PREDICTION OF SOIL TEMPERATURE BY AIR TEMPERATURE; A CASE STUDY FOR FAISALABAD.

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Abstract:

The agriculture productivity depends upon the soil type as well as other meteorological parameters. Soil temperature greatly affects most of the biological and physical processes occurring underground. Soil temperature plays an important role during the life cycle of the plants right from germination, root extension, emergence to the reproductive stage. The measurement of soil temperature is a cumbersome business and not as simple as air temperature be noted by single thermometer. Separate thermometers are required to measure the temperature of the soil at different depths. Sowing depth of seeds is commonly taken between 5 cm and 10 cm. major root density at reproductive stage of most of the cereal crops vary from 20 cm to 30 cm keeping in view the importance of these depths, an attempt has been made to estimate soil temperature from air temperature of that particular location at that time. In this study the regression equations between the seasonal daily mean air temperature and seasonal daily mean soil temperature have been derived for the Faisalabad region. Faisalabad soil is mainly loamy with significant proportion of silt. These soils represent vast agricultural plains of the Indus river system in irrigated parts of Punjab, NWFP and Sindh. These equations will be used to predict the daily mean soil temperature with the help of air temperature. Correlation coefficients between these two variables were derived. The value of R2 has different value for different season. Highest value (0.86) in spring season at 10 cm depth and the lowest value (0.32) in winter season at 20 cm depth. The least value in summer season may be due to vegetation cover. These regression equation can also be used for others stations with some changes. These equations can also be used for the estimation of missing data.

Introduction:

Pakistan has agriculture based economy. About 22 % of the GDP and 44.8 % of total employment is generated in agriculture. 65.9 % of the population living in rural areas depends upon the agriculture directly or indirectly for their livelihood. Contribution of agriculture in the export is also substantial (Year Book, 2005-2006, Ministry of Food, Agriculture and Live Stock, Pakistan).

The quality and quantity of the crop depends upon many factor including the soil. Soil temperatures significantly affect the budding and growth rates of plants. For example, with the increase in soil temperature, chemical reactions speed up and cause seeds to germinate. Soil temperature plays an important role in the decomposition of soil. It also regulates many processes, including the rate of plants development and their growth Soil temperature also plays an important role for setting life cycles of small creatures which

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live in the soil. For example, hibernating animals and insects come forth of the ground according to soil temperature.

Soil temperature is also regarded as sensitive climate indicator and stimulus. Scientists use soil temperature data in the research on variety of topics including climate change. (Sharratt et al., 1992). Soil temperature anomalies also directly affect the growth and yield of agricultural crops. For example cool spring season, soil temperature in shallow layers delays corn development and on the other hand warm, spring season, soil temperature contributes to an increase in corn yield (Bollero et al, 1996). Soil temperature although is integral in many ecosystem processes, is costly and its observation is difficult (Shannon E. Brown et al, 2000)

Soil temperature also determines the state of the water in the soil whether it will be in a liquid, gaseous, or frozen state. In cold soils, the rate of decomposition of organic matter will be slow because the microorganisms function at a slower rate, as a result the color of soil will be dark. In tropical climates intense heating causes increased weathering and the production of iron oxides, which results into the reddish color of soil. (**http://www.globe.gov/tctg/sectionpdf.jsp?sectionId=92#page=10**)

The objective of this study is to develop a general methodology for the prediction of soil temperature using air temperature. A significant relationship exist between averaged daily air temperature and observed daily soil temperature at 10 cm depth (Zeng et al. 1993) . Soil temperature also correlate with the soil respiration and soil moisture, there is an exponential correlation between soil temperature and soil respiration (Tang Xu Li et al, 2006). Air temperature can be used to determine soil temperature and the exchange of gasses between soil and atmosphere.

