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DIURNAL BEHAVIOR OF LAND SURFACE TEMPERATURE IN LUT DESERT

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ABSTRACT

This research analyzes some thermal behavior of various desert surfaces in different times by statistical analyses and thermal infrared channels 4 and 5 NOAA- AVHRR images.
This research was carried out in Lut Desert located in center of sub-tropical divergence dominant in Iranian plateau. The physical and thermal properties of the various desert surfaces have been determined using correlation relationships between the desert variables including: dark sand, normal sand, marl, saline soil, soil depth (10 cm), wet and dry bulb temperature in daytimes with the interval of two hours from 6 A.M to 20 P.M within 15 days.
The result shows that thermal conductivity, thermal capacity, physico-chemical properties of the studied materials and other thermal properties, are the most important factors affecting correlation coefficients. The highest correlation obtained around the sunrise (6 A.M) and especially before and after the sunset (18, 20 P.M). Minimum correlations were obtained around the noon at soil depth and the best fitted models are linear for light sand and marl in 18, 20 P.M and non-linear for soil depth and marl in 18 P.M. Therefore it is generally concluded that the study of diurnal behavior of land surface temperatures might be useful for thermal image interpretation.

Key words: *Lut desert, correlation, Surface temperature, Marl, light sand, Dark sand*

Introduction

Lut desert with an area of 80000 km^2 is located in southern of Iran between latitude 28°, 21′-32° N and longitude 55°, 55′-57°, 30′ E.

Some geographic specifications such as lack of moisture resources, permanent divergence of air in the upper layers of atmosphere, sky clearance and highness of solar radiation have lead to create hyper arid and warm condition in the region.

Lut desert, because of special climate, geological and physiognomical features, needs studying of various environmental aspects. But there is few data about surface temperatures of features and facies.

Diurnal temperature of land surface in deserts increased due to heat concentration and deficient relative humidity in the upper layers of aeolian sands (Kaviani, 2001).

The physico-chemical properties of land surface such as thermal conductivity, thermal capacity, thermal diffuse and specific heat are important to study diurnal temperature trend and behavior. The most important factor in heat generation is the energy absorbed by electromagnetic waves of the sun by land features.

The other factors affecting surface temperature are related to thermal and physical properties of features as well as dominate atmospheric condition (Alijani & Kaviani, 1992).

Electromagnetic radiations are absorbed, transmitted or reflected by land surfaces. Therefore, the reaction of these processes is important in thermal behavior of soil and rock surfaces (Jahedi & Farrokhi, 1996).

Temperature and its behavior pattern affect biological (growth and development of lants and animals), physical (degradation and erosion) and chemical systems associated with moisture (evapotranspiration and cryoclasty), especially in arid climates. Thus, they should be considered in earth science studies (Norman *et al*, 1995). The more the region is hyper arid, the more appearance of physical and thermal properties of materials. Although, in these regions, soil surface is suitable for thermal studies because of existing of sparse vegetation cover, top soil aridity, solar radiation, etc., but soil is complex in which color, crust and type of minerals affect its thermal patterns (Alavi panah, 2003). Soil temperature has periodical variations because of daily, monthy, seasonal and annual differences. These variations show a sinuous pattern (Bay Bordi, 1993). Periodical trend of soil temperature is more regular than other climatic parameters and thermal changes near the land surface are in accordance with land surface themperature. Thermal properties of soil surface such as thermal conductivity, specific heat (specific heat of soil minerals in dry condition is 0.2 cal), thermal diffusion (rate of materials heat due to thermal gradiant) are important for study of land surface temperature and demonstrate temporal variation of temperature (Kaviani, 2001). Thermal inertia is also one of the physical and thermal properties of materials and defined as thermal reaction of a substance to temperature variation of the environment. Rocks and minerals (compare to water and vegetation cover surfaces), have normally lower specific heat and thermal conductivity and higher daily temperature. Within soil and rock surfaces, heat transmission is controlled by diffusion. Soils with higher thermal diffusion have moderate regime compared to the soil with lowers thermal diffusion. The change diurnal temperature is low in soils having low thermal conductivity which shows that convergence flux removes sensitive heat in a thin layer near the land surface (Kaviani, 2001). Study of thermal characteristics in basalt showed that it has higher thermal ossciliations than sandstone inspite of its high thermal conductivity (Peel, 1974). In a study on thermal properties of granites in deserts of southern Morocco, Kerr *et al*, 1984 concluded that surface temperature of granite is 2°c higher than its 6 cm depth for maximum daily temperature. Also, the maximum temperature of granite surface is in 2 P.M. while for depth 6 cm, it happens at 12 noon. Smith (1977) studied thermal and physical properties of diurnal temperature for lime stone in Tunesia and obtained that the maximum difference in temperature happened in mid-noon and these a thermal blanche in early morning (Friedman, 1980).

