

A climate control apparatus and its application to evaluate evaporation process

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INTRODUCTION

The process of evaporation from soil surface is a function of soil properties and atmosphere physical parameters such as moisture, vapor pressure, temperature gradients, net radiation and air turbulence at the soil-atmosphere interface (Van de Griend, A. and Owe, M., 1994). Due to the involvement of this complex process, it has been a challenge to accurately estimate evaporation from soil. Accurate estimation of evaporation fluxes is essential for many fields such as geotechnical aspect of designing soil cover, agriculture field of reducing evaporation in arid region and environment field of evaluating migration of pollutants (Yanful, et al., 2003; Yamanaka, et al., 2004). Based on the widely used Penman method, numerous extended methods and models are proposed to calculate the evaporation rate, among which the concept of surface and aerodynamic resistance has become useful in understanding or representing the restriction of evaporation, thus improving its estimation (Penman, 1948; Monteith, 1965; Wilson, et al, 1993; Aluwihare and Watanabe, 2003). At aspect of laboratory or field measurement of evaporation, usage of microlysimeters is the most popular technique nowadays. Many investigators have developed evaporation measuring apparatus combining with other techniques, such as time domain reflectometry (TDR) technique, wind tunnel and so on (Baker and Spaans, 1994).

Since the errors related to evaporation measurements are mainly due to the alteration of natural profiles of atmospheric conditions, a climate control apparatus was develop in this study, of which the atmospheric conditions (temperature, humidity and wind speed) are controlled during evaporation process, Based on the experiment results, the properties of surface resistance is determined and analyzed.

EVAPORATION MEASURING APPARATUS

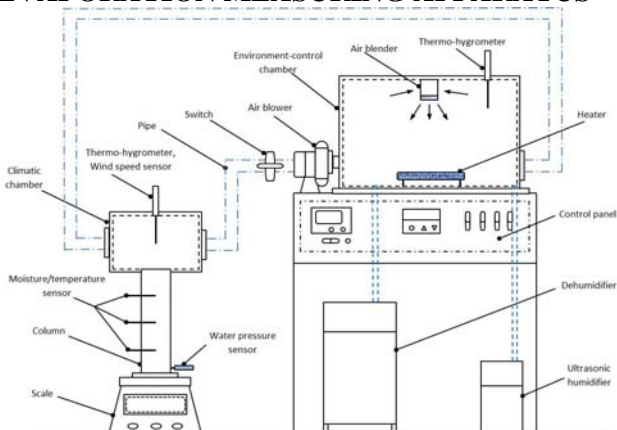


Fig.1. Schematic illustration of climate control apparatus
Fig.1 schematically illustrates the new experimental device used for measuring evaporation. The humidity and temperature in environment-control chamber were

controlled by dehumidifier, ultrasonic humidifier and heater, while monitored by a thermo-hygrometer at the top of chamber. Then the air was delivered to the climatic chamber by air blow at certain wind speed, in which the temperature, humidity and wind velocity were monitored. The specimen in the column was initially saturated, the profile of water content and temperature were monitored, together with the water pressure. The evaporation value was monitored by scale with accuracy of 1g, and there was no equipment for supplying radiation energy.

SURFACE RESISTANCE FORMULATIONS

Evaporation rate E (mm/h) can be presented by the following equation as an analogy of Ohm's law (Yamanaka, 2004).

$$E = \frac{\rho_a [q_{sat}(T_e) - q_{sat}(T_a)h_a]}{r_a + r_s} \quad (1)$$

Where ρ_a (kg/m³) is the density of humid air, $q_{sat}(T_e)$ is the saturation specific humidity of evaporating surface at temperature T_e (°C). $q_{sat}(T_a)$ is the saturation specific humidity of air with temperature T_e (°C) at a reference height, h_a is relative humidity of air, r_a (s/m) is aerodynamic resistance, the restriction to evaporation imposed on vapor while transferring from the water in pore space to soil surface, and r_s (s/m) is soil surface resistance, the restriction to evaporation imposed on vapor while transferring from soil surface to the atmosphere, which are shown in Fig.2. When the soil surface is sufficiently saturated, $r_s=0$. Due to the same atmosphere condition controlled by the new apparatus, the value of r_a is constant and can be calculated though Eq (1). Once the value of r_a is obtained, the value of r_s can be estimated for evaporation process.