Successful prediction of soil temperature with the help of Air temperature will lead to minimize the time, cost, and equipment maintenance necessary for on site monitoring and will help researcher to use data from other sources also. Instead of the fact that Pakistan is an agricultural country, we have to import wheat and also some type of cotton. This is because the production is not sufficient as compared to our demand. The per acre yield is very less. The reason behind this less productivity may be inappropriate manners of cultivation, old fashioned equipment and also the use of old species of certain crops. With the change in climatic conditions and availability of water one must switch to the specie of crop best suited to climate are more resistant to droughts. According to agroclimatic classification the 2/3 area of Pakistan is under arid climate (Chaudhry, Q.Z. and G. Rasul; 2004). This study can be used as a base to determine the condition of soil (temperature, moisture and respiration) to determine which type of crop will be beneficial and when it should be grown to be more productive. It can also be used to examine the soil temperature variations indicated by the Global and Regional Circulation or Climate Models and can be used to check the validity of models to describe the surface and atmosphere energy interaction.

Data and Methodology:

Pakistan Meteorological Department has five Regional Agromet. Centres (RAMC's), which record the data of different soil parameters. Seventeen (17) years data of Air temperature and soil temperature were used in this study. These data are recorded at RAMC Faisalabad w.e.f 1989 to 2005. Daily Mean Air temperature has been calculated from the average of Daily Maximum and Daily Minimum air temperature. The Daily Mean Soil temperature was calculated form the average of three observation taken daily at 0300 hr, 0900 hr and 1200 hr (GMT). Daily Mean Air temperature is assigned the variable name 'X' while the daily Mean Soil temperature is described as 'Y'.

The correlation coefficients between Daily Air temperature and Daily Soil temperature were calcuted using the Pearson's Formula for correlation coefficient. Actually it indicates the strength and direction of a linear relationship between two random variables. In general statistical usage, correlation or co-relation refers to the departure of two variables from independence (Faqir Muhammad)

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Where n represents the number of entries.

By calculating the correlation coefficient it becomes clear that how much one variable depends upon the other. Regression equation were formed in the form

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Where 'm' is the slope of the trend line and 'b' is the intercept of trend line with y-axis. Slope 'm' was calculated using the formula

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And intercept 'b' is calculated with the help of the following formula

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Where **Error! Objects cannot be created from editing field codes.**and **Error! Objects cannot be created from editing field codes.**are mean of soil temperature and air temperature of respectively.

Standard errors of Mean (SEM) for each season were also calculated. This represents the mean error in the predicted values.

Table 1: **Characteristics of soil of the area under the study (RAMC, Faisalabad)**

Depth (cm)	Sand%	Silt%	Clay%	PH%	Colour		Type
					Moist	dry	
0-23	50	26	25	8.1	dark/dark brown	Pale brown	silt loam
23-64	52	48	28	8.2	Dark yellowish brown	Pale brown	Silt loam
64-92	45	26	29	8.3	Brown	Pale brown	Silt loam
92-150	46	31	25	8.4	Yellowish Brown	Very pale brown	Silt loam

Results and Discussion:

The values of Correlation coefficients (R^2) calculated for the four seasons are 0.366999539, 0.864590297, 0.732919235 and 0.817574878 respectively for winter, spring, summer and autumn. The value of R^2 is quiet good for all seasons except the winter season, for which its value is less then 0.5. The reason for the lower values of correlation coefficient in autumn and winter may be that in these seasons the duration of sunshine hour is less. The air temperature changes rapidly as compared to soil temperature, so that coarse correlations exist during these seasons. Wheat crop is grown on the site where the data is collected. Winter season (Dec-Feb) is the growing period of wheat crop. In this season the plants of wheat comes out of the ground. So the area has a quite good vegetation cover. This change in vegetation cover will also cause to lower the R^2 value, because change in vegetation cover can impact the amount of energy reaching the soil (Balisky and Burton, 1993).

