Water Footprint Assessment in the Agro-industry: A Case Study of Soy Sauce Production

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Abstract. In terms of global water scarcity, the water footprint is an indicator of the use of water resources that given knowledge about the environmental impact of consuming a product. The sustainable use of water resources nowadays bring challenges related to the production and consumption phase of water intensive related goods such as in the agro-industry. The objective of the study was to assessment the total water footprint from soy sauce production in Grobogan Regency. The total water footprint is equal to the sum of the supply chain water footprint and the operational water footprint. The assessment is based on the production chain diagram of soy sauce production which presenting the relevant process stages from the source to the final product. The result of this research is the total water footprint of soy sauce production is 1.986,35 L/kg with fraction of green water 78,43%, blue water 21,4% and gray water 0,17%.

1. Introduction

Human activities are related with consume and contaminate a lot of water. On a global scale, most of the water use occurs in agricultural production, but there are also a volume of water consumed and polluted in the industrial and domestic. Water consumption and pollution can be associated with specific activities, such as irrigation, bathing, washing, cleaning, cooling and processing. The total water consumption and pollution are generally regarded as the amount of water requires a lot of activities and pollution evenly. A little attention is paid to the fact that, ultimately, total water consumption and pollution are relate to what and how much communities consume and to the structure of the global economy that supplies the various consumer goods and services. The issue of water consumption and pollution of the entire production and supply chain has been mentioned as being very important for the water management practices [1]. The virtual water content of a product is useful as an instrument to achieve water security and efficient water use, thus, tells about the environmental impact of consuming that product [2]. This concept evidences a complex net of relationship concerning to water and provides significant information for policy and economic actor, user and manager in order to planning and taking decision on this resources [3]

The water footprint has been introduces by Hoekstra (2002). This is a tool that assesses the amount volume of freshwater by considering both direct and indirect uses to produce the goods and services. It can also tell how much water is being consumed by a particular country or globally in a specific river basion or from an aquifer. The water footprint is expressed in water volume per unit of mass (m^3/ton or L/kg), unit of time (m^3/month or m^3/year). The water footprint is an aggregate and multidimensional indicator of water use, showing different sorts of water consumption as a function of space and time and differs from the traditional concept of water balance [1]. Water balance describes the flow of water in and out of a system considering only consumptive water use. Therefore, the water footprint is a way to describe virtual water volume and include the water volume offered by rainfall (green water), the water volumes polluted (gray water) and excludes water volume consumption (blue water) insofar as water is returned to where it comes from. The blue water refers to the consumption of fresh surface water or groundwater that evaporates. It is incorporated in the product, it does not return to the same catchment area, or indeed return, or indeed return but in the different time. The green water footprint is a volume of rainwater consumed during the production process. The different between the blue and green water footprint is important because the hydrological, environment and social impact, as well as the economic opportunity cost of surface and groundwater use for production. The gray water footprint does not represent of the polluted water volume, but it is indicating the level of pollution of the water, expressed in terms of the freshwater volume required to assimilate the existing load of pollutant below the threshold value or exo-toxicological end point [4].

The water footprint assessment is a helpful tool for the calculation of water use throughout the supply chain, providing valuable insights of the largest components and location of water consumption and the potential effects on local watersheds and future water availability

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to serving the need of communities, nature, companies, producers and suppliers [5]. The water footprint assessment framework aims to illustrate the full impact of water consumption during the life cycle of a product, from direct water extraction to water pollution [6]. Water footprint assessment is a developing method that is being increasingly applied to quantify water use, priorities reduction, assess sustainability and provide information to achieve sustainable efficient and equitable water use [7]. The water footprint consist of three components, there are blue, green and gray water footprint. The blue water footprint refers to surface and groundwater in a catchment area that evaporates during crop growth. The green water footprint refers to the rainwater that evaporated during crop growth. The gray water footprint is the volume of freshwater for assimilating waste water base on ambient water quality standards [1].

Water footprint can be relevant to environmental sustainability metric by addition of green water consumption in the analysis [8]. Nearly 80% of green water footprint are associated with global agriculture production [9], which includes wheat, animal products, cotton and bioenergy [10].

Soy sauce is a fermented product of vegetable or animal high protein in salt solution. The raw material of soy sauce are soybean, brown sugar and salt. There are 3 main stage in the process of soy sauce production is boiling and drying soybean, fermentation process and mixing and cooking soy sauce.

2. Materials and methods

The objective of the study was to assessment of the total water footprint from soy sauce production plant. Firstly, the water footprint from crop land of soy bean has been obtained from Research Report Series: The Water Footprint of Indonesian Provinces Related to The Consumption of Crop Products. The next step was to calculate of the water footprint for the operational and supply chain stages. The research method followed the systematic guidelines of the Water Footprint Assessment Manual by [1].

2.1. Materials

Research material and all data that obtain through field investigation. If domestic data is not available, a combination of available literature and provincial or national data was used international literature is referred. Field investigation was conduct in the soy sauce industry in Grobogan Regency.
The water footprint of the soybean crop in Central Java can be seen in table 1.

Table 1. Water footprint from the soybean crop in Central Java [11].

Green water footprint (L/kg)	1.558
Blue water footprint (L/kg)	418
Gray water footprint (L/kg)	-

From the data that obtained from field investigation, this industry uses 3300 L water to produce soy sauce of 360 kg. The water used for the production process is obtained from the PDAM (is a regional water supply company) Grobogan Regency. The gray water footprint estimate the volume of water required to dilute the pollutant that reaches the water body.

