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EVALUATION OF AQUACROP MODEL TO PREDICT CROP WATER PRODUCTIVITY FOR PADDY

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Abstract: *Water and nutrient are critical inputs for crop production, especially in meeting challenges from increasing fertilizer cost and irregular water availability associated with climate change. The Land and Water Division of Food and Agriculture Organization of the United Nations (FAO) has developed AquaCrop, an integrated application software to simulate the interactions between plant, water, and soil. Field management and irrigation management are the factors that need to be considered since it affects the interactions. Four critical components are needed in the AquaCrop model, viz. climate, crop, field management and soil conditions. In our case study, climate data from a rice field in UtanAji, Kangar, Perlis was applied to run a simulation by using AquaCrop model. The rice crop was also assessed against deficit irrigation schedules and found that optimum water level usage increases the field yield. Results derived from the use of the model corresponded conventional assessment. This model can be adopted to help farmers in Malaysia in planning crop and field management to increase the crop productivity, especially in areas where the water is limited.*

Keywords: *AquaCrop Model, Crop Water Productivity and Crop Productivity*

Introduction

Climate change plays a major role in determining crop performance. The climate factors as expressed by the amount of rainfall, sunshine hours, temperature, relative humidity, and length of the drought period result in a year to year variability of crop production. Climate change affects agriculture most significantly out of other economic sectors because of its worldwide distribution and dependence on environmental factors. Thus, the effects of climate change on the agricultural production impact the socio-economical dimension at both the macro and micro-scales. Floods and droughts are the most common phenomena that directly affect the relationship between agriculture and climate change.

The effects of climate change on paddy rice production are likely to be small to moderate (Toriman et al., 2013). However, regional impacts could be significant. Rice yields and changes in productivity vary considerably across regions (Toriman et al., 2013). These regional variations in gains and losses probably result in a slight overall decrease in world cereal grain productivity. The effect of the temperature on paddy rice mainly governs the timing of the physiological process, the rate of expansion and survival of the reproductive structures (Toriman et al., 2013). Increases in temperature affect the moisture availability through effects on evaporation; in general, evaporation increases by about 5% for each 1 ºC increase in main annual temperature. This would be significant in tropical regions where most crops, particularly rice, are generally constrained by water availability (Al-Amin &Siwar, 2008).

Kangar, Perlis is one of the regions in Malaysia affected by the climate changes, particularly drought, for a short period. It always happens in early December until the end of February in the following year. The lowest precipitation of rainfall is in January, every year. A decrease in the rainfall will affect crops that need wet conditions such as rice. In addition, rice grain yields might decline by 9 to 10% for each 1 ºCrise (Baharuddin, 2007). Drought periods make it not feasible to maintain the rice ecosystem, thus affecting food security. Due to the short dry season in Kangar, farmers need to use the total available water for their paddy rice crops efficiently. Failure to manage water resources will lead to water wastage and increase in production costs.

In order to solve problems associated with water management, the Land and Water Division of Food and Agriculture Organization of the United Nations (FAO) has developed AquaCrop, integrated application software to simulate the interactions between plant, water, and soil. Field management and irrigation management are the factors that need to be considered since it affects the interactions. Four critical components are needed in the AquaCrop model. viz. climate, crop, field management and soil conditions (Pawar et al., 2017). The described system is linked to the atmosphere through the upper boundary which determines the evaporative demand (ETo) and supplies CO2 and energy for crop growth. Water drains from the system to the subsoil and the ground water table through the lower boundary. If the groundwater table is shallow, water can move upward to the system by capillary rise.