Table 2: **R^2 values for different seasons at 10cm, 20cm and 30cm depth**

	10cm	20cm	30 cm
DJF	0.367	0.319	0.424
MAM	0.865	0.839	0.829
JJA	0.733	0.668	0.594
SON	0.818	0.851	0.727

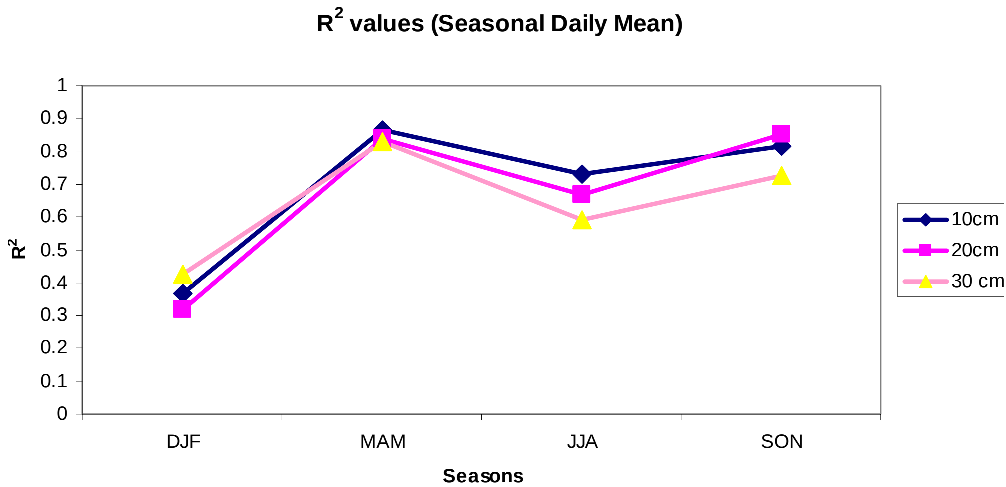


Figure 1**: Comparison of R^2 Values for different Seasons and Depths.**

Seasonal Classification:

Winter = December, January and Feberuary

Spring = March, April and May

Summer = June, July and August

Autumn = September, October and November

Four equations calculated for the four seasons are listed below.

For 10 cm Depth:

YDJF =0.0.739x + 5.234 (1)

YMAM =1.157x + 0.9935 (2)

YJJA =1.346x – 5.738 (3)

YDJF =1.231x - 3.407 (4)

For 20 cm Depth:

YDJF =0.614x + 6.084 (5)

YMAM =0.014x + 2.15 (6)

YJJA =1.075x + 1.304 (7)

YSON =1.199x – 2.089 (8)

For 30 cm Depth:

YDJF =0.5697 x + 6.894 (9)

YMAM =0.9701x + 2.298 (10)

YJJA =0.946x + 4.723 11)

YSON =1.087x + 0.2566 (12)

For winter, spring, summer and autumn season respectively

While the values of SEM for the four seasons of year for the depth of 10 cm and 20 cm are given in the following table.

Table 3: **Standard Error of Mean**

	10 cm	20 cm	30 cm
DJF	1.36	1.26	0.93
MAM	1.24	1.21	1.195
JJA	1.39	1.30	1.34
SON	1.14	0.98	1.30

The standard error of a method of measurement or estimation is the estimated standard deviation of the error in that method. Specifically, it estimates the standard deviation of the difference between the measured or estimated values and the true values.

These general equations can be applied to find out the soil temperature of most of the sites, but individual coefficients and constants will have to be calculated first.

The graphs of the plotted data and trend line are given below.

