Water Footprint Assessment of Palm Oil Biodiesel Production in Southern part of Thailand

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Abstract

The water footprint of palm oil biodiesel depends upon climate and production systems. The weighted average of the total water footprint is 5,714 m^3/ton in a study area which has a mean annual rainfall of 1,905 mm per annum and where the average Fresh fruit bunches (FFB) yield is 3.02 tonnes per annum. The share of indirect water footprint to the total water footprint of biodiesel is 99% and that due to direct water footprint is 1% (Only blue water). The highest contributors to the indirect and direct water footprint are the water consumption of the oil palm crop and the water consumption in the production of palm oil biodiesel, respectively. From this study, Surat-Thani is the suitable area for using oil palm crop to produce biodiesel in water perspective.

Keywords*:* water footprint / biodiesel/palm oil/Thailand

1. Introduction

The Government of Thailand is promoting biodiesel for transportation in order to reduce the importation of fossil fuels and to improve the energy security of the country. The Government of Thailand also plans to increase the national renewable energy share from 10% in 2012 to 25% by the year 2021 (Department of Alternative Energy Development and Efficiency, 2012). Palm oil has been considered as a prospective feedstock for biodiesel production, particularly due to the fact that, it produces the highest yield of all Thailand's biofuel oil plants. In order to achieve the national renewable energy plan's target, one of the most important factors to be considered is freshwater availability. Freshwater is essential for crop cultivation, and also in the biodiesel production processes. The idea of considering water use along supply chains has gained interest after the introduction of the 'water footprint' concept by Hoekstra et al. (2009). The number of countries implementing biofuel programmes has increased rapidly (Gerbens-Leenes and Hoekstra, 2010; 2011; Gerbens-Leenes et al., 2012; Wu et al., 2009; 2011) including Thailand (Pongpinyopap and Mungcharoen, 2011; 2012).

This study aims to assess the water footprint of biodiesel production from palm oil. Two main parts of water usage are crop growth and the biodiesel production process itself. The area for this study is the southern region of Thailand because most palm oil mills and agricultural lands cultivated with oil palm are found in this area. Krabi, Chumphon and Surat-Thani provinces were selected as study areas (Office of Agricultural Economic, 2012).

The final results will cover the water footprint of palm oil biodiesel production from palm oil throughout the production chain. Data from these results can be used as the basis for managing water resources not only in Thailand but also in other regions.

2. Methodology

2.1 The water footprint concept

The Water Footprint of a product is the volume of freshwater appropriated to its production covering the volumes of water consumed and polluted in the different steps of the supply chain. The water footprint of a product considers both direct (operational) and indirect (supply chain) water use. The water footprint has basically three components: green, blue and grey water footprint. The full water footprint assessment consists of four distinct phases: 1) Setting goals and scope 2) Water footprint accounting 3) Water footprint sustainability assessment and 4) Water footprint response formulation (Hoekstra et al., 2009; 2011). In this study, only phases 1, 2 and 4 were carried out in order to identify critical components in its water footprint and set priorities for response. As there were no standardized methodologies for the water footprint sustainability assessment, this as not carried out in this study (Jeswani and Azapagic, 2011).

