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The Water Footprint of Pa La-U Durian

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Abstract

The study's objectives of this research were to assess the water footprint of Pa La-U Durian in Huai Sat Yai, Hua Hin, Prachuap Khiri Khan Province. By collecting primary data from interviews with farmers and related secondary data which were calculated by CROPWAT 8.0 program, the water footprint of Pa La-U Durian had an average of 2,284.67 m^3/rai (2.79 m^3/kg), divided into the amount of rainwater used (Green water), which was equal to 1,008.46 m^3/rai (1.23 m^3/kg), irrigation water consumption (Blue water), which was equal to 692.36 m^3/rai (0.85 m^3/kg), and the amount of water used in pollution treatment (Grey water) which was equal to 583.91 m^3/rai (0.71 m^3/kg). According to the study's findings, which took into account each growth period, the branch growing period has the highest water footprint, measuring 745.39 m^3/rai (0.91 m^3/kg), because it contains the most green water and grey water in comparison to other growth periods. Grey water should be reduced, and farmers should be encouraged to use organic fertilizers, bio fertilizers, or microorganisms, as part of a strategy to reduce the water footprint of the production process. Due to the proportion of nitrogen in fertilizer in organic fertilizers being less than chemical fertilizers and leaching-runoff of organic fertilizers equal to 0.06 [1], while chemical fertilizers equal to 0.1 [2], resulting in a decrease in the grey water footprint from 583.91 m^3/rai (0.71 m^3/kg) to 24.81 m^3/rai (0.03 m^3/kg). As a result, the water footprint will be reduced to 1,725.59 m^3/rai (2.11 m^3/kg), which will not only lessen its negative effects on the environment but also encourage the growth of sustainable agriculture. In addition, the results of this research can be used for the monthly water footprint to plan the allocation of irrigation water to support the needs of Pala-U durian in each growth period.

Keywords : Pa La-U Durian; Water footprint

Introduction

At present, the shortage of water resources in Thailand is increasing, which causes water shortages for household consumption, agriculture and industry and economic damage. The shortage of agricultural water, which has caused serious damage to farmland and agricultural productivity. Therefore, modern farmers must optimize water resources management to adapt to the changing situation. Alternatives to water management such as agricultural technology development, effective sharing of land and water, choosing low moisture crops or high profit and efficient water retention crops. However, water footprint is also one of the tools to, directly and indirectly, evaluate water consumption, aiming at finding ways to improve water use efficiency and maximize its benefits.

Water resources are an important factor in agricultural products. Especially industrial crop that generate income for farmers and affect the growth of the country's income. One of them is durian. There are more than 200 varieties of durian cultivated in Thailand, but there are about 5 varieties that are popular for consumption and trade and have been promoted as follows: Chani, Mon Thong, Kan-yao, Kra-dum Thong and Phuang ma ni. Furthermore, 14 durian varieties that are known as geographical indication:GI from the Department of Intellectual Property [3] that represent products originating from specific locations, where products derive their unique quality and reputation [4]. Hence, it has a relatively high selling value because it is a premium-grade durian.

One of the important factors that can improve the quality and yield of GI durian is the availability of sufficient water resources for planting. One solution is irrigation projects and effective water management for farmers. From the above-mentioned statements, it causes interest in choosing Pa La-U Durian, registration number GI 57100062 from the Ministry of Intellectual Property0 the climate is characterized by high relative humidity and the temperature is low at night in the rainy season, there will be water flowing down from the mountain bringing nutrients to replenish the agricultural areas every year. The taste is less sweet, firm texture, and has no strong smell, which is different from other areas. Moreover, the value per unit is as high as 250-400 baht per kilogram and has become more and more popular until it's not enough to meet the needs of consumers. Due to water shortage, the planting area in Huai Sat Yai district is limited to 1,328.50 rai with an average is 0.817 tons/rai [5]. Therefore, Royal Irrigation Department has constructed the Ban Pa La-U Reservoir in Prachuap Khiri Khan Province to solve the problem of drought and water shortage for agriculture in the area of 5 villages of Huai Sat Yai district with reservoir storage of 10.46 million cubic meters [4]. Currently, it is under construction and is expected to be completed in 2024. When starting the water distribution system Pa La-U Durian production area will get enough water to make durians, with more quality and quantity. In addition, it can also increase the area for planting Pa La-U Durian as well.

At present, in Thailand, not only there is little data on calculating the water footprint of Pa La-U Durian but most of them are durians in Rayong, Chanthaburi and Trat province, as shown in Figure 3 but also the program automatically calculates the water use of plants for water allocation planning of the Royal Irrigation Department is CWR-RID and ROS, there is still a lack of data on Pa La-U Durian to be used in the calculation. Therefore, this study could bring information about the monthly water demand and crop coefficient (K_c) of Pa La-U Durian to be one of the plant databases. This could assess the water demand more consistent with the plants.

