WATER REQUIREMENTS AND IRRIGATION SCHEDULING OF BAN KHAI IRRIGATION PROJECT USING GIS AND CROPWAT MODEL IN RAYONG PROVINCE THAILAND

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ABSTRACT

In the wake of changing climate the present water crisis seems to tighten its hold on the Mankind hence water resources estimation is integral part of planning, development and management of water resources of the country and the estimation of water resources is based on several hydrological and meteorological parameters. Due to overexploitation of available water resources, it has become very important to define appropriate strategies for planning and management of irrigated rice paddy field and farmland. In this paper, Ban Khai area located in Rayong province of Thailand, was chosen as our case study area for its special political and economic status and its severe water problem. To achieve effective water allocation and planning, the information about crop water requirements, irrigation withdrawals, soil types and climate conditions were gathered in the study area. In the meantime, a GIS-based method was adopted, which extends the capabilities of the crop models to a regional level. The main objectives of the study area are: 1) to estimate the spatial distribution of water requirement (i.e., evapotranspiration) in Ban Khai study area; 2) to estimate climatic water deficit; 3) to estimate the yield reduction of Ban Khai under different rainfed and irrigated conditions. Based on the water deficit analysis, recommended supplemental irrigation schedule can be developed ising CropWat model to reduce water stress. Compared to the rainfed control, the two or three times of supplemental water irrigated to Ban Khai area at the right time reduced the loss of yield, under a wide spectrum of scenarios for future management of water resources.

Keywords: CROPWAT; Crop Water Requirement; Evapotranspiration; Effective Rainfall; Irrigation Schedule

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1. Introduction

Water is of vital importance to socio-economic development. Increased water demand brought about by rapid population growth has created the necessity to increase food production through the expansion of irrigation and industrial production to meet basic human needs. Thailand is still agriculture-based, with a total agricultural area of about 265,200 km2. More than 60% of the population engage in agriculture, yet agricultural production accounts for only 12% of GDP. Serious water shortages are developing in Thailand and water for agriculture is becoming increasingly scarce in the light of growing water demands from different sectors. The agricultural sector remains the main user of available water and accounts for 71% of the total water demand in Thailand; the industrial sector accounts for 2%; the domestic sector for 5%; and the remaining 22% are for ecological balance.

Water is an essential input for crop production. Even though the mean annual rainfall in Thailand is approximately 1,500 mm/yr, its temporal distribution is highly uneven, resulting in a long dry spells are the norm rather than the exception in all seasons. In 2005, severe drought in the country, especially in the Eastern Seaboard region, led to a conflict in water resources allocation among the agricultural, industrial, and domestic consumption sectors. The issue highlights the importance of improved management and planning of water resources to ensure proper use and distribution of water among competing users. Accurate planning and delivery of the necessary amount of water in time and space can conserve water. The primary objective of irrigation is to apply water to maintain crop Evapotranspiration (*ET*) when precipitation is insufficient. Hess (2005) defined crop water requirements as the total water needed for evapotranspiration, from planting to harvest for a given crop in a specific climate regime, when adequate soil water is maintained by rainfall and/or irrigation so that it does not limit plant growth and crop yield. Each and every crop has individual water requirements.

CROPWAT is a decision support system developed by the Land and Water Development Division of FAO for planning and management of irrigation. CROPWAT is meant as a practical tool to carry out standard calculations for reference evapotranspiration, crop water requirements and crop irrigation requirements, and more specifically the design and management of irrigation schemes. It allows the development of recommendations for improved irrigation practices, the planning of irrigation schedules under varying water supply conditions, and the assessment of production under rain fed conditions or deficit irrigation (FAO 1992). Water use requirement for same crop varies under different weather conditions. To achieve effective planning on water resources, accurate information is needed for crop water requirements, irrigation withdrawal as a function of crop, soil type and weather conditions. However, a detailed study by comprising all the data on water requirement and availability is also not available under humid tropical conditions. Keeping all this in background, hence, in this paper an attempt has been made to compute the crop water requirements of major crops in Ban Khai irrigation project using CROPWAT 8.0 (FAO 2009) and comparing with the available water resources in that area to assess the current status and future demand, which is essential for water resources management and planning, especially in the area with limited water supply among competing sectors.

2. Materials and Methods

2.1 Study Area

We select Ban Khai irrigation project as our study area. It covers 30,000 rai of Ban Khai weir located in Bang Boot subdistrict, Ban Khai district, Rayong province, in the Eastern part of Thailand. Ban Khai weir construction was completed in 1952 with the purpose to serve as a local water resources storage and irrigation for agricultural sector.

