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Carbon, Water, and Ecological Footprints Analysis and Potential Environmental Improvements in Palm Oil and Rubber Production in Thailand

Charongpun Musikavong[1,*], Trakarn Prapaspongsa[2] and Shabbir H.Gheewala[3,4]

[1]Department of Civil Engineering, Faculty of Engineering, Prince of Songkla University, Hatyai 90112, Songkhla, Thailand
[2]Department of Civil and Environmental Engineering, Mahidol University, Nakhon Pathom, Thailand
[3]The Joint Graduate School of Energy and Environment, King Mongkut's University of Technology Thonburi, Bangkok, Thailand
[4]Centre of Excellence on Energy Technology and Environment, PERDO, Bangkok, Thailand
*Corresponding author. Tel.: +66-742-7112, Fax: +66-74-287112, E-mail address: mcharongpun@eng.psu.ac.th and charongpun@gmail.com

Abstract: This research is aimed at integrating assessment of carbon footprint (CF), water footprint (WF), and ecological footprint (EF) of oil palm and rubber products in the production stage and unit process level for potential environmental improvements. For plantation, one tonne of fresh fruit bunch (FFB) and fresh latex were set as the functional units. For the factory, the functional units are one tonne of crude palm oil (CPO), concentrated latex (CL), blocked rubber (Standard Thai Rubber 5, STR 5), STR 20, and ribbed smoked sheet (RSS). Secondary data were used in this study. The rain water and irrigation water were determined as the major sources of WF and EF of FFB and fresh latex whereas CF had nitrogen fertilizer production and use as major source. The hot spot of unit process of CF did not completely relate to the WF and EF. It was acquisition of input from plantation, wastewater, and production process. Most of the EF and WF for CPO, CL, STR 5, STR 20, and RSS production was contributed by rain and irrigation water from plantation. The plantation stage was the main contributor of CF, WF, and EF. The policy makers must focus on potential environmental improvements in this stage.

Keywords: blocked rubber; concentrated latex; crude palm oil; fresh fruit bunches; fresh latex, ribbed smoked sheet.

1. Introduction

Oil palm and rubber are important industries in Thailand. The fresh fruit bunch (FFB) is the main product of oil palm plantation and used as raw material for the palm oil mill. Crude palm oil (CPO) is the main product of the mill. For the rubber plantation, the fresh latex is the main product. In some areas, the fresh latex is left in its collection container to obtain cup lump rubber or used for producing unsmoked sheet. The fresh latex is the raw material for producing concentrated latex (CL), ribbed smoked sheet (RSS), and blocked rubber (Standard Thai Rubber 5, STR 5). The cup lump rubber is utilized as the raw material for producing blocked rubber (Standard Thai Rubber 20, STR 20). The unsmoked sheet is used for producing RSS. Environmental impacts such as greenhouse gas (GHG) emissions or so-called carbon footprint (CF), water use in terms of water footprint (WF), and the total of land and water ecosystem requirements for providing resources and absorbing emissions as "ecological footprint (EF)" are important environmental assessment tools. The CF, WF, and EF of oil palm and rubber products and their reductions have been determined separately by several researchers. However, an integrated assessment of CF, WF, and EF in the production stage and unit process level for potential environmental improvements has never been conducted. This research has been conducted including such an integrated assessment to support sustainable development in the oil palm and rubber industries. Recommendations on the reduction of CF, WF, and EF from the main production stage and unit processes are also proposed.

2. Material and Methods

For the plantation, one tonne of FFB and fresh latex (dry rubber content of 30%) were set as the functional units. For the factory, the functional units are one tonne of CPO, CL, STR 5, STR 20, and RSS. The secondary data of CF, WF, and EF for oil palm and rubber products were collected from several publications as presented in Table 1. The integration of hotspots of CF, WF, and EF, potential environmental improvements were determined and policy recommendations proposed for oil palm and rubber production.

