Water Footprint Assessment of Durian Monthong Before Harvesting and the Harvesting Period in Rayong Province

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Abstract

This research analyzed the Water Footprint Assessment of Durian Monthong orchards before harvesting and during harvesting periods in Rayong Province. Analysis of data was done using the CROPWAT 8.0 program. The data was collected from responses to a questionnaire from 56 farmers in five districts of Rayong province. The data from the study area revealed that only five districts of Rayong had Durian Monthong orchards. Secondary data included climate data, rainfall data, crop water use, and soil series data.

The results of this study determined the volume of water used for cultivation from rainwater, water reservoirs, and open canals. Fertilizers and pesticides were used during the maintenance period. The crop water usage of Durian Monthong orchards before harvesting (1-5 years) showed that the crop water use (CWU_{proc}) was 4,672 m^3/rai, consisting of 1,029 m^3/rai of green water use (CWU_{green}), 1,372 m^3/rai of blue water use (CWU_{blue}), and 2,271 m^3/rai of gray water use (CWU_{gray}). The first harvesting period (6-10 years) indicated that the total water footprint (WF_{proc}) was 4,527 m^3/ton, consisting of 1,140 m^3/ton of green water footprint (WF_{green}), 1,520 m^3/ton of blue water footprint (WF_{blue}), and 1,867 m^3/ton of gray water footprint (WF_{gray}). In addition, the second harvesting period (11-20 years) showed that the water footprint (WF_{proc}) was 3,592 m^3/ton, consisting of 850 m^3/ton of green water footprint (WF_{green}), 1134 m^3/ton of blue water footprint (WF_{blue}) and 1,608 m^3/ton of gray water footprint (WF_{gray}). The results of this research could be used for managing the water used for agriculture.

Keyword: Water footprint/ Durian Monthong/ Before Harvest/ Harvesting Period

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1. Introduction

Global climate change causes several impacts to water cycles such as prolonged droughts or shortened rainy seasons. These impacts affect the water security of many countries (Vörösmarty et al., 2000; Hangermann et al., 2013). Thailand is one of the countries that is affected by the aforementioned impacts. Due to the change of climate and prolonged drought, some agricultural areas cannot perform agricultural activities as usual or have lower production yields compared to the past (Office of Agricultural Economics 7, 2016). Moreover, increasing global population leads to increasing demand of water usage for food, energy, and consumer goods production (Arnell, 2004). This water usage situation draws great attention to various industries since water resource is crucial for every production process. Similarly, agricultural industry is also emphasized on the water resource situation because water resource is a major factor in cultivation and has a direct effect on production yield (Wallcae, 2000).

Thailand is an agricultural country. Thailand exports various agricultural products to many different countries around the world. This can be compared to exporting water resource in a form of agriculture products (Office of Agricultural Economics 7, 2016). From the information of Thailand agricultural products export 2018, Thailand exported agricultural products worth 1,388,541 million baht, where fruit products are the top 10 exported products of Thailand with a value of 142,310 million baht. The most exported fruit is fresh durian worth 30,187 million baht (Centre for Agricultural Information, Office of Agricultural Economics, 2019). A durian species that is popular among farmers is Monthong, since Monthong has a color, odor, and taste that is preferred by consumers and favored by the exporting market (Johnny Sawangsrisakulpon, 2017).

The agricultural statistical data in Thailand from the Office of Agricultural Economics shows that, during 2017-2019, the eastern part of Thailand had the highest production of durian with 424,094 tons, 405,428 tons, and 497,851 tons, respectively. Rayong province has become a province of interest since it is the second highest durian production province in the eastern region and it is also a province in the Eastern Seaboard development project which will be a main economic community in the region. Due to this development project, Rayong has high urban expansion and increase in industrial area. According to the information from Land Development Department 2016 and 2018, agricultural land use in this type of orchard (durian) has a total area of 60,781 rai, which increased from 2016 by 16,340 rai. At the same time, community and buildings type of land use has also increased while many areas have changed to industrial area and households. In some areas, release of wastewater into agricultural water resources has become a problem, as well as water resource conflict between agricultural and industrial sectors which can cause impact on fruit plantation in the future (Agricultural Development Policy and Planning Division, Office of Agricultural and Economics, 2019).