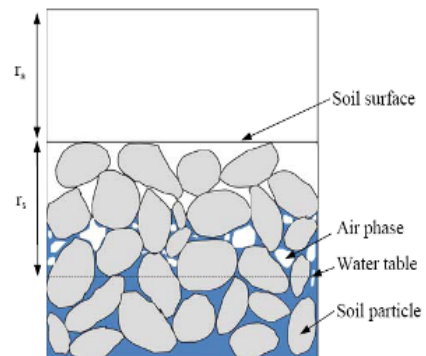


Fig.2. Schematic illustration of resistance to vapor diffusion from bare soil surface

EXPERIMENT RESULT AND DISCUSS

Laboratory experiment was conducted using the new developed evaporation apparatus. The atmosphere temperature was generally ranged from 24.5 °C to 27 °C, relative humidity from 29.5% to 32.6%, and wind speed

from 3.1 m/s to 3.7 m/s, which were shown in Fig.3 and Fig.4, and it's proved that the new apparatus can well control the atmosphere condition in constant. The fluctuations of temperature at soil surface and atmosphere have similar characteristics, which is mainly due to the temperature change between day and night in laboratory.

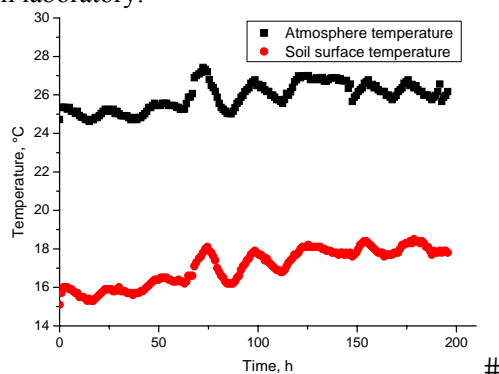


Fig.3 Atmosphere and soil surface temperature measured during evaporation test.

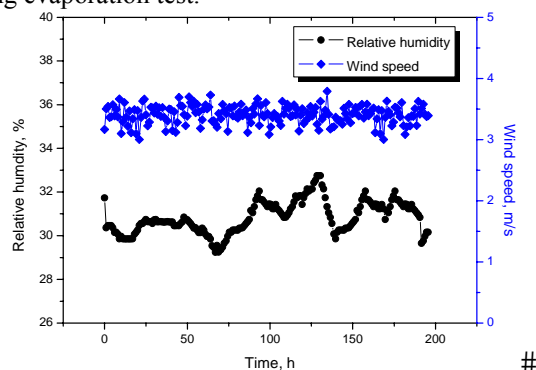


Fig.4 Relative humidity and wind speed measured during evaporation test.

The Variations of surface resistance and cumulative evaporation and the water content profile during experiment are shown in Fig.5 and Fig.6, respectively. At high water contents thus a high hydraulic conductivity, the evaporation occurs at a certain ratio, which is related to atmosphere condition, and surface resistance is nearly constant at the value of 0 and should theoretically be equal to the resistance to molecular diffusion across water surface itself. When the water content falls below a lower limit, the evaporation rate decreases gradually while the surface resistance increases dramatically. And it can be summarized that the surface resistance has a functional relationship with water content.

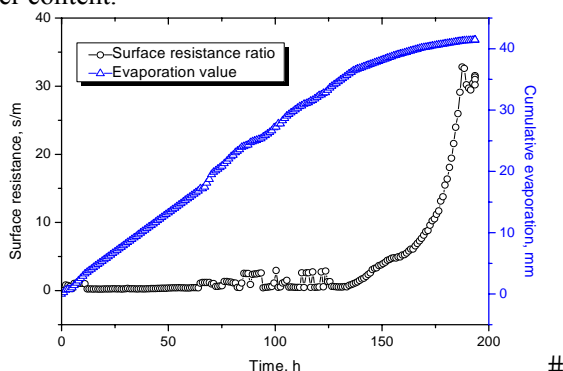


Fig.5 Variations of surface resistance and cumulative evaporation during experiment.

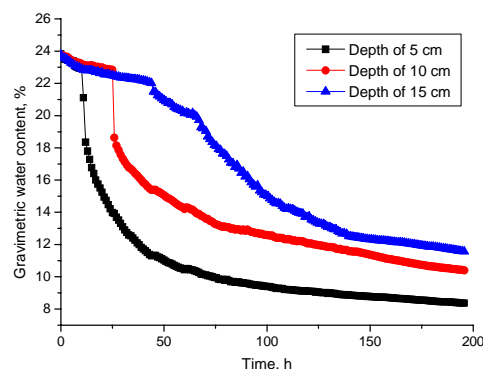


Fig.6 Measured water content at the depth of 5 cm, 10 cm and 15 cm versus time.

CONCULATIONS

In the present study, a new apparatus with the atmosphere condition controlled was developed and used to evaluate evaporation process from bare soil. The result indicated that the apparatus can satisfy the requirement but still be influenced by the laboratory condition. The surface resistance has a functional relationship with water content, and further theoretical evidence should be studied.

ACKONELEDGEMENT

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