Research Article

Water Demand Estimation for Rice in An Giang Province by Hargreaves Evapotranspiration Model

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Abstract: Rice production in An Giang has been developing sustainably in recent years, contributing to ensuring national food security. However, it is facing the effect of climate change, sea level rise, salinity intrusion, drought which threatens food production. Therefore, it is necessary to calculate water demand for agriculture in order to properly plan water resources. Especially,the calculation of water demand for rice, because rice accounts for more than 80% of the area compared to other plants in the region. In this study, we was using Hargreaves model to calculate potential evaporation (ET). Through ET, we can calculat the water demand for the study region. The calculation results showed that the average water demand for the Summer-Autumn crop was 6,650m^3/ha, while the Winter-Spring rice area was higher than the Summer-Autumn crop, but the water demand was only 5,929m^3/ha. The lowest water demand wa the Autumn-Winter crop 3,424.7m^3/ha. The total water demand for rice crops in 2020 of the whole An Giang province was 3,506,429,880 m^3.

Keywords: ETo, Water demand, Hargreaves, An Giang province

1. Introduction

An Giang provine is an upstream province in the Mekong River, and is one of the provinces with the largest cultivated land area in the Mekong Delta. In 2019, the rice cultivation area in An Giang was 625,400ha in total, the paddy land accounts for more than 82% (Irrigation Departments in An Giang province, 2019). The rice yield of An Giang province is 6.43 tons/ha, the annual rice production of the province is 4,022 million tons, accounting for 20% of the Mekong River Delta's rice output, making an important contribution to ensuring the national food security. Contributing significantly to the country's rice export (Statistical Yearbook of An Giang Province, 2019). The current way growing irrigared rice in most farming rice farms requires large amounts of water (International Rice Research Institute, 2007). Because the recent introduction of high-yielding, nitrogen-responsive rice varieties, the acctual yield of rice cultivation now depends greatly upon the water supplied. So it is very important that irrigation water is used wisely and efficiently. In recent years, rice cultivation in this region 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, 2019). It has been anticipated that direct impact of climate change on water resources will be mainly through evapotranspiration (Trenberth et al., 2003). Hydrological changes constitute one of the most significant potential impacts on global climate change in the tropical regions (IPCC, 2007). It is now clear that climate change will cause a rise of temperature and changes in rainfall pattern. Higher temperature will induce higher evapotranspiration which in turn will affect the hydrological cycle and water resources (Shahid, 2011). On the other hand, yields of the rice are adversely affected with excess or inadequate water supply. For better crop production, water should be supplied in proper quantities and at specific intervals. While water resources in the study area in annual scales are still sufficient at present, there are seasonal problems. In fact, water resources in the dry season are very limited and of declining quality. The cause of this phenomenon is because of saltwater intrusion and drought. Some 215,000 people in the southern province of An Giang are staring at water shortage in summer, 2018 (Vietnam News, 2018). The estimation of water requirements of rice is very much essential for agricultural planning and design of irrigation projects. The total regional water demand is dominated by processes strongly bound to evaporation and evapotranspiration (ETc). Therefore, Hargreaves evapotranspiration model was using in this study to calculate water demand for rice in An Giang province.

2. Method

Study area

An Giang province is located on the north western side of the Mekong delta, on the eastern side of the Vietnam-Cambodia border. The land area is 3536.7km^2, accounting for 70.74% of the total Long Xuyen Quadrangle area, An Giang Province's population was 1.908.352 people in April, 2019 (Statistical Yearbook of An Giang, 2019). The area stretches from 10º11 'to 10º58' north latitude; from 104º46' to 105º35' east longitude (Figure 1). The project area is adjacent to:

- The Northern border is adjacent to Cambodia.
- The East and Southeast border is adjacent to Dong Thap province
- The Southern border is adjacent to Can Tho province.
- The west and southwest borders are adjacent to Kien Giang province.