2.2.Methodology

Based on the Water footprint Assessment Manual: Setting the Global Standard [1], The water footprint was calculated, as follows:

$$WF_{total} = WF_{green} + WF_{blue} + WF_{gray} \quad (1)$$

The blue water footprint (WF_{blue}) is the volume of surface and consumed by the process. The green water footprint (WF_{green}) is the volume of rainwater evapotranspirated and incorporated by the process and the gray water footprint (WF_{gray}) is an estimate of the freshwater needed to dilute the load of pollutans. Real (blue and green) and virtual (gray) water volumes are summed to compute the total of water footprint. The gray water footprint of a product is an indicator of freshwater pollution that can be associated with the production of the product over its full suplly chain.
The water footprint of product is equal to the sum of the relevant process water footprints divided by production quantity of the product:

$$WF\ prod = \frac{\sum_{s=1}^{k} WF\ proc\ [s]}{P[p]} \quad (2)$$

in which $WF_{proc}[s]$ is the process water footprint of process step s (volume/time) and P[p] the production quantity of product p (mass/time).
The water footprint assessment manual provides a clear guideline for accounting approach of the assessment.

3. Result

Based on the equation 2, can be obtained the water footprint from soy sauce production process as seen in the table below.

Table 2. Water footprint of soy sauce process production in Grobogan Regency.

Green water footprint (L/kg)	-
Blue water footprint (L/kg)	6,94
Gray water footprint (L/kg)	3,41

The water footprint of soy sauce production consist 2 part, there are soybean crop stage and soy sauce process production. Using equation 1, obtained the total water footprint of soybean crop stage 1.976 L/kg is divided into green and blue water footprint. While the total water footprint on soy sauce production process amounted to 10,35 L/kg is divided into blue and gray water footprint.
The total water footprint of soy sauce production is 1.986,35 L/kg with fraction of green water (78,43%), blue water (21,4%) and gray water (0,17%). Green water component account for more than 50% of the total water

footprint for soy sauce production in Grobogan Regency, indicating that these crops are more reliant on natural rain water, making them more suitable for selection based on input criteria.

Table 3. Water footprint of soy sauce production.

Soybean crop stage				Soy sauce production process			
Green water footprint (L/kg)	Blue water footprint (L/kg)	Gray water footprint (L/kg)	Total water footprint of soybean crop stage (L/kg)	Green water footprint (L/kg)	Blue water footprint (L/kg)	Gray water footprint (L/kg)	Total water footprint of soy sauce production process (L/kg)
1558	418	-	1976	-	6,94	3,41	10,35

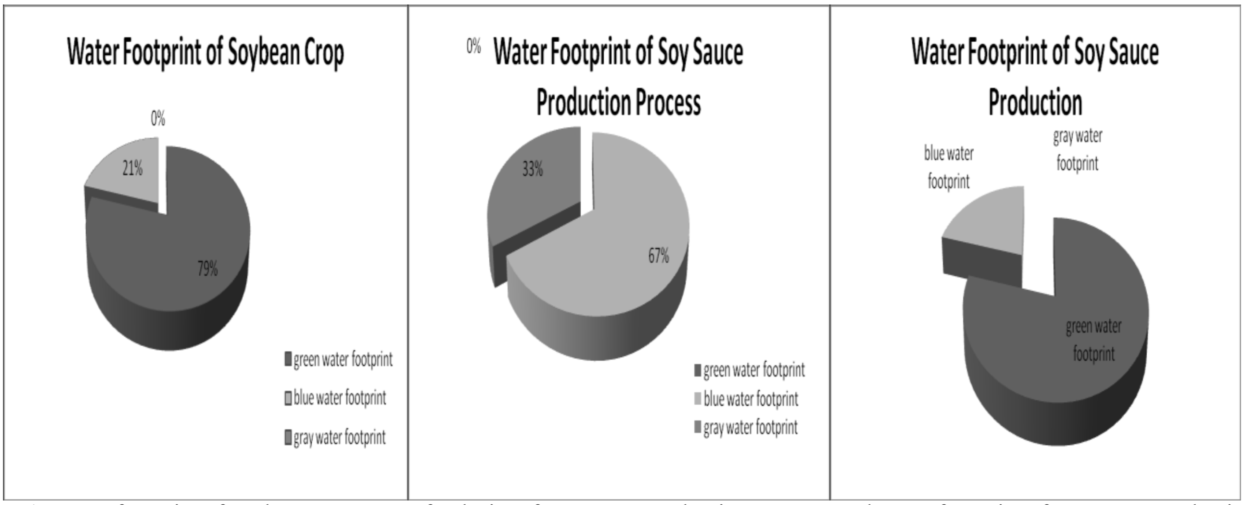

Fig. 1. Water footprint of soybean crop water foodprint of soy sauce production process, and water footprint of soy sauce production

4. Conclusion

The study shows the water footprint of soy sauce production in Grobogan Regency. It has show the volume of freshwater use per average soy sauce product yield. By calculating the water use over the whole production process including green water, blue water and gray water, so that awareness is given to the soy sauce industry to highlighting the water intensive stages that serving as a basic for formulating strategies in order to reduce water use. Water footprint assessment identified where the water was used in the soy sauce production and what type of water used.

The water footprint of soy sauce production reached 1.986,35 L/kg with fraction of green water (78,43%), blue water (21,4%) and gray water (0,17%). Green water component account for more than 50% of the total water footprint for soy sauce production in Grobogan Regency, indicating that these crops are more reliant on natural rain water

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