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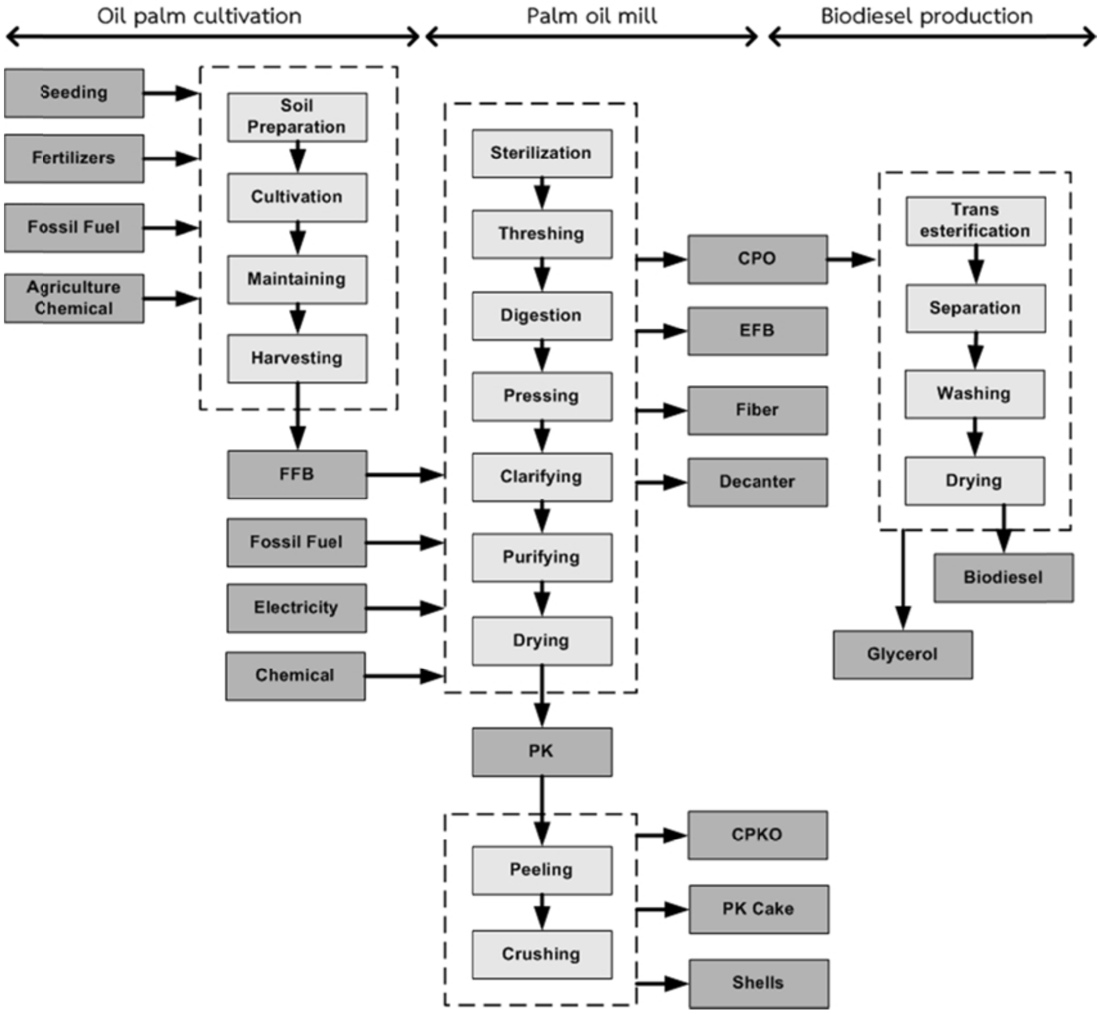

Figure 1: System boundary of biodiesel production from palm oil

2.1.1 Goals and Scope

The goal of this study was to assess the water footprint of biodiesel production from palm oil in Thailand. The scope included the oil palm plantation and harvesting, crude palm oil (CPO) and biodiesel production (Figure 1). The functional unit (FU) was defined as 1 ton of biodiesel produced from palm oil as transportation fuel. All of the three components of water footprint to be considered were green, blue and grey. The reference year of the data used for the study was 2012.