From the above-mentioned statements, the assessment water footprint of Pa La-U Durian from the beginning until the end of the production process. The total water footprint of the process of growing Pa La-U Durian is the sum of the green water footprint (The amount of water in the form of moisture in the soil due to rainwater used in the production), the blue water footprint (The amount of irrigation water that plants need to increase) and the grey water footprint (The amount of water used to dilute pollutants in water should reach the specified standard value of plants). The study of water footprint allows better understanding of water scarcity and water pollution level problems in the area and leads to proper efficient water management in the area to make water security along with economically sustainable. Furthermore, the results provide water use information for each growing stage and help farmers plan their crops which will make the production of products more efficient.

Materials and Methods

Data collection

Primary data is the data on planting, fertilizer usage and watering of Pa La-U Durian from an interview with the director of Huai Sat Yai Agricultural Cooperative, Pa La-U Durian plantation farmers and staff of Hua Hin Agricultural Extention Office. According to interviews with farmers in this area, it was reported that in the case of insufficient rainfall, farmers withdrew water from Palao brook, Pranburi river and groundwater, which results in higher production costs for farmers due to the cost of electricity used for pumping water.

Secondary data is the data gathered from various agencies to use for the water footprint assessment of Pa La-U Durian in the study area. The secondary data includes climate data, rainfall data and crop data. Details about the secondary data are as follows. Climate data provided average climate data in the past 30 years (1991-2020), minimum and maximum temperature, rainfall, wind speed, relative humidity and amount of light from the Meteorological Department, Hua Hin station. Water quality analysis of nitrate-nitrogen (NO_3-N) in 2018-2020 [6]. Crop data included information on crop coefficient (K_c) which can be classified into seven stages, maintenance of leaves, branches, and trunks of durian stage, induce flowering stage, flower development stage, produce fruit stage, young fruit development stage, fruit growth stage, and ripening stage [7].

CROPWAT 8.0 program calculation

Use CROPWAT 8.0 program to calculate Effective Rainfall (P_{eff}) and Reference Crop Evapotranspiration (ET_o) by using Hua Hin station climate data consisting of minimum and maximum temperature, humidity, wind speed, and amount of light. Rainfall data is the average twelve-month rainfall in the past 30 years (1991-2020).

Calculation of Crop Evapotranspiration (ET_c)

Crop Evapotranspiration (ET_c) can calculate by using data on Effective Rainfall (P_{eff}) and crop coefficient (K_c) in each of the growth stages.

$$ET_c = K_c x ET_o$$

Calculation of water footprint

This method is the assessment of water usage from the beginning until the end of the production process with the Water Footprint Assessment Manual [8]. Which is the calculation of the total amount of water used for all three types as follows:

1. Green water footprint (WF_{green}) is an indicator of the plant use of rainfall, the amount of water in the form of moisture in the soil due to rainwater. that was used in the production of Pa La-U Durian, which can be calculated from the ratio between the quantity of rainfall used by plants with the amount of yield per crop area

$$WF_{green} = \frac{CWU_{green}}{Y}$$

When WF_{green} is the green water footprint of plants [m^3/ton], Y is yield [tons/rai] and CWU_{green} is the quantity of rainfall used by plants [m^3/rai] which is calculated from comparison with ET_c and P_{eff} (calculated from CROPWAT 8.0 program by using Hua Hin station climate data consist of minimum and maximum temperature, humidity, wind speed, and amount of light. Rainfall data is the average twelve-month rainfall in the past 30 years (1991-2020)).

If $P_{eff} > ET_c$; $ET_{green} = ET_c$
If $P_{eff} < ET_c$; $ET_{green} = P_{eff}$

Then unit convert ET_{green} [mm.] to CWU_{green} [m^3/rai].

2. Blue water footprint (WF_{blue}) is an indicator of consumptive use of irrigation water, the quantity required by plants during periods of insufficient precipitation. It will happen during the dry season. which is during the development of the durian.

$$WF_{blue} = \frac{CWU_{blue}}{Y}$$

When WF_{blue} is the blue water footprint of plants [m^3/ton] (in this study refers to irrigation water from a Pa La-U Reservoir), Y is yield [tons/rai] and CWU_{blue} is the amount of irrigation water required for plants [m^3/rai] which is calculate from compare with ET_c and P_{eff}

If $P_{eff} > ET_c$; $ET_{blue} = 0$
If $P_{eff} < ET_c$; $ET_{blue} = ET_c - P_{eff}$

Then unit convert ET_{blue} [mm.] to CWU_{blue} [m^3/rai].

