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IRRIGATION WATER NEEDS OF RICE CROPS WITH EMPIRICAL METHOD

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Abstract

Experiments were conducted to in An Giang province in a paddy rice field in 2020 and 2021 to determine ET (evaporation) by pan method. And then, comparing these parameters with the model method. From that, calculating water needs for rice crops. In addition, the study pointed out a treatment that had the highest rice yield but the lowest amount of irrigation water to to make recommendations to farmers. Results showed that ET_C ($mm.day^{-1}$) and in Winter-Spring, Summer-Autumn, and Autumn-Winter crops are 4.95, 5.27; 3.48 respectively. Rice yield in most of the treatments were higher than the control treatment (Blank test) in both experiment. In the Winter-Spring crop, the yield and percentage of filled grain were higher than in the other two crops. The results also showed that water need were intaken into the rice field determining the survival of the plants by counting the plant density. The selected treatments for recommendations to the population are respectively: TM4 in experiment 2 for Winter-Spring crop (rice yield about 14 tons/ha, water need of 14,000m^3/ha); TM4 in experiment 1 for the Summer-Autumn crop (rice yield 5.8 tons/ha; water need of 7,312m^3/ha); TM2 in experiment 1 for the Autumm-Winter crop (rice yield of 6.74 tons/ha, water demand is 3,204m^3/ha).

Index-terms*;* Water needs, Rice, ET, Seepage, An Giang.

I. INTRODUCTION

In recent years, rice cultivation in An Giang province faces many difficulties due to the high variability of weather conditions. It has been observed that severe droughts, which recently take place during the first growth stage in February or March, and heavy rains, which often fall in September or October, cause a lot of damage to the Winter-Autumn crop. On the other hand, the October crop normally suffers from water logging and floods at the vegetative phase, and also from the shortage of water at the late reproductive phase (Irrigation Departments in An Giang province, 2015). Climate change is one of the most significant potential impacts on Hydrological change in the tropics (IPCC, 2007). It will make increasing temperature and changing precipitation. Higher temperatures produce higher evapotranspiration, which in turn affects the hydrological cycle and water availability (Shahid, 2011). Currently, there are many methods to estimate ET and apply to each specific climate zone. Most of the methods are modified versions of other methods. Since many methods have been developed from a certain view for a particular climate zone, they often fail to estimate evapotranspiration that may occur under other climatic conditions. This is also a challenge in accurately forecasting ET values.

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Therefore, estimate ET with empirical method was done. From that we calculate irrigation water needs of rice in An Giang province.

Many researchs were done to calculate water demand. Water requirement for rice crops was calculated for Long Xuyen Quadrangle, Vietnam by Lee, 2018. The results showed that winter-spring and summer-autumn harvest needed irrigation water approximately 8,186 and 5,830m^3/ha, respectively, while autumn-winter harvest needed approximately 2,204 m^3/ha. The lowest value of the reference evapotranspiration (ETc) was approximately 607.8 mm/crop occurred in Autumn-Winter crop, while the highest value 709.9 mm/crop occurred in Summer-Autumn crop (Lee, 2018). The study results of Nguyen 2020) showed that, the temperature will increase by 0.4-1.2^{o}C by 2035 and the rainfall is relatively heavy (increasing from 0.6 mm to 8.9 mm). In 2035, the total demand for irrigation water of crops will increase of about 4% compared to 2015 (Nguyen, 2020). Vietnam-Netherlands Mekong Delta Master plan project (2011) calculated water needs for the 120 irrigation subdivisions. The calculated data showed that the water demand for agriculture is the largest, accounting for 68% of the total water demand. The months of January and February require the largest amounts of water use due to the lack of rain. Average monthly water demand for rice 354.40 (m^3/s). Research by Nguyen, 2019, forecasts the water demand of major land use types in the Srepok River basin using the tool CROPWAT 8.0. Irrigation water demand in 2015 with the highest level is winter-spring rice land 7,746 m^3/ha/crop, forecast for the future (2045) shows that irrigation water demand tends to decrease at different levels (11.7% for the low scenario, 18.59% for the medium scenario and 4.25% for the high scenario) compared to 2015. Climate change has been impacting agriculture, increasing crop water demand and increasing evaporation. This is evidenced by the study of Le Tuan Anh in 2012 on the irrigation zone of Trung Ha, Suoi Hai. Research results have shown that the irrigation water demand of the crop rice increases by at least 0.6% in 2050 and 1.9% by 2100, corresponding to the B2 scenario (Le, 2014). According to the development investment bank, if the temperature increases by 1 degree Celsius, rice yield will decrease by 10% (Vu, 2015). Many programs have been used to calculate water demand for crops. The CROPWAT model implementing the Penman-Monteith equation was already used to calculate water demand for agriculture in Ninh Hoa, Vietnam (Bui, 2012). From the above reference results are the basis for comparison with our experimental results. The main objective of this research is to determine of evaporation, seepage and irrigation water for rice by empirical method, and then comparing with the FAO-Penman calculations for rice grown by traditional farming. So as to give substantiated recommendations for scientists and farmers on use of FAO-Penman model for practical purposes and to establish whether it is suitable for study area. Evaluation of rice yield was affected by irrigation time (alternate wet and dry watering) of 04 treatments of different irrigation. From that, find out a treatment of high yield but amount of low used water to improve water management in irrigated agriculture.

