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Measurement of the Soil Temperature in Soil Columns with AD/DA Converter Card-Sensors and its Simulation along with the Determination of the Thermal Conductivity

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Soil temperature was studied in soil columns at steady and unsteady flow conditions at different moisture content rates. Changes in temperature in soil columns were determined both with sensors and mathematical models. AD/DA converter cards and sensors were determined to be sensitive for measuring external heat sources. Thus, AD/DA converter cards and sensors are suitable for utilising in soil temperature studies. Moreover, mathematical models are also determined to be in accordance with measured results.

Key Words: Soil temperature, Regine mathematical modelling, AD/DA converter card, Heat sensor.

INTRODUCTION

Soil temperature significantly effects plant growth, at 0-5ºC. Germination and root development can not be healthy, below freezing point and biological activity stops. Each plant requires specific heat levels for growing, since chemical reactions, micro organism activity, aeration, water holding and movement are all heat dependant parameters. Soil colour, specific heat, water content, soil surface relief, type and intensity of vegetation cover are effectiveness soil heat[1].

Recent studies on plant growth revealed models are that successfully used and applied in agricultural sciences. Plant growth models, based on blocks principle, should be individually outlined and correlated with suitable software. Soil head is an important parameter in block based modelling of Energy-Mass and plant growth of currently developing agro ecosystem studies[2].

Mathematical modelling and digital analyses of soil temperature is an important approach. When mathematical modelling of soil temperature is evaluated at 2 conditions *i.e.* unsteady flow limit and initial condition can be expressed as flow[2].

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$$C_s(\theta)\frac{\partial T}{\partial t}=\frac{\partial}{\partial x}(\lambda_s(\theta)\frac{\partial T}{\partial x}) \quad (1)$$

Higher and lower limits can be respectively expressed as follows;
Higher limit condition:

$$T|_{x=o} = T_a+(3*(1+1.16*\sin((2*\pi*t_k/24)-2.09)) + 0.56*\sin((2*\pi* t_k/24)-0.785) *\ln(\varphi))*\cos(0.0464*n) -(0.85*\ln(u+1)) \quad (2)$$

Lower limit condition:

$$T\ (N)=\text{Constant} \quad (3)$$

Initial condition:

$$T_{i(x)}=f(x)$$

In eqn. 1, $C_s(\theta)$ (cal $cm^{-3}*^oC$) is the volume heat capacity related to soil moisture content, $\lambda_s(\theta)$ (cal $cm^{-1}*^oC^{-1}*h^{-1}$); soil heat conductivity T(ºC); soil temperature t (h) ; time, x (cm); thickness of the soil layer, N soil depth. Other parameters are, T_a : air temperature, n: cloud cover, u: wind speed, φ: relative air moisture.
Equation expressed above is defined below[3]:

$$T_i\ (t_{k+1}) = T_i\ (t_k)+A_t\ (T_{i-1}\ (t_k) - 2\ T_i\ (t_k) + T_{i+1}\ (t_k)) \quad (4)$$

For simplifying this expression, determination of temperature in homogenous soil can be expected as follows;

$$T_j=\frac{NR-J}{NR}\cdot T_0+\frac{J}{NR}\cdot T_{NR} \quad (5)$$

As seen in this equation, for any J layer temperature surface and sub layer temperature and layer position are in relation to each other, whereas NR is the number of layers.

For testing the approaches (steady and unsteady conditions) in both condition experiment were undertaken is soil columns and probable similarities were investigated. Data were stored in computers by utilizing AD/DA converter card and sensors.

EXPERIMENTAL

The soil sample used in the experiment was taken from the Experimental and Research Station of the Department of Field Crop Sciences of Agricultural Faculty of University of Çukurova. Some physical and chemical properties of the disturbed and undisturbed soil samples were determined according to the following methods. Dry bulk density was measured by the core method[4], saturated hydraulic conductivity was determined according to the method[5] and particle size distribution was determined by the Bouyoucos hydrometer method[6]. Organic matter content, calcium carbonate, pH and total salt were all determined according to the method[7]. Water retention capacity (pF) was measured according to the method[8]. Some properties of soil are given in Tables 1 and 2.

TABLE-1
PHYSICAL AND CHEMICAL PROPERTIES OF THE SOIL USED IN THE EXPERIMENT

Bulk density (g cm^{-3})	Hydraulic conductivity (cm h^{-1})	Sand (%)	Silt (%)	Clay (%)	Textural class	Total salt (%)	pH (1:2.5)	$CaCO_3$ (%)	Organic matter (%)
1.16	0.39	28.23	34.78	36.99	CL	0.053	7.53	26.89	1.34

TABLE-2
SOIL WATER CHARACTERISTIC VALUES OF THE SOIL USED IN THE EXPERIMENT

Volumetric water content (%)						
1 cm	100 cm	333 cm	1000 cm	5000 cm	10000 cm	15000 cm
57.57	34.49	29.95	27.66	20.67	19.74	18.81

Analog/Digital (AD/DA) converters used for measuring the heat properties. Data collectors capability of data storage and capacity use of varying methods. With the aid of the software, data-collecting system collects data *via* suitable modules or sensors. For heat measurements, Super (output impedance 2K ohm) 14 byte AD/DA card is used in computer, capable of converting data to digital data, which were attained 16 different points. Analog data can be calculated less than 2 ms by sensors.

