Comparison of Surface Temperature and Evaporation Rate between Wet and Dry Paddy Field

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1. INTRODUCTION

In tropical watersheds where paddy field spreads, the amount of evapo-transpiration from paddy field is a major water loss from the watersheds and thus affects river discharge from the watersheds. In dry season, a large area of paddy field becomes uncultivated and dry up due to lack of water. Evapo-transpiration from cultivated wet paddy field, which is almost potential evaporation, is easy to estimate from metrological data by using Penman-Monteith equation. Conversely, actual evaporation in dry uncultivated paddy field, which depends on how much it dries, is difficult to estimate or measure. Commonly, according to energy balance, the higher surface temperature should be observed on dry soil with the less evaporation. Nowadays, soil surface temperature can be detected by remote sensing, such as satellite remote sensing or infrared thermometer. As a first step to create method to estimate evaporation by using remote sensing, the authors measured and compared evaporation and soil surface temperature on wet and dry paddy field; then we calculated energy balance components.

2. MATERIALS AND METHOS

Field measurement was conducted in paddy fields in Cidanau watershed, Indonesia during dry season on September 2006. The irrigated wet paddy field and uncultivated dry paddy field are in the same area. The soil of the paddy fields is highly swelling clay. Therefore on the dry paddy field the soil became very hard and large cracks appeared.

A microlysimeter method was applied to measure evaporation from the soils. Thin wall samplers were inserted into wet soil to take sample; but for dry soil, soil blocks were taken and wrapped the bottom with plastic bag to make the samples. After weighing each sample by electric balance, returned them to field as they were to allow evaporation, and then measured how much they loose weight. The amount of evaporation from water surfaces in containers was also measure as reference.

Another measurement was carried out in order to calculate energy balance components. Air temperature, surface temperature of dry and wet soil, and relative humidity were monitored and stored in data loggers. Instantaneous temperature measurement using infrared thermometer was also done.

Thermal conductivity of soil was also measured on site using Thermal Conductivity Probes controlled with a data logger (CR-100, Campbell Scientific Inc.) Thermal conductivity in relation with its water content and bulk density was also measured in laboratory.

Other data needed was acquired from nearest meteorological office which are solar radiation and average wind speed. Incoming solar radiation was estimated by using Amstrong formula which take into account extraterrestrial radiation and relative sunshine duration.

The energy balance on soil surface is described by:

$$R_n = G + H + LE \qquad (1)$$

where R_n = net radiation [W m^{-2}]; G = ground heat flux [W m^{-2}], H = sensible heat flux [W m^{-2}]; LE = latent heat flux [W m^{-2}]. Each component of Eq.(1) is calculated as follows.

- Net Radiation (R_n)

Calculation performed from equation :

$$R_n = (1-\alpha)\cdot R_s + \varepsilon_a \cdot \sigma \cdot T_a^4 - \varepsilon_s \cdot \sigma \cdot 4 \cdot T_a^3 (T_s - T_a) \qquad (2)$$

where $\sigma = 5.678 \cdot 10^{-8}$ [W m^{-2} K^{-4}] (Stefan-Boltzmann constant); R_s = incoming solar radiation [Wm^{-2}]. ε_a = clear skies emissivity; ε_{ac} = cloudy sky emissivity; α = soil albedo. T_a = air temperature [^{o}C]; and T_s = surface temperature [^{o}C].

- Ground Heat Flux (G)

Calculation performed by applying measured surface temperature (T_s) for boundary condition (repeated daily periodic function) to heat conduction equation in soil (Eq.(3)). G was calculated after solving Eq.(3).

$$C_T \frac{\partial T}{\partial t} = \frac{\partial}{\partial z}\left(k_T \frac{\partial T}{\partial z}\right) \qquad (3)$$

$$G = -k_T \frac{\partial T}{\partial z}, \quad z = 0 \qquad (4)$$

where C_T = soil heat capacity [J m^{-3} K^{-1}]; k_T = soil thermal conductivity [W m^{-1} K^{-1}];

- Sensible Heat (H)

Sensible heat flux calculated using equation :

$$H = K_h \cdot (T_s - T_a) \qquad (5)$$

where K_h = boundary layer conductance [W m^{-2} K]; T_s = surface temperature [^{o}C]; T_a = air temperature [^{o}C]

- Evaporation (E)

Evaporation (latent heat) calculated as residual value from energy balance equation (Eq.(1)) :

$$LE = R_n - G - H$$

was compared with the one from measured in the field.

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Key words : watershed, surface temperature, actual evaporation

3. RESULT AND DISCUSSION

Fig.1. shows the relation of thermal conductivity and bulk density to water content. Unlike no swelling soil, this swelling soil shows slight decrease in thermal conductivity with increase in water content due to bulk density increase, except for very dry condition.