2.2 Hydro-Meteorological Data Collection

The main important data for analyses in this study are composed of climate data, local agricultural data, crop types, crop growth periods, and water allocation scheme in the study area. Meteorological parameters used for calculation of ET_0 are latitude (12.38 Deg. North), longitude (101.21 Deg. East) and altitude of the station (3 m above M.S.L.), maximum and minimum temperature (°C), maximum and minimum relative humidity (%), wind speed (km/day), and sunshine hours which was collected from TMD and local authorities (between year 2007-2010). ET_0 was calculated for every 10 days (defined as 'decade' by FAO) and then cumulated to monthly data. Soil characteristics considered for estimation of crop water requirement are available water content (mm/m) and depth of soil (cm).

2.3 Crop Water Requirement (CWR) Estimation

FAO (2005) defines crop water requirement (CWR) for a given crop as:

$$\boldsymbol{CWR_i(mm) = \sum_{t=0}^{T}\left(kc_i \cdot ET_0 - P_{eff}\right)}$$

where kc_i is the crop coefficient of the given crop i during the growth stage t and where T is the final growth stage; $ET_c = K_c \times ET_0$; K_c = crop coefficient; ET_0 = reference crop Evapotranspiration (mm/day), which may be defined as follows:

$$ET_0(mm/day) = \frac{0.408\,\Delta(R_n - G) + \gamma\left(\frac{900}{T+273}\right)u_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)}$$

Where ET_0 = reference evapotranspiration (mm/day); R_n = net radiation at the crop surface (MJ m^{-2} d^{-1}); G = soil heat flux density (MJ m^{-2} d^{-1}); T = mean daily air temperature at 2 m high (°C); u_2 = wind speed at 2 m high (m s^{-1}); e_s = saturation vapor pressure (kPa); e_a = actual vapor pressure (kPa); e_s-e_a = saturation vapor pressure deficit (kPa); Δ = slope vapor pressure curve (kPa $°C^{-1}$); γ = psychrometric constant (kPa $°C^{-1}$). The equation uses standard climatological records of solar radiation (i.e., sunshine), air temperature, humidity, and wind speed. To ensure the integrity of computations, the weather measurements were kindly prepared and provided from TMD and RID.

The reference evapotranspiration ET_0 of individual crop are calculated by FAO Penman-Monteith method, using decision support software—CROPWAT 8.0 developed by FAO, based on FAO Irrigation and Drainage Paper 56 (FAO 1998). The FAO CROPWAT program (FAO 2009) incorporates procedures for reference crop evapotranspiration and crop water requirements and allow the simulation of crop water use under various climate, crop, and soil conditions (www.fao.org).

2.4 Crop Evapotranspiration (ET_c)

ET_0 is multiplied by an empirical crop coefficient (K_c) to produce an estimate of crop evapotranspiration (ET_c) as follows:

$$ET_c = K_c \times ET_0$$

2.5 Crop Data

The major cultivated crops in the study area are rice, pineapple, cassava, Long Kong, durian, mango, rambutan, jackfruit, mangosteen, coconut, rubber, and palm. The salient details of crops considered for the study are as per FAO and package of practices of Rayon local authorities. Crop coefficient values (K_c) are taken from available published data. K_c values for initial, mid, and late growth stages of annual and seasonal crops are used. In the case of perennial crops, same K_c value is used for the whole year.

3. Results and Discussions

3.1 Reference Evapotranspiration (ET_0)

The ET_0 of different crops in the study area ranged from 1,481 to 1,555 mm/yr (from year 2007 to 2010). This indicated the differences observed in the meteorological parameters (from relatively dry to relatively wet year) within the study area and stress the need for having scientific water requirement assessment.