Previously, we have Soil Water Balance Model (SWBM) to access field water availability for lowland rice production only. The toposequence of the rice-growing lowland is characterized by lower, middle and upper positions and whilst this model has satisfactorily predicted soil water conditions in rice fields in the middle, it fails to perform well in the lower and upper reaches of the toposequence (Vote et al., 2015). This can be attributed to the inability of the model to estimate lateral water movement in the landscape which is highly dynamic and variable through space and time (Ithavong et al., 2011). Thus, in this study, climate data from a rice field in UtanAji, Kangar, Perlis was applied to run a simulation by using AquaCrop model. The rice crop was also assessed against deficit irrigation schedules and net irrigation requirement. Soil water condition in the lower, middle and upper positions of the toposequence were also been considered in the input of the AquaCrop model.The objectives are to predict and then compare the yield and water use efficiency of the rice paddy crop by the two methods of irrigation used.

Methodology

Input Requirement of AquaCrop Model

This software is very useful to formulate guidelines for farmers to meet their needs. To achieve that, AquaCrop requires several data or inputs that visualize crop characteristics. The important inputs are weather data (from a weather station at the rice field), soil characteristics, crop type, and management practices, which include field management and irrigation management (Figure 1). Weather data comprises of reference evapotranspiration (ETo), minimum and maximum temperature, rainfall and mean annual carbon dioxide (CO_2). For soil profile, the user needs to select types of soil used for the selected crop such as sandy loam, silt, heavy clay, silty clay, silt loam and loamy sand soil. For irrigation purposes, there are three methods provided by AquaCrop, viz. net irrigation water requirement, irrigation schedule and generation of the irrigation schedule. Crop productivity can also be predicted by suitable field management practices. Soil fertility, mulches, and field surface practices are important factors in field management application in AquaCrop. For this study, we are focusing on the use of irrigation inputs to predict and determine the best irrigation method to obtain high crop productivity with the effective use of the crop, water, soil and field management practices.

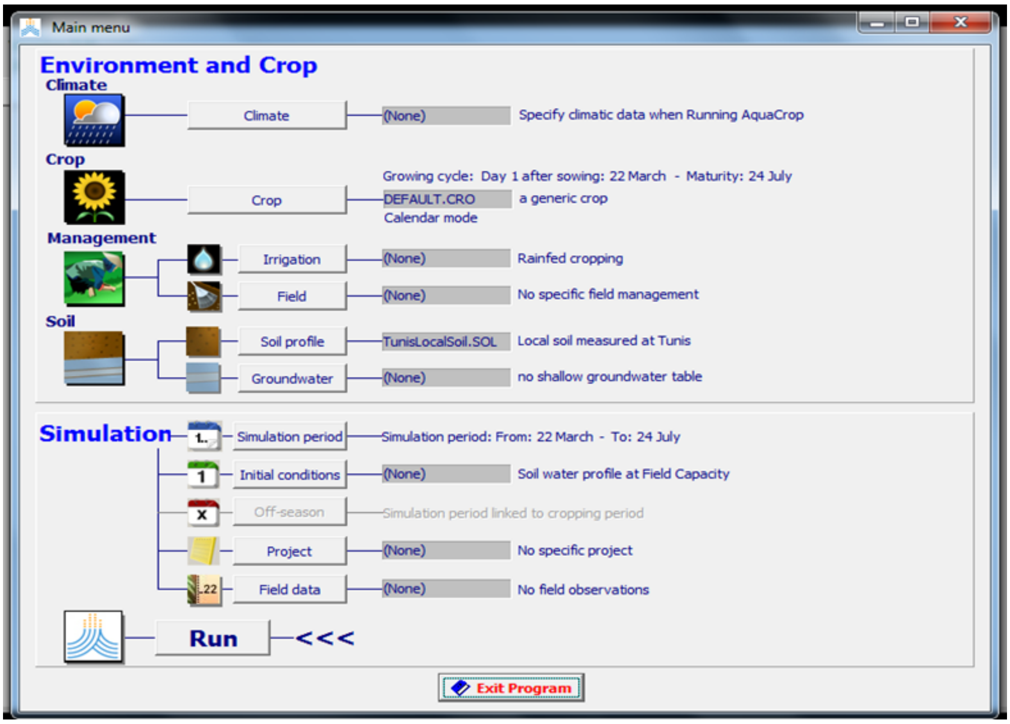

Figure 1: Important inputs in AquaCrop software (Climate data, crop, irrigation and field management and soil profile)