3. Grey water footprint (WF_{grey}) is an indicator of the degree of freshwater pollution that can be associated with the process step.

$$WF_{grey} = \frac{(\alpha * AR)/(C_{max} - C_{nat})}{Y}$$

When WF_{grey} is the amount of water used to dilute pollutants in water to reach the specified standard value of plants [m^3/ton]. α is a leaching-runoff fraction that is assumed equal to 10% [8]. AR is the quantity of fertilizer usage in a plantation [kg/rai] this study considered only nitrogen fertilizers. C_{max} is the acceptable maximum concentration [kg/m^3] this study will use the surface water quality standard of nitrate-nitrogen (NO_3-N) is equal to 5 mg/l [9]and C_{nat} as a natural concentration in the receiving water [kg/m^3] this study uses an average nitrate-nitrogen (NO_3-N) in 2018-2020 of Pranburi River at the end of the irrigation area which is the convergence point between Pa Lao brook and Pranburi River, the water that flows through it contaminated with agricultural water. Due to the land use along the river before the confluence, there are fruit trees, rubber trees, and field crops, including community waste water. Which may cause of nitrate-nitrogen contamination in water, is equal to 0.00055 kg/m^3 (0.55 mg/l) [6].and Y is yield [tons/rai].

Calculation Water Scarcity Index (WSI)

This study was based on Pfister et al. WSI assessment methodology in analyzing the impact of water use on Pa La-U Durian plantation. The irrigation area of Ban Pa La-U Reservoir was 6,490 rai as shown in Figure 1. Calculated from the proportion of water demand per year compared to the volume of water resources available in the area (Withdrawal-to-Availability: WTA*).

$$WTA^* = \frac{WU}{WA}$$

When WTA* is the proportion of water demand per year compared to the volume of water resources available in the area, WU is the annual water demand in the agricultural, industrial, household, livestock and preserve the ecosystem (m^3/yr), WA is the amount of water resources available in the area (watersheds) (m^3/yr)

$$WSI = \frac{1}{1+e^{-6.4WTA^*(\frac{1}{0.01}-1)}}$$

This study is divided into two cases:

Case 1 Non-irrigation, the volume of water resources available (WA) is only rainfall data in the past 30 years (1991-2020) from the Meteorological department, Hua Hin station.

Case 2 Irrigation (have Ban Pa La-U Reservoir), the amount of water resources available (WA) is rainfall and storage capacity of Ban Pa La-U Reservoir is equal 10,460,000 m^3/yr.

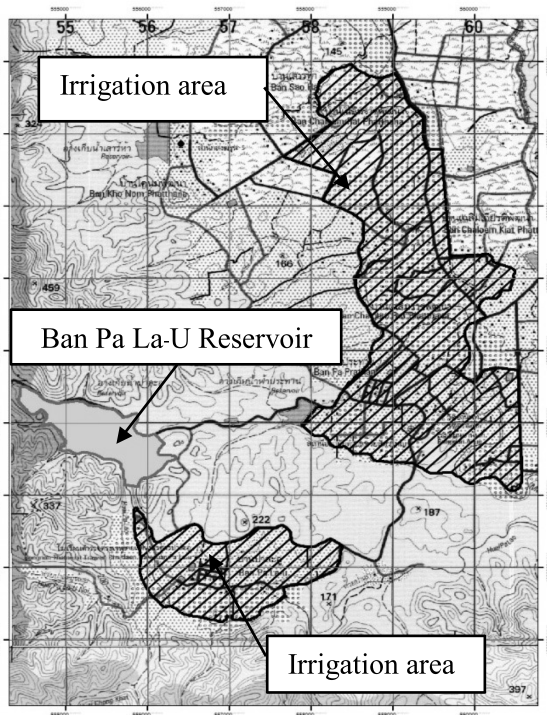

Figure 1 Irrigation area of Ban Pa La-U Reservoir
(Adapted from :Ban Pa La-U Reservoir EIA report [10])

Calculation Water Pollution Level (WPL)

The effect of the grey water footprint depends on the amount of runoff in the waste-receiving area [2], the water pollution level (WPL) has been studied as an indicator of impact. Calculated from the proportion of grey water footprint. (WF_{grey}) with runoff in each area (R_{act}). If the WPL is greater than 1, it means the quality of the water source is contaminated.

