最大表面温度を用いた異なる水分をもつ土壌からの蒸発量の推定
Estimation of Evaporation from Soil Column under Different Soil Water Content by Maximum Surface Temperature

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1. INTRODUCTION

The limited available water and the high evaporation are the main characteristics of the arid regions (Le Meur, 1990). In general, for large scale area the meteorological data are lack, which makes difficult to estimate the evaporation accurately. On the other hand, for large scale the soil surface temperature data are easily available by satellite image. In this respect, the objectives of this study are to measure the surface temperature and evaporation on soil columns with different initial soil moisture during observation and evaluate the effect of salinity on evaporation, and to develop a model for estimating evaporation basing on surface temperature.

2. MATERIALS AND METHODS

2. 1 Description of experimental design and maximum surface temperature model (MSTM)

A typical soil (loam) and sandy soil were sampled for our evaporation experiment from Hetao Irrigation District, China. Some fundamental physical properties of soil are presented in **Table 1**. The treatments of soil are designed depending on salinity, soil texture, and initial soil moisture, as shown in **Table 2**. The layout of the column experiment is presented in **Fig. 1**.

Table 1 Some fundamental physical properties

Soil texture	$EC_{1:5}$	Clay	Silt	Sand	Bulk density	Porosity
	mS cm^{-1}		%*		g cm^{-3}	%
Loam	0.6	21	35	44	1.46	44.3
	4.9	16.2	46.5	37.3	1.48	44.2

* U.S.D.A. classification scheme

Table 2 Experiment treatments in this study

Soil water content	Loam		Sand
(SWC)	Saline soil	Non saline soil	
30%	LSW	LNW	――
12%	LSD	LND	――
4%	――	――	SD
0%	――	CT	――

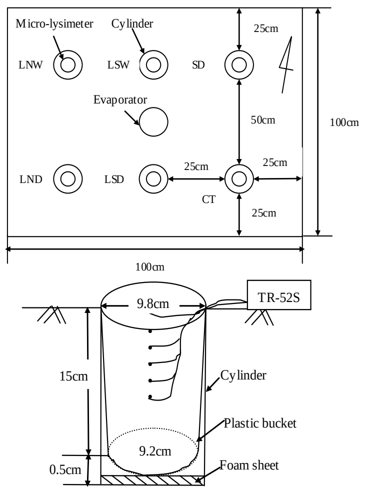

Fig. 1 Layout of experiment and structure of micro-lysimeter

2. 3 Description of the basic theory

The energy balance of each soil column can be written (Ben-Asher, 1983; Evett, 1994) as follows:

Dry soil column: $R_{no} = H_o + G_o$ (1), $H_o = \rho c_p c_h (T_o - T_a)$ (2)

Wet soil column: $R_{nd} = H_d + G_d + \lambda E_d$ (3), $H_d = \rho c_p c_h (T_d - T_a)$ (4)

Where R_n, H, G and λE are the flux density of net radiation, sensible heat, soil heat and latent heat, ρ is air density, c_p is specific heat of air at constant pressure the subscripts *o* and *d* refer to the dry and the wet soil samples, respectively. The c_h is the exchange coefficient for sensible heat flux (m/s).

Subtracting the **Eq. (1)** from the **Eq. (3)** and combining **Eq. (2)-(4)**, we can obtain the latent heat flux expressed by the **Eq.(5)** as follows:

$$\lambda E_d = R_s(\alpha_o - \alpha_d) + (G_o - G_d) + (H_o - H_d) + \varepsilon\sigma(T_o^4 - T_d^4) \quad (5)$$

In integrating both sides of the **Eq. (5)** on time t, and $\int R_s(\alpha_o - \alpha_d)dt$ and $\int (G_o - G_d)dt$ terms were neglected (Evett's ,1994); the integrating is given by **Eq. (6)**: $\int \lambda E_d dt = \int [\rho C_p c_h (T_0 - T_d) + \varepsilon\sigma(T_0^4 - T_d^4)]dt$ (6)

Supposing soil surface temperature is given by a sine wave: $T(0,t) = (T_{max} + T_{min}) + 0.5(T_{max} - T_{min})\sin \omega t$ (7)

Here, setting $T_m = (T_0 + T_d)/2$, $\Delta T = T_0 - T_d$ and then the term $T_0^4 - T_d^4$ in **Eq. (6)** can be rewritten as

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follows: $$T_0^4 - T_d^4 = (T_m + \Delta T/2)^4 - (T_m - \Delta T/2)^4 = 4T_m^3 \Delta T + T_m (\Delta T)^3 \quad (8)$$

