Establishment of irrigation schedule for rice cropping seasons in the Long Xuyen Quadrangle, Vietnam using Cropwat model

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ABSTRACT
This study is conducted to determine the appropriate irrigation water amount for three main cropping seasons (TMCS) of rice in the Long Xuyen Quadrangle, Vietnam (LXQ). In the work, the Cropwat crop model was used to calculate irrigation water amount for winter-spring (WS), summer-autumn (SA) and autumn-winter (AW) crops based on meteorological data collected in period from 1998 to 2017. Simulation results carried out that WS crop was needed more irrigation water than SA and AW crops. The highest irrigation water requirement (IWR) of WS, SA and AW crops occurred on development stage with approximately values 207.1 mm, 205.8 mm and 102.3 mm respectively. The results showed that the proposed model is successfully applied to define crop water requirement (CWR) and irrigation requirement in the context of climate change leading to irrigation water scarcity.

Key words: Climate variability, Crop model, Crop yield, Irrigation water, Water scarcity.

INTRODUCTION
In recent two decades, Mekong Delta of Vietnam, where it has the presence of study area is impacting by drought leading to water scarcity, due to climate variability and flow from the Hau River where it supplies the main irrigation water for rice fields in the study area, has decreased significantly in the dry season (Dinh et al. 2012; Vu et al. 2018). Assessing the impact of sea level rise due to climate change on seawater intrusion in Mekong Delta, Vietnam. Water Science & Technology. Doi: 10.2166/wst.2018.038.) that it is the main reason leading to lack of fresh water for irrigation and this has seriously affected the production activities of farmers in the study area. Therefore, it is necessary to determine the appropriate irrigation time and volume of irrigation water for TMCS of rice in the study area is more concerned (Surendran et al. 2014; Vu et al. 2018) and especially in the context of the climate change. Climate change is leading the spatial and temporal change of precipitation distribution (Poudel and Shaw, 2016). It resulted in the increasing in air temperature and evaporation of water vapor and they are two of the main causes leading to water scarcity. Surendran et al. (2014) reported that the total of irrigation water requirement (IWR) is increasing in recent years along with the rising of air temperature thereby increasing the IWR. In that context, it is the necessary for determining the appropriate irrigation time and volume of irrigation water for agricultural production.

MATERIALS AND METHODS
Study area: The area (09°57'-10°42'N and 104°29'-105°29' E) also known as a part of Mekong Delta of Vietnam (MDP, 2013; RCSA, 2016). It covers 498141 ha of land with agricultural production belonging to An Giang, Kien Giang and Can Tho provinces (Hanington et al. 2017; Vo and Huynh, 2014). The terrain is lowered from north to south with an average elevation of approximately 0.3-2.0 m (Vu et al. 2018; Vo and Huynh, 2014) (Fig.1). Agricultural is the dominant sector in the study area with growing two or three main rice cropping seasons per year based on irrigation water from Hau River, which is one of the two main rivers of the Mekong River flowing through Vietnam and local precipitation. In the context of climate change, irrigation water is the main factor deciding the crop yield, therefore precipitation is also considered a support source (Zhong et al. 2014; Dinh et al. 2014). About 10% the annual average precipitation is taking during the dry season and it is one of the main cause leading to water scarcity during the dry season (Dinh et al. 2014; RCSA, 2016).

Model description: Cropwat crop model was created by the Land and Water Development Division of Food and Agriculture Organization (FAO), Italy (FAO, 1992; Hess, 2005). It is considered a useful tool to defining CWR, planning irrigation schedule and irrigation management. In addition, the proposed crop model can support the user to define the practice irrigation status, the planning of irrigation schedules under the impact of climate change (Allen et al. 1998; Banik et al. 2014).

Input data: Cropwat model requires air temperature, relative humidity, wind speed, solar radiation, sunshine duration, rainfall to calculate crop evapotranspiration, effective rainfall and crop water requirement in each decade of a month. The
meteorological data was collected from the Southern Regional Hydro-meteorological Center of Vietnam in the period (1998-2017) (Fig: 2).

Besides the climate data, to calculate CWR, other input data such as cultivation pattern, plant coefficient, area under cultivation, irrigation scheduling, soil type, available soil moisture, root depth, water content in the soil and crop planting calendar are also needed. The mentioned above input data obtained from Department of Agriculture and Rural Development of An Giang, Kien Giang and Can Tho Provinces (MNRE, 2016) and are given in Table 1.