Kaviani (2001) studied the relations between microclimate and thermal properties of land surfaces, features and its surrounding air. Alavi panah *et al* (2002) studied temperature of surface features of marginal yardangs in Lut desert using satellite data and obtioned an increasing trend of thermal radiation in a NW-SE direction of Lut desert.

Materials and methods

1- To study thermal variation of the study area, surface temperature of marl, dark and light sand, saline soil, soil depth (10 cm) and meteorological factors such as wet and dry temperature in daytimes were measured with the intervals of two hours from 6 A.M. to 8 P.M. within 15 days.

2- The data were entered into Microsoft Excel and statistical analyses were conducted and the relevant models were fitted.

3- Using statistical models, coefficient of correlation, the fitted models, trend line and regression were tested. Then the graphs related to thermal factors with the highest coefficient of correlation were examined.

4- Regression model was tested to determine the trend of diurnal temperature range and then the best fitted polynomial (non-linear) and linear regression models were selected.

Polynomial regression shows oscillation wave in diurnal trend of temperature. The category of trend line is determined using number of waves as follows:

$$Y = b + c_1x_1 + c_2x_2 + ...c_6x_6$$

Where:

b, c are constant coefficients and x is independent variable. The linear regression suggests increase or decrease of a material with steady trend.

5- Trend of dry air temperature was selected as constant variable because of long term data availability and high correlation with other features, while other surface properties were considered as dependent variables for regression and correlation relationship.

Results and discussion

Based on the statistical analysis of direct measurement of surface temperature in daytimes, the following results were obtioned:

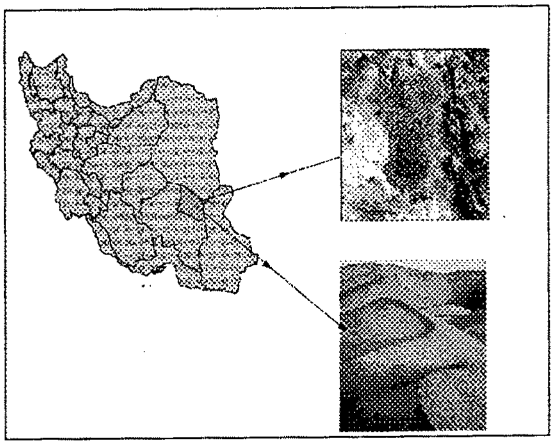


Figure 1: The location map of Lut desert and environmental features of the study area

The highest absolute temperature is related to marl (56.2°c) in 2 P.M. while the highest mean temperature is in 2 P.M. Meanwhile, the highest mean temperature over 15 days was 52.3°c for sand in 4 P.M. Generally, there were differences between thermal trend of sand and marls. Sand temperature was lower than of marl before noon, but higher than in afternoon. The lowest measured wet temperature was 11.8°c at 6 A.M. the mean of lowest wet temperature over 15 days was measured at 6 A.M. (Table 1).

