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ANALYSIS OF SOIL TEMPERATURE AT COMPTON RESEARCH SITE, WEST MIDLANDS, UK BETWEEN 1975-2008

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Abstract:

Temporal trends in soil temperature over the 33 years (1975-2008), were examined. The study analyzed soil temperature data records at four depths (5, 10, 20 and 30 cm). 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, soil temperature at Compton Experimental Site significantly increased between 1975-2008 at a rate of ~0.1^0C year $^{-1}$. The mean monthly soil temperature at all depths increased from 4.8^0C and continuously increased up to July-September, thereafter soil temperature decreased up to December. It was also found that a dramatic fluctuation at 5 cm depth was apparent. Temperature fluctuated widely in response to constant shift in meteorological variables acting on the soil system. Therefore, analysis of mean annual temperature and mean monthly soil temperature revealed that soil temperature significantly increase over time. The study concludes that this analysis contribute to the growing knowledge and understanding on temporal temperature trend, as there was a clear, overall secular trend of significant increases in soil temperature.

Key words: soil temperature, climate change, temperature fluctuation, variation trend.

Introduction:

Studies on soil temperature are very important, especially for analysis of climate. Bai *et al.* (2010) demonstrated, that annual mean soil temperature, a typical index for the thermal climate of soil, is indispensable for precise records of soil resources and for research on climate. Generally, it has been considered as an independent variable affecting the average response of bio-physical processes occurring in the soil environment. Lee, (1969; cited in Bai *et al.* 2010), observed that measurements of mean temperature commonly entails assimilation and sampling over prolonged time scales.

Zhang and Chen (2005) reported that changes in soil temperature related to atmospheric warming may affect hydrologic state and topography, changes in the development of plants, thawing of permafrost, enrichment of soil organic carbon (SOC) disintegration, as well as enhancement of Co_2 emission from the soil to the atmosphere.

Giro *et. al.* (2015) observed that increase in temperature would augment the velocity and disintegration of soil organic matter (SOM) in lowland thus, added considerably at upper elevation in view of the fact that they are more susceptible to increase in temperature.

Sierra *et. al.* (2015) argued that although well-built position reliant co-variation involving soil temperature and moisture on a series of occasion may possibly have a deep consequences on forecasting the effects of changes in climate on the speed and break down of soil organic matter as well as carbon release from the soils.

Marhan *et. al.* (2015) noted that the action of decomposer organisms may likely have an effects due to the increase in soil temperature and possibly improve element rotation and greenhouse gas (N_{20} and $C0_2$) discharge. However, elevated soil temperatures as well decreased the quantity of haul out organic C and N_{H4}, other than enhance the quantity of N_{03}, and signify increase nitrification activity in warmed soils.

Jungqvist *et. al.* (2014) in a study of the effect of climate change on soil temperature in Swedish Boreal Forests reported that several factors control soil temperature. The shielding consequences of snow and alteration in the timing and strength of snowfall have a considerable response on soil temperature activities in the northern boreal countryside during the period of frost and spring.

Over the years, considerable progress has been made to investigate soil temperature behavior at different depths. For example, Yoshioka *et. al.* (2015), Adrie *et al.* (2011), Rinna *et al.* (2011), Uvarov *et al.* (2011), Kohn and Royer (2010), Subedi and Fullen (2008) among others, their contribution demonstrate huge level of knowledge and interest on soil temperature.

Albergel *et. al.* (2015) noted that soil temperature is the key variable for the arrangement of several substantial processes in statistical form to forecast weather condition. It is the main force for the entire surface release of water, carbon dioxide and energy and further function for every satellite sensors receptive to land.

Soil temperature plays a very essential role in the growth and development of crops, control the rate of seed germination and influences the growth and development of roots. Hu and Feng (2003), Ghahreman *et al.* (2010), Subedi and Fullen (2009), Ikeda (2002), and Martinez *et al.* (2008). Hu and Feng (2003), reported similar findings where he argued that several crops (such as wheat, beans, oats and maize) are notably influenced by soil temperature anomalies at different depths. To a large extent, soil temperature influences the development and harvest of these agricultural crops.

Poll *et. al.* (2013) argued that changes in rainfall pattern and temperature owing to climate change will probably impinge on carbon cycling and soil respiration in global environment. In spite of significant reaction system of ecological unit to climate change, there is still need of research in agricultural systems.

Ozturks *et. al.* (2015) observed that on the whole both air temperature and soil temperature is a useful meteorological factor in leaf penology of deciduous temperate woodland. Similarly, soil temperature control serial leaf growth of deciduous trees.

