV. CONCLUSION

The study illustrates that mean monthly soil temperature at all depths significantly increase, while a dramatic fluctuation at 5 cm depth was apparent. The soil temperature decreased to around mid-April and then increased steadily, where it attained the maximum in August. It has been observed that mean monthly soil temperature at all depths increased from 4.8$^0$C. Soil temperatures fluctuate at 5 and 10 cm depths. The temperature range at 5 cm depth was 16.5$^0$C and 10.5$^0$C at 10 cm depth. Similarly, variation occurs at different soil depths and the pattern of fluctuation was in response to periodic shifts in meteorological variables acting on the soil system. Many scholars analyzed soil temperature fluctuation at different depths and the results of the investigation revealed a comparable trend. In addition, more detail analysis of soil temperature trend is still in progress at Compton with a view to provide a clear understanding on temporal temperature trends.

## V. REFERENCES

[1] Bai, Y., Scott, T. A., Chen, W. & Chang. A, C. (2010) Evaluating methods for measuring the mean soil temperature. Geoderma, 157, 222-227.

[2] Brandsma, R. T. (1997) Soil conditioner effects on soil erosion, soil structure and crop performance. Ph.D Thesis, University of Wolverhampton.

[3] Ghahreman, N., Bazrafshan, J. & Gharekhani, A. (2010) Trends analysis of soil surface temperature in several regions of Iran. 71-74

[4] Gutknecht, J, L. M., Field, C. B. & Balser, T. C. (2012), Microbial community and their responses to simulated global change fluctuate greatly over multiple years. Journal of Global Change Biology 18(7),2256-2269

[5] Hu, Q. and Feng, S. (2003) A daily soil temperature data set and soil temperature climatology of the contigous United states. Journal of Climate and Bio-atmospheric Science. 42, 1139-1156.

[6] Lambertty, B. B., Wang, C. & Gower, S. T. (2005) Spatio-temporal measurement and modeling of stand-level boreal forest soil temperatures. Journal of Agricultural and Forest Meteorology 131 (1-2), 27 40.

[7] Lascalar, J.N, and Pereira, A. R. P. (2003) Modelling short term temporal changes of bare soil C02 emissions in a tropical agro-system by using meteorological data. Journal of Applied Soil Ecology 24 (1),113-116.

[8] Lu, X. and Cheng, G. (2009) Climate change effects on soil carbon dynamics and green house gas emissions in

Abies fabri- forest of sub alpine, south-west China. Journal of Soil Biology and Biochemistry 41(5),.3-8
[9] Mila, A. L. & Yang, X, B. (2008) Effects of fluctuating soil temperature and water potential on sclerotia germination and apothecial production of sclerotinia sclerotiorum. Journal of plant disease 92 (1),78-82
[10] Sierra, J., Brisson, N., Ripoche, D. & Deque, M. (2010) Modeling the impact of thermal adaptation of soil micro-organisms and crop system on the dynamics of organic matter in a tropical soil under a climate change scenario. Journal of Ecological Modeling 22 (23),1
[11] Schindlbacher, A. Jandl, R. & Schindlbacher, S. (2014) Natural variations in snow cover do not affect the annual soil CO2 efflux from a mid elevation temperate forest. Journal of Global Change Biology 20 (2),622-632
[12] Tang, C. S., Shi, B., Gao, L., Daniels, J. L., Jiang, H. T & Liu, C. (2011) Urbanization effect on soil temperature in Nanjing, China. Journal of Energy and Building 43 (11), 3090-3098.
[13] Tange, A., J. Kaihura, F., B, S. Lal, R. & Singh, B., R. (1998) Diurnal soil temperature fluctuations for different erosion classes of an oxisol at Mlingano, Tanzania. Soil and Tillage Research 49 (3), 211-217.
[14] Uvarov, A. V., Tiunov, A. V. and Scheu, S. (2011) Long term effects of seasonal and diurnal temperature fluctuations on carbon dioxide efflux from a forest soil. Journal of Soil Biology and Chemistry 38 (12), pp. 3387-3397.
[15] VAZ, S. (2001) Multivariate and spatial study of the relationship between plant diversity and soil properties in created and semi-natural hay meadows. Ph.D. Thesis, University of Wolverhampton.
[16] Wu, B., M. and Subbarao, K., V. (2008) Effects of soil temperature, moisture and Burial depths on carpogenic germination of sclerotinia sceletiorum and S. minor. Journal of Ecology and Epidiomology 98(10), 114-1152.
[17] Zhang, Y., Chen, W., Smith, S. L. Rise, B. D. W. & Cihlar, J. (2005) Soil temperature in Canada during the Twentieth Century: Complex responses to atmospheric climate change. Journal of Geophysical Research 110, 10-1029.