$$WPL = \frac{WF_{grey}}{R_{act}}$$

Results and Discussion

Water footprint of Pa la-u-Durian

An in-depth interview questionnaire for water footprint assessment of Pa La-U Durian plantations from farmers in Huai Sat Yai district and gather of the production yield from Agriculture and Cooperatives Office Prachuap Khiri Khan province, Thailand. The results showed that an average Pa La-U Durian plantation area was equal to 1,328.50 rai (2,125,600 m^2). The production yield from Pa La-U Durian was equal to 0.817

tons/rai [5]. The majority of farmers did annual maintenance of leaves, branches, and trunks of durian during September-November and started to reduce the watering of durian in December-January to induce flowering. They returned to watering of durian during February-March which was the flower development stage and in April was a induce young fruit stage then young fruit development stage in May after that they did maximum watering of durian for fruit growth in June and reduce watering in July to August for ripening stage of durian fruit. In terms of the amount of fertilizer used in planting, according to interviews with farmers, the use of formula fertilizer 16-16-16 was equal to 96 kg/rai, 4-24-24 was equal to 64 kg/rai and 12-12-18 was equal to 67.2 kg/rai. After that, taking the amount of fertilizer usage to calculate the nitrate-nitrogen ratio and found that it was equal to 25.98 kg/rai.

From the assessments of water footprint of Pa La-U Durian of 2.79 m^3/kg. This included green water footprint is equal to 1.23 m^3/kg, blue water footprint is equal to 0.85 m^3/kg and grey water footprint is equal to 0.71 m^3/kg, as shown in Table 1.

From Table 2 WF_{grey} was calculated from the use of chemical fertilizers in cultivation. But if the cultivation was organic agriculture the amount of WF_{grey} will be decreased. In this study, in the case of using organic fertilizers to take care of durian trees, 25 kg/tree/yr of manure from dry cow dung mixed with rice straw [11]. And assuming that the yield per plantation area is equal to the case of using chemical fertilizers, 0.817 ton/rai. In the calculation of WF_{grey}, the percentage of nitrogen in organic fertilizer from dry cow manure is 0.46% [12] and the nitrogen leaching ratio of organic fertilizers from the IPCC guidelines [1] was 0.06. The result as shown in Table 2.

Table 1 Water footprint of Pa La-U Durian

yields (ton/rai)	WF_{green}		WF_{blue}		WF_{grey}		WF	
	m^3/rai	m^3/kg	m^3/rai	m^3/kg	m^3/rai	m^3/kg	m^3/rai	m^3/kg
0.817	1,008.46	1.23	692.36	0.85	583.91	0.71	2,284.67	2.79

Table 2 Water footprint of Pa La-U Durian in the case of using organic fertilizers

	Chemical fertilizers	Organic fertilizers
the proportion of nitrogen in fertilizer	3 formulations as follow: 16-16-16 = 0.16 4-24-24 = 0.24 12-12-18 = 0.12	0.0046
chemical application rate per hectare (AR) (kg/rai)	25.98	1.84
leaching fraction (α)	0.1	0.06 [2]
crop yield (ton/rai)	0.817	0.817
WF_{grey} (m^3/rai)	583.91	24.81
WF_{grey} (m^3/kg)	0.71	0.03
WF (m^3/rai)	2,284.67	1,725.59
WF (m^3/kg)	2.79	2.11

And Figure 2 shows the water footprint of Pa La-U Durian at each stage of the plantation, maintenance of leaves, branches, and trunks stage from September to November is the highest water footprint about 35.6% of the total water footprint. Due to this stage of plantation has the greatest demand for water and fertilizer, as dry branches are trimmed after harvest and ready to induce flowering. Because water is an important component of cells by making plant cells to be mature. If the cell is dehydrated or there is not enough water, the shape of the cell will be distorted. In addition, water is a solvent that helps to dissolve plant nutrients in the soil into a solution that plants can absorb. and water as a starting agent for various processes within plants [13].

Furthermore, the green water footprint has seasonal fluctuation due to climate change [14] using insufficient rainfall to plant Pa La-U

Durian. Therefore, there must have blue water footprint, which is the irrigation water from the Ban Pa La-U Reservoir to supplement during the dry season and gradually decreases in the rainy season, from February to August and November. So that if there is enough irrigation water to meet the needs of planting Pa La-U Durian at all times. It will more productivity. In addition, it is possible to expand the area for planting. From Table 3 based on the EIA report of Pa La-U Reservoir [10], The data of agricultural irrigation water demand in 2007 and the next 30 years are studied, which are 9.124 million cubic meters and 9.45 million cubic meters per year respectively. This will increase the amount of water for agriculture by 0.326 million cubic meters per year or 326,000 cubic meters per year, if farmers continue to grow crops as before but change from the area of planting fields crops (Nam Wah banana and pineapple) and waste land to Pa La-U Durian that will be able to increase the planting Pa La-U Durian area approximately 455 rais., as shown in Table 3.