From the above-mentioned statements, the study of water usage in agricultural activities is crucial and should be done urgently since the information can be used to estimate the water resources sufficiency in the area. Water footprint study is an important tool to evaluate water usage in agricultural industry. This method is the assessment of water usage from the beginning until the end of the production process (Hoekstra et al.,2011). This study will clearly demonstrate farmers' hidden water usage in the production process. Furthermore, this can evaluate impacts to water usage caused by the production process (Chapagain et al., 2006). The study of water footprint allows a better understanding of water scarcity problems in the area and leads to proper water management. For these reasons, the researcher aimed to study the water footprint assessment of Durian Monthong orchards before fruit can be harvested (1 to 5 years old trees) and during the harvesting period (6 to 20 years old trees) in Rayong province to have a better understanding on the actual water usage of Durian Monthong plantations for a better water management guideline in the area.

2. Methodology

2.1 Data collection

Data used in water footprint assessment of Durian Monthong before harvesting and the harvesting period in Rayong province was separated into two parts including primary data and secondary data. The details are as follows.

2.2.1 Primary data

Primary data is the data gathered in the study area via an in-depth interview with Durian Monthong plantation farmers both male and female. The 56 key informants from the in-depth interview in five districts of Rayong province are selected by specific criteria of 1) the farmers only plant Durian Monthong and 2) The age of durian plantation is the the range of 1-5 years, 6-10 years, and 11-20 years. All three age ranges needed to be in the same district of Rayong province. Three farmers were selected from each of the durian plantation age range from the names registered with the district agricultural office or provincial agricultural office. The researcher initially contacted the farmers that fit the criteria through phone call. If a farmer was willing to give information, the researcher made an appointment for data collection in the area. The questions include water usage data in Durian Monthong plantation, Durian Monthong yield in the past year, fertilizer or chemical usage in Durian Monthong plantation, and cost in planting Durian Monthong.

Furthermore, the questionnaire had been granted Ethical Approval by the Institutional Review Board, Institute for Population and Social Research, Mahidol University. The code was COA. No. 2020/07-346.

2.2.2. Secondary data

Secondary data is the data gathered from various agencies to use for water footprint assessment of Durian Monthong in the study area. The secondary data includes climate data, rainfall data, crop data, and soil data. Details about the secondary data are as follows. Climate data uses an average climate data in the past 30 years (1989-2019), minimum and maximum temperature, humidity, wind speed, and amount of light from the Meteorological department, Rayong station. Rainfall data uses the average rainfall data in the past 30 years (1989-2019) from the Meteorological department, Rayong station. Crop data includes information on growth stages of crops which can be classified into four stages, initial stage, development stage, mid-season stage, and last stage, and information on crop coefficient (K_c) . Soil data is the data provided in CROPWAT 8.0 program which was chosen to suit with the study area. This data will include soil profile, maximum water seepage, soil humidity, and rooting depth.

2.2 CROPWAT 8.0 program calculation

The data usage in CROPWAT 8.0 program calculations included climate data, rainfall data, crop data, and soil data. 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. Crop data includes Durian Monthong growth stages and crop coefficient (K_c). Soil data provided in CROPWAT 8.0 program.

3. Results

3.1 Data from in-depth interview in the area

An In-depth interview questionnaire of water footprint assessment of Durian Monthong plantations before harvesting and during the harvesting period in Rayong province was done with 56 key informants from five districts of Rayong. The data from the study area revealed that only five districts of Rayong had Durian Monthong orchards. Moreover, from the interview, farmers in Ban Chang district, Pluak Daeng district, and Nikhom Phatthana district are not planting Durian Monthong, but the majority will plant pineapple, cassava, and rubber tree. The results showed that an average Durian Monthong plantation area is equal to 29 rai with the largest area of 120 rai and smallest area of 5 rai. In an area of 1 rai, farmers commonly plant 20 durians. The production yield from durian during year 6-10 is equal to 1.19 tons/rai, during year 11-20 is equal to 1.68 tons/rai, and during year 20 onward is equal to 1.44 tons/rai. The majority of farmers will do an annual maintenance of leaves, branches, and trunks of durian during May-October and will start to reduce watering of durian in November-December to induce flowering. They will return to normal watering of durian during January-April which is a young fruit development stage until the ripening stage of durian fruit. A length stage for durian plantation is approximately 365 days. Watering of durian is commonly done by sprinkler system which uses the water from surface water resources, such as ponds, though some farmers also use water from underground resource. Watering frequency of durian is around 6-15 times/month, depending on climate conditions of the plantation year. Furthermore, there are chemical fertilizer, organic fertilizer, and pesticide usage throughout the season.