An Giang includes 7 administrative units: Long Xuyen city, Chau Doc city, Chau Thanh, Chau Phu, Thoai Son, Tri Ton, Tinh Bien districts. The area is low and flat, over 80% of the area lies within elevation of 0–1.0m; 10% of the ground elevation is from 1.0–2.0m above sea level; 10% of the area is mountainous focused in Tri Ton and Tinh Bien districts has elevation from 2–700m. An Giang is located in the tropical monsoon climate, which is hot and humid all year round. There are two seasons: dry and wet season. The rainy season is from May to November and the dry season is from November to April next year. The average annual temperature is about 27 degrees Celsius, the average annual rainfall is about 1,130mm. Monthly total sunshine during the year is about 180.9-268hr. The annual average humidity is 75-80% (Statistical Yearbook of An Giang, 2019).

An Giang is the first area to receive and use the water of the Mekong River from Cambodia when it flows into Vietnam through two major rivers: the Hau and Tien rivers. These rivers run parallel to each other from the Northwest to the Southeast to the sea, over almost 220-250km. Annual average flow of this river system is 13,800m^3/s, but flows up to 24,000m^3/s in flood season and in dry season only 5,020m^3/s. According to the An Giang Centre for Hydro-Meteorological Forecasting, 2019, flows of canals in the floodplain range from 30-130m^3/s during floods. Annually, area of the whole province has nearly 70% of the flooded area with high water levels from 1–2.5 m for 2.5–5 months, impeding the process of agricultural production and domestic use of the region (Irrigation Departments in An Giang province, 2019). Although abundant, water resources are unevenly distributed in space and time. Therefore, although many sub regions have too much water, caused by severe flooding, there are also somewhere where is shortage of water for production and households. Both states are more or less affected by the water environment in general.