In spite of latest increase in the integer of research in the study area, there has been little research on soil temperature at Compton, previous published studies focused on soil conservation, plant experiment, soil temperature fluctuation and impact of soil temperature on Miscanthus (elephant) plant. Based on the above background therefore, the aim of the study is to examine whether there has been a significant increase in soil temperature at Compton Experimental Site over the period 1975-2008.

The study Area:

The study area is in the University of Wolverhampton, Compton Campus West Midlands (UK). It is approximately 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). Statistical analysis of the database showed that mean annual temperature was 10.0^{0}C in 1975, although variations have occurred through time. The study area was established in 1970, also measurement of soil temperatures began in 1975 and has over the years been used for research on soil conservation, plant experiment and meteorology. The meteorological station at the upper flat section has a short grass cover and Miscanthus (elephant) plant 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 from the Compton site 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)reported.

Materials and Methods:

The materials for temperature measurement at Compton include: the bare earth minimum thermometer which is used to measure the temperature in open air on short grass, 60 cm deep thermometer, slab minimum 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) as well as an Anemometer. The soil thermometer were installed at four depths of 5, 10, 20 and 30 cm. Readings were taken twice in a day (morning and evening) since 1975.

Data on soil temperature were collected at Compton research site. These soil temperature data were measured at different soil depths based on thirty seven 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.

Results and Discussion:

The mean monthly soil temperature mean of 5, 10, 20 and 30 (cm) soil depths during the years 1975-2008 increased from 4.8^{0}C and continuously increased up to July-September, thereafter soil temperature decreased up to December. Recurrent variations of soil temperature patterns were evident at Compton. Mean monthly soil temperatures ranged between 19.3^{0}C (July at 5 cm soil depth) and 5.2^{0}C (January at 30 cm) depths (Figure1).

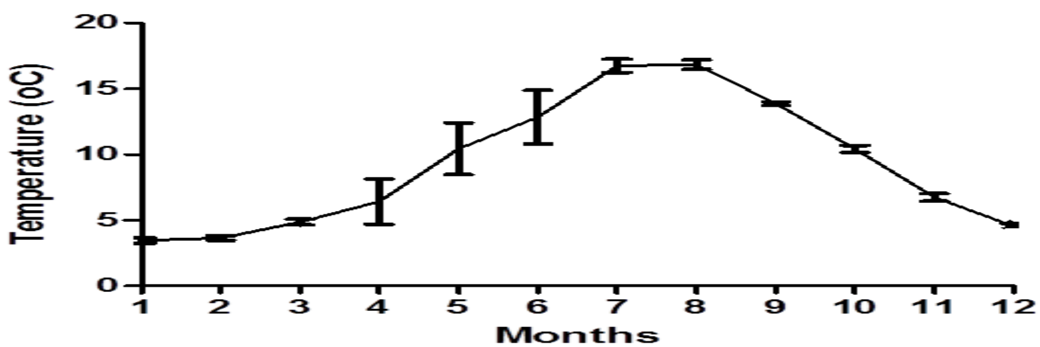

Figure 1. Mean monthly soil temperature (mean of 5, 10, 20 and 30 cm depths during 1975-2008), at Compton Experimental Site, Wolverhampton, UK.

