Journal of Cleaner Production 134 (2016) 574–582

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Water scarcity footprint of products from cooperative and large rubber sheet factories in southern Thailand

Charongpun Musikavong [a,*], Shabbir H. Gheewala [b,c]

[a] Department of Civil Engineering, Faculty of Engineering, Prince of Songkla University, Hatyai 90112, Songkhla, Thailand
[b] The Joint Graduate School of Energy and Environment, King Mongkut's University of Technology Thonburi, Bangkok, Thailand
[c] Centre of Excellence on Energy Technology and Environment, PERDO, Bangkok, Thailand

ARTICLE INFO

Article history:
Received 24 October 2014
Received in revised form
3 October 2015
Accepted 4 October 2015
Available online 20 October 2015

Keywords:
Consumptive water use
Fresh latex
Ribbed smoked sheet
Water deprivation
Water stress index

ABSTRACT

The water scarcity footprints (WSF) of ribbed smoked sheet (RSS) from 14 cooperative rubber sheet factories (CRSF) in nine provinces in southern Thailand were evaluated. The WSF of ribbed smoked sheet bales (RSSB) was determined in two large rubber sheet factories (LRSF) in two provinces. Average values of consumptive water use (CWU) for RSS and RSSB were 549 and 592 m^3/tonne, respectively. The CWU for both CRSF and LRSF was found to be very small in comparison to that for producing inputs from the rubber plantation. The CWU used for producing RSS arose from acquisition of fresh latex. Acquisition of unsmoked sheet and RSS had a major contribution for the RSSB production. WSFs of RSS and RSSB in terms of water deprivation ranged from 0.12 to 72.8 and 5.12 to 52.4 m^3 water-equivalent/tonne, respectively. The major difference of CWU in the rubber plantations caused the difference of WSF for RSS and RSSB. The results of this study revealed that the policy makers should focus on the rubber plantation as the first priority. CWU and WSF values should be included as indicators for determining suitable areas of rubber plantation and for getting government support. In the factories, technologies or processes that used less water must be employed in the washing process to reduce CWU.

1. Introduction

Thailand is the leading producer of natural rubber in the world producing 3.86 million tonnes of natural rubber products in 2013. This accounted for almost a third of the total production of natural rubber in the world (FAO, 2015). The rubber industry, therefore, is one of the most important economic sectors in Thailand. In 2013, Thailand produced 0.91 million tonnes of ribbed smoked sheet (RSS) accounting for 21.9% of total natural rubber production in the country with an approximate export value of RSS of 2.25 billion United States dollars (USD) (RRIT, 2015; OAE, 2015).

There are two types of RSS factories in Thailand, the cooperative rubber sheet factory and the large rubber sheet factory. For the supply chain of the cooperative rubber sheet factory, the fresh latex is produced in the rubber plantations and transported to the factory either directly or via collection points. RSS is the main product and bubbled latex, rubber cuttings, and scrap rubber are co-products from the factory. The RSS is subsequently transported to central rubber markets or the large rubber sheet factory.

The large rubber sheet factory receives unsmoked sheets (USS) from cultivators and collection points, and RSS from central rubber markets and the cooperative rubber sheet factories. Ribbed smoked sheet bales (RSSB) are the only product of the factory. RSS is the initial raw material for producing several products such as aero tyres, tubes, extruded hoses, footwear items, tyres, and tread carcasses (Thomson Group, 2011).

Currently, the problem of water scarcity is a serious concern in many countries including Thailand. This is because water is a necessary resource for communities and industrial as well as agricultural activities. Most of the freshwater consumption in the world is for agricultural activities; irrigation consuming approximately 70% of the freshwater withdrawal in the world (Scanlon et al., 2007; Gordon et al., 2010; WWAP, 2012). The RSS and RSSB are products of the agricultural sector and are used worldwide as commodity products. Therefore the freshwater consumption for producing RSS and RSSB are of considerable general concern.

The manual for evaluation of water footprint (WF) of products was developed by Hoekstra et al. (2011) as an alternative tool to

* Corresponding author. Tel.: +66 742 7112; fax: +66 74 287112.
E-mail addresses: mcharongpun@eng.psu.ac.th, charongpun@gmail.com (C. Musikavong).

http://dx.doi.org/10.1016/j.jclepro.2015.10.012

manage water use properly and address the problem of water scarcity. The WF is composed of three components: green water; blue water; and grey water from the direct and indirect water consumption in a production process. The green water is the amount of rainwater utilized by crops in growing. Blue water is the surface and groundwater used for irrigating the crops. Grey water is the amount of freshwater that is required for diluting or treating wastewater to ensure its quality in accordance with required standards (Hoekstra et al., 2011). Many studies have determined the WF of agricultural products or their related products. These have dealt with tomatoes (Chapagain and Orr, 2009), rice (Chapagain and Hoekstra, 2011), tea (Jefferies et al., 2012), maize (Bocchiola et al., 2013), bioethanol energy crops (Su et al., 2015), wine (Lamastra et al., 2014), potatoes (Herath et al., 2014a,b), and dairy (Palhares and Pezzopane, 2015). In Thailand, the WFs of rice, maize, soybean, mungbean, peanut, cassava, sugarcane, pineapple, oil palm, and coconut have been determined on a country-wide scale (Gheewala et al., 2014).

