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Charting the water footprint for Malaysian crude palm oil

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A B S T R A C T

Water scarcity is a serious issue facing our planet right along -side with climate change. The purpose of this study was to evaluate the impacts associated with the use of water by the oil palm trees and the industry for the production of crude palm oil in Malaysia; evaluate the uncertainties of the outcome of a study based on pathway assumptions and the choice of allocation. A full life cycle assessment and a stand-alone water footprint value based on the local water stress index has been determined. The system boundary included the oil palm nursery, plantation (with land use change of oil palm to oil palm and from logged over forest) and palm oil mill (biogas capture scenario). The results showed that the direct water used by the crops and process was minimal because the oil palm plantations in Malaysia were firstly rain fed and not irrigated and secondly Malaysia is located in a region with high availability of renewable water resulting to a low water stress index. The water footprint concluded that the main potential impacts within the system boundary were dominated by land conversion, production and use of fertilisers and pesticides. These findings contradict the general perception of any agriculture system where the notion to assume that the water used by the crop will have the major potential impact. The findings also highlighted the importance of the choice of pathway, government initiatives and managerial intervention for biogas capture which resulted to a 117% reduction in the water footprint. Economic allocation had a 21% increase in the water footprint as compared to weight allocation. It was recommended that plantations implement Good Agricultural Practices that addresses the key elements of land, water management, fertiliser and integrated pest management and the choice of pathways and allocation procedures are made transparent with the results as outcomes may differ as shown in this paper.

1. Introduction

The year 2017 marks 100 years of oil palm cultivation in Malaysia commercially (Zunaira and Hanim, 2017). After 100 years Malaysia is the second largest oil palm producer in the world after Indonesia with an oil palm planted area of over 5.74 M ha (Kushairi, 2017). The oil palm industry has been a strong contributor to the nation's economic growth with annual high export revenues of palm products which was over RM 64.59 G just in the year 2016 (Kushairi, 2017).

Today water scarcity is a serious issue facing our planet right along -side with climate change. Water scarcity arises when the demand for the water exceeds the supply in a certain region (Harhay, 2011). Recognizing the importance of water, focus is now being given to water through water footprint (WF) of products just like carbon footprint. Green-house gas (GHG) emissions are determined using the Life Cycle Assessment (LCA) approach and in the same manner for the quantification of WF the LCA approach has to be used. As defined in WULCA (2014), LCA is a method that is used to evaluate the potential environmental impacts for a product or process over its entire life cycle. WF is a fraction of the whole LCA study. WF accounts for the impacts that are associated with the consumption and discharge of water as well as the availability of water for humans and eco-system (WULCA, 2014).

There have been a large number of studies on WF. Jeswani and Azapagic (2011) reviewed the WF approaches, strengths and limitations reported that there are huge variations in the results

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between different methods. Lovarelli et al. (2016) also conducted a review on WF indicators which highlighted that 78% of the studies aimed to quantify WF, 22% analysed methodology, uncertainty, future trends and comparisons with other footprints and most studies that quantified WF concerned cereals. This shows the high interest of agriculture based industry to quantify their WF. The study in China by Wei et al. (2016) wanted an improved WF model to quantify the WF caused by water diversion. The study also wanted to quantify the crop WF which increased during the transfer. The study concluded that the crops with higher WF_{blue} tend to be more strongly influenced by the water diversion project, due to high water dependency for irrigation. This shows how WF was used to gauge the outcome of a certain projector initiative. Morillo et al. (2015) conducted a joint evaluation of crop WF accounting and irrigation management indicators as a diagnostic tool to identify the hotspots of irrigated agricultural systems. Based on this analysis, specific actions were defined to improve water use efficiency, reduce water abstractions and polluted water returns, while maintaining production rates. In this case WF was used as a tool to identify the hotspots where mitigation actions could be taken to better manage the irrigation system. The study by Pellegrini et al. (2016) which compared WF of different olive agronomic cropping systems found that the high-density cropping systems was found to be most competitive due to the reduced WF. Wong et al. (2016) reported that the differences in water use between feed stocks and conversion process indicated that the choices of biomass feedstock and conversion pathways were crucial factors affecting the WF for the study which quantified the WF of hydrogenation-derived renewable energy. Sabli et al. (2017) created a method in calculating WF found the method can only provide water degradation levels in the plantations. Xu et al. (2015) estimated the total water consumption of crop production in Beijing and found that crop production shows a greater blue WF than green and grey. Chiu et al. (2015) calculated the WF of 2nd generation bioethanol. Dourte et al. (2014) reported the development of a web based tool which provides a local water stress index (WSI) based on regional water use and available supplies. This showed how WSI is an important indicator in WF as well. Lovarelli et al. (2016b) created a pollution water indicator to denote the water pollution intensity. This was mainly to identify the effect of the main polluting substances in crop cultivation. This study again shows how important WF studies are in agricultural based systems. Duarte et al. (2014) examined the evolution of domestic water consumption in Spain due to the increase of agricultural production and found that pressures on water resources exerted as a result of the expansion of the Spanish agricultural sector. Mekonnen and Hoekstra (2014) established a set of global WF bench mark values for a large number of crops grown in the world. There was also a study charting the WF of all the various vegetable oils and crops (Gerbens et al., 2008). A study in Malaysia quantified the WF of crude palm oil (CPO) (Subramaniam et al., 2014) and recently a study in Thailand quantified the blue, green and grey WF of CPO (Suttayakul et al., 2016). The findings of both these studies showed that the highest impact was from of the water used by the oil palm trees which was the green water. Both these studies reported the quantity of the water used by the crop without considering the impact of the water used based on the availability of water in the region. This paper aims to study the impact of the consumption of water by the crop based on the availability of the water in the region.