Comparison of Water Scarcity Index (WSI) with non-irrigation and have irrigation

It is one of the most commonly used tools to assess the level of water stress in an area. In this study, WSI assessment principles were referenced from [15]. And The levels of water stress are still classified into five categories including extreme condition (WSI >0.9), Severe (0.5 < WSI ≤ 0.9), Stress (WSI = 0.5), Moderate (0.1 ≤ WSI < 0.5) and Low (WSI < 0.1) [16]. In analyzing the effects of water use in Pa La-U Durian cultivation at the level of the irrigation area Ban Pa La-U Reservoir in Huai Sat Yai district, 6,490 rais, was shown in Figure 1. Calculated based on the proportion of annual water demand in the agricultural, industrial, household, livestock and preserve the ecosystem from Ban Pa La-U Reservoir EIA report [10]. It was found that the estimated water demand in irrigation areas in 2037 was 10.942 million cubic meters. compared to the amount of water resources available in the area (watersheds), this will be divided into two cases:

Case 1 Non-irrigation, WSI results is equal 0.93 that is extreme water stress.

Case 2 Irrigation (have Ban Pa La-U Reservoir), WSI results is equal 0.24 that is moderate water stress.

From the results of the study, it was clear that if there is a reservoir in the area, it will result in the level of water stress decreasing from extreme sector to have enough water for the water use of plants. Make the output quality and quantity more in the future.

Water Pollution Level (WPL)

As a relevant local impact indicator, one can calculate the 'water pollution level' (WPL) within a catchment, which measures the degree of pollution. It is defined as the fraction of the waste assimilation capacity consumed and calculated by taking the ratio of the total of grey water footprints in a catchment (ΣWF_{grey}) to the actual run-off from that catchment (R_{act}) and if WPL values exceed 1.0, ambient water quality standards are violated [2].

Assessment of water pollution in this study was caused by the use of nitrogen-containing fertilizers for nourishing the Pa La-U Durian. In the area of Huai Sat Yai district, there are 1,328.5 rais of crop areas. It can be estimated from the water pollution level (WPL) calculation using the equation from [2]. Which used the average monthly runoff the Pranburi River (basin code 1804) from SEA report of Phetchaburi-Prachuap Khiri Khan River Basin Area [17], the catchment area is 1,605.10 km^2 covered in the area Pranburi district Sam Roi Yot district, Hua Hin district, Prachuap Khiri Khan province and Kaeng Krachan district Cha-Am district Tha Yang district, Phetchaburi province that originated from the Tanaosri mountain range in Pranburi.

