III - A301 An Investigation of Wind Effect on the Soil Resistance Parameters to Evaporation

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1. Introduction

Evaporation is one of the main processes that governs the air-land energy exchange, but much about this process remains to be solved (Kondo et al. [1]). The process is controlled not only by soil physical parameters but also by atmospheric conditions. The influence of the action of wind on evaporation and resistance parameters for various types of soil surfaces should be explored in order to achieve a better understanding of the evaporation phenomenon. This study focuses on evaluating the wind effect on bare soil surfaces as well as on surfaces covered with dead leaves, by laboratory experiments.

2. Laboratory experiments and measuring apparatus

Inspite of the changes adopted in the present experiment, the evaporation measuring technique used is almost the same, which was proposed by Mohamed et al.[2]in 1997. Figure 1 schematically illustrates the setup of measuring equipment. The evaporation measuring equipment is based on the idea that when an air stream is injected into ventilation chamber, the vapor flux from the soil surface into the chamber, increases the absolute humidity of the extracted air. Relative humidity and temperature, for both injected and extracted air are measured in order to calculate the absolute humidity of the air. The soil surface temperature was measured continuously using eight thermistors placed just beneath the soil surface, while chamber air temperature was measured using two thermistors placed above the soil surface.

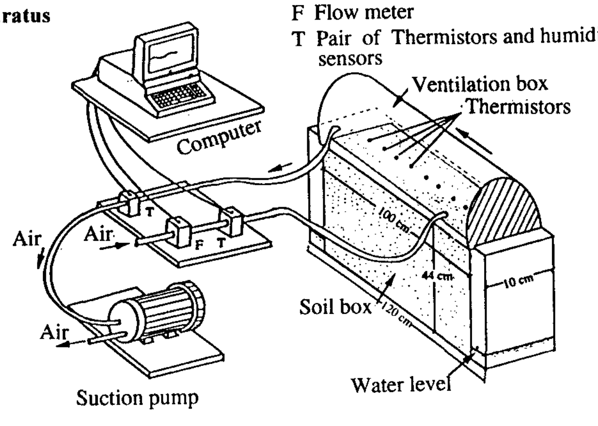

Figure 1. Schematic illustration of the laboratory experimental set up

The soil material used was clean and fine sandy soil (Toyoura standard sand). The water table of the soil box was kept constant at 40 cm from the soil surface throughout the experiment and the air circulation in the system was carried out using a suction system. Both bare and dead leaf covered surfaces were studied by experiments. Each experiment was performed continuously for 5 hours. In case of covered surface, dead leaves were distributed on the surface of the soil, with a thickness of approximately 4 cm. By injecting air at different flow rates through the ventilation box facilitated to explore the effect of air flow on evaporation and resistance parameters for both bare and covered soil surfaces.

3. Results

The evaporation from the soil surface into the ventilation box can be estimated using the absolute humidity values of the injected and extracted air (Equation 1). The absolute humidity values are calculated using the measured relative humidity and temperature values, which The absolute humidity varies considerably from one experiment to another. The calculated evaporation rates for both bare and covered cases are plotted against the variation of the wind flow rate in figure 2. The total resistance for each trial is calculated, using the difference between the surface vapor pressure and vapor pressure of air in the chamber, evaporation rate, density of water, and total pressure of the air (Equation 2). Figure 3 gives the variation of total resistance with wind flow rate for both the cases. If it can be assumed that the aerodynamic resistance to water vapor and sensible heat flux to be the same, the aerodynamic resistance can be calculated using soil surface, chamber, inflow and outflow temperatures, volume flow rate and the covered area of the box . The variation of aerodynamic resistance with wind flow rate is illustrated in figure 4. Subtracting the aerodynamic resistance from total resistance gives the value of surface resistance to evaporation (Equation 4). Figure 5 shows the variation of surface resistance with wind flow rate for both bare and covered cases.