2.1.2 Water footprint accounting

The water footprints of biodiesel were calculated according to the accounting method outlined in the Water Footprint Manual and based on available information (Hoekstra et al., 2011). The water footprint of biodiesel production in Thailand consists of the water used in the supply chain to produce raw material (indirect) and the water used in biodiesel production processes (direct). The relevant activities of indirect water usage are oil palm cultivation, crude palm oil extraction and raw materials acquisition.

$$WF_{\text{palm oil biodiesel}} = WF_{\text{oil palm cultivation}} + WF_{\text{crude palm oil extraction}} + WF_{\text{biodiesel production}} \quad (1)$$

2.1.2.1 Indirect water use

2.1.2.1.1 Oil palm cultivation

In the southern part of the country, more than 70% of the oil palm cultivation area is located especially in Krabi, Chumphon and Surat-Thani provinces. Oil palm starts bearing bunches 2½–3 years after field planting. The water footprint of Fresh Fruit Bunch (m^3/ton) was evaluated as the ratio of the volume of water (m^3/rai) needed during the entire period of oil palm crop growth to the corresponding crop yield (ton/rai). The sufficient volume of water in the oil palm field can be classified to 1) the use of effective rainfall (green water) and, 2) the use of irrigation water (blue water). The CROPWAT model developed by the Food and Agriculture of the United Nations (FAO) can estimate the effective rainfall and irrigation water requirements for the oil palm plant

(FAO, 2009). The crop coefficients for the oil palm plant were taken from Allen et al. (1998). The climate data required as input factor into the CROPWAT model were taken from the Thai Meteorological Department (2013). The data on crop production per unit area of land (ton/rai) were obtained from the Office of Agricultural Economics (2012).

The volume of polluted water was estimated using nitrogen (N) as a representative element for estimations of the grey water footprint following Chapagain et al. (2006). In this study, a flat rate of nitrogen leaching at 5% of the nitrogen application rate was assumed. The permissible limit of 50 mg nitrate-NO_3 per litre was used to estimate the volume of water necessary to dilute the leached nitrogen (Chapagain and Hoekstra, 2011). The data on average fertilizer application rates for oil palm crop growth was collected from interviews (National Metal and Materials Technology Center, 2013).

2.1.2.1.2 Crude palm oil extraction

Fresh fruit bunches (FFB) from the palm oil plantation are transported to crude palm oil mills after harvested and the oil has to be extracted within 24 h, otherwise the quality of the extracted palm oil will deteriorate. Thus, the crude palm oil mills should be located as close as possible to the palm oil plantation. The production of the palm oil mill consists of seven processing units namely (Figure 2): 1) fruit bunch sterilization, 2) bunch threshing,3) fruit digestion, 4) pressing, 5) clarification and centrifugation, 6) purification and 7) nut drying, cracking, and kernel recovery. The main product is crude palm oil (CPO) and the co-product is palm kernel (PK). The data were obtained from palm oil mills in the south of Thailand (National Metal and Materials Technology Center, 2013)

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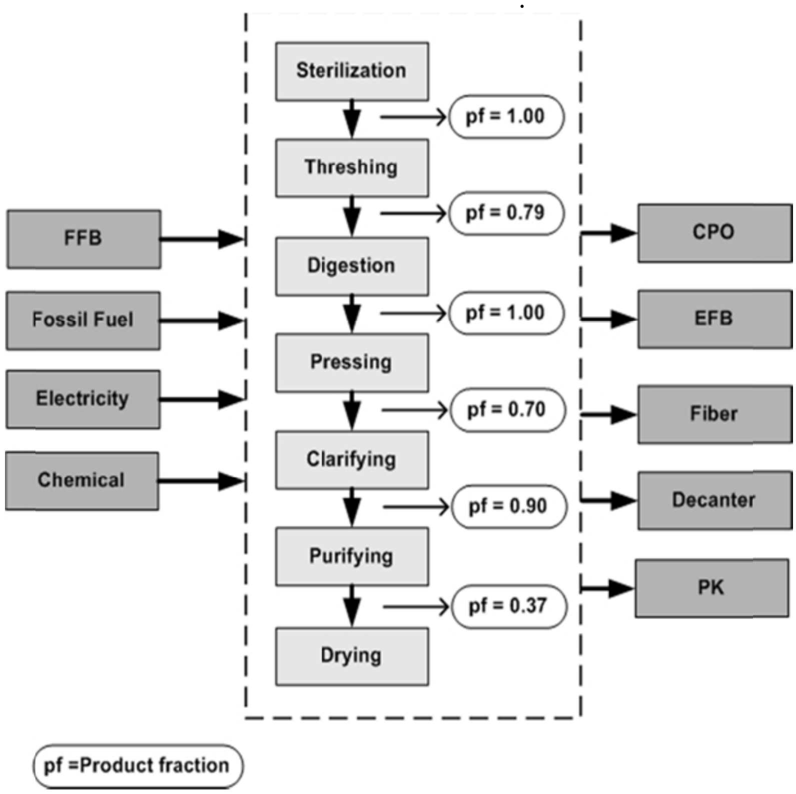