And, from observed temperature the minimum temperature of dry and wet soil is equal ($T_{o\min}$=$T_{d\min}$), so $\Delta T = T_o - T_d = 0.5(T_{o\max} - T_{d\max})(1+\sin\omega t) = 0.5\Delta T_d(1+\sin\omega t)$ (9)

$$T_m = 0.5(T_0 + T_d) = 0.25\left[(T_{o\max} + T_{d\max})(1+\sin\omega t) + 2T_{0\min}(1-\sin\omega t)\right] \quad (10)$$

The **Eq. (6)** is rewritten as **Eq. (11)** $\int \lambda E_d\,dt = \int \left\{\rho C_p c_h + 4\varepsilon\sigma T_m^3 (1 + (\Delta T/2T_m)^2)\right\}\Delta T\,dt$ (11)

Combining **Eq.(8)** and **(9)** and integrating from 9:00 to 18:00, a daily evaporation obtained **Eq.(12)**:

$$E_d = 8.7(\rho c_p c_h + 4\varepsilon\sigma T_m^3)\Delta T_d \big/ \lambda \quad (12)$$

Tm is given $T_m = 0.5(T_{o\max} + T_{d\max})$ from the maximum temperature. To determine proper value of c_h, Eq. (12) was solved on c_h using evaporation and maximum temperature of each day, then the average $\bar{c}_h$ (-0.004) was used in prediction model 'maximum surface temperature' (MSTD) in **Eq.(13)**

$$E_d = 8.7(\rho c_p \bar{c}_h + 0.5\varepsilon\sigma(T_{o\max} + T_{d\max})^3)(T_{o\max} - T_{d\max}) \big/ \lambda \quad (13)$$

3. RESULTS AND DISCUSSION

Fig.2 shows the difference in surface temperature among treatments. The maximum surface temperature (MST) was in the order of LNW<LND<CT under nonsaline soil**,** as shown in **Fig.2** (***a***). However, in **Fig.2** (***b***), the maximum surface temperature was in the order of LSW<CT<LSD, except the first 3-day period of observation may due to salt influence.

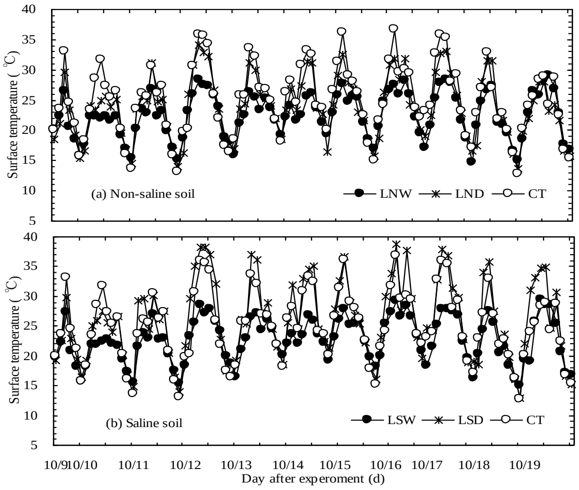

Fig.2 Hourly surface temperature during daily

Fig.3 shows that the estimated daily evaporation and measured evaporation are in agreement. However, the values estimated from the MSTM method are relatively low for the first 4 days of the observation and are relatively high for the end of period of measurement. The performances of the model developed were evaluated by using root mean square error (RMSE). The RMSE was 0.4mm/d for LNW and LND, 0.26mm/d for LSW, and 0.32mm/d for LSD.

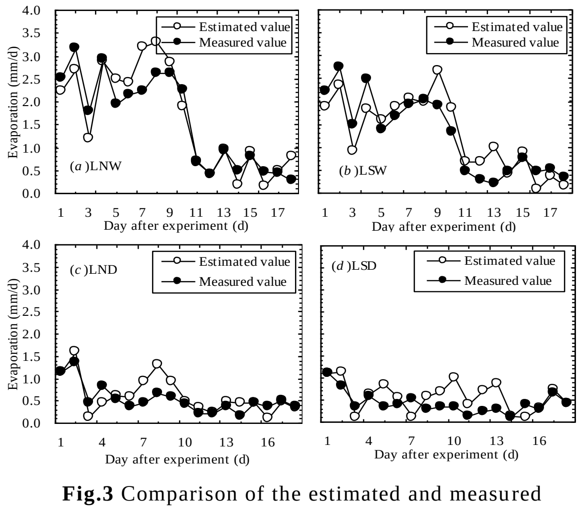

Fig.3 Comparison of the estimated and measured evaporation

4. CONCLUSION

The results obtained from this study concluded that the maximum surface temperature appeared in saline soil due to the effect of salt. The results showed that the trends of estimated and measured evaporation rate were in good agreement. The estimated average cumulative evaporation resulted in 3.3% overestimation than the measured values. It was indicated the MSTM can be used to estimate the evaporation.

5. REFERENCES

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