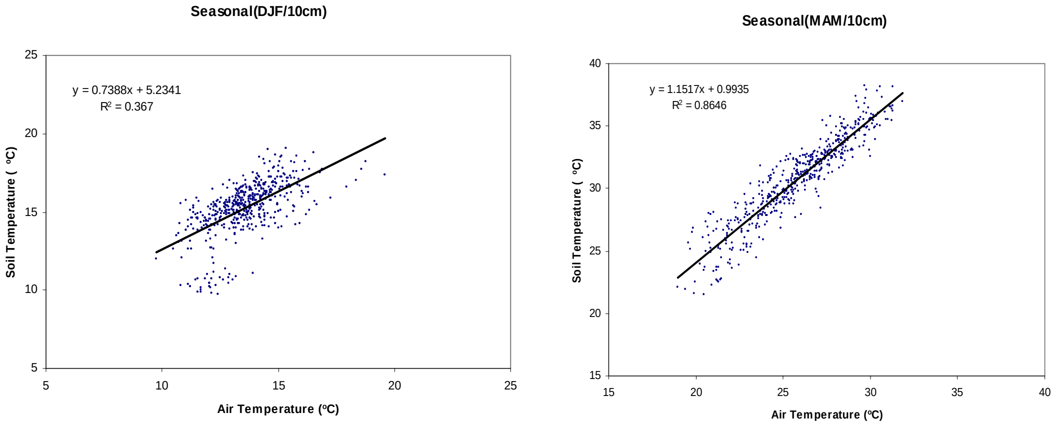
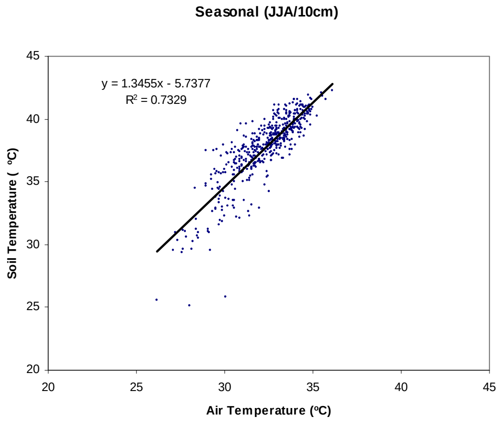


Figure 2: **Trend line of air temperature and soil temperature in winter and spring season (10 cm depth)**

In the Fig. 2 in the graph of winter season (Dec-Feb) the dispersion in the data is quite large. Due to this large dispersion the value of R2 is very low. Winter season (DJF) is the growing period of wheat crop, and this vegetation may prevent soil temperature to rise as rapidly as air temperature. Because of this contrast the correlation coefficient R2 is also very weak. The reason of large dispersion seams to be the different moisture contents and canopy cover in different years which caused the variation in thermal conductivity patterns in the same soil. In spring season (MAM) R2 is the largest as compared to the remaining three seasons. Data points are very close to the trend line. This high correlation may be due to the fact that April and May are dry months as compared to the other seasons and the dry soil is less resistant to heat penetration as compared to wet soil. The insolation received on the soil through crop canopy if any (wheat harvested in April-may and fields are directly exposed to sun) and heated up the soils simultaneously. It may be noted that specific heat of dry soil less than wet soil therefore heat exchange between air and soil is much faster.

In summer season the dispersion in the data is not very large but due to some outliers, the value of correlation coefficient is not very high as compared to that in the spring season. One more reason of this relatively weaker correlation may be effect of monsoon season. In Faisalabad monsoon starts from July and last till the end of September. Due to difference of specific heat of air and water the heat conductivity characteristics widely vary on temporal and spatial scale. The correlation coefficient for the autumn season is quite good. After the wet spell of monsoon season in autumn the dry soil and relatively moderate temperature causes the correlation coefficient to become large as compared to JJA.



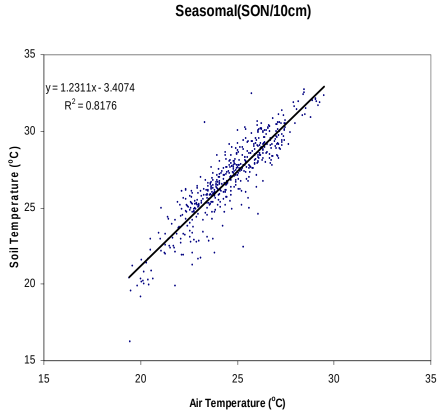
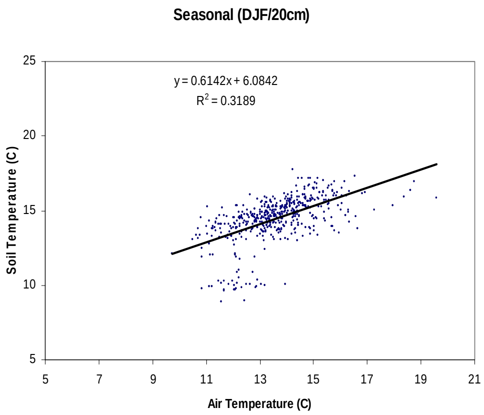