Table 1: The features of mean daily temperature during 15 days in Lut desert

Variables	Sand	Dark sand	Marl	Surface of salt	Dry air	Top 10cm depth	Humid air
6a.m	30.5	30.2	30.6	31	15.3	32.3	30.3
8a.m	33.6	33.5	34.5	36.1	15.7	36.1	32.3
10 a.m	39.6	40.5	42.6	44.1	17.1	43.5	35.2
12p.m	47.8	47.9	50.9	50.7	18.5	52.0	38.3
14 p.m	50.3	50.1	51.9	50.5	19.2	50.7	40.0
16 p.m	52.3	50.8	51.8	48.5	19.4	48.1	41.4
18 p.m	48.2	47.4	46.9	43.9	19.3	44.1	40.8
20 p.m	45.8	44.6	44.3	41.6	18.5	41.5	40.0

The highest daily temperature for light and dark sand, soil surface and soil depth (10 cm) and marl was seen at 4 P.M., 12 noon and 2 P.M., respectively. According to table 1, the maximum range of positive thermal variation between 10-12 A.M. for marl was as 8.3 light and dark sand as 8.2, 7.4, soil depth as 8.5, wet and dry temperature as 3.1, 1.4. While the highest variation of surface soil temperature was 8°c at 8-10 A.M. The intensity of solar radiation had a declining trend in the afternoon and was increased at 4-6 P.M. In this condition, thermal variation for light and dark sand was as 4.1, 3.4, marl as 4.9, soil depth as 4, wet and dry temperature as 0.6, 0.1 and soil surface as 5.4°c. The highest range of daily temperature for dark and light sand was high as 8.6 and 8°c, respectively while soil depth and was air temperature was low as 5.8 and 6°c, respectively (Table 2).

Table 2: Thermal properties of different soil surfaces in Lut desert at different day times

Phenomena	Mean daily temp.	Max. Daily temp.	hours	Min. daily temp.	hours
Light sand	8	10.8	12	5.8	8
Dark sand	8.6	14	14	5.6	8
Top 10cm depth	5.8	10.4	14	6	16
Marl	6.2	11.6	10	6	16
Surface of soil	6.2	9.4	14	5.2	12
Dry air	6.6	9.6	20	6.2	16
Humid air	6	9.6	10	3.6	20

Generally, variation of surface soil temperature in deserts is high in day times. The highest variation range of daily temperature is seen in soil arid rock surfaces in mid-days. The lowest variation of daily temperature is seen in the early of morning and at 4 P.M (Table 2). With measuring correlation coefficient of mean daily temperature for various levels (Table 3), the highest correlation was found between dark and light sand as 0.943 and between 10cm depth and soil surface one as 0.958. In this case, the lowest correlation was measured between wet air and soil surface as 0.67 and between wet and dry air as 0.757.

The best fitted model with the highest coefficient of correlation were selected and totally, 30 regression models were established for the studied parameters of daytime which showed high correlation (Table 4).

Table 3: correlation of mean daily temperatures in Lut

	Saline soil surface	marl	Dark sand	Light sand	top 10cm soil	Dry air
Surface of salty soil	1	--	--	--	--	--
Marl	0.846	1	--	--	--	--
Dark sand	0.812	0.897	1	--	--	--
Light sand	0.891	0.937	0.943	1	--	--
Top 10cm depth	0.958	0.928	0.874	0.922	1	--
Dry air	0.855	0.846	0.858	0.609	0.858	1
Humid air	0.67	0.848	0.803	0.798	0.813	0.757

The relation between soil depth (10 cm) and saline soil surface at 8 P.M. with the coefficient of correlation which was 0.94 (Figure 2) and 0.93 (Figure 3), respectively showed the best linear fitness.

Table 4: Correlation coefficient and linear equation of air dry temperature as independent variable (X)

Models	R_2	Y=aX±b	R_2	Y=aX5
Surface of salty soil	.81	Y=1.3413x - 6.7316	.8419	$Y=0.502X^{1.2302}$
Marl	.913	Y=1.7416 x - 20.769	.9305	$Y=0.1589\ X^{1.5532}$
Dark sand	.962	Y=1.7652 x - 22.708	.9693	$Y=0.1323\ X^{1.5974}$
Light sand	.975	Y=1.863 x - 25.976	.9807	$Y=0.107\ X^{1.6583}$
Top 10cm depth	.786	Y=1.2853x- 4.3986	.8251	$Y=0.654\ X^{1.1588}$