The top three motives of Durian Monthong planation are the desirable breed of durian by the customers, the high value of product, and the preferable breed for exporting market, respectively. The farm gate price of durian is 128 baht/kilogram.

3.2 Water footprint value of Durian Monthong before harvesting and during the harvesting period in Rayong province.

From the assessments of water usage of Durian Monthong, it shows that crop water usage of Durian Monthong before harvesting (1-5 years) is equal to 4,673 cubic meters/ton, and the water footprints of Durian Monthong during the harvesting period years 6-10 and years 11-20 are equal to 4,528 cubic meters/ton, and 3,592 cubic meters/ton, respectively, as shown in Table 1.

The information in Table 2 was calculated by the statistic methodology; Analysis of variance test (ANOVA). The result showed that the average water footprints of Durian Monthong in the harvesting period of 6-10 years and 11-20 years have significantly different means at the alpha 0.05. The detail is shown in Table 3.

Table 1. Water footprint values of Durian Monthong before harvesting and the harvesting period in Rayong province.

Period	Year	Yield	CWU_{proc}	CWU_{green}	CWU_{blue}	CWU_{grey}
		(ton/rai)	(m^3/rai)	(m^3/rai)	(m^3/rai)	(m^3/rai)
Before harvesting period	1-5	0	*4,672	*1,029	*1,372	*2,271
Harvesting period	6-10	1.13	4,527	1,140	1,520	1,867
	11-20	1.60	3,592	850	1,134	1,608

Table 2. Water footprint calculation of Durian Monthong harvesting period in Rayong province

Code	Amount of Fertilize	Amount of Yield	WF_{green}	WF_{blue}	WF_{Grey}
	kg/rai	ton/rai	m^3/rai	m^3/rai	m^3/rai
6-10 years					
001	67.2	0.8	1,287	1,715	1,680
002	135.6	0.8	1,287	1,715	3,390
003	154.8	2.6	396	528	1,191
004	28.8	0.6	1,716	2,287	960
005	70.2	0.8	1,287	1,715	1,755
006	70.0	1.6	643	858	875
007	94.8	1.4	735	980	1,354
008	157.6	1.6	643	858	1,970
009	74.0	0.6	1,716	2,287	2,467
010	28.8	0.8	1,287	1,715	720
011	56.0	1.0	1,029	1,372	1,120
012	157.6	0.6	1,716	2,287	5,253
013	45.0	0.8	1,287	1,715	1,125
014	70.0	1.0	1,029	1,372	1,400
015	157.6	1.8	572	762	1,751
016	116.8	0.6	1,716	2,287	3,893
017	74.0	0.6	1,716	2,287	2,467
018	41.6	0.6	1,716	2,287	1,387
019	92.0	2.0	515	686	920
020	166.8	2.0	515	686	1,668
Average			1,140	1,520	1,867
11-20 years					
001	67.6	0.8	1,287	1,715	1,690
002	157.6	0.8	1,287	1,715	3,940
003	94.8	1.4	735	980	1,354
004	41.6	1.0	1,029	1,372	832
005	192.8	3.0	343	457	1,285
006	166.8	2.0	515	686	1,668
007	198.8	3.4	303	404	1,169
008	154.8	3.0	343	457	1,032
009	107.0	1.2	858	1,144	1,783
010	45.0	0.8	1,287	1,715	1,125
011	70.2	1.0	1,029	1,372	1,404
012	116.8	0.8	1,287	1,715	2,920
013	28.8	0.8	1,287	1,715	720

Table 2. Water footprint calculation of Durian Monthong harvesting period in Rayong province (cont.)

Code	Amount of		WF_{green}	WF_{blue}	WF_{Grey}
	Fertilize	Yield			
	kg/rai	ton/rai	m^3/rai	m^3/rai	m^3/rai
014	115.6	1.0	1,029	1,372	2,312
015	111.6	3.0	343	457	744
016	140.0	1.6	643	858	1,750
	Average		850	1,134	1,608

Table 3. ANOVA test of average water footprints data of Durian Monthong in harvesting period.