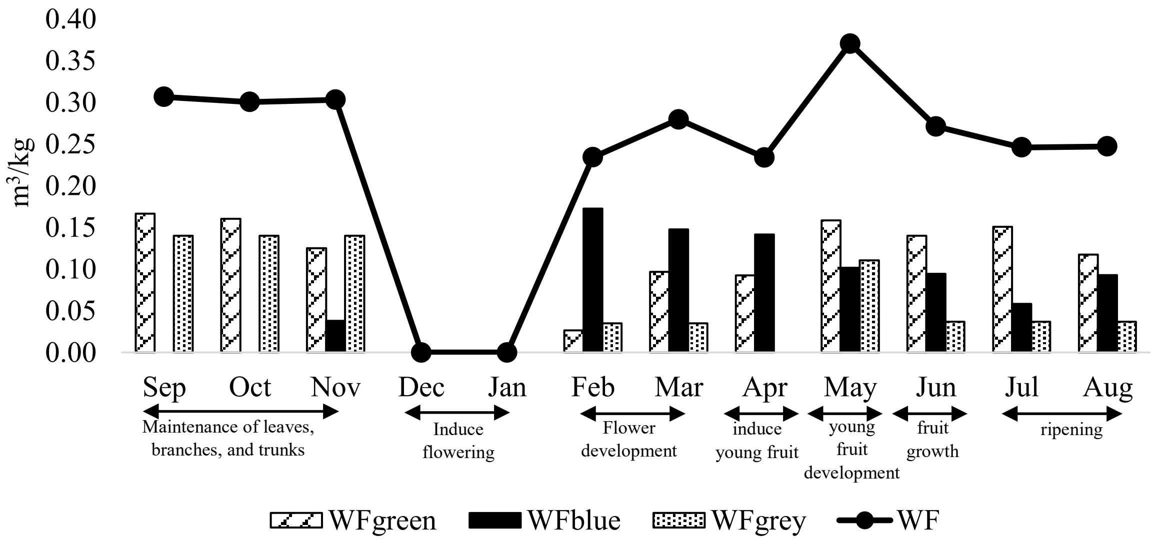

Figure 2 Water footprint of Pa La-U Durian each stage of plantation

Table 3 Past and future crop patterns

Crop	Area (rais)	
	In 2007	In 2027
Rice	35	35
Rubber	85	85
Fruit (lime, jackfruit, mango, coconut and Pa La-U Durian)	4,480	4,480
Soilage (Purple guinea grass, Ruzi Grass)	1,435	1,435
Field plant (Nam Wah banana, pineapple)	405	
Pa La-U Durian		455
Waste land	50	
Total	6,490	6,490
Irrigation water demand (m^3)	9.124×10^6	9.45×10^6

From Table 4, Overall, every month the WPL value is lower than 1 which is low water pollution, so the water pollution level will fluctuate within the year as well. WPL values lower than 1 indicate that there is an average enough river water to dilute the pollutant to below the maximum acceptable level at the basin scale [18].

Water Footprint of Pa La-U Durian and other durians

From Figure 3, When taking the water footprint of Pa La-U Durian comparison with the water footprint of other durians, it was found the water footprint of durian of Mon Thong durian in Rayong province [16] had the highest water footprint value of 3,592 m^3/rai followed by water footprint of Pa La-U Durian, equal to 2,282.06 m^3/rai due to the analysis of the grey water footprint. If analyzing the types of water footprints, it was found that as follows:

Green water footprint found that the Rayong Durian, Chanthaburi Durian, Trat Durian and Pa La-U Durian have a similar green water footprint due to the similar requirement water for durians. But Rayong Durian [19] is most valuable because that area has the amount of rain that is sufficient to requirement water of durian in each growing period, which farmers can rely on rainfalls in the area so there is no need for watering during that time and the amount of effective rainfall depends on the meteorological conditions of each area.

Table 4 Water Pollution Level (WPL) of Pa La-U Durian

Month	Quantity of nitrogen fertilizers (kg/rai)	WF_{grey} (m^3/rai)	WF_{grey} (MCM)	R_{act} (MCM)	WPL
Sep	5.12	114.54	0.15	95.06	0.002
Oct	5.12	114.54	0.15	179.27	0.001
Nov	5.12	114.54	0.15	90.2	0.002
Dec	0	0	0.00	20.23	0.000
Jan	0	0	0.00	9.28	0.000
Feb	1.28	28.64	0.04	6.02	0.006
Mar	1.28	28.64	0.04	10.25	0.004
Apr	0	0.00	0.00	12.56	0.000
May	4.03	90.20	0.12	20.16	0.006
Jun	1.34	30.07	0.04	42.65	0.001
Jul	1.34	30.07	0.04	57.26	0.001
Aug	1.34	30.07	0.04	124.4	0.000

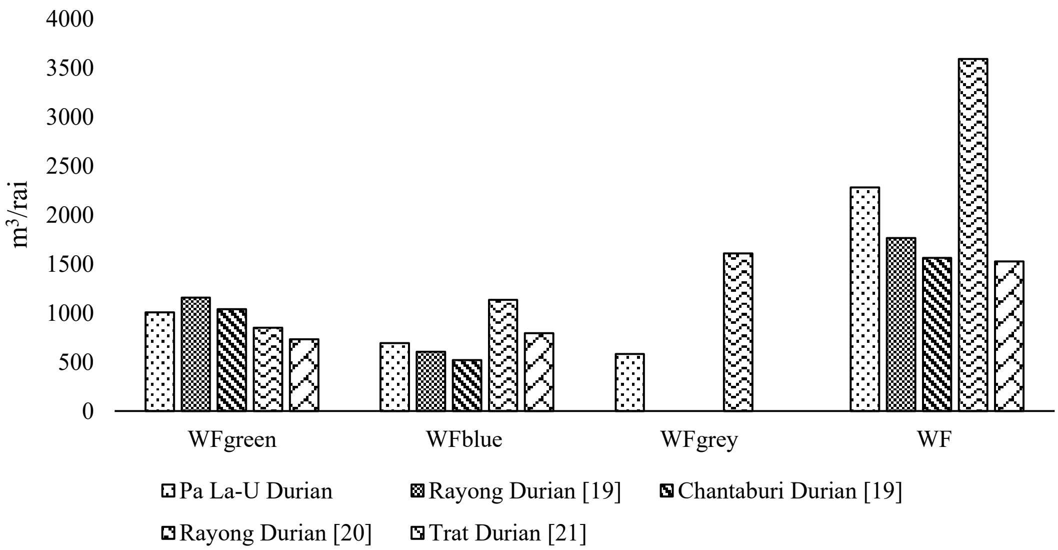

Figure 3 Water Footprint of Pa La-U Durian and other durians

Blue water footprint foot print found that the Rayong Durian, Chanthaburi Durian, Trat Durian and Pa La-U Durian have a similar blue water footprint. But the Rayong Durian [20] is the most valuable because the result of the study has the highest requirement water of durian compared to other research. And the amount of effective rainfall is insufficient to requirement water of durian in each period of growth the most. Therefore, water from irrigation or other water sources must be supported during times of water shortage.