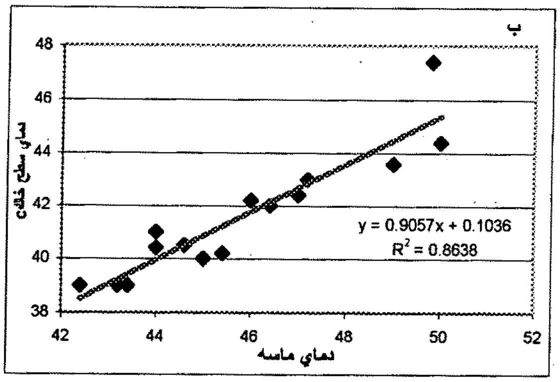
The significant non-linear regression between marl surface and soil depth (10cm), and between dry air temperature and light sand show sinuous pattern of temperature behavior at 4 and 6 P.M. over 15 days (Figures 5, 6). Thermal variations of these surfaces have logical correlation with each after. They have only one concave or convex wave in which non-linear regression shows two periodical variations of temperature over 15 days. But linear regression measures the gradiant between two variables and has a steady increase or decrease. Figures 5 and 6 show non linear behavior of temperature trend line between marl and soil depth (10 cm) while convex part and concave of figures 6 and 4 suggest that there is an increase at 8 P.M. While is decrease at 12 noon and 6 P.M. This is mainly related to the moisture or others thermal factor entering into the system.

The soil depth (10 cm) had the highest correlation with marl, common sand and soil surface especially at 6 and 8 P.M. (Figures 1-8) and showed acceptable correlation. With soil surface temperature in most of daytimes. Figures 2, 3 and 8 indicate that thermal variation of soil surface and depth (10cm) are highly into correlated and soil depth difference (10 cm) has no effect on thermal behavior. The highest correlation in 6 and 8 P.M. is related to marl, light sand, soil surface and depth (10cm). It is due to cooling of long wave radiation in the afternoon which causes density of sensitive thermal flux to be negative (Kaviani, 12001).

Based on specific heat, thermal capacity and diffuse rock and soil surface show different behavior to solar electromagnetic waves. The surfaces such as marl, dark and light sand which have low specific heat, thermal capacity and diffuse lose heat stored in the upper thin layers while soil surface depth (10 cm) show even temperature in the deeper layers. But at the peak tines or solar radiation (mid day), physical and thermal properties are the most important factors responsible for low thermal correlation.

The lowest regression was obtained between dry and wet air temperature and saline soil surface. Generally, wet and dry air temperature show weak correlation with other surface factors. Figure 10 indicates different thermal conditions of the mentioned factors compared to the land surface of desert. Wet and dry temperature are in accordance with solar radiation while plain surfaces receive negative flux of radiation waves and leads to the rapid cooling of the surface compared to the surrounding atemosphere (Kaviani, 2001).

Figure 2: Linear trend and optimum temp. model of soil surface and light sand at 6p.m (A), 8p.m (B) & soil surface temp. & dark sand at 6a.m (C) & 8p.m (D) & soil surface temp. & marl at 6 p.m (E)