SUMMARY				
Groups	*Count*	*Sum*	*Average*	*Variance*
6-10 years	20	90551.98	4527.599	3810333
11-20 years	16	57470.68	3591.917	2203169

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	7,782,219	1	7,782,219	2.509	0.122	4.130
Within Groups	105,443,868	34	3,101,290			
Total	113,226,086	35				

4. Discussion

From the calculation of crop water use of Durian Monthong before harvesting and the water footprint of Durian Monthong during the harvesting period in Rayong province, the results show that before harvesting period (year 1-5) has a total crop water use in plantation process, green, blue, and grey crop water use of 4,673 m^3/rai, 1,029 m^3/rai, 1,372 m^3/rai, and 2,271 m^3/rai as maximum values, respectively. For the plantation of Durian Monthong during harvesting period year 6-10, the total water footprint, green water footprint, blue water footprint, and grey water footprint are equal to 4,528 m^3/ton, 1,140 m^3/ton, 1,520 m^3/ton, and 1,867 m^3/ton, respectively. During the harvesting period year 11-20, the total water footprint, green water footprint, blue water footprint, and grey water footprint are equal to 3,592 m^3/ton, 850 m^3/ton, 1,134 m^3/ton, and 1,608 m^3/ton, respectively. Since before harvesting period durian will not produce any yield, this factor is an important variable in water footprint calculation. It can be said that water footprint is inversely proportional with production yield, as shown in Figure 1.

When comparing green water footprint and blue water footprint in every stage of Durian Monthong plantation in Rayong province, blue water footprint is higher than green water footprint. It can be interpreted that the effective rainfall in Rayong province is not sufficient for Durian Monthong plantations and leads to high water usage of surface water or irrigation water, which in this study is blue water footprint.

Moreover, grey water footprint in every stage of Durian Monthong plantation is very high, as shown in Figure 1. This resulted from the intense use of organic and chemical fertilizers through out the plantation stages including branches development stage, flower inducement stage, fruiting stage, young fruit development stage, fruit maturation stage, until ripening stage of fruit. From this reason, the crop cannot use all the mineral which in this case is nitrogen in fertilizer. So, the calculated grey water footprint is like the amount of water used to dilute chemicals before release into water resources without exceeding the environmental standard of 5 mg/L. Nevertheless, over fertilization can cause nitrogen to remain in the area and lead to water pollution if it gets washed by the rain.

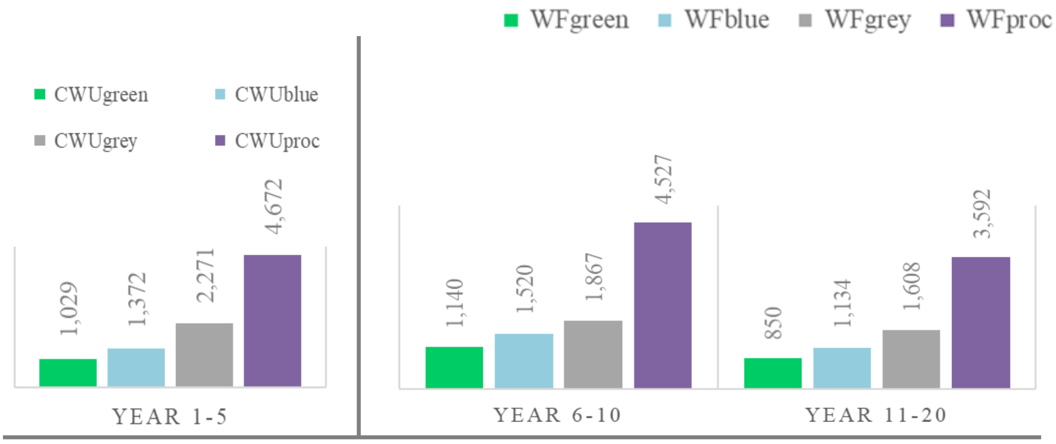

Figure 1. Comparison graph of water footprint of Durian Monthong plantation before harvesting and the harvesting period in Rayong province.

When comparing water footprint of durian plantation in a large scale agricultural extension in Trat province by the Office of Agricultural Economics 6 (2015), the total water footprint in crop plantation is equal to 868 m^3/ton, green water footprint is equal to 417 m^3/ton, and blue water footprint is equal to 452 m^3/ton while grey water footprint was not calculated in the study. Fom this information, it causes a difference in calculated Water Footprint Process values. However, Blue Water footprints trends of both studies are similar. They showed that the Blue water footprints are higher than the Green water footprints.

From the comparison, the resulting values show significant difference due to the different constant values used and different calculation method, for example, the data collection process of this research. The data collection process of this research was divided into two groups which were before harvesting (year 1-5) and harvesting period (year 6-10 and 11-20). On the other hand, the research from the Office of Agricultural Economics 6 did not mention about the age of the durian trees nor the breed of durian which is different from this research study that focus on durian Monthong plantation only.