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II. METHODOLOGY

2.1 Traditional farming techniques

The rice variety CK92 *(Oryza sativa L. Var. Glutinosa Tanaka)* was used in this study. This variety is well adapted to the soil in An Giang, easy to cultivate, It has a growth cycle of 105 days, and fluctuates in yield from 7-12 tons/ha. Plant height from 100–110cm, large flowers, percentage of high filled grain. This variety is susceptible to cold weather. It can grow 3 crops in a year. Traditional farming techniques include the following steps:

- Soil preparation: Burning straw and then plowing or drying the soil for 2 weeks to kill pathogens and harmful insects. Then pump water into the field about 01m for plowing. After that a week, pumping water for the second time to make the soil smooth and flat, killing weeds and hitting drainage ditches, then sowing seeds.

- Prepare seeds, soak and sow:

+ Selection of varieties: Seeds must be checked carefully before soaking. Seeds are soaked directly in water, removing the float seeds above. Filled grains are soaked in water for 24 hours. Then, remove the seeds out of water and incubate for 15 to 36 hours. Using 17 kg of seeds corresponds to an experimental area of 600m^2.

- Crop and water management:

+ Pump water to the field so that the grass has no chance to survive and use Herbicide (Pyribenzoxim) to kill snail after sowing one week.

+ The water level is pumped into the field 0.1m. During the rice season the number of times to pump water was 10 times.

+ Three times of fertilizer application: 10 days after sowing (6kgUREA+DAP7kg); 20 days after sowing (UREA7kg+DAP 8kg+Kali 2kg); 40 days after sowing (UREA7kg+Kali 5kg).

+ Spray pesticides 02-03 times if there are pests.

- Harvest: stop supplying water to the paddy rice two weeks before harvest.

2.2 Experiment design

The experiment was carried out for 3 rice crops in 2020-2021 in Phu Tan district, An Giang province. The soil in cultivated fields is medium silt mixed with clay; pH 6-7; porosity 46-57; N (%) 0.1-0.14; OC% 0.9-1.56.

The experiment was designed on an area of 600 m^2 (excluding the dike) (Figure 1) divided into 2 experiments (300m^2 for each experiment): Experiment 1: The water level was take into the field is 50 mm; Experiment 2: water level 100 mm. The two experiments were similar in terms of farming techniques: rice seed CK92 (105 days), soil preparation, cropping schedule, sowing techniques, and spraying. However, different irrigation techniques (alternating dry flooding for both experiments). Irrigation techniques are shown as below:

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Experiment 1: The water level taken into the rice field is (50) mm arranged according to the irrigation formula (treatment) as follows:

- Treatment 1 (TM1): Water is taken into the rice paddy when when the field runs out of water.
- Treatment 2 (TM2): The field is dry, 3 days later water is pumped into the field.
- Treatment 3 (TM3): The field is dry after 6 days, water is pumped into the field.
- Treatment 4 (TM4): The field is dry after 9 days, water is pumped into the field.
- Blank Test (BT): The traditional water intake technique. On average, the whole rice crop has 10 times to pump water into the field (the same in 3 rice crops).