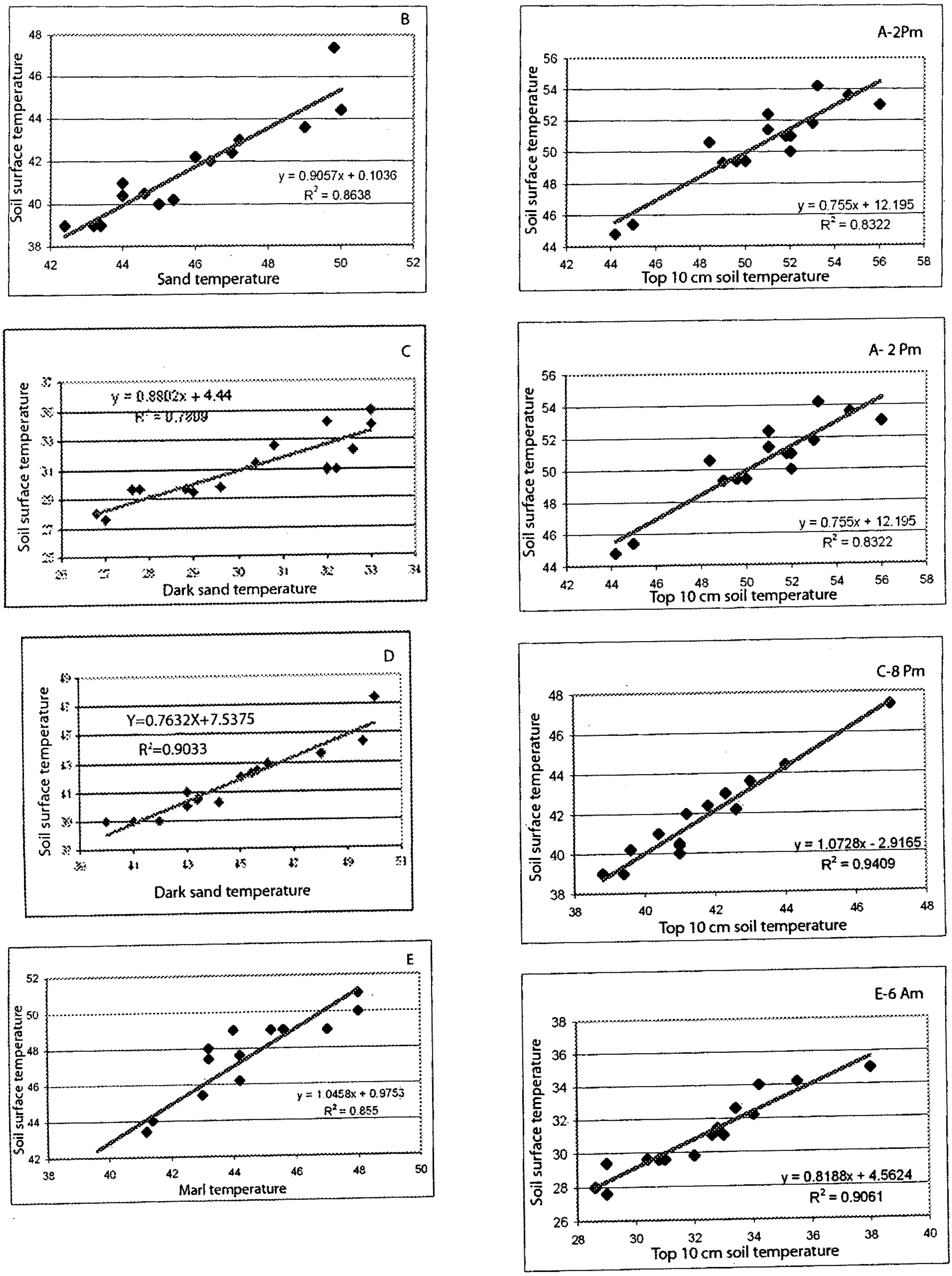


Figure 2: Linear trend and optimum temperature model of top 10cm & surface soil at different daily hours