Net Irrigation Requirement

According to local practices at UtanAji, Kangar, Perlis, farmers sow irrigated paddy at the end of October (31st October) on heavy clay soil. Short dry season occurred from December until February of the following year. The purpose of applying this method is to ensure that the entire soil profile is at field capacity and that crop canopy development is never affected by water stress. Before we start the simulation, correct crop file was selected (paddy rice crop). Then, a net irrigation requirement file with 0% RAW (allowable root zone depletion) was created (Figure 2). The net irrigation requirement file was saved as PaddyNetReq.IRR. A project

(Utan_Pad_NetIrr.PRM) specifying the local environment and the correct simulation settings was created for five successive years (2009 – 2014) (Figure 3). We started the simulation before the sowing date on 15th August (Not linked to growing cycle) for each run. Initial condition was at field capacity for each run (Figure 3). The project was run and yield and net irrigation requirements were assessed for every season.

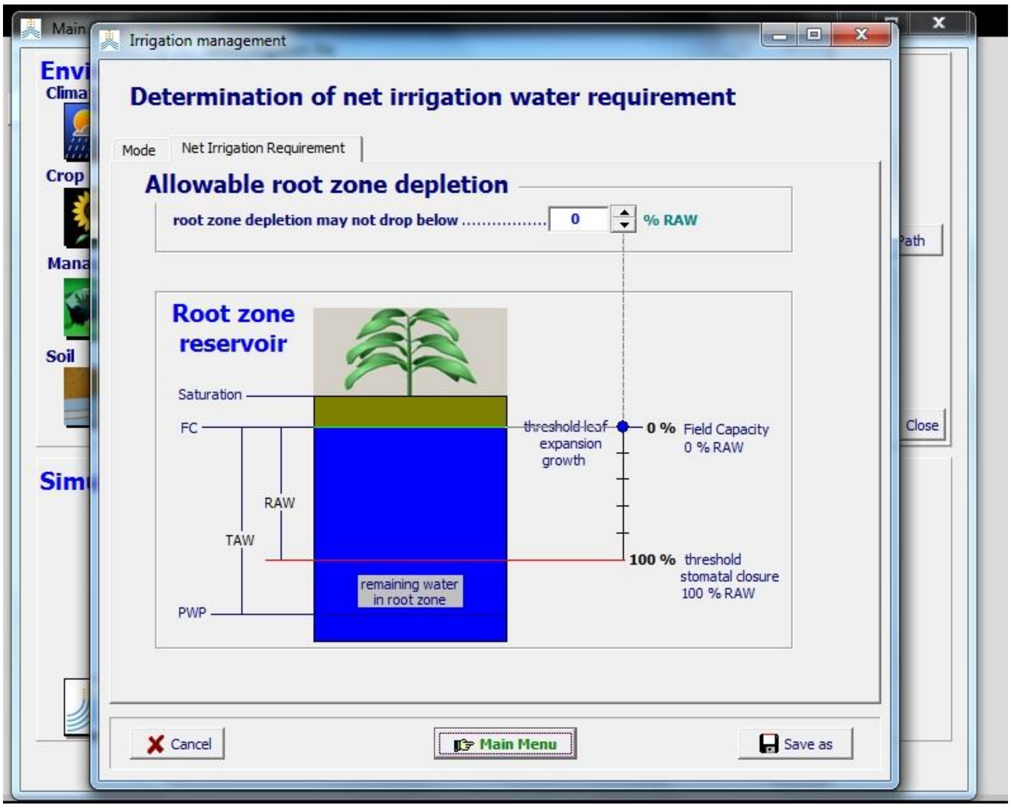

Figure 2: Paddy rice net irrigation water requirement file with 0% RAW

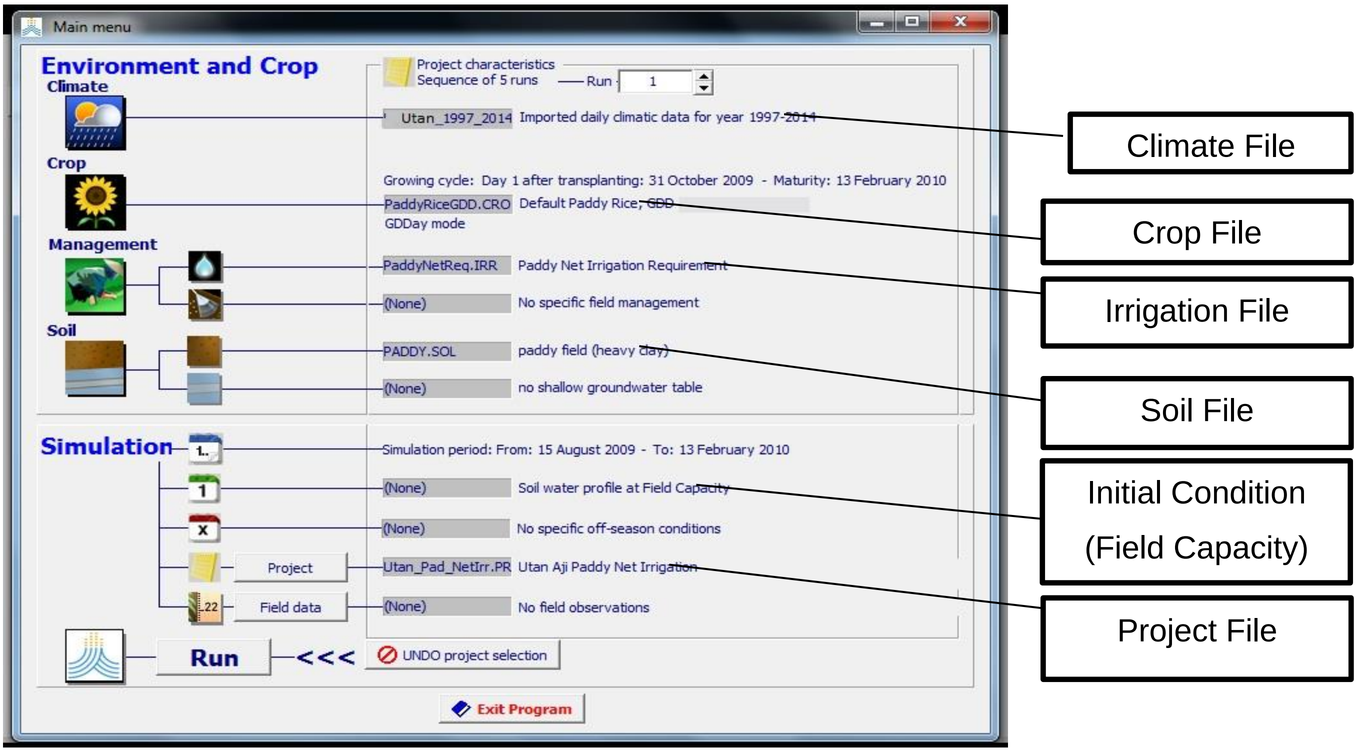

Figure 3: Full view of AquaCrop data that consists of climate, crop, irrigation, soil, initial condition and project file

Deficit Irrigation Schedules

All the files for this irrigation method were created, similar to the net irrigation requirement method with the exception of the irrigation file. Since irrigation water is limited, water is only available i) for a 30 mm at sowing to assure good germination, ii) 30 mm on the first month of dry period (19th December) and iii) 40 mm on the second month of dry period (18th January on the following year). Basin irrigation systems are common in the region. The file name for this irrigation method is PaddyDeficit.IRR**(Figure 4)**. We have simulated a time series of five historical data (2009 – 2014) and assumed non-limiting soil fertility. A project was created from the accumulated data (Utan_Paddy_Deficit.PRM).