Each treatment was repeated 3 times. Size of each plot: 5x5m. A total of 20 plots for each experiment. In each plot put 2 barrel (or pan) with rice grown inside it (01 barrel or pan with closed bottom and 1 barrel (pan) with open bottom) and 02 non-rice pans (01 closed bottom and 01 open bottom) to measure seepage. The size of the pan is 48cm x 60cm x 40cm and it is put into the ground with a depth of (-0.3 m), the height of the pan from the ground surface is 0.1 m. Besides, we also put a pan to measure the rainfall.

Experiment 2: The design was the same as experiment 1, but each time water was taken into the rice field at a water level of 0.1m.

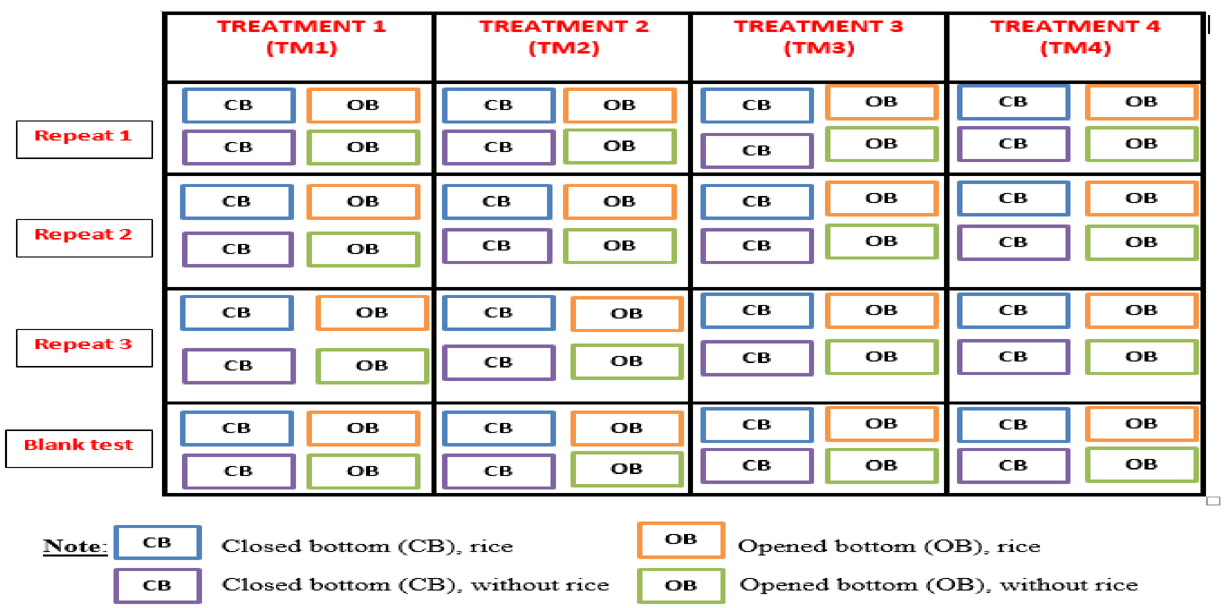

Fig 1: Experimental layout diagram

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2.3 Monitor and measure parameters

2.3.1 Yield parameters of rice

Crop yield of rice depends on the so-called yield components (number of panicles, number of spikelets and percentage of filled-grain and grain weight) which are genetically fixed parameters for a certain rice variety and which govern rice grain yield (Đe, 2008).

+ Density of trees/m^2.

+ Number of panicles (flowers)/m^2 and weight of panicles (flowers)/m^2 and dry grains weight g/m^2.

+ Number grains/panicle; Number of filled grains/panicle; Percentage of filled grain.

+ Actual yield (tons/ha) = Rice production/area.

2.3.2 Measure the water level

The water level was measured every day in the barrel and in the field at 4pm every day. When the field was dry, pumped water into the rice field according to the experimental design above for each treatment.

2.3.3 Irrigation water need of rice

Irrigation requirement is the total quantity of water applied to the land surface in supplement to the water supplied through rainfall and soil profile to meet the water needs of crops for optimum growth (My agriculture information bank, 2018).

According to FAO, the determination of the irrigation water need for paddy rice requires the following steps:

- Determine the reference crop evapotranspiration: ETo

- Determine the crop factors: K_c

- Calculate the crop water need: ET crop = ETo × K_c

- Determine the amount of water needed to saturate the soil for land preparation (W_s).