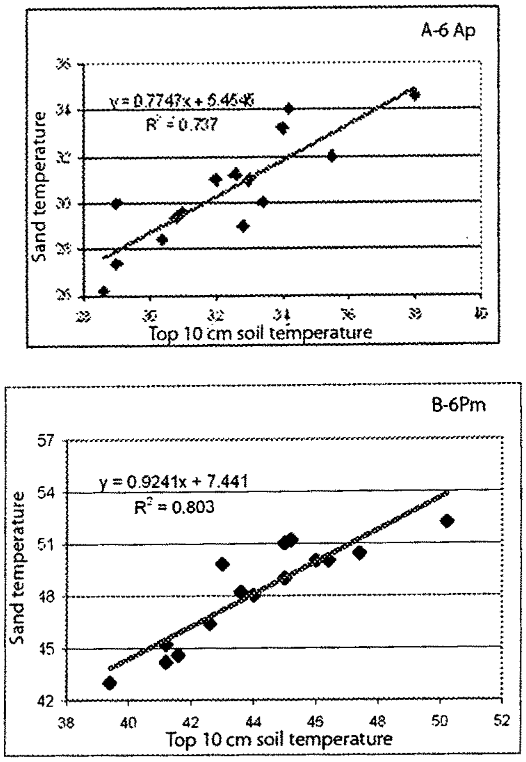


Figure 3: Linear trend and optimum temperature of top 10cm soil and light sand

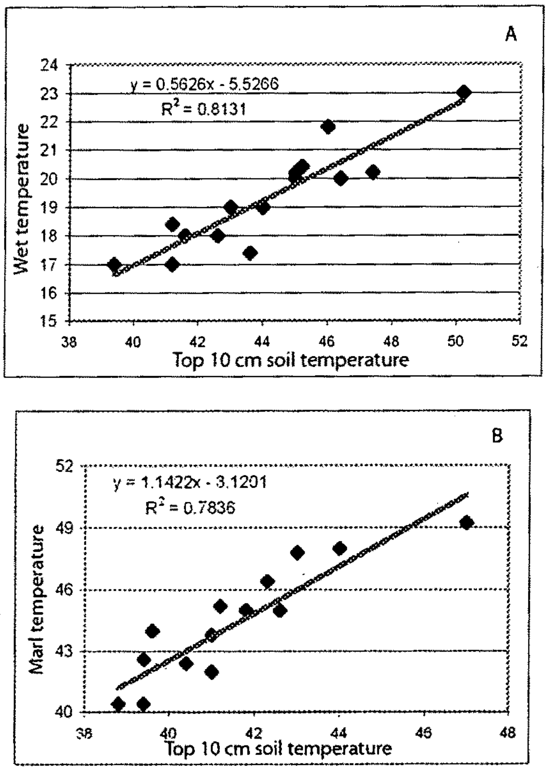


Figure 4: Linear trend and optimum temp. model of top 10cm soil and humid temp. at 6p.m (A) and top 10 cm soil and marl temp. at 8p.m (B)

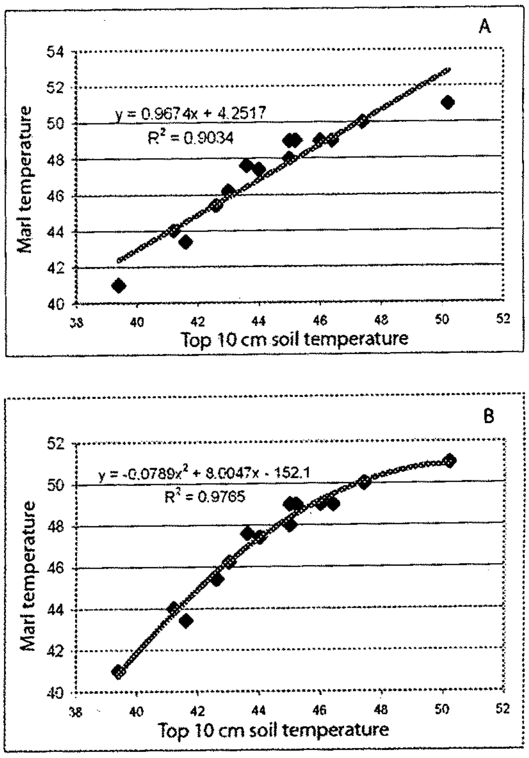


Figure 5: Linear trend and optimum temperature model of top 10cm soil and Marl at 6p.m (A): Linear regression (B): non-linear regression