3. Results and Discussion

For the plantation stage as presented in Figure 1, nitrogen fertilizer production and use was the main source of CF for both oil palm and rubber plantation accounting for more than 80% of total GHG emissions. The acquisition and use of potassium and phosphorus fertilizers and transportation were less significant (Jawjit et al., 2010; OAE and GIZ, 2012). More than 99.5 % of water use for producing FFB and fresh latex originated from the crop cultivation. Rain water accounted for

Table 1. Sources of CF, WF, and EF of oil palm and rubber products.

Products	Sources		
	Carbon footprint	Water footprint	Ecological footprint
Plantation			
FFB	[1]	[4]	[9]
Fresh latex	[2]	[5-6]	[9]
Factory			
CPO from palm oil mill	[3]	[4]	[10]
RSS from rubber sheet factory	[2]	[7]	[10]
STR20 from blocked rubber factory	[2]	[8]	[10]
CL from concentrated latex factory	[2]	[8]	[10]

more than 85% of the total water requirement. The amount of rain was not sufficient for oil palm and rubber growing; the remaining crop water requirement after accounting for rain was met by irrigation. The small percent distribution of irrigation water for production and use of inputs was determined (MTEC, 2014; Musikavong et al. 2016; Suttayakul et al., 2016; TRF, 2015). The percent of irrigation water for oil palm plantation is higher than that of rubber plantation. This should be a concern for the policy development of the expansion of oil palm plantations. The rain water and irrigation water were the main contributors to the EF accounting for more than 90% of the total EF. Other EF sources were fertilizer, energy, and cropland (Musikavong and Gheewala, 2016b). The rain water and irrigation water were determined as the major sources of both WF and EF of FFB and fresh latex. The CF has a different major source – nitrogen fertilizer production and use.

In the production stage of CPO (Figure 2), wastewater treatment and acquisition of FFB contributed 58 and 43% of the total GHG emissions, respectively, [3]. For the RSS and CL production, 97 and 83% of the total GHG emissions were from the production of fresh latex in the plantation, respectively. The production process contributed 3 and 17% of the total GHG emission for RSS and CL production, respectively. For STR20 production, the plantation and energy used in the mill were the major contributors to the total GHG at about 56 and 44%, respectively (Jawjit et al., 2010). The WF and EF of CPO, CL, STR 5, STR20, and RSS mostly originated from water used for producing the raw material from the plantation including FFB, fresh latex, cup lump, and unsmoked sheet (MTEC, 2014; Musikavong et al. 2016; Musikavong and Gheewala, 2016b; Musikavong and Gheewala, 2016c; Suttayakul et al., 2016; TRF, 2015). Thus the results show that the hotspot for CF did not completely relate to the WF and EF. Most of the EF and WF for CPO, CL, STR 5, STR20, and RSS production were contributed by rain and irrigation water.

The promotion and action on the cultivation of oil palm and rubber varieties with high yield should be done. When the amount of fertilizer use per ha was set to be similar to the existing amount, the increase in yield of oil palm by 6.25 tonne/ha/year resulted in decrease CF, WF, and EF by approximately 25, 29, and 29%, respectively. For the rubber plantation, the increase in yield of fresh latex by 1 tonne/ha/year resulted in decrease CF, WF, and EF by approximately 35%. Considering only CF in the plantation, the optimization of nitrogen fertilizer use should be employed. The organic fertilizer should be used instead of chemical fertilizer (OAE, and GIZ, 2012). Reducing the CF, WF, and EF of plantation will inevitability reduce CF, WF, and EF of their products. In the production stage, there are options for reducing the CF of CPO by upgrading the existing wastewater treatment plant [11]. The energy audit should be conducted for STR20 factory to determine the major sources of energy consumption. Then, the optimization method should be developed, proposed and used for STR20 factory.