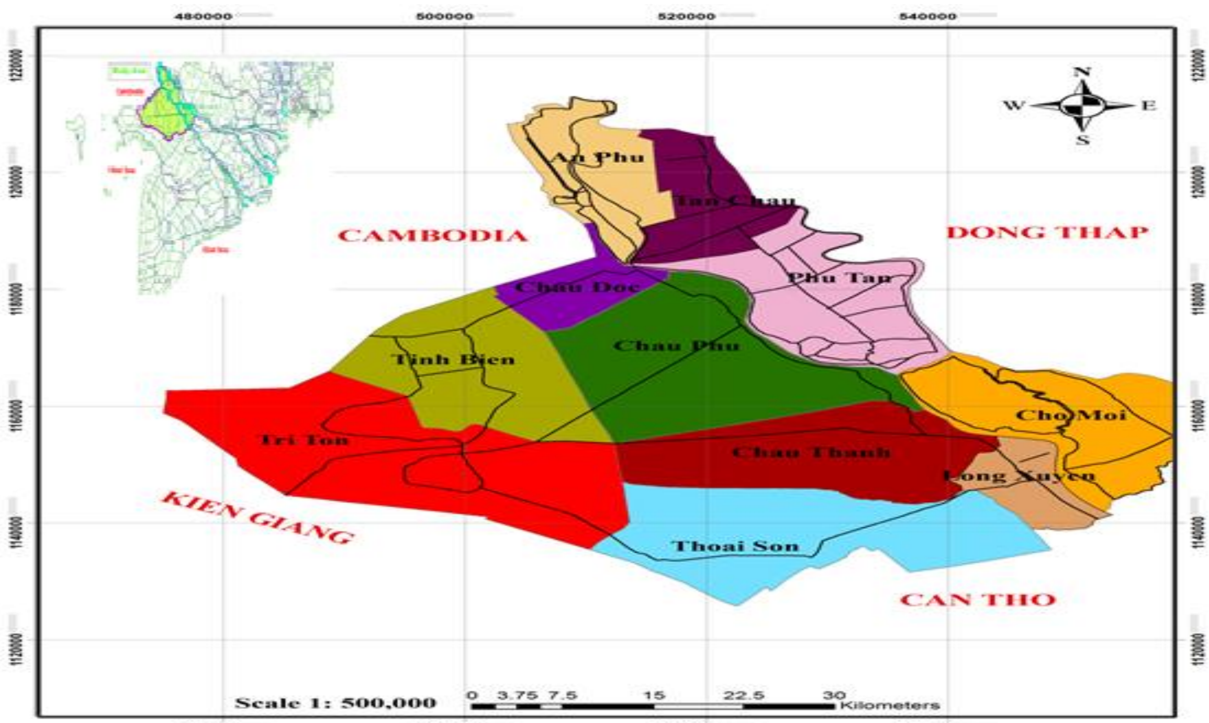

Figure.1 Location of the study area An Giang Province

Hydro-meteorological data

Monthly hydro-meteorological data (temperature, air, relative humidity, rainfall) are available in An Giang's Statistical and Hydrological Yearbooks for the past 6 years (from 2015 to 2020). The reference evaporation model of Hagreaves & Samani was carried out in the climatic conditions of AnGiang province, in the South of Vietnam.

Hargreaves evapotranspiration model

The Hargreaves method can be considered as a semi-empirical approximation as it incorporates extraterrestrial radiation in combination with temperature as indicators of global radiation, and the daily temperature range as an indicator of humidity and cloudiness (Shuttelworth, 1993; Stefano and Ferro, 1997). Cloudiness is inversely related to the temperature range, and the influence of relative humidity is also related to that range, as there is a linear relationship be-tween both variables (Hargreaves and Samani,1985). According to Hargreaves, the incorporation of the temperature range in the equation compensates for the influence of advection as it depends on the interaction of temperature, relative humidity, vapour pressure and wind speed, all of them related to the temperature range (Hargreaves and Allen, 2003). Jensen et al. (1997) recommended the Hargreaves equation as the easiest and most accurate em-pirical method at stations where standard reference conditions are not present, when not all the variables required in Penman-Monteith are measured, or in situations where measurements contain errors, especially concerning relative humidity data.

We calculated potential evapotranspiration (ET_0) on the daily scale by the modified Hargreaves. The Hargreaves model is an empirical model based on extraterrestrial radiation and temperature:

$$ET_0 = a + b\ 0.0023\ (Tx - Tn)^{0.50}\ (T + 17.8)\ Ra/\lambda$$

Where ET_0=reference grass evapotranspiration estimated (mmd^{-1});Tx = maximum daily temperature(∘C),Tn = daily minimum temperature (∘C), T = daily mean temperature, $T=(Tx+Tn)/2$; Ra = extraterrestrial radiation (MJ m^{-2} d^{-1}), λ = latent heat of vaporization (MJ kg^{-1}). The a and b coefficients can be used to fit the equation to local conditions, their default values are a=0 and b=1.

Actual crop evapotranspiration

Potential evapotranspiration for non-reference crops (ETc) was calculated through potential evapotranspiration (ET0) and the crop coefficient by using the formula:

$$ET_c = K_c ET_0$$

Where: Kc is the crop coefficient. Kc varies between crops, the cultivation season and growth stages of plants (germination, growth, flowering, fruiting, harvesting). A locally valid seasonal relative Kc curve has been determined experimentally by Le (Le, M. T, 2012). Values for Kc were assumed based on the experimental results and studies of FAO for rice in Southeast Asia (Tab.1).

Table 1: The crop coefficient (Kc) for the different growth phases of rice in Southeast Asis according to the experimental results of FAO (FAO, 2001).

Growth Phase	Initial	Development	Middle	Late	Harvest
Kc	1.1-1.15	1.1-1.15	1.1-1.3	0.95-1.05	0.95-1.05

Results and Discussion

The calculated results showed that, ET_0 values of the Hargreaves-Samani model ranged from 4.14 to 6.29mm.d^{-1}, averaging 4.83 ± 0.46 mm.d^{-1}, the highest ET_0 values is December to May (Table 2). Annual potential evapotranspiration suggested significantly high values 1,761mm.yr^{-1}. Dry season and wet season ET_0 is 5.13 mm.d^{-1} and 4.60 mm.d^{-1} respectively.