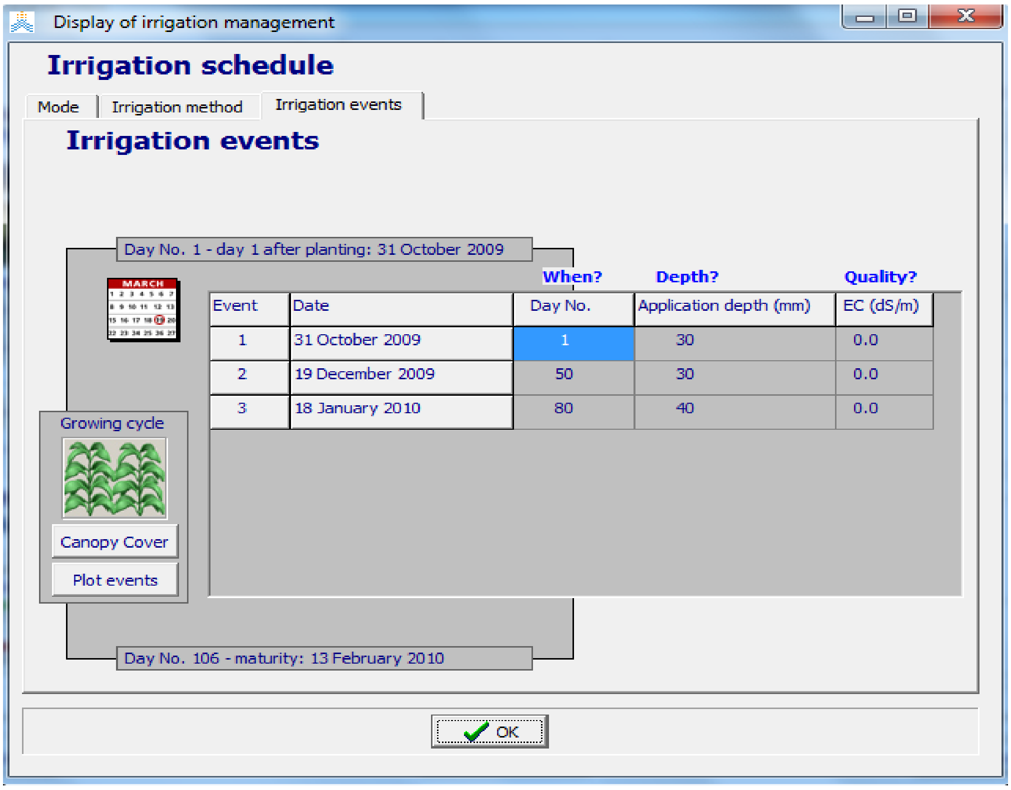

Figure4:Irrigation events of Deficit Irrigation method

Results

Referring to **Table 1**, the results indicated that the highest yield obtained was 7.33 t/ha which was in 2014. In 2010, the total available water was used efficiently with the value of 2.51 kg/m^3. The highest usage of water for irrigation was in 2009, which was the first year of planting the paddy crop.

Table 1: The net irrigation requirement method resultsfrom the AquaCrop simulation

Year	Average Yield (t/ha)	Water Use Efficiency (kg/m^3)	Net Irrigation Requirement (mm)
2009	7.02	2.06	255.3
2010	7.08	2.51	44.5
2011	6.92	2.48	105.7
2013	6.95	2.14	144.2
2014	7.33	2.24	144.2

Referring to **Table 2**, the results indicated that the highest yield obtained was 7.09 t/ha in 2014. In 2011, the total available water was used efficiently with the value of 2.57 kg/m^3. Overall, water usage for irrigation every year was same (100 mm).