- Determine the amount of percolation and seepage losses (Seepage is the water escaped through the soil under gravitational forces): W_p.

- Determine the amount of water needed to establish a water layer: W_l

- Determine the effective rainfall: W_r

- Calculate the irrigation water need: W_i

- The amount of water rising to the arable soil layer due to capillary: W_c

$$W_i = W_s + W_l + W_p + ET_c - W_r - W_c \qquad (1)$$

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2.3.4 Calculation Ws

+ During the land preparation stage, there are 2 times to pump water into the field: First time: The amount of water put into the field is 0.1 m, the purpose is to make the soil soft to prepare for plowing. After 7 days, continue to pump water a second time at the water level of 0.1m to make the soil smoother.

$$Ws = (H_1 \times S) + (H_2 \times S) \quad (2)$$

Where: H_1, H_2: Water level height at 1st and 2nd time

S: Area of rice field

2.3.5 The amount of irrigation water for rice includes 2 stages

- Phase 1 (first 20 days after transplanting): During this time, water is brought into the field 2 times:

+ First time: The amount of water put into the field is 0.05m for experiment 1 and 0.1m for experiment 2. Water levels are monitored every day. The results showed that the field running out of water after 7 days. Continue to let the field dry for 3 more days, then pump water into the field for the second time.

+ Second time: The amount of water put into the field is 0.05m for experiment 1 and 0.1m for experiment 2. After 7 days, the field was running out of water, continue to dry the field for another 3 days.

+ At this stage, the amount of irrigation water for rice in 20 days after sowing is calculated as follows:

$$W_{20days} = W_1 + W_2 + W_{seepage} + W_{ET} - W_{rain} - W_c \quad (3)$$

$$W_1 = H_1 \times S \quad (4)$$

Where:

W_1, W_2: The amount of water taken into the rice field at the 1st and 2nd time.

H_1, H_2**:** Water level height at 1st and 2nd time

S: Area of rice field

$$W_{seepage\ (20days)} = W_{OB} - W_{CB} \quad (5)$$

Where:

$W_{seepage(20days)}$: Total water loss due to seepage in 20days

W_{OB}: The amount of water lost at barrel of the open bottom (OB) = The amount of water lost in the open bottom barrel due to evaporation and seepage.

W_{CB}: The amount of water lost in the close bottom (CB) barrel due to evaporation.

$$W_{ET} = W_{CB,\ rice} = W_{CBsoil} \quad (6)$$

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W_{rain} = H (water level) x S_{barrel} (Area of the barrel) (7)

W_c: The amount of water rising to the arable soil layer due to capillary

- Phase 2 (next 75 days):

Calculation results showed that the amount of water lost in the rice growing barrel of closed bottom was nearly equal to the amount of water lost in the closed bottom barrel without rice. Therefore, the amount of water supplied to the rice in the 75 days period is the transpiration volume of rice. This is true with the statement of FAO and some other authors. So, we have:

$$ET_c = W_{CB,\ rice} \quad (8)$$

At this stage, the amount of irrigation water for rice in 75 days next was calculated as follows:

$$W_{75days} = \sum_1^i W_i + W_{Seepage} + W_{ET} - W_{rain} - W_c \quad (9)$$

2.3.6 Irrigation water need of a rice crop

$$Wi = Ws + W_{20day} + W_{75day} \quad (10)$$

2.3.7 Determine Crop coefficients (Kc)

$$K_c = K_{cb} + K_e = (E_t + E_g)/ET_0 \quad (11)$$

Where; Kcb is the basal crop coefficient;

Ke is the soil water evaporation coefficient beneath the canopy;

ET_c is actual evapotranspiration, mm/d;

Et is plant transpiration, mm/d;

Eg is the evaporation from soil surface beneath the canopy, mm/d;

ET_0 is reference evapotranspiration, mm/d was calculated by the Penman-Monteith Equation. However, empirical ET_0 (water surface evaporation above the rice canopy) was using to calculated Kc. ET_0 was measured by using a round pan ($W_{CB,\ soil}$).

We have: $E_t + E_g = ETc = W_{CB,\ rice}$ (12)

$$ET_{0Pan} = W_{CB,rice} - W_{CB,soil} \quad (13)$$

Where;

ET_0 pan is reference evapotranspiration, mm/d was calculated using a round pan.