Table 2: ET_0 and Ra value (mmd^{-1}) of Hargreaves model

Time	Delta T	Ra (MJ m^{-2} d^{-1})	ET_0 (mm.d^{-1})	ET (mm.yr^{-1})
January	10,2	37,04911064	4,583957358	139,428703
February	11,2	40,07447563	5,231070888	159,1117395
March	9,7	42,82476927	5,343210882	162,5226643
April	11,7	43,97615215	6,290914554	191,348651
May	8,7	43,60767894	5,209432906	158,4535842
June	8,1	42,9997204	4,77333469	145,1889302
July	7,7	43,07257658	4,682914675	142,4386547
August	7,5	43,13443279	4,649136162	141,4112249
Sep	7,6	40,66325862	4,37242854	132,9947014
October	7,7	40,56365065	4,430904803	134,7733544
November	8,2	37,61937203	4,144860556	126,0728419
December	9,5	35,9279006	4,202240777	127,818157

According to a study by Seyed (2009) for the southern climates of Kuala Lumpur, Malaysia ET_0 values ranged from 3.91-4.89mm.d^{-1} (Seyed Reza Saghravani, 2009). Meanwhile, the ET_0 value studied by Nurul (2012) im Malaysia was in the range of 4.0-5.0mm per d^{-1}, the highest ET_0 value was found in February, March, April. The lowest ET was in September, October and November (Nurul Nadrah Aqilah Tukimat, 2012). This data is consistent with the value of ET_0 in Southern Vietnam in our study in the period (2015-2020). In the 1980s, the average ET value in the tropics was about 5.0-7.0mm.d^{-1} (Tomar, 1980). These values are expected to change depending on specific factors of site as well as seasonal climate interactions and differences in farming (Tomar, 1980).

Seasonal schedule, yield, planted area of paddy in An Giang (AG) province

In 1987, the area with high yielding rice in AG was only 39.730 ha, and 83.847 ha of wild rice still existed. Food output of AG was 444.712 tons, accounting for 50% of the yield of the whole province. AG in this period had 20,000 hectares of natural acid sulphate soil which were not exploited. The period from 1988 to 1999, saw AG exploitated with many dynamic, innovative, groundbreaking policies and solutions which were applied by AG province as the construction of large irrigation work, including drainage project into the sea west, the interior irrigation work, transportation systems, and infrastructure facilities saw investment. Since 1999 focus has been on investment for this AG under the policies of the new rural construction. Since 2005, AG has been focusing in the intensive and crop increasing cultivation, many works of dykes and culverts have intended to serve three rice crops. Consequently, the cultivation area of autumn-winter rice crop (the 3rd crop) continued to increase along with the increasing number of anti-flood dykes. In 2005 the rice area was only 529,698 ha, the output was 3,141,544 tons, the yield was 59.31 quintal/ha. In 2015, there are 631,470 ha rice, 100,000 ha more than 2005. The output reached 4,022,888 tons, the average yield is 64.27 quintal/ha. The output increase is due to the 3rd crop area rising. Nevertheless, the spring-winter crop holds an important position in the structure of rice production with an area of 238,125ha, and a yield of 77.36quintal/ha. The Autumn- Summer rice crop was 230.127ha, the yield is 55.57 quintal/ha. Winter-Autumn rice crop was 163,218ha, the yield is 57.57 quintal/ha (An Giang statistical Office, 2015). According to the report of the Department of Agriculture and Rural Development of An Giang province, in 2019, the total rice cultivation area in An Giang is 625,400 hectares, reaching 100.89% of the plan, an increase of nearly 2,400 hectares compared to 2018; in which, the winter-spring crop cultivated more than 235,000hectares; the Summer-Autumn crop is about 230,000 hectares and the Autumn-Winter crop is about 150,000 hectares. The average rice yield in 2019 is estimated at 62.71 quintal/ha, a decrease of 0.31 quintal/ha compared to 2018. An Giang's rice output for the whole year of 2019 reached nearly 4 million tons, a decrease of 5,000 tons. Particularly, the yield of sticky rice and quality rice varieties is about 1,050 million tons, an increase of 73,700 tons.