In addition, soil characteristics are collected and analyzed using the Soil Water Characteristics Program software (Saxton et al. 1986; Oyeogbe et al. 2012). Soil type is predominantly silly-clay mix clay with soil pH about 4.0 showing the soil is mostly acidic, which means that the soils available have high potentials for retaining plant nutrients (Table 2).

RESULTS AND DISCUSSION

Effective rainfall (ER): Effective rainfall is considered as a part of the precipitation which is effectively used by the crop planting season after precipitation losses due to runoff and deep percolation (Bouraima et al. 2015; FAO, 1992). The results showed that ER varied from 0.0-10.2, 11.2-56.9 and 20.1-63.4 mm/decade respectively WS, SA and AW crops (Fig.3). The maximum ER was 63.4 mm/week of 10 days on third week of the AW crop. The main cause can be explained by high precipitation period in the rainy season.

Crop water requirement (CWR): Analyzed results showed that the CWR of TMCS was varied from 4.5-347.8, 80.3-360.1 and 18.3-80.5 mm/stage respectively WS, SA and AW crops (Fig.4). Winter-spring crop was needed more irrigation water volume than SA and AW crops. The total of the CWR of WS, SA and AW crops was approximately 856.45 mm, 512.26 mm and 273.89 mm, respectively. The highest CWR of the WS and SA crops was defined on the development stage and was calculated approximately 365.73 mm and 263.78 mm, respectively while this value of AW crop was only 21.56 mm. Zhong et al. (2014) reported that the high

Table 1: Planting and harvesting dates, growing and crop growth stage.

| Crop | Crop coefficient \(K_C\) | Growth stages (day) | Crop length (day) | Sowing date | Harvesting date |
|------|-----------------|---------------------|-------------------|-------------|----------------|
| WS   | 0.32 0.53       | I II III IV         | I II 60 25 105    | 15-Dec      | 27-Mar         |
| SA   | 1.04 1.18       | I II 65 25 110      | 15-Apr 01-Aug     |             |                |
| AW   | 1.03 1.16       | I II 65 25 110      | 15-Aug 05-Dec     |             |                |

I is land preparation stage, II is initial stage, III is development stage, IV is late stage
air temperature period, high evaporation and soil moisture will rapidly decrease and these lead to increased irrigation water demand. The CWR of WS crop is increasing with the passage of time and required peak amount of water in the growing and developmental stage. Contrary, the lowest irrigation water demand was close to zero occurred on development stage of the AW crop because this period irrigation water from rain is plentiful.

Irrigation requirements (IR): Simulation results of IR for TMCS were shown in Fig. 5. The high IR occurred on initial stage of WS and SA crops with approximately values 207.1 mm and 205.8 mm while the value of AW crop was only 102.3 mm. The main reason is that this period coincides with the high rainy period of rainy season therefore rice do not require much irrigation water.

CONCLUSION
The winter-spring crop needed more irrigation water than summer-autumn and autumn-winter crops. The highest CWR occurred on initial stage of WS and SA crops while the autumn-winter crop occurred on initial stage. On the contrary, the lower CWR occurred during the rainy season. These results were in consistent with a similar study which was constructed by Bouraima et al. (2015) in Northern Benin. They reported that the CWR would be increased on initial stage of WS crop. The results could be considered as a useful guide to farmer to provide the amount and consistent watering schedule for each crop.

The study results will enhance defining CWR which help to improve the efficiency of agricultural production and minimize the negative impacts of climate change to crop productivity. Results also showed that the proposed crop model is a useful tool to define ER, CWR and irrigation requirement in the context of climate change leading to scarcity of irrigation water. The Cropwat crop model can be applied to planning and design the irrigation projects for other areas where the freshwater scarcity problems are being faced.

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Table 2: Relevant soil characteristics.

| Soil description                        | Medium          |
|-----------------------------------------|-----------------|
| Maximum rain infiltration rate          | 95 mm/day       |
| Plowing depth                           | 20 cm           |
| Maximum water depth                     | 70 cm           |
| Water availability at planting          | 7.5 mm WD       |
| Maximum rooting depth                   | 120 cm          |
| Maximum percolation rate after puddling| 395 mm/day      |
| Critical depletion for puddle cracking  | 95 mm/day       |
| Drainable porosity (SAT-FC)             | 15%             |
| Initial soil moisture depletion (%)     | 60%             |
| Initial available soil moisture         | 130 mm/m        |
| Total available soil moisture (FC-WP)   | 140 mm/m        |
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