$W_{CB,rice}$: Closed bottom (CB), grow rice

$W_{CB,soil}$: Closed bottom (CB), without grow rice, only soil and water.

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2.3.8 Data analysis

- Using Excel to calculate the measured parameters in the field.
- Compare the difference in mean values of yield, growth index of treatments in the same experiment by Duncan test in analysis of Anova. The aim was to find a treatment with high yield but lower used water than other treatments.
- Compare each treatment of the two experiments each other by using the T-Test method related to mean values of yield and growth index.

III. RESULTS

3.1 Irrigation water needs by empirical method

Water was pumped into paddy rice at the same water level for all 4 treatments; however, with different number times of water intake, the results of the total irrigation water demand of the treatments were different. Irrigation water demand of 4 treatments in experiment 1 (Table 4.6) in Winter-Spring crop ranged from 10,768 m^3/ha to 18,892 m^3/ha, followed by Summer-Autumn crop (7,312 m^3/ha-15,024 m^3/ha), the lowest is the Autumn-Winter crop (536 m^3/ha -7,712 m^3/ha). In experiment 2 (Table 1) Winter-Spring crop fluctuated in the range of 14,452m^3/ha-29,640m^3/ha, 1.46 times higher than that of experiment 1. Summer-Autumn crop was 10,820m^3/ha-25,872 m^3/ha is 1.61 times higher than that of experiment 1. Autumn-Winter is 4,080m^3/ha-18,848m^3/ha, is 2.98 times higher than that of experiment 1.

Table 1: Total irrigation water needs for a rice crop

Unit: m^3/ha

Treatments	Experiment 1			Experiment 2		
	Winter spring	Summer-Autumn	Autumn -Winter	Winter spring	Summer-Autumn	Autumn -Winter
BT	15,000	12,000	7,500	15,000	12,000	7,500
TM1	18,892	15,024	7,712	29,640	25,872	18,848
TM2	13,700	9,936	3,204	19,716	15,992	9,084
TM3	12,360	9,128	1,680	17,464	14,044	7,152
TM4	10,768	7,312	536	14,452	10,820	4,080

Note: BT (Blank test treatment)

Of which,

The amount of water needed for soil preparation in two experiments was the same: Winter-Spring crop needed 2,000m^3/ha, Summer-Autumn crop required 1.676m^3/ha, Autumn-Winter required 536m^3/ha.

Evapotranspiration in experiment 1 of Winter-Spring crop was 4,360-4,660m^3/ha (436-466mm). Meanwhile, Summer-Autumn crop was 4,356m^3/ha-4,448m^3/ha (435-448mm), Autumn-Winter was 2,900m^3/ha-2,964m^3/ha (290-296mm). In the experiment 2, Winter-Spring was 4,432-4,620m^3/ha (443-462mm) and Summer-Autumn was 4,336m^3/ha-

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4,472m^3/ha (433-447mm). Autumn-Winter was 2,804m^3/ha-3,036m^3/ha (280-303mm) (Table 2). The results showed that the evapotranspiration of treatments in experiment 1 was not significantly different compared with evapotranspiration of the treatments in experiment 2 in all 3 rice seasons. Calculation results of the model of FAO–Penman showed Winter-Spring (4,671m^3/ha =467mm) is higher 202m^3/ha (4.34%) than empirical results (4,468m^3/ha), lower than 990 m^3/ha (18.37%) compared with empirical results (4,400m^3/ha) in Summer-Autumn. However, in Autumn-Winter, the empirical results (2,932m^3/ha) were higher 184m^3/ha (6.27%) than the FAO-Penman method. According to Doan Doan Tuan, 2012, water demand for rice in Delta of Vietnam (ET) ranged from 4,063.4 m^3/ha to 4,489.8 m^3/ha. Compared with the results of Tuan, crop water demand (ET) of rice in our study is very suitable.