Moreover, the Crop coefficient (K_c) value used in Water Footprints calculations did not vary according to the age of durian tree and could affect the calculated value. By using Crop coefficient (K_c) value according to the age of durian tree as well as the breeds, the calculated Water Footprints value would be more accurate.

The study of Soytong et al. (2017) shows that industrial development process has rapidly increased in the Eastern part of Thailand under the Eastern Sea Board development project and causes changes in land use. This correlated with field surveys that show an increased rate of land use change from agricultural land use in orchard type (durian) to industrial and urban area such as in Nikhom Phatthana district, Pluak Daeng district, and Ban Chang district.

According to the study of Soytong et al. (2017), a change in land use can generate higher water needs and can lead to water resource conflict in the area. Furthermore, climate change is also a major factor that affects water resources. Some areas face flood problems while others face drought. These problems directly affect agricultural production. From the study, “Effect of Climate Change on Durian Production” (Chanthaburi Horticultural Research Center, 2015), fluctuations of climate affect durian plantation in all stages, such as flowering, flowering inducement, flowers development, fruiting, fruit development, and harvesting stage as well as the quality of the product. This information is correlated with an interview with farmers of durian Monthong plantation in Rayong province. From the interview, the farmer indicated that durian Monthong production was reduced in 2019 due to prolonged drought period. The effect from durian Monthong production and in accordance with higher demand for durian Monthong lead to higher selling price of durian. Due to the aforementioned problems, organizations related with agriculture should rasie awareness about affects from climate change, educate and communicate warnings about climate change, provide appropriate mitigation measures for the farmer in order to plan for their proper production, as well as set up policies on the development of production technology to reduce the impact of an increasing climate change in the future.

In addition, a study of Hoekstra et al. (2003) found that, during 1995-1999, Thailand was the third in net virtual water export in the world. Virtual water trade is the trade of water in the form of product or goods that had high water consumption in the production process since trading actual water is not possible due to high cost and transportation difficulty. From the interview with farmers, the majority of durian production in 2019 was sold to a middle man at the farm gate before selling to an agricultural product export company that exports them to China. This can be compared to vitual water trade of water resources in the area. In the future, the water resources availability in the area needs to be taken into consideration since the need for water consumption of both agricultural and industrial sectors has increased.

5. Conclusions

The water footprint of Durian Monthong plantations in Rayong province was assessed by field survey and in-depth interview with the key informants. The topics of the questionaire included crop water use and chemical use in every crop length stage, starting from land preparation, branches development, flower inducement, flower development, fruiting, young fruit development, fruit maturation, until the fruit ripening stage. Moreover, this study also included climatological data in the past 30 years (1989-2019) of Rayong province along with crop coefficient (Kc).

The studied and analyzed data were calculated in CROPWAT 8.0 program. The results show that before harvesting period (year 1-5) has a total crop water use in plantation process, green, blue, and grey crop water use of 4,672 m^3/rai, 1,029 m^3/rai, 1,372 m^3/rai, and 2,271 m^3/rai For the plantation of Durian Monthong during harvesting period year 6-10, the total water footprint, green water footprint, blue water footprint, and grey water footprint are equal to 4,527 m^3/ton, 1,140 m^3/ton, 1,520 m^3/ton, and 1,867 m^3/ton, respectively. During the harvesting period year 11-20, the total water footprint, green water footprint, blue water footprint, and grey water footprint are equal to 3,592 m^3/ton, 850 m^3/ton, 1,134 m^3/ton, and 1,608 m^3/ton, respectively. Since before harvesting period durian will not produce any yield, this factor is an important variable in water footprint calculation. It can be said that water footprint is inversely proportional with production yield. Regarding the water scarcity footprint of Durian Monthong before harvesting and the harvesting period year 6-10 and year 11-20 in Rayong province, the value is equal to 20.6 $m^3 H_2O$eq, 22.8 $m^3 H_2O$eq, and 17.0 $m^3 H_2O$eq respectively.

Moreover, the comparison of the results of water economic valuation and economic return shows that the production cost of Durian Monthong plantation, including the cost of water before harvesting and the harvesting period year 6-10 and 11-20, in Rayong province has a value of 35,928 baht/rai, 36,829 baht/rai, and 28,420 baht/rai, respectively. The profit from Durian Monthong during the harvesting period year 6-10 and year 11-20 is 107,810 baht/rai and 166,379 baht/rai respectively. This shows that the economic returns obtained are worth the cost of production.

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