The experiment set consists 2 soil columns and in each column 8 sensors were placed. Temperature changes were observed in one column by using varying moistures. Also, for determining the sensitivity of the sensors 500 W and 100 W heat sources were utilized. Soils were placed in plastic columns (R = 11 cm) and kept in field conditions (Fig. 1). Holes are opened at 10 cm intervals in columns and heat sensors were placed in to the holes. Changes in temperature and periodic measurements were transferred to computer. Software was developed for the use and calibration of AD/DA card. Temperature values were calibrated and analysed in MS Excel software. The valid equation, trend and validity values were observed for each channel. These trends were also used for temperature the measurement program.

The height of PVC column is 1 m with a radius of 5.25 cm, having 10 layers with 10 cm thickness with soil of known bulk density (Fig. 1).

RESULTS AND DISCUSSION

In eqn. 1, the thermal conductivity and the heat capacity can be measured by using finite differences method and $c_s = 0.20\ \rho_b + \theta$ equation[9], respectively as in the following formula:

$$\lambda = \frac{c_s \cdot \frac{T^s{}_1 - T^i{}_1}{\Delta t}}{\frac{T_1 - T_2}{\Delta x^2}} \quad (6)$$

in the equation T_1^s, T_1^i are same layer, (Δt) initial and final temperature in certain period, T_1 and T_2 represents adjoining layer temperatures and Δx is the thickness of the layer. The heat conductivity were calculated by taking into account moisture ($\theta = 33.5$ %) and low moisture ($\theta = 15$ %) conditions along with measured values. The heat conductivity value for the moisture conditions were higher than low moisture contents of the soil (Table-3).

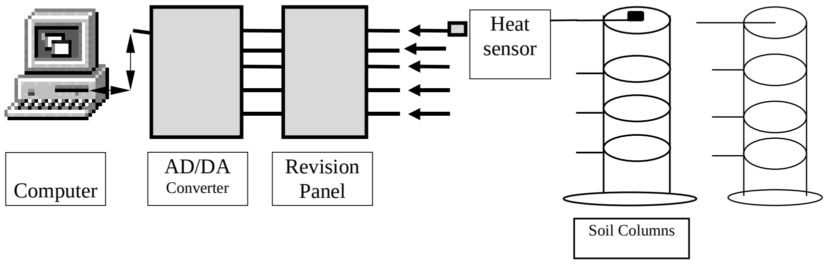

Fig. 1. Soil column and measurement system

TABLE-3
HEAT CONDUCTIVITY VALUE FOR THE MOISTURE AND LOW MOISTURE CONDITIONS OF THE SOIL (h: 11:00-12:00)

Date	λ (θ= %33.5)	λ (θ= %15)	λ Difference
29.05.2001	0.010	0.007	0.003
09.06.2001	0.037	0.007	0.030

Measurement values and results obtained from the model are given in Figs. 2 and 3.

Temperature changes due to external heat resource application are given in Fig. 4 at moisture condition.

Two different methods were utilised for the determination of temperature values in soil columns. In first method, values were obtained using the Analog-Digital (AD/DA-14 byte) card, connected to 16 different sensors. The card converter sensored temperatures to digital data in relation to time and depth.

In second method, the advanced step of the study, the simulated soil temperature related to time and depth were also measured using the mathematical model developed in this work. Basic physical laws, soil temperature capacity and flux values along with initial soil moisture were the main components of the model.