Figure 2: Product fraction of crude palm oil extraction factory.

2.1.2.2 Direct water use

2.1.2.2.1 Biodiesel production

Crude palm oil is transported to biodiesel plants. The conversion processes of biodiesel production consist of four processing units namely 1) CPO pretreatment: to get rid of the gum and impurities from the CPO and neutralize. 2) Reaction step, or transesterification: the process of exchanging the triglyceride group with an ester group by using alcohol (e.g., methanol, ethanol) with a base catalyst (e.g., NaOH, KOH), under high-temperature conditions (60–80 °C). 3) Washing: by gravity separation the glycerol can simply be drawn off from the bottom of the settling vessel. 4) Drying: to evaporate water from the biodiesel.

The main product of the production system is biodiesel and the co-product is glycerol. The inventory data have been gathered from the commercial biodiesel plants with a production capacity of 685,800 liters a day. The process flow diagram of biodiesel production was shown in

Figure 3. In the processing process, the weight of the remaining product (Biodiesel) is smaller than the original product (Crude Palm Oil). Adapting the methodology according to Chapagain and Hoekstra (2004), the product fraction (pf) in each processing step can be referred to the ratio of the weight of the resulting product to the weight of the original product. The water footprint of the resulting product (m^3/ton) was evaluated by dividing the water footprint of the original product by the product fraction. This causes the waterfootprint of the studied product to be larger than the original product.

Since the processing steps require water, the amount of water needed (m^3/ton of original product) was added to the initial water footprint of the original product before transferring into a value for the water footprint of the resulting product. There is no need to score the grey water footprint because the wastewater can be reused within the factory.

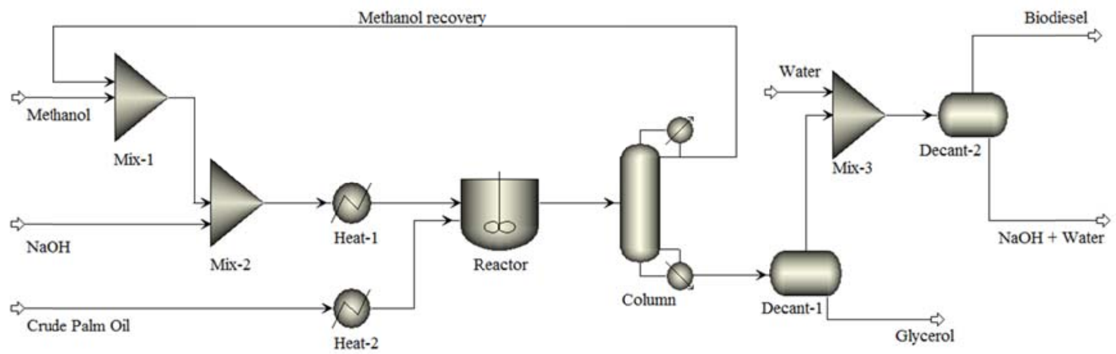

Figure 3 Process flow diagram of biodiesel production from crude palm oil.

