SOIL PROFILE TEMPERATURE AS AN INDICATOR FOR POTENTIAL EFFECTS OF CLIMATE CHANGE UNDER ARID ECOSYSTEMS OF KUWAIT

ABDIRASHID ELMI

Department of Environmental Technology Management, College of Life Sciences, Kuwait University, P.O. Box 5969 - Safat 13060 Kuwait
E-mail: a.elmi@ku.edu.kw

Abstract- Globally, one-third of the total land area is classified as arid land. Aridity is usually expressed as a function of rainfall and temperature. An arid index of 0.03 comprises dryland areas without vegetation, with the exception of a few scattered shrubs, and no farming except with irrigation. Annual rainfall is low, rarely exceeding 100 millimeters, with huge temporal variability. All these descriptions fit well climatic conditions of Kuwait and the larger Middle East region. Soil temperature change plays an important role in many processes which take place in the soil, and is regulated by multiple factors such as: heat capacity, albedo, leaf coverage, soil moisture and texture. Daytime temperatures can typically reach 45 ^{o}C during the "hot" dry season and drop to 15 ^{o}C during the night. High temperatures in the surface layer of the soil result in rapid loss of soil moisture due to the high levels of evapotranspiration. Deserts ecosystems are sensitive to changes in environmental conditions to the extent that land use pressure has become so serious that dry land agriculture and natural habitats may be threatened in the long term. Two way analysis of variance (ANOVA) comparing the soil temperatures from 2007 to 2009 did not show significant change in temperature across the years. The findings from this study represent original contribution to our understanding of the impacts of land use intensity soil, and soils are also subject to indirect impacts arising from human activity as it sheds some light on whether or not soil temperature changes can be used as a reliable indicator of global climate change.

Keywords- Dessert, Soil, Surface layer, Temperature.

I. INTRODUCTION

Soil temperature change plays an important role in many processes which take place in the soil, and may change in response to atmospheric temperature fluctuations. Soil temperature warming is linked to atmospheric temperature increase through a complicated process of heat transfer. Consequently, soil temperature changes respond differently than atmospheric temperatures, because soil temperature fluctuation is regulated by multiple factors such as: heat capacity, albedo, leaf coverage, soil moisture and texture (Bai, 2009). Soil temperature fluctuation is important in regulating the biogeochemical processes that occur in the subsurface soil profile (Bai, 2009). Temperature change may alter the diversity and distribution of plant species leading to a change in animal feeding behavior and distribution as well (Goldblum and Rigg, 2009). Soil temperature affects the growth and yield of agricultural crops. Corn for instance flourishes if the spring soil is warm, and suffers a delay in growth and productivity if the spring soil temperature is cold (Hu and Feng, 2004). Higher soil temperatures lead to an increase in soil fertility. Microbial activity is accentuated with higher soil temperatures. The decay of organic matter in the soil is increased providing the needed nutrients to support higher plant productivity (Frazer, 2009).

The primary objectives of this study were to: 1) quantify changes in temperature in the soil profile at different locations under different management practices in the state of Kuwait, and 2) examine whether or not soil temperature fluctuations follow a similar trend to air temperature fluctuations.

II. MATERIALS AND METHODS

Description of Study Area

The State of Kuwait [latitudes 28° and 31° N, and longitudes 46° and 49° E] is situated in the north-east of the Arabian Peninsula in Western Asia. It is bordered by Saudi Arabia to the South, and Iraq to the North. It lies on the north-western shore of the Arabian Gulf. Kuwait is one of the smallest countries in the world in terms of land area, covering an area of 17,820 square kilometers (6,880 square miles) with about 3.6 million inhabitants. Its flat sandy Arabian Desert terrain is generally low lying, with the highest point being 306 m (1,004 ft) above sea-level. The land area is considered arable and sparse vegetation is found along its 499 km long coastline.

Kuwait has four distinct seasons: summer, winter, autumn and spring. The summer months are: June, July, August, and part of September. Autumn starts in September, October and November. The winter season spans December, January, February and part of March. Finally, spring is a very shifty season. Spring months are part of March. The spring season is warm with occasional thunderstorms. The frequent winds from the northwest are cold in winter and spring and hot in summer. Southeasterly winds, usually hot and damp, spring up between July and October; hot and dry south winds prevail in spring and early summer. The shamal, a northwesterly wind

common during June and July, causes dramatic sandstorms. The average Annual high in atmospheric temperature is 33.2˚C and the low is 15.8˚C.

Data Collection

Kuwait's meteorological department initiated as recently as 2007 a survey program to monitor soil temperature, comprising of five stations, to monitor soil temperatures at different depths. The stations selected were: Kuwait's International Airport (KIA), Abdaly, Rabyah, Sulaybiyah and wafra (Fig. 1). Except for the KIA station, all other stations were located under agricultural land use. The temperature probes were placed at soil depths of: 5cm, 10cm, 20cm, 50cm, and 100cm. For the purpose of this study, data collected from the four agricultural stations, spanning 2007 to 2009, was analyzed for fluctuation in soil temperature in response to atmospheric global warming. Atmospheric temperatures at Kuwait's International Airport for the years 2007, 2008 and 2009 were obtained for comparison. Any temporal or seasonal flux in soil temperature is compared to the previous year across the different depths.



Figure 1: Map of Kuwait showing (yellow pins) the five study areas: Kuwait international Airport, and the four agricultural areas include Wafra, Rabyah, Sulaybiyah, and Abdaly.

