The Water Footprint of Coconut Production: A Preliminary Assessment

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ABSTRACT

Water footprinting has widely been used to quantify the environmental impact of water use around the world to provide consumers with metrics of sustainability. The present study attempts to quantify the impacts of water use in rain-fed coconut cultivation in Sri Lanka and also to identify the major gaps of information required to an accurate quantification of water footprints. The impact of water use in coconut cultivation on water resources was assessed through quantification of the green-, blue- and grey-water footprints. The consumptive green-water footprint was amounted to 577 L/nut harvested. There has not been blue-water use as there is no irrigation, and therefore, the cropping system has no adverse impact on the quantity of blue-water resources. However, the impact of leaching of nutrients from the system on the quality of water resources as indicated by the grey-water footprint was 56 L/nut and 337 L/nut for the scenarios of 10% and 60% leaching of the applied nitrogenous fertiliser, respectively. These results are the first approximations of water footprints, and further verification through measurements and modelling is needed in future applications. The study also reveald the knowledge gaps that need further studies for accurate quantification of water footprints.

Keywords: Coconut cultivation, Environmental impacts, Nutrient leaching,Water footprint

INTRODUCTION

Agriculture has widespread impacts on quantity and the quality of water resources. The concept of water footprinting (WF) emerged as an indicator that shows water use or consumption during a production process (Hoekstra *et al.*, 2011). In water footprinting, three water colours are distinguished: blue, green and grey. The 'blue water' refers to the surface and/or groundwater used by the production system. The 'green water' refers to the rain water stored in the soil and then transpired by the plants. The 'grey water' indicates water pollution due to leaching and runoff of agrichemicals from the production system(Hoekstra *et al.*, 2011).

There have been a large number of assessments carried out in different parts of the world to quantify water that is consumed during the production of various products (Ridoutt and Pfister, 2010; Deurer *et al.*, 2011; Herath *et al.*, 2013a) . The total water consumption during the production of an agricultural product is much greater than the water physically present in the final product (WFN, 2014), the latter of which is also termed as virtual water. Recently, the developments in methodologies of WF, together with the life cycle assessment principles, have been used in quantifying the impact of water use in a particular production system on the environment (Ridoutt and Pfister, 2010; Deurer *et al.*, 2011; Herath *et al.*, 2013a). Accurate assessment of the impacts of water use, nonetheless, requires quantification of all hydrological components of a cropping system, including the crop water use and the drainage below the root zone.

Considering all hydrological aspects, water footprinting assessment has many advantages. The quantification of nutrient loss through leaching and runoff will be useful in developing improvement options to increase the fertiliser use efficiency. Matching crop water use with different water availability scenarios of the changing climate will be useful in identifying adaptation strategies for the risks related to climate change. Furthermore, where required, footprinting enables accurate quantification of irrigation water requirement and irrigation scheduling.

Coconut is the most widely-grown and consumed plantation crop in Sri Lanka. The coconut plantations cover around 19% of the agricultural land in Sri Lanka. It plays a dominant role in Sri Lankan agriculture. According to current practices, fertiliser for adult coconut is applied once a year when the soil is wet. Furthermore, coconut is mostly grown well on sandy loam soils in lower altitudes in the wet and intermediate zones of Sri Lanka. These areas receive an annual rainfall of 1250-2500mm. Under these conditions, the nutrients applied are highly prone to leach and therefore, have potential impacts on the environment. However, there has not been any study conducted to assess those impacts related to water use. This preliminary assessment aims to quantify the impact of water use in coconut cultivation on the environment, especially on water resources, using the concept of water footprint. The study will also identify knowledge gaps that deserve further investigations for an accurate quantification of water- related environmental risks.

MATERIALS AND METHODS

Among different agro-climatic regions where coconut is grown, the coconut cultivation under rain-fed conditions in the low-country intermediate zone was considered in this study, as this system represents the majority of Sri Lankan coconut cultivation. The reported data, herein, on crop water use and nutrient leaching were used for the calculations.