$y = -74.28 + 19.10x$

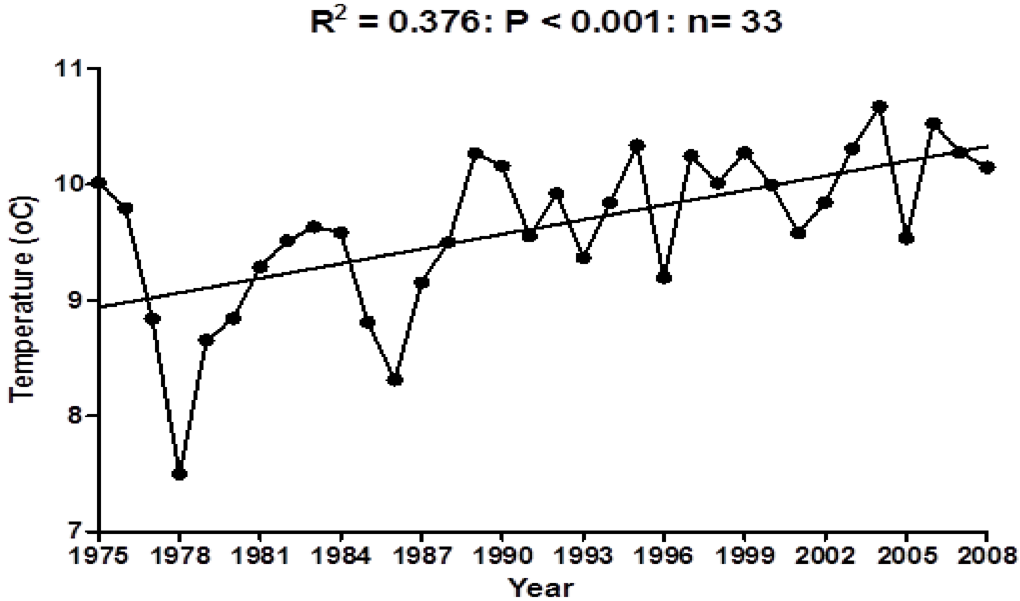

Figure 2. Mean annual soil temperature (mean of 5, 10, 20 and 30 cm depths) during the years 1975-2008 at the Compton Experimental Site.

Mean annual soil temperature variation trends were observed during this period. The mean annual temperature (mean of all depths) decreased from 10^0C in 1975-1978 due to cold winter and snowfall and thereafter, temperature continuously fluctuated. This follow a linear trend ($r = 0.548$; $p < 0.001$; $n = 33$). The regression statistics trend reveals that there was a significant increase in soil temperature between 1975-2008 at a rate of ~0.1^0C year $^{-1}$.

Figure 3. Temperature fluctuations at different depths:

Soil temperature at all depths increased considerably, though there was a dramatic fluctuation at 5 cm depth. The soil temperature decreased to around mid-April and then increased gradually, where it reached the maximum in August (Figure 3). Mean monthly soil temperature at 10, 20 and 30 cm depths increased from 4.8^0C, 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.

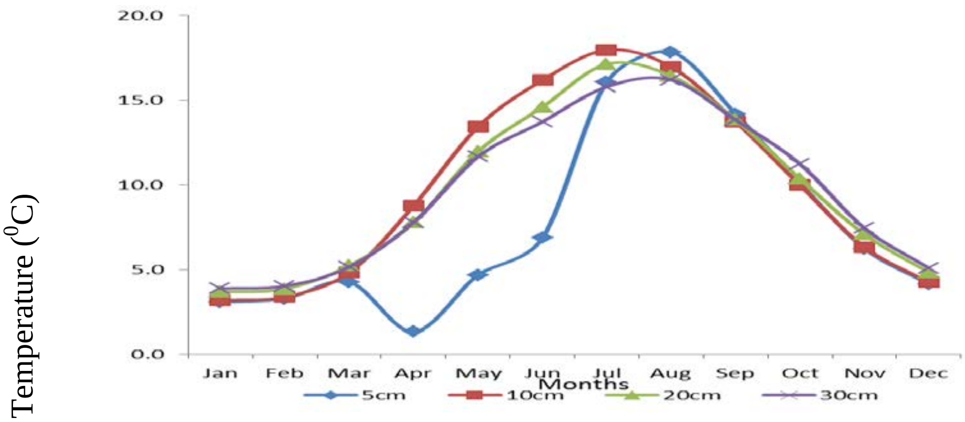

Figure 3 Mean monthly soil temperature at different depths at Compton (1975-2008)

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

Depths (cm)	Mean (°C)	Minimum (°C)	Maximum (°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 (Table1). At 5 cm depth soil temperature was moderate and gradually decreased with increased depth. 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 the pattern of soil temperature fluctuations with depth and time are the result of heat transfer processes functioning in the soil.

Conclusion:

The study illustrates that soil temperature at Compton Experimental Site significantly increased at a rate of ~0.1^{0}C year $^{-1}$ between 1975-2008. However, a dramatic fluctuation at (5 cm) depth was detected and the pattern of fluctuation was in reaction to constant shift in meteorological variables operating in the soil system. Therefore, analysis of mean monthly soil temperature and annual mean temperature showed that soil temperature significantly increase over time. This analysis contributes to the growing knowledge on temporal temperature trends, as there was a clear, overall secular trend of significant increase in soil temperature. Many scholars also analyzed soil temperature at different depths and the results of the investigation revealed comparable trends.

In addition, a more comprehensive investigation of the lasting (39 year record) of usual measurements of soil temperature trends at different depths at a research site are still in progress and this should provide a suitable plat form for further research on soil temperature and considerably add to the information on temporal temperature trends.

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