Table 2: Crop water demand (ET) of rice crops

Unit: m^3/ha

Treatments	Experiment 1			Experiment 2		
	Winter spring	Summer-Autumn	Autumn-Winter	Winter spring	Summer-Autumn	Autumn-Winter
TM1	4,660	4,372	2,964	4,620	4,336	2,908
TM2	4,492	4,424	2,912	4,552	4,472	2,804
TM3	4,360	4,448	2,900	4,432	4,444	3,036
TM4	4,368	4,356	2,956	4,456	4,372	2,980

In Experiment 1, water losses in clay soils (seepage) in Winter-Spring ranged from 1,140m^3/ha-1,472m^3/ha (114mm-147mm), while in Summer-Autumn was 936m^3/ha-1,076m^3/ha (93.6mm-107mm), Autumn-Winter was 676m^3/ha-768m^3/ha (67.6mm-76.8mm). In experiment 2, water loss due to seepage was slightly lower (2.42%-15.5%) than in experiment 1 in most treatments for all 3 rice crops (Table 3). Our results, the water loss in in clay soils was less than 200mm because the soil here is loam soil mix much clay, therefore this will help to reduce water loss by seepage.

Table 3: Water losses in clay soils (seepage) of rice crops

Unit: m^3/ha

Treatments	Experiment 1			Experiment 2		
	Winter spring	Summer-Autumn	Autumn-Winter	Winter spring	Summer -Autumn	Autumn-Winter
TM1	1,472	1,048	676	1,260	932	592
TM2	1,448	936	740	1,404	928	660
TM3	1,240	1,076	696	1,272	996	576
TM4	1,140	952	768	1,236	872	608

In Winter-Spring crop, there was no increase in water volume due to capillary in both experiments. However, this phenomenon occurred in the first 20 days of Summer-Autumn crop, the water volume increased by capillary was about 28-100m^3/ha in experiment 1 and 14-28m^3/ha in experiment 2 (Table 4). In the Autumn-Winter crop, capillary

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phenomenon occurred throughout rice crop. Because during the wet season, this period coincided with flood season, the water table will often rise to be near the soil surface, due to the influence of tides, in experiment 1 the volume of water increased from 224m^3/ha-664m^3/ha, twice as much as in experiment 2 (116 m^3/ha-388m^3/ha). This difference may be due to the inhomogeneity of soil texture and soil elevation in the two experiments.

Table 4: The water volume increased by capillary in rice crops

Unit: m^3/ha

Treatments	Experiment 1			Experiment 2		
	Winter spring	Summer-Autumn	Autumn-Winter	Winter spring	Summer-Autumn	Autumn-Winter
TM1	0	0	664	0	0	388
TM2	0	28	224	0	14	116
TM3	0	0	252	0	0	198
TM4	0	100	292	0	28	244

Rainfall in Winter-Spring crop was 240m^3/ha (24mm), Summer-Autumn season was 3,072m^3/ha (307mm). Autumn-Winter 6,800m^3/ha (680mm). Rainfall was the same in the two experiments.

The results of ETc, ranging from 3.48mm.day^{-1}-5.27mm.day^{-1}. Meanwhile, ET_0 pan (reference evapotranspiration) was slightly lower than the ETc ranged from 3.85-4.9mm.day^{-1}. From ET_c and ET_0 pan, we calculated crop coefficient Kc for the growing period of rice from 20-75days. Specifically, Winter-Spring, Summer-Autumn Autumn-Winter crop, Kc was 1.15; 1.21; 0.93 respectively (Table 5). Meanwhile, FAO coefficient Kc in Winter-Spring crop 1.19, Summer-Autumn 1.31, Autumn-Winter crop 0.76.

Table 5: Kc empirical and FAO during rice growing seasons.

Seasons	Empirical method			Model method (FAO)		
	ET_c (mm.day^{-1})	ET_0 pan (mm.day^{-1})	Kc = ET_c/ET_0pan	ET_c (mm.day^{-1})	ET_0 (mm.day^{-1})	Kc (FAO) = ET_c/ET_0
Winter spring	4.95	4.30	1.15	4.45	3.74	1.19
Summer-Autumn	5.27	4.35	1.21	5.13	3.90	1.31
Autumn-Winter	3.48	3.75	0.93	2.62	3.44	0.76

3.2 Winter-Spring

In experiment 1: Yield ranged from 6.62 -12.85 tons/ha. Meanwhile, the control treatment reached 6.48 tons/ha. The results indicated that the alternate wet and dry irrigation method would give higher yields than the traditional farming methods, typically in the TM1 treatment, the amount of water supplied was 18,892 m^3/ha, but the yield was only 6.62 tons/ha. In treatment TM2 (13,700m^3/ha), water need decreased nearly 1.38 times compared to treatment TM1 but yield increased more than TM1 and reached 6.74 tons/ha. However, the yield difference in these two treatments was not statistically

