水田熱収支モデルおよび気象予報データを利用した田面水温モデルの検討

Examination on a Forecast Model of Paddy Water Temperature Applying Heat-Balance Model in Paddies and Weather Forecasting Data

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1.Introduction　Because of the global warming, the quality of rice grain is reduced due to the high water temperature. Therefore, it is necessary to figure out the water temperature dynamics of paddy fields. Recently, using the heat-balance model to calculate water temperature is a common way. It is a method of calculating the water temperature using the heat balance of vegetation, water and ground. However, there are few studies focus on prediction. This study used weather forecast data (Meso-Scale Model) from the Japan Meteorological Agency to predict 24-hour water temperature changes in paddy fields and discussed the results. As space is limited, we will focus on LAI, the leaf area index, and the method of converting cloud cover into solar radiation.

2.Model　Differentiate the leaf temperature function and water temperature function, the difference form is forward difference.

$$T_{c_{n+1}} = T_{c_n} + \frac{Rn_{c_n} - H_{c_n} - lE_{c_n}}{c_c \rho_c l_c LAI} \Delta t \quad (1) \qquad T_{w_{n+1}} = T_{w_n} + \left(\frac{Rn_{w_n} - H_{w_n} - lE_{w_n} - G_n}{\rho_w c_w h_n} \right) \Delta t \quad (2)$$

Where, T_c is vegetation temperature, T_w is water temperature. Rn_c and Rn_w are net radiation of vegetation and water. H and lE are sensible heat flux and latent heat flux. c_c is specific heat of leaf, ρ_c is leaf density, l_c is leaf thickness and LAI is leaf area index. G is soil heat flux, ρ_w is the density of water, c_w is the specific heat of water and the h is flooding depth. The R_{nw} can be expressed by following equation as

$$R_{nw} = f_v\{(1-\alpha_w)(1-\alpha_c)S + L_{da}\} + (1-f_v)L_{dc} - L_{uw} \quad (3)$$

where S is solar radiation. $\alpha_w$is albedo of water body and α_c is albedo of vegetation. L_{dc} and L_{da} are downward long wave radiation of plants and atmosphere. L_{uw} is upward long wave radiation of water. The f_v is radiation transmittance of vegetation.

3. Method　LAI is an important factor to affect the heat-balance on the water and vegetation. There are two major methods for estimating LAI: direct estimation and indirect estimation. The direct estimation includes clipping and litter trapping, and the indirect estimation is by using the optical instruments to measure LAI. However, the direct estimation will destroy the vegetation, and the cost of indirect estimation are relatively high. This study uses the relationship between measured temperature difference and f_v to calculate LAI. combine (2) and (3), the equation is as follows.

$$f_{v_n} = \frac{\frac{T_{w_{n+1}} - T_{w_n}}{\Delta t} \rho_w c_w h_n + H_{w_n} + lE_{w_n} + G_n + L_{dc_n} + L_{uw_n}}{(1-\alpha_w)(1-\alpha_c)S_n + L_{da_n} - L_{dc_n}} \quad (4) \qquad f_v = \exp(-k \cdot LAI) \quad (5)$$

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where k is extinction coefficient.

Since there is no solar radiation in the data provided by the weather forecast, we used the Zhang-Huang method[1] to calculate the solar radiation by cloud cover. The formula is as follows.

$$S = [I_0 \sin\alpha \{c_0 + c_1(CC) + c_2(CC)^2 + c_3(T_{a_n} - T_{a_{n-3}}) + c_4\varphi + c_5 V_w\} + d]/k \quad (6)$$

Where, I_0 is solar constant, α is solar altitude angle, CC is cloud cover in tenths, T_{a_n} and $T_{a_{n-3}}$ are air temperature at hours n and n-3, φ is relative humidity and V_w is wind speed. c_0, c_1, c_2, c_3, c_4, c_5, d, k are regression coefficients.

4. Experimental procedure The experimental site was located in Tochigi City, and the experiment period was from 7/19 to 9/19 in 2016. The observation items include the water temperature, solar radiation, air temperature, relative humidity, pressure, wind direction and wind speed. The observation interval is 10 minutes.

Firstly, the measured meteorological data was used to inverse analysis of the LAI during the experiment. Then the daily water temperature was predicted using the LAI and the weather forecast data published at 0:00 Am per day. Finally, we compared the result.

5. conclusion The results of LAI are shown in **Fig.1** where the "LINE" is an approximate line of LAI. The data during the midsummer drainage period and heavy rain days were removed.

The calculation results of water temperature are shown in **Fig.2**.

In summary, this study proposes a new method for calculating LAI, and we also obtaining more accurate results of water temperature, The RMSE (Root Mean Square Error) of water temperature per hour is 1.57℃. Unfortunately, there is no data to verify the accuracy of LAI, but we will follow the relevant experiments. Moreover, the irrigation system can be pre-managed by this method, for example, continuous irrigation can be performed before the water temperature is too high to protect rice from high temperature damage.

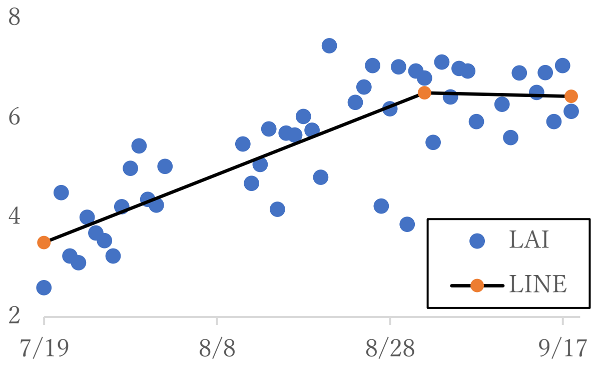

Fig.1 result of LAI

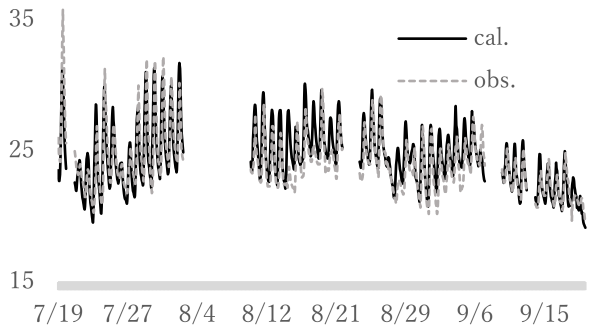

Fig.2 water temperature

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REFERENCES: [1] Zhang Q., Joe Huang and Lang S. (2002): Development of Typical Year Weather Data for Chinese Locations, ASHRAE Transactions 2002, v. 108. Pt. 2, held June 2002, Honolulu, Hawaii.