Key words: Wind effect, Bare soil, Covered soil, Aerodynamic resistance, Surface resistance, Evaporation

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$$E = \frac{Q(\beta_{out} - \beta_{in})}{A} \quad \text{.............(1)}$$

$$r_{total} = \frac{-0.622(e_{surf} - e_a)\rho}{PE} \quad \text{.............(2)}$$

$$r_{ah} = \frac{A(T_{surf} - T_a)}{Q(T_{a(in)} - T_{a(out)})} \quad \text{.............(3)}$$

$$r_{Surf} = r_{total} - r_{ah} \quad \text{............ (4)}$$

Where, E is the evaporation rate, β_{in} and β_{out} are the absolute humidity values of injected and extracted air respectively. r_{total} is the total resistance to evaporation, e_{surf} and e_a are the vapor pressure at the surface and vapor pressure of air in the chamber respectively. P is the total pressure of the air , A is the covered area of the box. Q is the air flow rate and $T_s, T_a, T_{in}, T_{out}$ are soil surface, chamber, inflow and outflow temperatures respectively. r_{ah} and r_{surf} are the aerodynamic resistance and surface resistance to evaporation respectively.

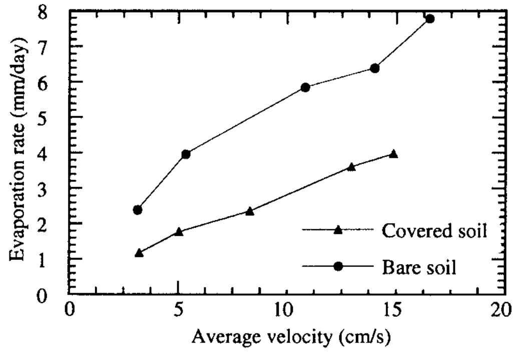

Figure 2. Variation of evaporation with average velocity

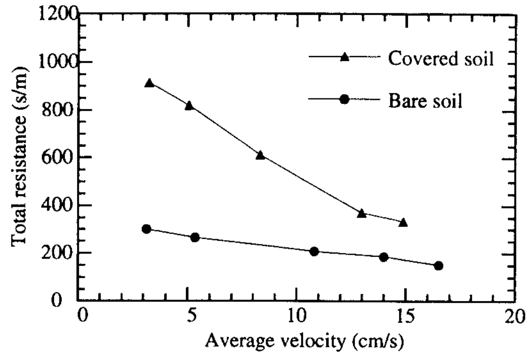

Figure 3. Variation of total resistance with average velocity

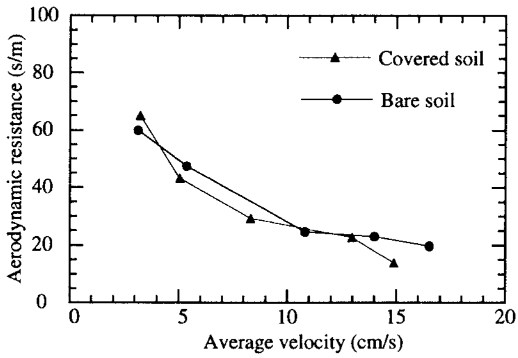

Figure 4. Variation of aerodynamic resistance with average velocity

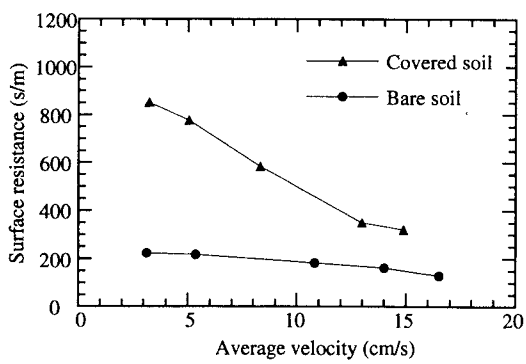

Figure 5. Variation of surface resistance with average velocity

4. Conclusions

Aerodynamic and surface resistances to evaporation can be measured by the proposed technique. Evaporation rate from bare soil surface is higher than that of covered surface, although in both cases it increases with the increase of wind flow rate. Aerodynamic resistance exhibits a power relation with wind flow rate for both the cases, but a distinguishable variation could not be seen in between bare and covered cases. Incase of bare surface, surface resistance can be considered to be independent of the wind flow rate.

References

1. Kondo J., Saigusa N. and Sato T. (1990): A parameterization of evaporation from bare soil surfaces. *Journal of Appl.Meteorology*, 29, 385-389
2. Mohamed, A.A., Watanabe K., Kurokawa U., (1997): Simple method for determining the bare soil resistance to evaporation. *Journal of ground water Hydrology*, 39(2), 97-113
3. Camillo, P.J., Gurney R.J., (1986): A resistance parameter for bare soil evaporation models. *Soil Science*, 141(2), 95-105