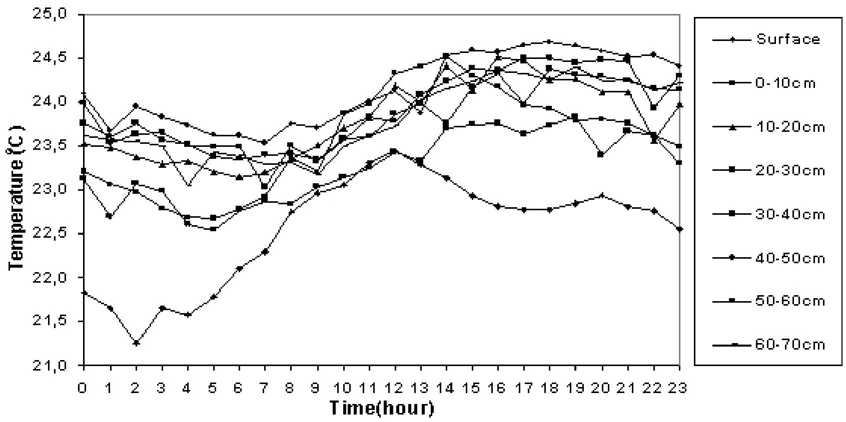

Fig. 2. Soil layer temperatures changes

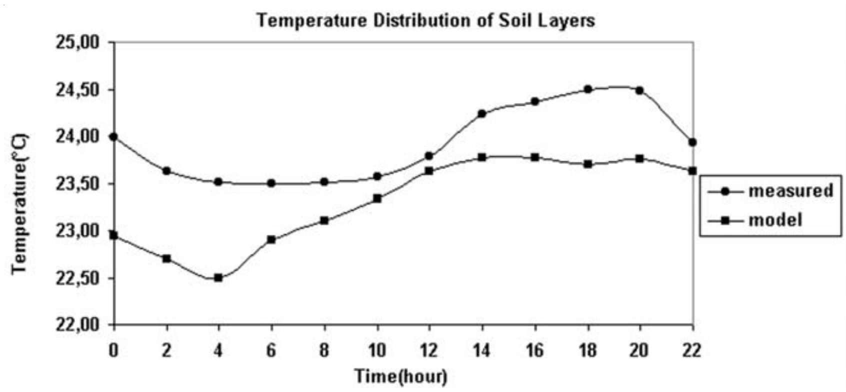

Fig. 3. Measured and mathematical model values of temperature at 30-40 cm depth.

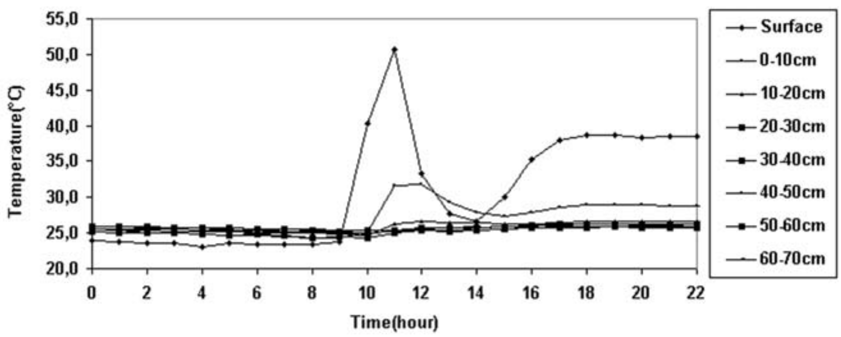

Fig. 4. Temperature distribution in 30.05.2001 at wet conditions (500W projector heat source) between 10:00-11:30 and at 15:00 (100W lamp were used as heat source)

Methods used in this study gave satisfactory results. However, there are negligible differences between measurement and model values. These differences occurred due to the continuous evaporation of the soil moisture from the surface of the soil, which is effective on soil temperature. Also, balancing the parameters according to the constant moisture content in the model has been the main factor causing the difference. Mean difference in other layers is relatively low and well correlated.

Thus, in similar soil temperature studies the use of suggested method will yield satisfactory results.

Results revealed that AD/DA converter card and sensors are determined to be sensitive for measuring the effect of external heat sources. Thus, AD/DA converter card and sensors can be successfully used for measuring other physical and chemical properties of soils when they are effectively calibrated.

REFERENCES

1. M.S. Yesilsoy, TUBITAK V. Scientific Conference (1975).
2. R.A. Poluektov, Simulation of Agroecosystem Dynamics, Gidrometoizdat, St-Petersburg, p. 312 (1991).
3. A. Sariyev, C. Aydin, M. Yusufova and M.S. Yesilsoy, International Symposium on Arid Region Soil, Menemen, Izmir, Turkey, pp. 336-344, (1998).
4. G.R. Blake and K.H. Hartge, in ed.: A. Klute, Bulk Density, In: Methods of Soil Analysis, Part 1, Physical and Mineralogical Methods, Agr. Monogr. 9, ASA and SSSA, Madison WI, pp. 363-375 (1986).
5. A. Klute and C. Dirksen, in ed.: A. Klute, Hydraulic Conductivity and Diffusivity Laboratory Methods, In: Methods of Soil Analysis, Part 1, Physical and Mineralogical Methods Agr. Monogr. 9, Madison WI, pp. 687-734 (1986).
6. G.J. Bouyoucos, *Agron. J.*, **54**, 464 (1962).
7. A.L. Page, R.H. Miller and D.R. Keeney, Methods of Soil Analysis, Part 2, Chemical and Microbiological Properties, Agron. Monogr. 9, ASA-SSA, Madison, WI, edn. 2 (1982).
8. A. Klute, Water Retention: Laboratory Methods. In: Methods of Soil Analysis, Part 1, Physical and Mineralogical Methods, Agr. Monogr., ASA and SSSA Madison WI, pp. 635-662 (1986).
9. R.J. Hanks and G.L. Ashcroft, Applied Soil Physics. Springer-Verlag, p. 151, (1985).

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