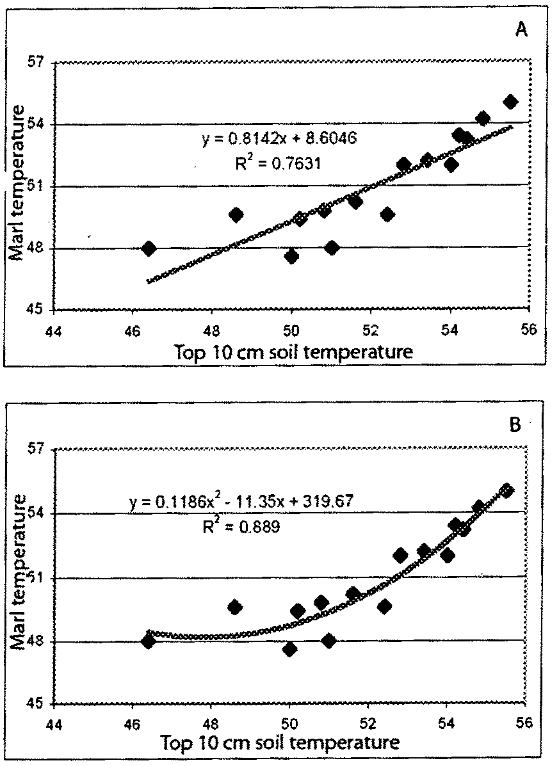


Figure 6: Linear trend and optimum temperature model of top 10cm soil and marl at 12 O'clock (A): Linear regression (B) non-linear regression

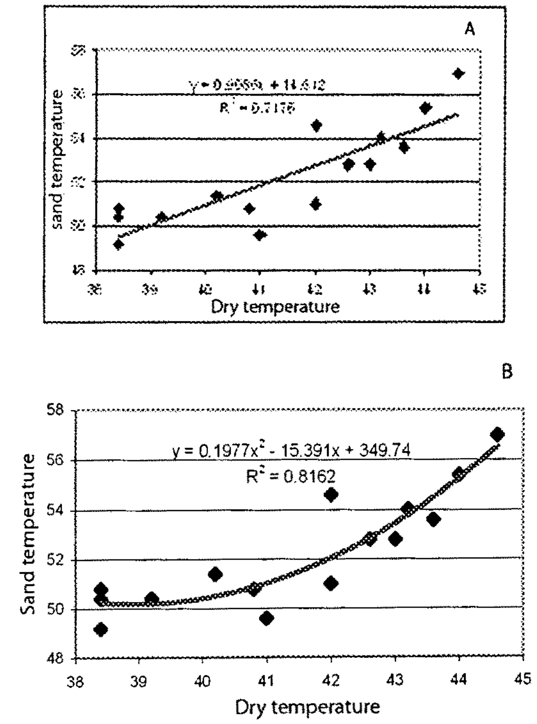


Figure 7: Correlation coefficient between dry air temperature at 4p.m (A): linear regression (B): non-linear regression

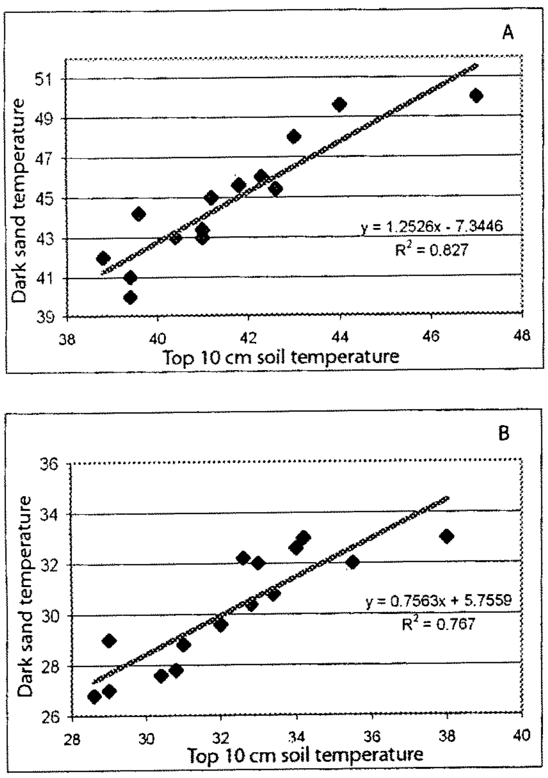


Figure 8: Linear trend and optimum temp. model of top 10cm soil and dark sand at 8p.m (A) and 6a.m (B)