Table 2: The deficit irrigation schedules method results from the AquaCrop simulation

Year	Average Yield (t/ha)	Water Use Efficiency (kg/m^3)	Irrigation Requirement (mm)
2009	3.47	1.58	100
2010	7.08	2.54	100
2011	6.93	2.57	100
2013	6.91	2.17	100
2014	7.09	2.33	100

We also calculated the average of five years data of yield (t/ha), water use efficiency (kg/m3) and water used for irrigation (mm) for both net irrigation requirement method and deficit irrigation schedules method. We found that the average yield and water use efficiency are about the same (Figure 5). The average yield from both methods for the five years was near (7.06 t/ha = Net Irrigation Requirement) and (6.3 t/ha = Deficit Irrigation Schedules) as well as water use efficiency (2.29 kg/m3 = Net Irrigation Requirement) and (2.24 kg/m3 = Deficit Irrigation Schedules). The irrigation requirement by deficit irrigation schedules is lesser as compared with net irrigation requirement.

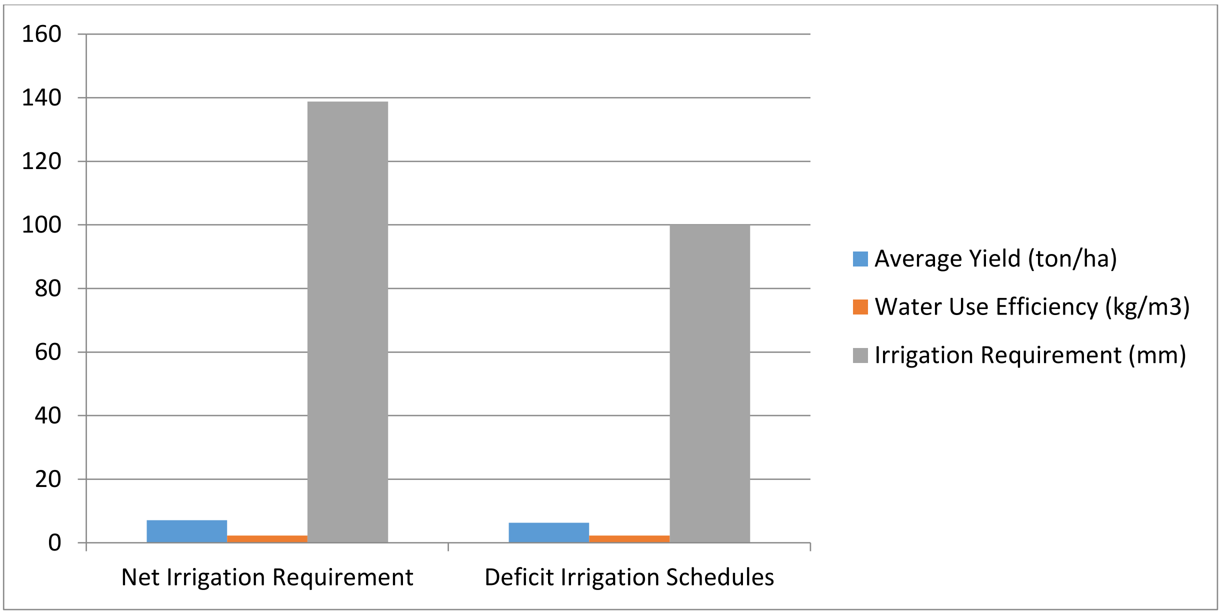

Figure 5: The average of five years data of yield (t/ha), water use efficiency (kg/m^3) and water used for irrigation (mm) for both net irrigation requirement method and deficit irrigation schedules method.

Conclusion

As a conclusion, the results derived from the AquaCrop software by assessing the available data towards deficit irrigation schedules corresponded conventional assessment (net irrigation requirement method). However, the water usage (irrigation requirement) by deficit irrigation is 38.8 mm less as compared to the net irrigation method. The result showed that we can save more available water and indirectly save production cost through deficit irrigation. This model can be adopted to help farmers in Malaysia in planning crop and field management to increase crop productivity especially in areas where water is limited.

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