Green and blue-water footprints

The main water use by this cropping system is consumptive water use through transpiration from coconut palms. All of the water used in this cropping system is sourced from soil water storage that originates from rainfall. Therefore, total water consumption is green water. The crop water use was estimated using the values reported by Madurapperuma *et al.*, (2009) and Jayasekara and Jayasekara (1993).

As no irrigation was used in this system, the consumptive blue-water use was zero. The impact of coconut cultivation on water resource was quantified using net water balance. However, accurate assessment needs quantification of drainage and runoff (Herath *et al.*, 2013a). As the coconut is mostly grown on sandy soils with high infiltration of flat to undulating terrain, the runoff is minimal. The impact on the blue-water resources, both in terms of quantity and quality, due to this cropping system was, therefore mainly from the quality of the drainage component. However, there has not been any study on quantification of drainage in the coconut cultivation. Therefore, in this study, the drainage was indirectly estimated by subtracting the crop water use from the rainfall. The crop yield and the weather data were collected from two research stations, namely, Rathmalagara and Bandirippuwa in the intermediate zone.

Grey water footprint

The grey-water footprint which is the volume of freshwater needed to 'dilute' the most concentrated pollutant in the leachate reaching the blue-water resource of ground or surface water to an acceptable water quality standard (Hoekstra et al., 2011) (Equation 1). Among the agro-chemicals (fertiliser and pesticide) used for coconut cultivation, soluble fertilisers dominate as the potential contaminants of water resources. Urea and Muriate of Potash are the readily soluble fertilisers in the general recommendation for coconut given by the Coconut Research Institute. According to the WHO guidelines for drinking water quality, potassium has a very low risk of becoming hazardous (WHO, 2011), ecological problems due to surface water contaminations are notwithstanding. Therefore, only the impact of contamination of water trough leaching nitrogenous fertiliser was considered in this study.

$$WF_{Grey} = [L/(C_m - C_n)]/Y \qquad \text{Equation 1}$$

where, WF_{Grey}, is the volume of freshwater (per unit yield) required to 'dilute' the leached pollutant to an accepted water quality standard, L is the netload of pollutants [mg /ha] that is leached and reached the water resources. In this study, the leached nitrogen fertiliser was considered. The C_m is the maximum acceptable concentration of nitrate [mg-NO_3-N/L] given by the water quality standards. The standard used in this study was the guidelines established for drinking water quality by the World Health Organisation (WHO), which is 11.3 mg NO_3-N/L (WHO, 2011). The natural concentration C_n is the NO_3-N concentration in the receiving water body as if there has been no human intervention (Hoekstra *et al.*, 2011). This was considered to be zero by considering the NO_3-N concentration found in the groundwater of this region. Y is the coconut yield in nuts per ha. Nut yield was recorded from two experimental stations in the intermediate zone in Rathmalagara and Bandirippuwa Estates.

RESULTS AND DISCUSSION

The concept of water footprinting can effectively be used to understand the impacts of production system, first through quantifying the total water consumption, and then by assessing the consequences of the said consumption on the availability and the quality of water resources. The assessments also consider the opportunity cost of the consumed water that could perform many other ecosystem services if it was not consumed or degraded (Herath *et al.*, 2013a; Herath *et al.*, 2013b).

Green- and blue-water footprints

Since the cropping system studied is a rain-fed cultivation, the total crop water use is sourced from the water stored in the soil profile which is the green-water resource that originated from rainfall. The estimated crop water use from the field measurements of transpiration by Madurapperuma *et al.*, (2009) and Jayasekara and Jayasekara (1993) was 530mm/yr. The average nut yield of the past six years was 9,164 nuts/ha in the considered locations in the intermediate zone. Therefore, the total consumptive water footprint was 577 L/nut harvested. However, the impact of this water use on the environment is what is more important. The impact of green-water use can be interpreted in different ways. The transpired water could be considered as a 'loss' since it is immediately unavailable for other uses (Hoekstra *et al.*, 2011). Yet, another argument is that the use of green water has no adverse impact as this type of water tends to evaporate irrespective of the presence of particular cropping system (Ridoutt and Pfister, 2010). It is unambiguous that the impact of green-water use has a less impact compared to the use of blue water as surface and ground water has many other alternative uses while green water can only be utilised through vegetative lands.