Grey water footprint it was studied that in Pa La-U Durian and Rayong Durian [20]. The grey water footprint of Rayong Durian is 2.76 times more than Pa La-U Durian because the amount of fertilizer used per planting areas will have the greatest impact on the grey water footprint. Obviously, Rayong Durian uses more fertilizer than Pa La-U Durian, may be based on soil data from Land Development Department [22], found that the soil in Huai Sat Yai district was more fertile. The soil series found in Klaeng district, Rayong province, which is the district that grows the most durians in Rayong province, most of the areas are soil group 45 and soil group 34. Which is a soil with low to medium fertility, the soil is brown, yellow or red. While in Huai Sat Yai district most of the area is soil group 36, which is moderately fertile soil, brown soil color. So, the color of the soil indicates the amount of organic matter, the soil is dark brown to black, it means that the soil is very fertile. And also the terrain, Klaeng district is plain while Huai Sat Yai district is mountains interspersed with plain and Pranburi River is the main river flowing through, the climate is characterized by high relative humidity and the temperature is low at night. In the rainy season, there will be water flowing down from the mountain top bringing nutrients to replenish the agricultural areas every year. As mentioned above, it may be the reason why Pa La-U Durian uses less quantities of chemical fertilizers.

Water Footprint of Pa La-U Durian and other economic crops

Economic crops refer to plants that are important to life not just used as a food source to generate energy for humans and animals or used as a material for building housing only. But it includes consumption in all forms, it also has outstanding commercial characteristics both within the country and abroad, can be cultivated as a career generate income for farmers and the country. Currently, an important economic crop of Thailand and make money for farmers and the country continually including rice, rubber, sugar cane, cassava and oil palm, can be seen that all 5 plants are classified in the field crops group. But durian is classified as garden plant and also a fruit that creates value in exports to China as number 1.

From Figure 4, When taking the water footprint of Pa La-U Durian comparison with the water footprint of other economic crops, it was found that the highest water footprint is rubber and then Pa La-U Durian, rice, Rayong durian, oil palm, cassava and sugarcane, respectively. Because when considering the yield product in 2020, rubber has a yield equal 224 kg/rai, while sugarcane has a yield equal 7.90 ton/rai [23]. Obviously increasing productivity will result in a reduction in the water footprint. So effective water resources management and enough for crops that will make crops more productive.

And comparison with the water footprint of Rayong durian, that is lower than water footprint of Pa La-U Durian. Because The yield of Rayong durian is more than twice, that of the main durian grown in Thailand, located in the eastern part of Chanthaburi and Rayong, in the southern is Chumphon Province. And about 60-70% of total domestic production will be exported. Eastern durians are grown for both domestic and international trade, while Pa La-U Durian are only sold for domestic consumption. Due to the limitation of the planting area only in Huai Sat Yai district and water shortages in the area.

Conclusion

According to the water footprint assessment of Pa La-U Durian when compared with the total water requirement, green water footprint is 44.2%, blue water footprint is 30.3%, and grey water footprint is 25.5%. It can be seen that the rainfall is not enough to plant Pa La-U Durian. So, irrigation water is needed to support the requirement. Which the Ban Pa La-U Reservoir it will make the Huai Sat Yai district have more water resources for agriculture. Along with efficient irrigation water allocation planning according with the monthly requirement of Pa La-U Durian by using the water footprint. And it can expand the planting area of Pa La-U Durian, thereby increasing farmers' income because the sales value of this product is as high as 250-400 baht per kilogram.

Guidelines for reducing the water footprint by reducing the grey water footprint farmers should be encouraged to using organic fertilizers, biological fertilizers or microorganisms. The amount of grey water footprint was reduced by 559.1 m^3/rai (0.68 m^3/kg), using chemical fertilizers equal to 583.91 m^3/rai (0.71 m^3/kg), but using organic fertilizers 24.81 m^3/rai (0.03 m^3/kg). This will result in a decrease in the water footprint of 1,725.59 m^3/rai (2.11 m^3/kg). Besides that, to reducing the impact on the environment it will contribute to the development of sustainable agriculture.