4. Conclusion

The plantation stage was the main contributor of CF, WF, and EF. Thus the policy makers must focus on potential environmental improvements in this stage. For CF, the amount of nitrogen fertilizer used must be significantly reduced. The WF and EF results had the similar hotspot which was the crop water requirement. Policy makers should support the growth of oil palm and rubber that have high yield within the area with sufficient rainfall for reducing both WF and EF.

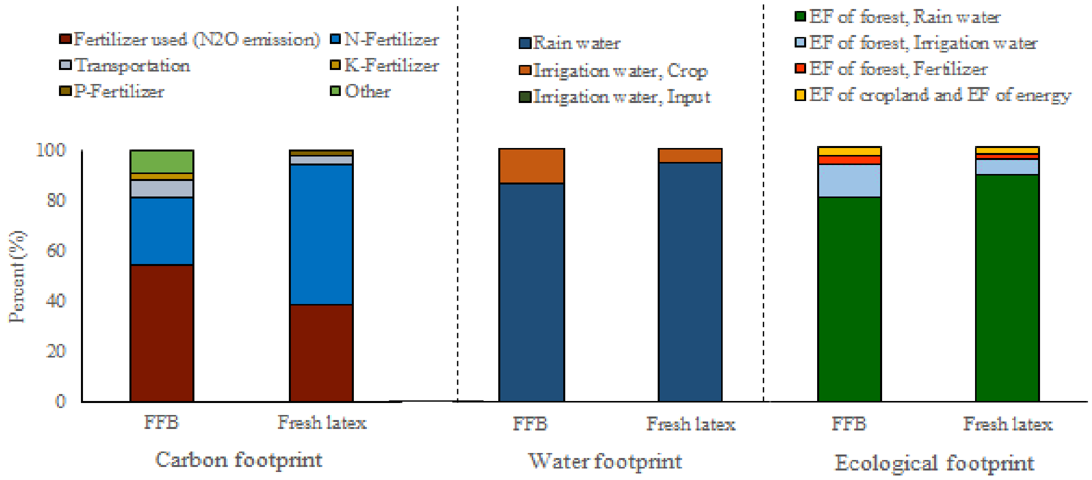

Figure 1. Percent of CF, WF, and EF of FFB and fresh latex production (references of data sources are presented in Table 1).

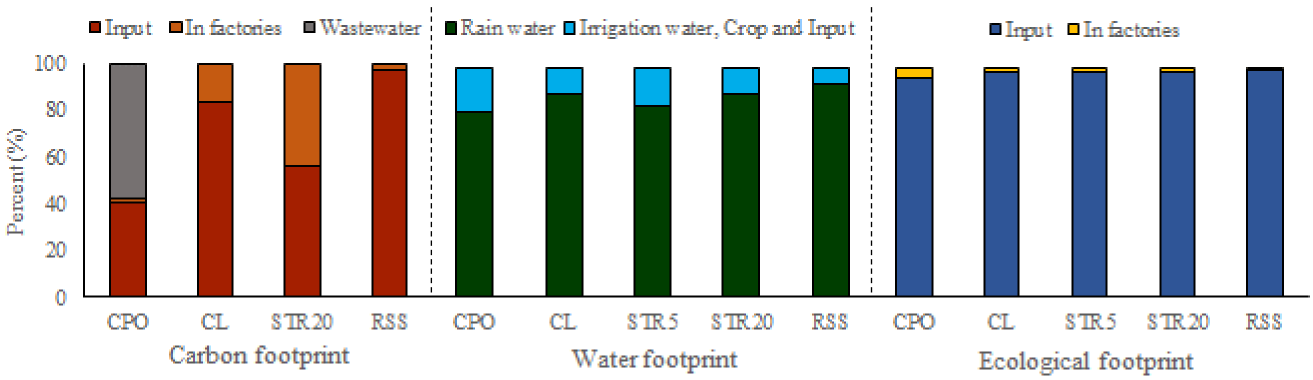

Figure 2. Percent of CF, WF, and EF of CPO, CL, STR20, and RSS productions (references of data sources are presented in Table 1).

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