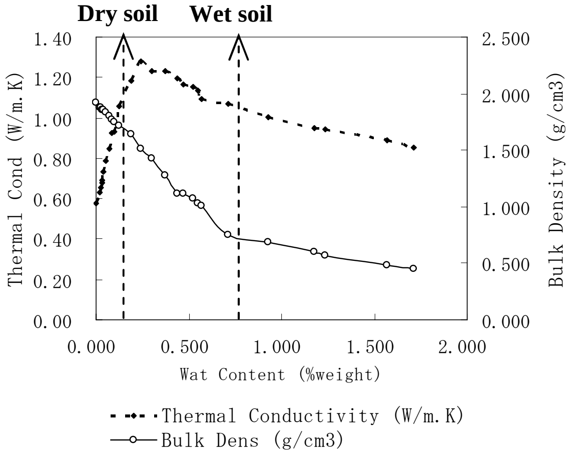

Fig. 1. Measured thermal conductivity and bulk density as water content change.

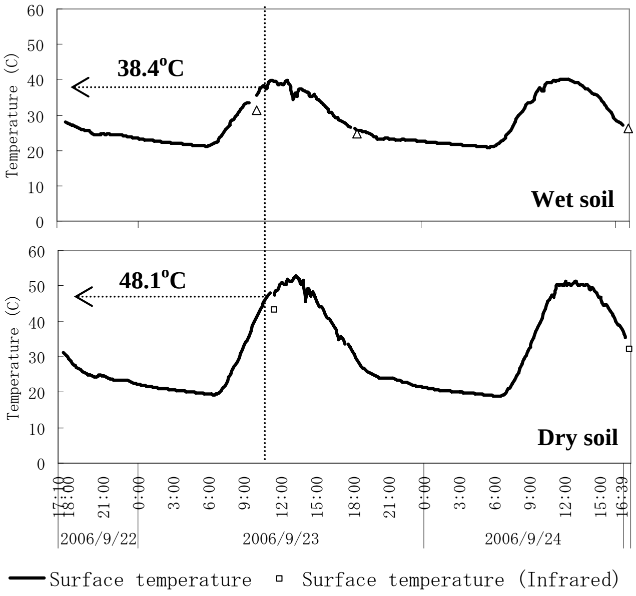

Fig. 2. Measured surface temperature in wet and dry bare paddy field surface. Arrows indicate temperature at 10.30 a.m. when Landsat pass the watershed

Fig.2. shows surface temperature on wet and dry soil. Maximum temperature n wet soil was about 40° C, while that for dry soil was 53°C. Surface temperature at 10.30 a.m. when Landsat pass the watershed is noted.

Fig. 3 compares evaporations measured by microlysimeter from wet soil and dry soil. Fig.3 also shows calculated evaporations from energy balance, accumulated over the corresponding periods. Daily evaporations from dry soil were about 2.7 mm while those from wet soil were 4.6 mm.

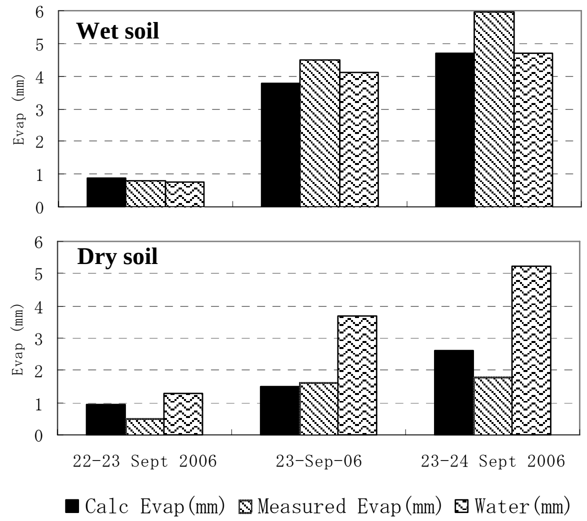

Fig. 3. Cumulated evaporation in wet and dry soil surface

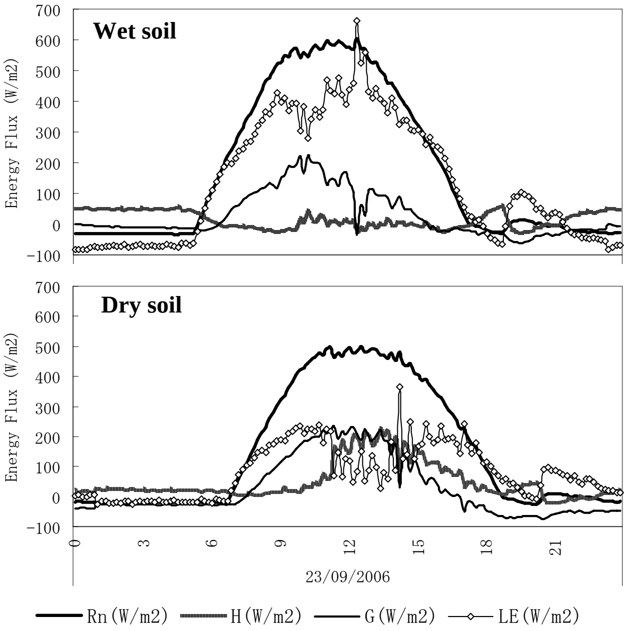

Fig. 4. Evaporation and energy balance in wet and dry soil surface

Measured and calculated evaporations are similar. Fig.4 shows components of energy balance calculation.

4. CONCLUSION

Estimation of evaporation on dry bare soil with remote sensing is not easy because available data that relates surface temperature will be that of one moment at specific time in a day. However, it may be possible by developing the present model, which combines heat conduction in soil with heat exchange on soil surface.