Data Analysis

Soil temperatures across years might differ according to the depth of the reading and the location within the country of Kuwait. Monthly soil temperature averages, spanning from 2007 to 2009, were compiled from Kuwait's Meteorological Department and analyzed for any apparent fluctuations or trends. Two way analysis of variance (Two Way ANOVA) tests were conducted onto collected soil temperatures across the four agricultural locations: Abdaly, Rabyah, Sulaybiyah, and Wafra. For each year, soil temperatures were examined for significance across the different locations, depths, and their interaction. Also, all three years were compared for any significant yearly variations. Atmospheric temperature data trends from Kuwait's International Airport for the years 2007, 2008 and 2009 were compared to soil temperatures for any change in monthly averages that could be attributed to global warming.

RESULTS AND DISCUSSION

Temperatures increase with soil depth, and this trend persists over all three years. Performing the Tukey's HSD (Honestly Significant Difference) post hoc test was employed to detect where significance lays between the mean soil temperatures according to depth for a given year. A 0.05 level of significance is revealed when testing the interaction of the 5 cm depth with all other depths, except at the 10 cm level where no significant difference was found. This finding was consistent across all three years and different locations (Table 1). A plausible explanation for this observation is that soil and atmospheric heat exchange is highest at the soil surface layers. Soil

moisture content has an important impact on heat energy flux between the land surface and the atmosphere (Bell, 2009). Soil moisture content is regulated through the input of precipitation or irrigation and moisture loss comes through evaporation and plant respiration. Water's heat capacity is five times that of mineral soil particles (Bell, 2009). Thus, wet soils warm up slower than dry soils, and their particle heat conductivity is expected to increase. Heat loss is amplified by surface evaporation (Bai, 2009). For instance, the soil temperature of the Mojave Desert would be cooler than normal under El Niño conditions. El Niño is an atmospheric phenomenon that causes increased precipitation in the Mojave Desert region, thus an increase in evaporation. Bai (2009) observed strong negative temperature anomalies during El Niño events. Surface heat loss leads to cooler soil temperatures within the first 5 to 10 cm in depth. Water percolating to lower soil depths will slowly warm up as heat is transferred down to lower depths. Water accumulating in lower depths tends to retain heat compared to the upper surface layers where evaporation accelerates cooling. Therefore, lower soil depths, from 20 cm up to 100 cm, are significantly higher in temperature than surface depths, from 5 cm to 10 cm (Hu and Feng, 2004).

Mean soil temperatures showed significant variation according to depth within the three year study ($p = 0.001$) (Table 2). However, there was no significant difference ($p > 0.05$) in soil temperature across locations, or for the interaction between location and depth. Similarly, there were no statistically significant differences ($p > 0.05$) in soil temperatures throughout the years covered in this study (Appendix II).

Table 1: Summary of Statistical Significant Depths in (cm) Grouped by Years.

	Depth (cm)				
Year	5	10	20	50	100
2007	*	ns	*	*	*
2008	*	ns	*	*	*
2009	*	ns	*	*	*

*: significant ($p \leq 0.05$) ns: not significant ($p \geq 0.05$)

Table 2: Mean Soil Temperatures in (˚C) and Standard Deviations According to Depth in (cm) and Location Grouped into Years.

		Locations							
Year	Depth (cm)	Abdaly		Rabyah		Sulaybiyah		Wafra	
2007	5	22.58	(10.15)	22.13	(8.82)	21.88	(9.53)	19.79	(9.04)
	10	24.43	(10.45)	24.33	(9.20)	24.49	(9.97)	25.13	(9.71)
	20	26.08	(10.54)	26.50	(9.37)	27.32	(9.78)	27.67	(9.78)
	50	27.97	(9.75)	28.12	(8.16)	28.71	(8.40)	29.23	(8.84)
	100	28.12	(7.95)	27.93	(6.56)	28.68	(6.84)	29.55	(7.12)
2008	5	22.99	(10.16)	22.58	(9.27)	22.04	(9.96)	19.98	(8.50)
	10	24.82	(10.35)	24.83	(9.54)	24.47	(10.20)	24.81	(9.60)
	20	26.41	(10.32)	26.82	(9.62)	27.20	(9.70)	27.03	(9.82)
	50	28.12	(9.35)	28.33	(7.70)	28.47	(7.90)	28.52	(8.59)
	100	28.31	(7.52)	28.06	(5.96)	28.46	(6.14)	28.93	(6.66)
2009	5	22.64	(9.06)	22.16	(8.56)	21.77	(9.32)	22.98	(9.09)
	10	24.48	(9.21)	24.78	(8.79)	24.38	(9.47)	25.76	(9.25)
	20	26.10	(9.18)	27.02	(8.80)	27.26	(9.04)	27.48	(9.27)
	50	27.85	(8.38)	28.70	(7.69)	28.44	(7.65)	29.05	(8.34)
	100	28.13	(6.69)	28.65	(6.26)	28.48	(5.91)	29.28	(6.38)

*Values between parentheses represent the standard deviations of the means.

CONCLUSIONS

Soil temperature is significantly influenced by soil depth across the years spanning 2007 to 2009. However, there was no significant difference between the different locations included in this study. A two way analysis of variance comparing the soil temperatures spanning the study years did not reveal any significant change in temperature across the years.

Comparing air and soil temperature changes reveal a tracking pattern, where soil temperatures follow the atmospheric temperature fluctuations. Factors such as ground air conductivity and evaporation lead to shallow soil depths being lower than ambient air temperatures. Deeper soils have a higher temperature range compared to shallow depths because of their latent heat exchange. Additionally, the ability of the soil to store heat and the slow propagation of heat lead to elevated soil temperatures.

Finally, any extrapolations should be taken cautiously seeing that the years studied are limited and cannot show a long term trend of temperature change.

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