Local authorities predict that, the rice area of AG will increase slightly until 2025, due to increasing the soil's turnaround coefficient along with increasing the 3rd crop rice area. Therefore, the water demand for rice in general will also increase. Water demand is increasing not only due to the increasing crop area, but also another reason: science and technology today are increasing and are widely applied in the field, the crop structure is changing towards industrialization and modernization, many new plants varieties are highly intensive, and require large amounts of water. Hence water demand for agriculture will also increase.

Each rice crop usually lasts 4 months (120 days). The vegetables have a small proportion. Farmers in the project areas are sowing seeds simultaneously under decisions of the People's Committee of An Giang province. The seasonal schedule is as follows:

- Winter-Spring rice crop (the 1st crop): Start from November to February.
- Summer – Autumn rice crop (the 2nd crop): Begin from March to July.
- Autumn – Winter rice crop (the 3rd crop): Start from August to December.

Rice water demand

The results show that water demand for crops is generally high in the first month because this is the period of land preparation. During the next months, water demand greatly reduces. Water demand of the Summer-Autumn rice crop (the 2nd rice crop) is the highest (6,650.2m^3/ha). Next, the Winter-Spring season (the 1st rice crop) is 5,929m^3/ha. Lowest water demand is the Autumn-Winter rice crop (the 3rd rice crop), only 3,424.7m^3/ha, because this time coincides with the rainy season, so the extra water needed for rice is less than the remaining months. Particularly for the Summer-Autumn rice crop, water demand for rice is very high in March when it is hot, so the water is needed for soil preparation and sowing. Water demand for rice in the dry season is 6-8 times higher than the rainy season, but cultivation methods are not significantly different for each season.

Table.3 Calculation of the results of water demand for three rice crops

Unit: m^3/ha

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
The 1st crop	1,595	1,567	0	0	0	0	0	0	0	0	1,797	970	**5,929**
The 2nd crop	0	0	4,255	761.6	538.8	509.8	585	0	0	0	0	0	**6,650.2**
The 3rd crop	0	0	0	0	0	0	0	2,205.5	255.6	0	645.04	318.6	**3,424.7**
Total	1,595	1,567	4,255	761.6	538.8	509.8	585	2,205.5	255.6	0	2,442	1,288.6	**16,003.9**

Results Table 4 shows rice area and water demand in An Giang province in 2020. In Summer-Autumn rice crop, water demand is bigger than the remaining crops. Because this period is the dry season, it does not rain, so water demand for crops is relatively high. Particularly in March, water demand is much greater than the remaining months, because this is the time for soil preparation and seeding of the Summer-Autumn rice crop, and water demand is relatively large for this activity (4,255m^3/ha). So the total water demand of Summer-Autumn rice crop is higher than the remaining months and is up to 1,529 million m^3yr^{-1}. While Winter-Spring season, water demand at level is 1,393 million m^3yr^{-1}. Autumn-Winter rice crop are months that have the lowest water demand 583million m^3yr^{-1}, due to these months having relatively high rainfall, enough to meet water demands for crops.

Table.4 Total water demand for the rice crops of An Giang province in 2020.

Rice crop	**Winter-Spring**	**Summer-Autumn**	**Autumn-Winter**	**Total**
Area (ha)	235,000	230,000	170,400	**635,400**
Water demand (m^3)	1,393,315,000	1,529,546.000	583,568.880	3,506,429,880

Conclusions

Through the calculation of water demand, the province can take the initiative in examining and assessing the conveying capacity of canal systems. From there, there are plans to repair, dredge, and classify drainage and sewerage areas accordingly. Surface water sources in An Giang are currently being exploited, and for many different purposes, agriculture is the biggest water user. Presently on a regional and annual scale surface water is abundant due to the vicinity of large rivers. However, water shortage already occurs in certain districts due to insufficient irrigation infrastructure capacity and relatively large agricultural usage. Projections of future water demands suggest that water supply may be increasingly pressured during climate change if that causes a reduction of available assets. Spatially and temporally detailed water demand calculations highlight the pressure of exploitation overuse particularly in the dry season. To carry out these evapotranspiration needs to be calculated and monitored preferably on a sub-monthly scale.

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