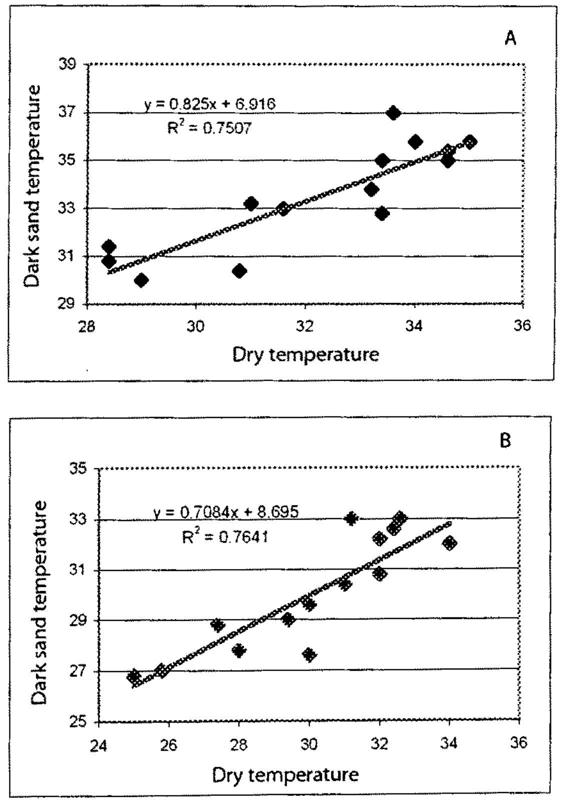


Figure 9: Linear trend and optimum temperature model of dry air and dark sand at 8a.m (A) and 6a.m (B)

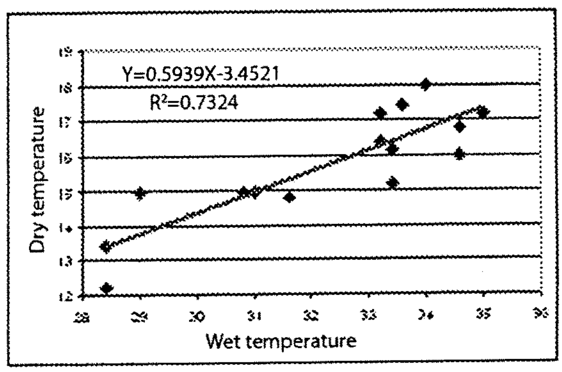


Figure 10: Linear trend and optimum temperature model of dry humid air at 8

Conclusion

The results of study in the region show that microclimate, thermal regime and features are controlled and affected by their physical and thermal properties. Since the materials consist of various minerals and textures, they show different thermal regimes when affected by similar atmospheric and solar radiation condition. Temporal trend of soil temperature is more regular than other climate variables (dry and wet air temperature). The diurnal wave of temperature in upper layer of soil is apparent and relatively coordinated with the upper layers of land surface in soil depth (10 cm). Different levels with extreme thermal differences in specific periods (early morning and late night) have regular condition which differs from other day times (noon). The equilibrium happens when electromagnetic waves of solar energy are deleted from system. Therefore, the difference of physical and thermal properties of materials is apparent in solar short wave radiation.

The results also show that thermal variation within a day has sinuous oscillation which is in similar phase with received solar energy so it has similar changes over continous days. The soil and rock surface have also higher thermal oscillations (low specific heat, thermal conductivity and thermal capacity) compared to dry and wet air temperature. The intensity of thermal variations has reverse relation with thermal capacity and direct relation with coefficient of thermal absorption. Then, it may state that coefficient of thermal absorption for marl is higher than sand which leads to low thermal variation of marl between 12-4 P.M., while light and dark sand have high variations (4.1 and 2.9°c) within the mentioned times. This high temperature is due to the high thermal capacity of marl resulted from moisture content of clay particles compared to the moisture content of sand (quartz). Moreover, soil surfaces are collections of mineral particles in which their reflective spectrum is due to individual spectrum of each mineral. Then, acidic rocks have the minimum yield of radiation in low wave length compared to the basic rocks.

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