When the blue-water use is considered, as no irrigation was used in the production system under consideration, the consumptive blue-water footprint is zero. Therefore, coconut cultivation has no direct adverse impact on blue-water resources. If there is drainage below the root zone, indeed through this drainage, coconut plantations contribute to groundwater recharge. However, this leachate could carry chemicals causing adverse impacts on the quality of receiving water bodies. This impact is quantified as the grey-water footprint. In this study, the drainage was indirectly estimated by subtracting the crop water use from the rainfall. The annual average rainfall over the last 34 years (1978-2012) at the two research stations in the intermediate zone was 1701 mm. The drainage was, therefore, quantified to be 1171mm/yr. This indicates that coconut land use contributes to recharge groundwater or surface waters.

Grey-water footprint

According to the current recommendation, urea is applied and incorporated at the rate of 0.8 kg/palm. This is equivalent to 126 kg of N/ha application at the normal planting density of 158/ha. As the leaching of fertiliser from coconut-growing system has not yet been quantified, the inferred values were used to quantify the leaching losses. It was also assumed that the nutrients leached meet ground water resources. Table 1 shows the two different nutrient leaching scenarios and the calculated grey-water footprints according to Equation1.

These results indicate that the freshwater needed to dilute 10% and 60% of nitrate-nitrogen leached was 56.1L and 336.9L, respectively for each coconut harvested. These values may be comparable with the quantified global average grey-water footprint of other agricultural products such as 166.9 L/kg for peanut, 50.4 L/kg for oranges and 63.1L/kg for potatoes (WFN, 2014). However, these values have to be used with caution since the applicability of global averages to a particular location will not appropriate as the water-related impacts are highly local and variable across the globe.

Coconut is grown in well-drained sandy soils (Somasiri *et al.*, 2006), and there is a high potential of leaching the applied agrochemicals. The general understanding is around 50% of the fertiliser applied in coconut cultivation is lost through leaching. However, there is no experimental evidence to substantiate this claim. Therefore, this aspect deserves detailed analysis of the drainage leachate for potential pollutants and their quantification.

In conclusion, the cropping system has no adverse impact on blue-water resources through extraction. Indeed, it contributes to replenishment of water resources at 1171mm/yr on annual basis, which would then be contributing to the vital ecosystem services provided by blue water. However, the leaching of nutrients from the system may have significant impact on the quality of water resources as indicated by the grey-water

Table 1 The grey water footprint of coconut cultivation under two different nutrient-leaching scenarios

Nutrient-leaching Scenario and related reference	**Load of N leaching**	**Grey-water footprint**
10% of the applied fertiliser (Chapagain *et al.*, 2006; Dabrowski *et al.*, 2009)	5.81 kg/ha	56.1 L/nut
50% - 70% of the applied fertilizer (Kottegoda*et al.*, 2011)	34.89 kg/ha	336.9 L/nut

footprint of 56.1 L/nut and 336.9L/nut for 10% and 60% leaching of the applied nitrogenous fertiliser, respectively. However, these results need to be considered as the first approximations, and further verification through measurements and modelling is needed.

In this study, drainage and nutrient leaching were estimated assuming leaching of a fixed percent from the applied nutrients as there was no reliable information on the quantity of nutrient leaching in coconut cultivation. Therefore, future research endeavours should focus on the methods of quantifying the drainage and leaching below the root zone. This would also be useful for accurate quantification of impacts on local water resources and for quantifying the efficiency of fertiliser use.

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