3. Results and Discussions

The water footprint of biodiesel production is shown in Figure 4. The total water footprint of biodiesel are 5,938, 6,130 and 5,183 m^3/ton for Krabi, Chumphon and Surat-Thani provinces, respectively.

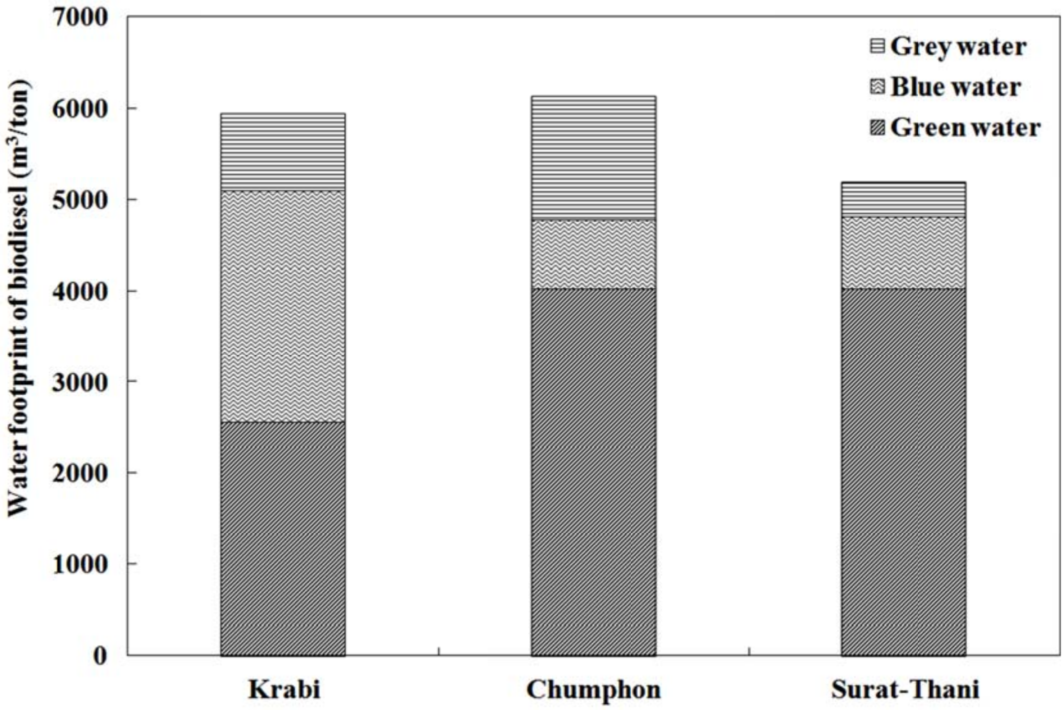

Figure 4: Water footprint of palm oil biodiesel.

exchange resin technology is a good practice. From the study, Surat-Thani has the highest efficiency of water use on limited annual water resource. It also indicated that cultivation on Krabi and Chumphon needs to be improved especially on the water management. It can be concluded that the oil palm crop from Surat-Thani is appropriated for the palm oil biodiesel production in Thailand compared among the most three potential areas.

4. Conclusions

This study presents the results of the water footprint analysis for palm oil biodiesel production. All production chains of palm oil biodiesel, including oil palm plantation, harvesting, CPO extraction, and biodiesel production, are evaluated based on 1 ton of biodiesel. The water footprint of biodiesel varies according to the different climate and agricultural production systems. The agricultural stage is the highest contributor to the total water footprints which results from the water consumption of oil palm crop required in the cultivation stage. However, the palm oil biodiesel production chain with a lower water footprint is more damaging to the environment since grey water is produced. The degree of damage is also dependent on where the water is sourced. Thus, Environmental Impact Assessments should include a comparison of each water footprint component to available water at relevant locations and time in further studies.

5. Acknowledgements

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