Figure 3: **Trend line of air temperature and soil temperature in summer and autumn seasons (10 cm depth)**



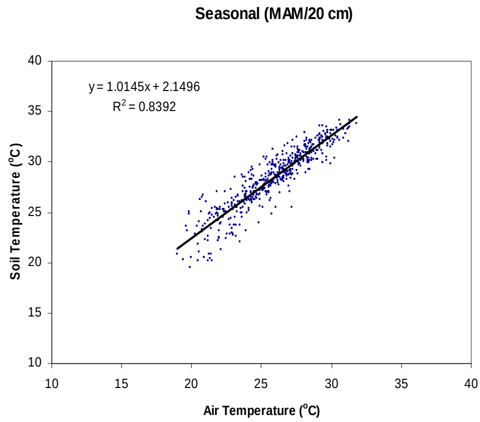


Figure 4: **Trend line of air temperature and soil temperature in winter and spring seasons (20 cm depth)**

Above Fig shows the trend of DJF and MAM for 20 cm depth. In the correlation coefficient is very weak. The effect may be the vegetation cover which plays its role to generate larger lags in air and soil temperatures. However, some data quality is also questionable. In spring season the correlation is very strong. The reason may be that wheat reaches its maturity in this season, allows more solar radiation to penetrate into the soil. The value of R2 is less then for 10 cm depth for the same season, because the thermal conductivity takes longer to deeper depths.

In summer season the land is almost bare because in these months the wheat crop is harvested in the area. Air temperature changes rapidly as compared to soil temperature, in the monsoon season some time the air temperature drops suddenly due to cloud formation but the soil does not respond so quickly. That's why R is less then the previous season.

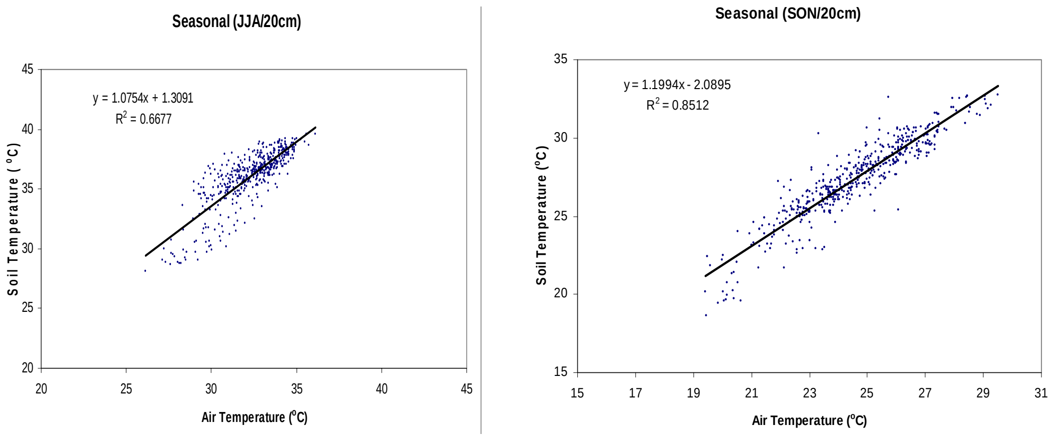


Figure 5: **Trend line of air temperature and soil temperature in summer and autumn seasons (20 cm depth)**