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significant. The TM4 of water need of 10,768m^3/ha gave a relatively high yield of 9.72 tons/ha, but this is not the optimal yield. Because in reality, an average yield of 7.3 tons/ha (Ngo Chuan, 2021) and the highest is about 1.2 tons/ha. Therefore, in this experiment, treatment TM3 was chosen to recommend to farmers because the highest yield was 12.85 tons/ha, corresponding to 12,360m^3/ha of irrigation water (Table 6). Testing the difference in yield between treatments TM3 and TM4, the results showed that there was a statistically significant difference at the 95% confidence level. This is the basis for us to choose the treatment TM3 to recommend to farmers.

In experiment 2: Yield ranged from 4.85-14.63 tons/ha. The lowest yield was 4.85 tons/ha in treatment TM2, the highest yield in treatment TM4 with 14.63 tons/ha. The results showed that, in treatment TM3 with water need of 17,462m^3/ha, the yield was 12.85 tons/ha, while in treatment TM4 the yield was 14.63 tons/ha but the amount of irrigation water was lower only 14,542 m^3/ha. Testing the difference between treatments in terms of yield, the results showed that there was a very significant difference at the 95% confidence level. Therefore, treatment TM4 were choosen to recommend to farmers.

In the control treatment (traditional farming), the water level taken into the rice field was 0.15 m. The total number of times water was taken into the rice field for a rice crop cycle is 10 times for Winter-Spring. Therefore, the total amount of irrigation water for Winter-Spring crop was about 15,000 m^3/ha. The selected treatment was TM3 with irrigation water demand of 12,360m^3/ha in experiment 1 which was lower 2,640m^3/ha (17.6%) than control treatment. And TM4 (14,542 m^3/ha) in experiment 2 lower than 458m^3/ha (3%) compare to control treatment (Table 6).

Table 6: Rice yield for Winter-Spring

	Density (Tree)/m^2	Dry grain mass (g/m^2)	Proportion of dry grain (%)		Rice yield (tons/ha)
			Filled grain (g/m^2)	Unfilled grain (g/m^2)	
Experiment 1					
BT	2,378.0	3,567	88.67	11.33	6.48[a]
TM1	1,854.0	3,708	85.64	14.36	6.62[ab]
TM2	1,872.6	3,776	86.28	13.72	6.74[b]
TM3	3,537.6	7,193	84.37	15.63	12.85[d]
TM4	2,721.0	5,442	85.75	14.25	9.72[c]
Experiment 2					
BT	2,378	3,567	78.7	21.3	6.48[b]
TM1	3,993	5,257.9	80.2	19.8	9.55[c]
TM2	1,779.6	2,669.5	79.3	20.7	4.85[a]
TM3	4,562.6	7,072.2	80.5	19.5	12.85[d]
TM4	6,117	8,054	83.7	16.3	14.63[e]

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Note: *In the same column, the letters (a, b, c, d, e) following the numbers are significantly different of Rice yield at 95% confidence level by Duncan's test.*

3.3 Summer - Autumn

In the Summer-Autumn crop, the yield ranges from 5.1 tons/ha to 5.8 tons/ha. In experiment 2 it was slightly lower than experiment 1 and ranged from 4.9 tons/ha to 5.3 tons/ha. Treatment TM4 was chosen to be recommend to farmers in both experiment because of high yield but low irrigation water demand. Thereby, it shows that the Summer-Autumn crop has a lot of rain, the rice yield is not equal to the Winter-Spring crop. In fact, in experiment 2 (water level 0.1m) the yield was lower than in experiment 1 (water level 0.05m). This suggests that over-watering rice also affects yield. Therefore, alternating wet and dry irrigation (TM4-9 days apart between two irrigations times) will be suitable for the Summer-Autumn crop than other treatments (Table 7). Duncan's test results showed that there was a significant difference in yield between the TM4 treatment compared with the other treatments at the 95% confidence level in both experiments.

