Evaluation of Rice Production Improvement in Terraced Paddy Fields under Water Shortage Condition

渇水条件下における棚田のコメ生産の向上に対する評価に関する研究

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1. Introduction

The current issue on reducing water use in rice cultivation has been extensively studied to find an effective way of producing rice optimally under limited water condition. Drought occurrence associated with El-Nino in the past 20 years as reported by IPCC in 2007 put a tough position for South-East Asian countries where rice is highly produced. Due to its abundant water availability, these countries have been majorly relied on inundated rice cultivation. Rice has a unique characteristic where it has high waterlogging tolerance but very susceptible to water stress (Bouman et al, 2006). As soon as soil water content decreases below saturation, rice plant responded physiologically so that it affects plant growth and yield.

Considering variability of climate condition either temporally or spatially, many researchers attempted on using a modelling approach to study the influence of water saving technologies in rice production (Belder et al, 2007; Soundharajan and Sudheer, 2009). Although the result of rice growth model showed high performance on predicting yield, few studies have not mentioned/examined clearly parameter setting on simulating water stress condition. This paper is focused on studying water stress parameter inside rice growth model and the effect of water shortage on rice production in terraced paddy area.

2 Study area and methods

Experimental design

Three paddy field plots from the upper, middle, and lowest plot of terraced paddy fields block will be set as observation plots (see Fig.1). The treatments comes from location of the plot themselves. Difference of plot location will result in the difference of water accessibility for each plot.

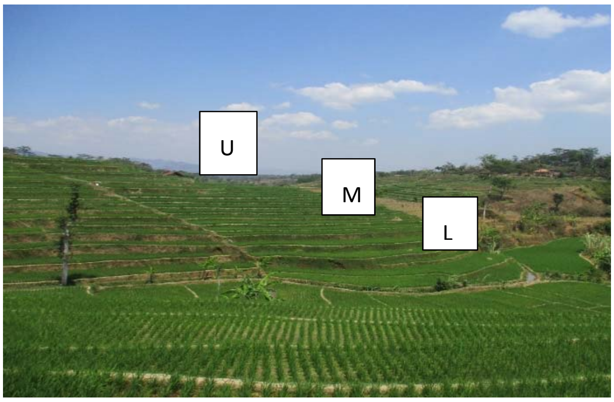

Fig.1 Plot location on the study area

Canopy temperature were acquired using FLIR C2 infrared camera of FLIR Company with measuring range of -10°C to 150°C, and with an

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accuracy of 0.07°C. Hydrology observation are conducted using HOBO U20L Water Level Logger for continuous monitoring. Other components such as rainfall are obtained from the nearest weather station data while evapotranspiration and infiltration will be calculated indirectly.

For model evaluation purpose, other than water stress value parameters such as LAI, emergence date, planting date, panicle initiation date, flowering date, and crop yield were recorded.

Measurement and calculations

Rice canopy thermal images were taken from a male standing position every week. The image acquisition time varied from 13:00 to 14:00 WIB (Western Indonesian Time), after the local solar noon (around 12:00 WIB). Thermography data acquired from FLIR camera then opened using ArcGIS 10.2 to obtain the digital number (DN) to be converted again to the temperature using the equation by Cohen, et al (2005).

Crop water stress index (*CWSI*) can be defined using the equation (Jackson, 1988)

$$\mathrm{CWSI} = \frac{(T_c - T_a) - (T_c - T_a)_{ll}}{(T_c - T_a)_{ul} - (T_c - T_a)_{ll}}$$

where *Tc* is the crop canopy temperature, °C; *Ta* is the air temperature °C; (*Tc*-*Ta*)*ll* is the crop canopy-air difference under fully watered, the lower bound of canopy-air difference; (*Tc*-*Ta*)*ul* is the crop canopy-air difference under an acute shortage of water, the formula (1) is the classical model of the *CWSI*. While upper and lower boundary condition can be calculated with

$$(T_c - T_a)_{ll} = \frac{r_a(R_n - G)}{\rho C_p} \cdot \frac{\gamma\left(1 + r_{cp}/r_a\right)}{\Delta + \gamma\left(1 + r_{cp}/r_a\right)} - \frac{VPD}{\Delta + \gamma\left(1 + r_{cp}/r_a\right)}$$

$$(T_c - T_a)_{ul} = \frac{r_a(R_n - G)}{\rho C_p}$$

where *Rn* is the net radiation of canopy, W/m-2; *G* is density of soil heat flux or flux density of canopy lower energy, W/m-2; p is the density of the air, kg/m-3; *Cp* is the air specific heat J/(kg-1°C-1); *γ* is the psychrometer constant, Pa/°C-1; *Δ* is the slope of the air saturated vapor pressure varies with temperature, Pa/°C-1; *ra* is the aerodynamic resistance , s/m-1; *rcp* is the water vapor diffusion resistance of the canopy under potential evaporation state,s/m-1, that is the minimum canopy resistance.

3. Ongoing Result and discussion

Location of the field plot in terraced paddy field area influenced with the accessibility of water for each plot. Though upper fields gain advantage of being close to irrigation canal, higher altitude made the shallow groundwater deeper so that it is possible to affect percolation rate and the other way around for the lower fields.

Terraced paddy areas itself usually located on the upstream area of watershed where water resources usually sufficient enough for crop production but prolong drought or decline of rainfall amount will have an impact on rice production on these areas. Therefore monitoring water stress occurrence on terraced paddy plots will help on studying mitigation process during water shortage condition and maintain rice production. This work was partially supported by JSPS KAKENHI Grant Number 18H02295.