Evaluating Irrigation Needs at a Field in a Semiarid Region Using the Two-Layer BBH Model of Soil Hydrology

2 層 BBH 土壌水文モデルを用いた半乾燥地における圃場の灌漑水深評価

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1. Introduction

Irrigated agriculture is depleting water supplies in the Yellow River basin like everywhere else in arid- and semiarid regions, and increased efficiency is being sought to conserve water. The key point in assessing the irrigation need is how to determine the "field capacity", which is the full point of the soil profile. As many researchers have pointed out, the definition of "field capacity" is not necessarily definite. We defined the "dynamic field capacity", which is not static but dynamic in nature and depends on the soil moisture condition and root distribution in the profile. It is evaluated using the two-layer BBH model of soil hydrology. This paper describes an example application of the dynamic field capacity to evaluate the irrigation need at a cornfield in the Yellow River basin in Inner Mongolia, China.

2. Two-layer BBH model

In the two-layer bucket with a bottom hole (BBH) model of soil hydrology, it is assumed that the soil profile is made up of the first layer with thickness D_1 and the second layer with thickness D_2 and the underlying layer (Fig.1).

Water balance equations for the upper two layers are written as follows:

$$W_1(t+1)-W_1(t)=Pr(t)-E_1(t)-Gd_1(t)-Rs(t) \qquad (1)$$

$$W_2(t+1)-W_2(t)=Gd_1(t)-E_2(t)-Gd_2(t) \qquad (2)$$

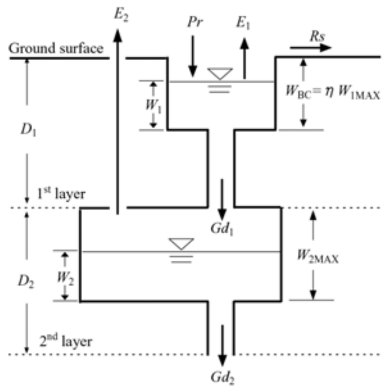

Fig.1

where W_i (i = 1,2) is daily mean amount of soil water contained in the i^{th} layer (mm), t indicates the day, Pr is daily precipitation, E_i daily evaporation including transpiration, Gd_i daily gravity drainage including capillary rise at the i^{th} bucket bottom, Rs daily surface runoff. All terms appeared on the right sides of Eqs. (1) and (2) are expressed in mm day^{-1}.

We assume the following parameterizations:

$$E_i(t)=M_i\cdot Ep(t),\ \ M_i\equiv\frac{W_i}{\sigma_i W_{i\mathrm{MAX}}},\ \ W_{i\mathrm{MAX}}=p_i\cdot D_i \quad (\mathrm{mm}) \quad (i=1,2) \qquad (3)$$

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where Ep is daily potential evaporation and p_i the porosity of the i^{th} layer.

$$Gd_i(t) = I \exp\left(\frac{W_i(t) - a_i}{b_i}\right) - c_i \qquad (i = 1,2) \qquad (4)$$

where $I \equiv 1\text{mm day}^{-1}$.

$$Rs(t) = \max\left[Pr(t) - (W_{\text{BC}} - W_1(t)) - E_1(t) - Gd_1(t), 0\right] \qquad (5)$$

where the capacity of the first layer, $W_{\text{BC}} = \eta W_{1\text{MAX}}$. For the parameter identification Iwanaga et al. (submitted) should be referred to.

3. Dynamic field capacity and irrigation need

The first term on the right side of Eq.(4) specifies the contribution of gravity forces to the vertical water movement and the second term that of capillary-rise forces. The "dynamic field capacity" in the i^{th} layer, $W_{i\text{FC}}$ is defined as the value of W_i when $Gd_i = 0$; that is,

$$W_{i\text{FC}} \equiv a_i + b_i \ln\left(\frac{c_i}{I}\right) \qquad (i=1,2) \qquad (6)$$

Therefore the irrigation need, Wa (mm), can be written as

$$W\text{a} = \left(\max\left[W_{1\text{FC}} - W_1, 0\right] + \max\left[W_{2\text{FC}} - W_2, 0\right]\right)(1+\alpha) \qquad (7)$$

where α is a parameter that specifies the extra water requirements for salt leaching etc.

4. Example application

This model was applied to an irrigation practiced at a cornfield in the Yellow River basin on 16 July in 2004 (Fig.2). The values of Wa at two points (Point 1 and Point 4) in the field were 113(1+ α) mm and 57(1+ α) mm, respectively. Since more than 150 mm of irrigation water was applied, the parameter α was estimated to be larger than 0.5. It seems that this value was too large to be optimum, because the groundwater level rose up to almost within the root zone just after the irrigation.

Ref: Iwanaga et al. J Japan Soc. Hydrol. & Water Resour. Submitted.

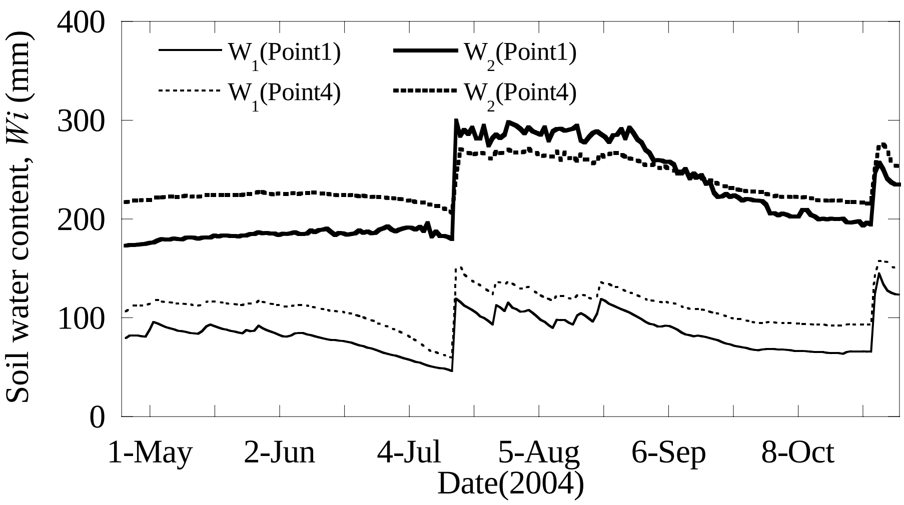

Fig.2