The International Organization for Standardization (ISO) published ISO14046:2014 Environmental management – Water footprint – Principles requirements and guidelines in 2014. The life cycle assessment (LCA) method is used for the evaluation of WFs of products, processes, and organizations. The water footprint inventory must be developed in the first stage. Then, the water footprint impact assessment can be evaluated. For reporting WF results, environmental impact categories related to both water availability and degradation must be determined. It must be clarified here that the definition of WF as per ISO14046 is different from that introduced earlier by Hoekstra et al. (2011). The green and blue water components of WF in the definition by Hoekstra et al. (2011) are actually water footprint "inventory" components according to the ISO14046:2014.

The water footprint indicates a quantified metric of potential environmental impacts related to each component of water used (ISO, 2014). The potential environmental impacts and management interventions of green water and blue water for cultivation of crops are entirely different. Therefore, assessments of green and blue water must be separately determined. Then, the interpretation of the potential environmental impacts and management of green water and blue water can be individually evaluated. For this research, only blue water is included in the assessment as it is directly related to the use of freshwater resources (Pfister et al., 2009; Ridoutt and Pfister, 2010). The main focus of this research is to evaluate the potential of environmental impacts and management interventions of consumptive water use (blue water) for production of RSS and RSSB in Thailand.

Pfister et al. (2009) determined the water stress index (WSI) of watersheds at the global level as the ratio between the total annual freshwater withdrawals to the hydrological availability of the region or watersheds. Methods developed by Pfister et al. (2009) and Ridoutt and Pfister (2010) were employed to evaluate WSIs of 25 major river basins in Thailand (Gheewala et al., 2014). In 2011, the water deprivation concept was developed by Pfister et al. (2011) to quantify the water scarcity to ecosystems and human users at downstream locations. It can be determined by multiplying the consumptive water use (CWU) for producing the product (blue water) with the WSI of specific watershed where the water for manufacturing the product is withdrawn. The CWU is defined as freshwater withdrawal from a basin and not returned to the same basin. The CWU can be caused by evaporation, transpiration, integration into a product, and discharge into a different basin or sea (ISO, 2014).

The term "water scarcity footprint (WSF)" is used to describe the potential environmental impacts of CWU for production of products, process, or organization in a specific location. The water deprivation developed by Pfister et al. (2011) was used as the indicator of WSF in this research. A high water deprivation indicates that the production of product, process, and organization in specific temporal and geographical coverage can cause high impact on water consumption because of the greater water competition with other categories of water consumers (Gheewala et al., 2014).

No studies on the CWU, WSF, and the method for reducing CWU of RSS and RSSB production have been reported. This work was thus aimed at determining the CWU and the hotspots of CWU of RSS and RSSB production on a regional scale in Thailand. In addition, WSFs of RSS and RSSB are evaluated in terms of water deprivation. Reduction of CWU for RSS and RSSB production are proposed and discussed. Recommendations are also made for policy makers on rubber plantation and RSS and RSSB production in accordance with CWU and water deprivation results.

2. Material and methods

2.1. Goal and system boundary

The total rubber plantation area in Thailand in 2013 was 3.58 million hectares, more than 60% of which being located in 14 provinces in southern Thailand (OAE, 2014). The rubber factories in Thailand are also mostly located in the southern part of the country. The goal of this research was fourfold. Firstly, to determine the CWU and the WSF of products and co-products for the acquisition of fresh latex and RSS production by the cooperative rubber sheet factory. Secondly, to determine these values for the processing of USS and RSS and RSSB production by the large rubber sheet factory in southern Thailand (Fig. 1). Thirdly, to provide the reduction options for CWU in RSS and RSSB production. Fourthly, to propose recommendations for policy makers on water management interventions of RSS and RSSB production in Thailand based on the obtained results.

The CWU in the raw material extraction, transportation, processing, and waste disposal were taken into account. The functional unit was 1 tonne RSS for the cooperative rubber sheet factory and 1 tonne RSSB for the large rubber sheet factory.

2.2. Production process

The fresh latex is transported from cultivators and collection points to the cooperative rubber sheet factory where it is goes through the following production processes: (1) filtration; (2) casting in split-forming boxes; (3) washing and rolling; (4) drying; (5) smoking, and (6) cutting (Fig. 1). Water, electricity, formic acid, and firewood are utilized in the production process. RSS is the main product and bubbled latex, rubber cuttings, and scrap rubber are the co-products.

For the production of RSSB, USS from cultivators and collection points, and RSS from cooperative rubber sheet factories and central rubber markets are transported to the large rubber sheet factory. The USS is washed and smoked in the process of producing RSS. Then the RSS is weighed and packed to produce only one product, RSSB. Water, electricity, solvents, calcium carbonate, and firewood are utilized in the production process. The wastewater from the production process of rubber sheet factories is treated in stabilization pond systems. In the final stage, treated wastewater is stored in the pond.

2.3. Data collection and the calculation of water scarcity footprint

The climate, which depends on location, has an important impact on water availability. Based on climate, the southern part of Thailand could be classified into two distinct regions: (i) the