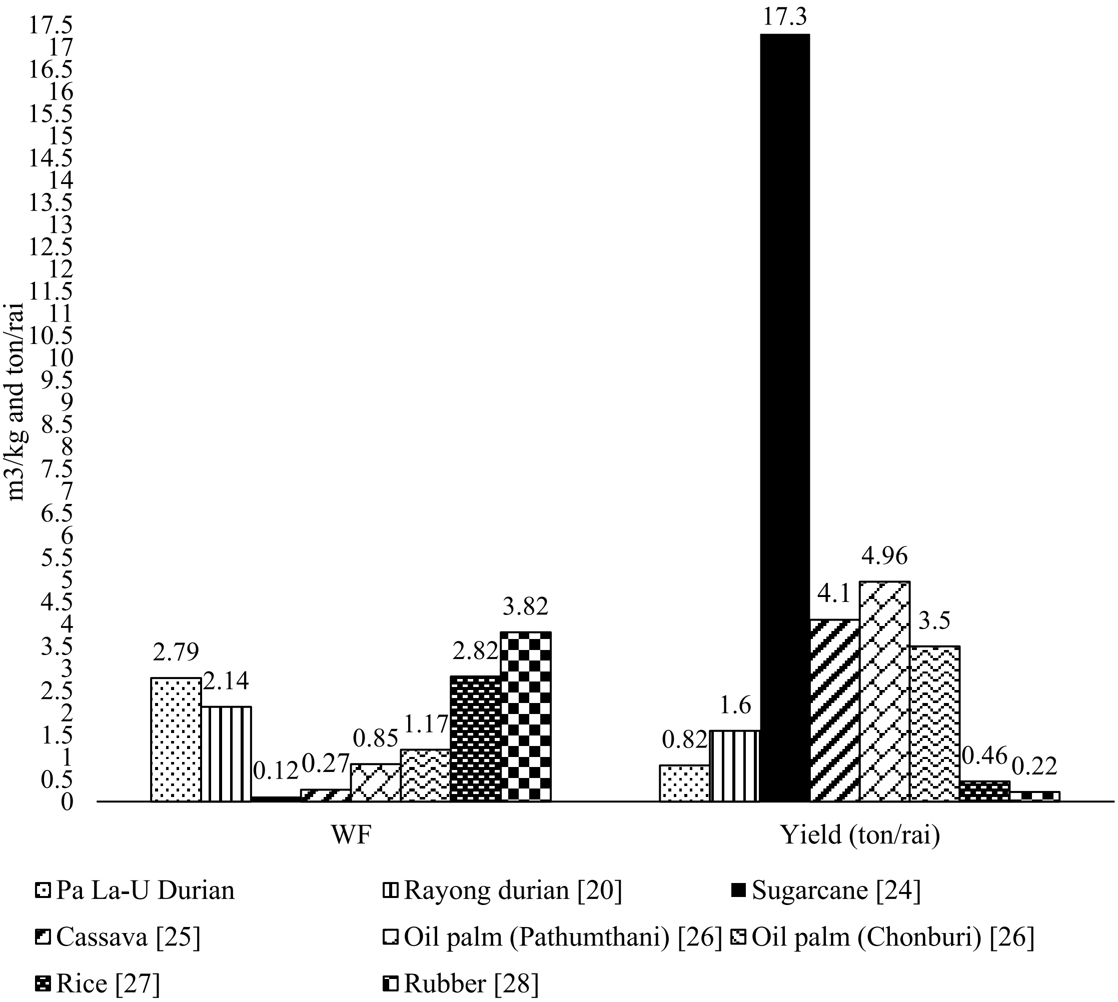

Figure 4 Water Footprint of Pa La-U Durian and other economic crops

For taking the crop coefficient (K_c) in each cultivation period from this research to be used to evaluate the amount of water consumption in CWR-RID and ROS program of the Royal Irrigation Department. It shows the demand for irrigation water that needs to be increased of Pa La-U Durian. in Huai Sut Yai Subdistrict, Ban Pa La-U Reservoir irrigation area. Approximately 692.36 m^3/rai which that needs irrigation water in November and February to August. And also used in gathering data to analyze water demand and plan appropriate water allocation in accordance with the needs of plants grown in irrigated areas and cover all aspects. Among them, the sufficiency of water is the main factor that makes decisions for farmers to change their crops from upland crops, such as pineapple and banana, to more easily durians in Pa La-U Durian. Because it gives a high return value, an average of 300 baht per kilogram.

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