There has been a lot of debate on the applicability and uncertainties regarding WF but these studies show that WF can bring about important managerial decisions and mitigation steps that can be derived for better utilisation of water. At the same time outcome of improvements and modifications to any system can be gauged with the WF as well.

This study is a National WF study having representative data from 243 palm oil mills (POMs) from all over Malaysia. This study also accesses the impact of the quantity of water needed by this industry to determine the hotspots where water is used along the supply chain and if the potential impact of the water used is coming from the crop water use (which is the general perception of any agricultural system) or if it is from other sources. This study also addresses the uncertainties of the outcome of a study based on pathway assumption (in this case when the biogas capture scenario was chosen) and choice of allocation.

The main motivations or problems statements of this study are as below:

1. An average oil palm plantation is planted with 136–148 oil palm trees per ha (Hashim et al., 2010). With a large land cover of over 5.74 M ha this accounts to having 780.64 M - 849.52 M oil palm trees standing in various ages in the country. The water requirement of these oil palm trees and the identification of areas that are suitable for planting are very crucial. The findings of this study was hoped to enable better decision making on areas that are suitable for planting oil palm trees as well as for the formulation of better water managerial practices at the plantation. The findings of this study can also inform the policy makers and the stakeholders of the hotspots of where the potential impact on water consumption exits along the supply chain of the system boundary.
2. The European Commission launched their pilot study on environmental footprint between 2013 and 2016 (European Commission, 2016). The Environmental footprint takes out the impact categories of global warming and air pollution (GHG emissions) and water pollution or scarcity (WF) from the full LCA for reporting purposes. The European Union being the second largest importer of Malaysian palm oil with a total export of 2.03 M t of CPO in the year 2016 (Kushairi, 2017) may require such accounting for their imports in the future and so WF conducted in accordance to ISO 14046:2014: Environmental Management WF- Principles, requirements and guidelines (ISO/TC207, 2014) is important for the Malaysian oil palm industry.
3. The Government of Malaysia has launched the National Key Economic Area (NKEA) where all POMs will have to capture the biogas (Pemandu, 2011). The adoption of this endeavor has only recently picked up. This study hopes to quantify the magnitude of this Government intervention towards the WF of the industry. Even though the GHG emissions have been gauged before but the WF has never been gauged. This study also aims to evaluate the importance of such interventions by the government to make a revolutionary change in an industry by doing a sensitivity analysis if the NKEA was never launched and to highlight how a pathway choice in a study can reduce the impacts drastically.
4. Allocation based on weight, energy or economics is a common step used in LCA. This WF study aims to show how an outcome of a study can change with just an allocation decision.

The purpose of this study was to

- Evaluate the impacts associated with the use of water by the oil palm trees and the oil palm industry and suggest mitigation measures if any
- Evaluate the uncertainties of the outcome of a study based on pathway assumptions (in this case when the biogas capture scenario was chosen)
- Evaluate the uncertainties of the outcome of a study based on the type of allocation decision.