3.2 Water Resources Assessment

3.2.1 Water Demand (Total Water Requirement)

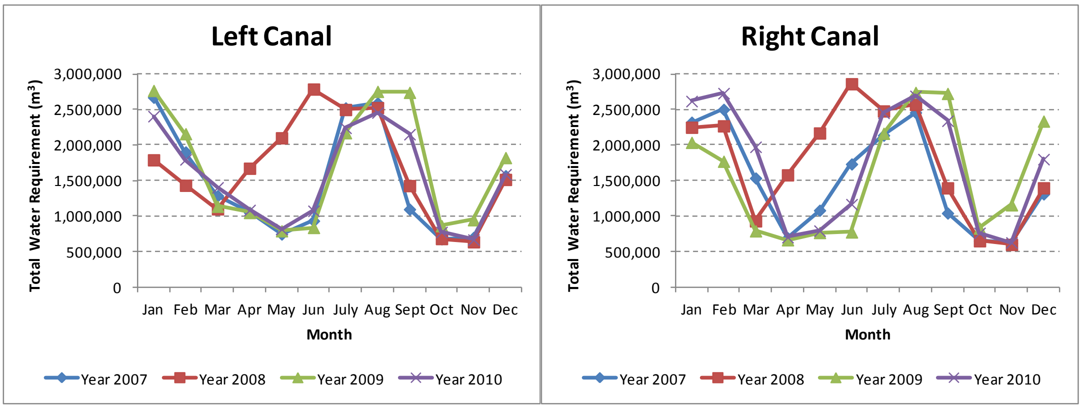
The total water requirement (m^3) was calculated by multiplying crop water requirement (mm) by crop area (m^2) for both sides of the canal as illustrated in Figure 1. The results obviously indicate that the total water requirements are fluctuating all year long with the highest value in Jan-Feb and Jul-Aug of the year.

3.2.2 Irrigation Water Requirements

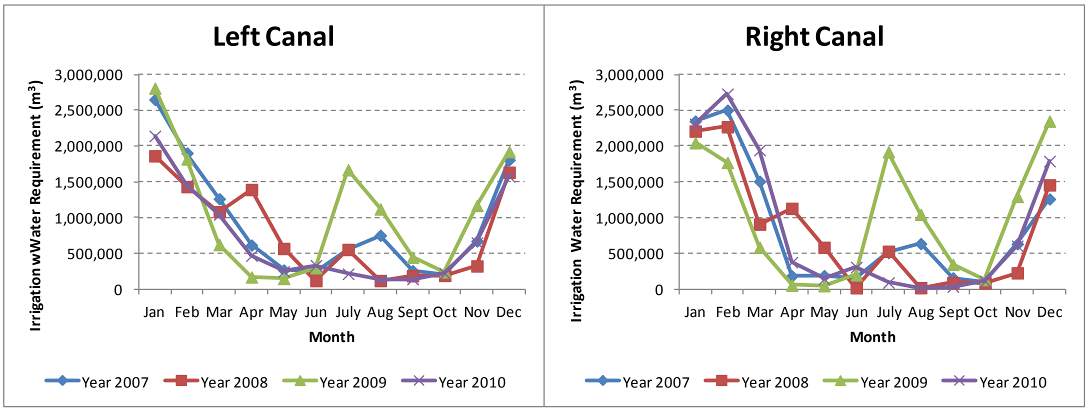
Based on the effective rainfall data in the study area, irrigation water requirements can be calculated from the difference between effective rainfall and the total water requirement. The results are presenting in Figure 2.

3.3 Status of Water Allocation for Irrigation

Based on the irrigation water requirement on both sides of the irrigation canals, and the water allocation schedule provided by Ban Khai weir, the results can be tabulated in Figure 3. It is noticeable that water was over-allocate to Ban Khai irrigation project most of the time year round, while some area has experienced some water shortage and could result in low irrigation efficiency



"Figure 1 Total Water Requirement in the Study Area"



"Figure 2 Irrigation Water Requirement in the Study Area"

Season	Month	2007		2008		2009		2010	
		Left	Right	Left	Right	Left	Right	Left	Right
Winter	January	✓	✗	✓	✓	✗	✗	✓	✗
Summer	February	✓	✗	✓	✓	✓	✗	✓	✗
	March	✓	✓	✓	✓	✓	✓	✓	✗
	April	✓	✓	✓	✓	✓	✓	✓	✓
Rainy	May	✓	✓	✓	✓	✓	✓	✓	✓
	June	✓	✓	✓	✓	✓	✓	✓	✓
	July	✓	✓	✓	✓	✓	✗	✓	✓
	August	✓	✓	✓	✓	✓	✓	✗	✗
	September	✓	✓	✓	✓	✓	✓	✓	✗
Winter	October	✓	✓	✓	✓	✓	✓	✓	✓
	November	✓	✗	✓	✓	✓	✓	✓	✓
	December	✓	✗	✓	✓	✓	✗	✓	✓

✓ = Field Water Supply > Irrigation Water Requirement
✗ = Field Water Supply < Irrigation Water Requirement

"Figure 3 Current Status for Irrigation Schedule "

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