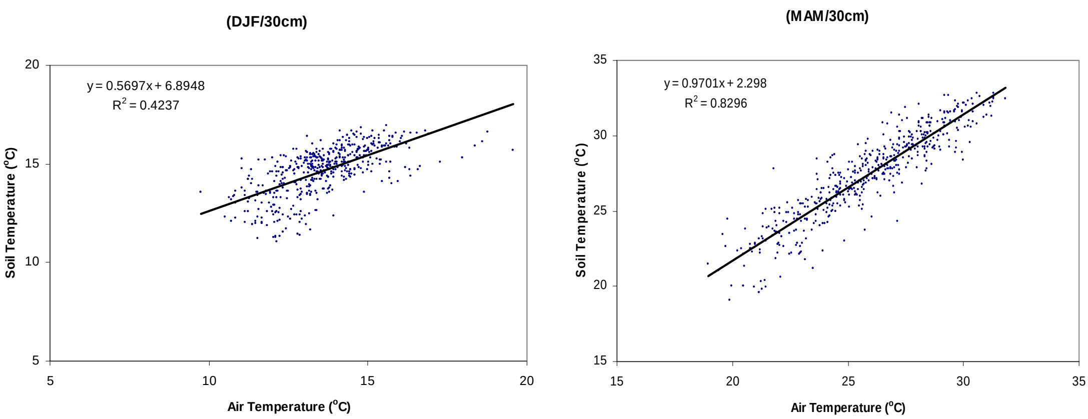


Figure 6: **Trend line of air temperature and soil temperature in winter and spring seasons (30 cm depth)**

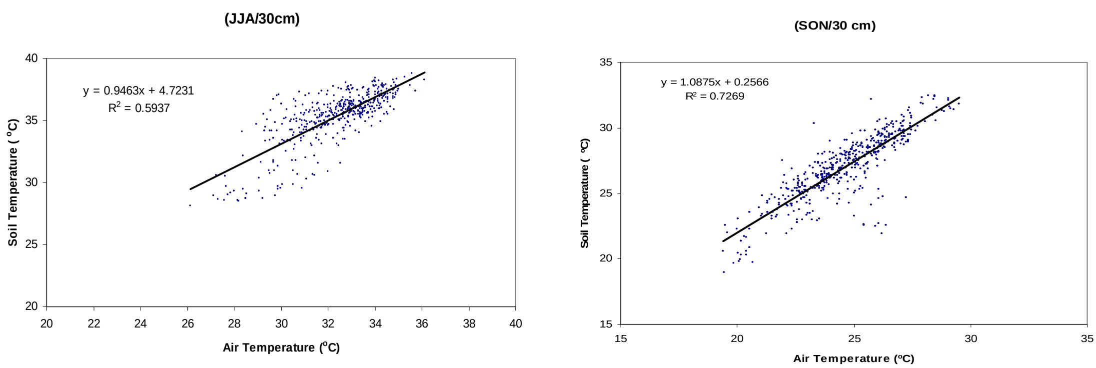


Figure 7: **Trend line of air temperature and soil temperature in summer and autumn seasons (30 cm depth)**

When comparing it with the 10 cm and 20 cm the correlation coefficient is little bit large. Also the standard error of the mean is less then that for the less depth The value of correlation coefficient is less as compared to that of the 10 cm and 20 cm depth. However SEM remains almost the same.

There is a very notable change in correlation coefficient in summer season when we compare it with the 10 cm and 20 cm depth. In autumn the correlation coefficient decreases with increase in depth.

The measurement of soil temperature is very important for the selection of suitable variety of crop to be grown in particular areas. Pakistan has very diverse climatic regions ranging from burning deserts in the south to the frozen cryoshpere in the north. Due to excessive heat, except monsoon season, the water balance over most of the central and southern parts of the country remains negative (chaudhry, et al, 2004). There are only five Regional Agromet Centers all over the Pakistan, which do not represent all the areas of the country. In this connection the regression equation obtained through this analytical study can be used to determine the soil temperature of different depths. This would help to choose the best suitable region and specie of crops to be cultivated. The site collection of the soil temperature is very complicated as well as costly. The installation of thermometer correctly in the soil is another very complicated technical matter. The use of these regression equations will save the time as well as the finances. Here one just has to input the air temperature and the result will be in the form of soil temperature with a sufficient accuracy to rely upon.

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