Table 7: Rice yield for Summer-Autumn

	Density (Tree)/m^2	Dry grain mass (g/m^2)	Proportion of dry grain (%)		Rice yield (tons/ha)
			Filled grain (g/m^2)	Unfilled grain (g/m^2)	
Experiment 1					
BT	1,088	2,720	75.3	24.7	4.86^a
TM1	1,434	2,868	78.2	21.8	5.12^b
TM2	1,527	3,080	76.1	23.9	5.50^c
TM3	1.473	2,996	79.2	20.8	5.35^c
TM4	1,624	3,248	76.8	23.2	5.80^d
Experiment 2					
BT	1,088	2,720	74.9	25.1	4.86^a
TM1	1,488	2,703	73.6	26.4	4.91^a
TM2	1,392	2,784	75.2	24.8	5.06^b
TM3	1,400	2,870	74.7	25.3	5.22^c
TM4	1.625	2,952	78.8	21.2	5.37^d

Note: *In the same column, the letters (a, b, c, d, e) following the numbers are significantly different of Rice yield at 95% confidence level by Duncan's test.*

3.4 Autumn-Winter

In the Autumn-Winter crop, the yield was ranging from 5.63 tons/ha to 6.74 tons/ha in Experiment 1 and from 5.57 tons/ha- 6.26 tons/ha in experiment 2. The yield was 0.5-1 ton/ha higher than the Summer-Autumn crop but around 2 times lower than the winter-

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spring crop. Treatment TM2 was significantly different from other treatments in yield and reached the highest level of 6.74 tons/ha corresponds to the water requirement of 3,204m^3/ha in Experiment 1. Compared with the control treatment (traditional farming) the water demand of TM2 (Experiment 1) will be 2.4 times lower. In experiment 2, there was a big difference in yield of MT3 (6.26 tons/ha) compared with other treatments with water demand of 7,152m^3/ha, almost equal the water requirements of control treatment. This once again confirms that rice will grow and develop well in the condition that water is not too excess and must have the right time to dry the ground surface in the right time (Table 8).

Table 8: Rice yield for Autumn-Winter

	Density (Tree)/m^2	**Dry grain mass (g/m^2)**	**Proportion of dry grain (%)**		**Rice yield (tons/ha)**
			Filled grain (g/m^2)	**Unfilled grain (g/m^2)**	
Experiment 1					
BT	1,224	3,060	81.5	18.5	5.47^a
TM1	1,574	3,148	80.6	19.4	5.63^b
TM2	1.871	3.774	82.4	17.6	6.74^c
TM3	1.704	3.466	84.7	15.3	6.19^d
TM4	1.649	3.298	81.2	18.8	5.89^e
Experiment 2					
BT	1,224	3,060	85.2	14.8	5.47^a
TM1	1,687	3,064	82.3	17.7	5.57^a
TM2	1,494	2,989	84.0	16.0	5.43^a
TM3	1,679	3,443	83.1	16.9	6.26^b
TM4	1,670	3,034	80.8	19.2	5.52^a

Note: *In the same column, the letters (a, b, c, d, e) following the numbers are significantly different of Rice yield at 95% confidence level by Duncan's test.*

V. CONCLUSION

Empricial ET parameter and irragation water need, crop coefficient were also determined based on the actual measurement in a paddy rice field in 2020 and 2021 by pan evaporation method without using any meteorological data. It was found that there were no much differences between the measured evapotranspiration by empirical and ET from FAO model. In two experiments involving improved irrigation methods, the following results will be drawn for recommendations to people: In Winter-Spring, farmer should get water into the field 5 times at water level 0.1m, 9 days apart between two irrigations times (TM4 in experiment 2). This will reach yield a round 14 tons/ha, water need of 14,000m^3/ha which was lower than 3% compare to traditional farming. In the summer-autumn crop, farmers should cultivate the same as the winter-spring crop, but the amount of water taken into the field is at 0.05m. Yield will reach 5.8-6 tons/ha, saving 1/2 amount of water (7,000m^3/ha) compared to traditional farming. In Autumm-Winter crop, farmers should taken water into paddy 10 times at water level 0.05 m, but 3 days apart between two irigations times, it will be yield of 6.74 tons/ha, water demand is 3,204m^3/ha, lower traditional farming 2.4times. Due to the climate change situation in the region, it is necessary to conduct experimental studies (capillary, seepage, soil moisture kinetics) for 3 consecutive years according to different ecological regions (soil types) to assess the appropriate ET and water demand for each specific farming area.

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