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Review

Water Footprint of crop productions: A review

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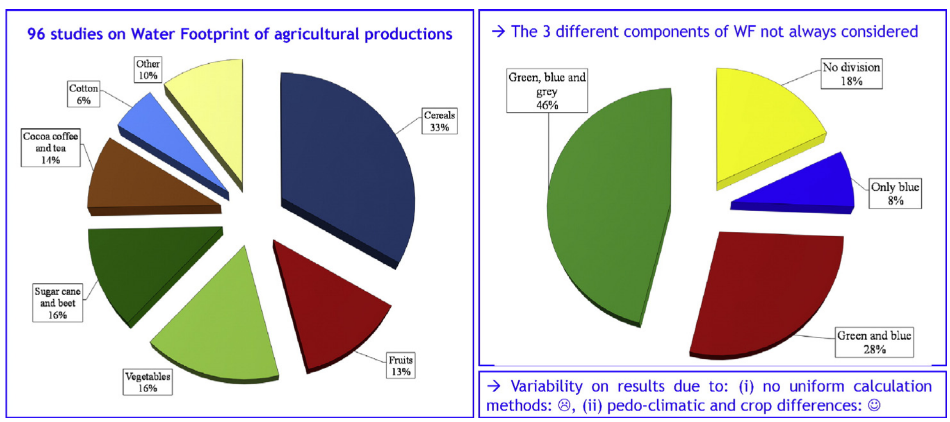
HIGHLIGHTS

- A literature review was completed on Water Footprint indicator.
- An advancement development of literature was followed.
- World and local studies with focus on agricultural productions were analysed.
- In 61% of studies a specific geographical area was considered.
- In 45% of studies grey water was assessed while in 18% only a total number was given.

GRAPHICAL ABSTRACT



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ABSTRACT

Water Footprint is an indicator recently developed with the goal of quantifying the virtual content of water in products and/or services. It can also be used to identify the worldwide virtual water trade. Water Footprint is composed of three parts (green, blue and grey waters) that make the assessment complete in accordance with the Water Footprint Network and with the recent ISO14046.

The importance of Water Footprint is linked to the need of taking consciousness about water content in products and services and of the achievable changes in productions, diets and market trades. In this study, a literature review has been completed on Water Footprint of agricultural productions. In particular, the focus was paid on crops for the production of food and bioenergy.

From the review, the development of the Water Footprint concept emerged: in early studies the main goal was to assess products' water trade on a global scale, while in the subsequent years, the goal was the rigorous quantification of the three components for specific crops and in specific geographical areas. In the most recent assessments, similarities about the methodology and the employed tools emerged.

For 96 scientific articles on Water Footprint indicator of agricultural productions, this literature review reports the main results and analyses weaknesses and strengths. Seventy-eight percent of studies aimed to quantify Water Footprint, while the remaining 22% analysed methodology, uncertainty, future trends and comparisons with other footprints. It emerged that most studies that quantified Water Footprint concerned cereals (33%), among which maize and wheat were the most investigated crops. In 46% of studies all the three components were assessed, while in 18% no indication about the subdivision was given; in the remaining 37%, only blue or green and blue components were quantified.

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Contents

1. Introduction

During the last years, high attention has started being paid on environmental analyses with multiple goals: quantifying environmental impacts of processes, identifying environmental hotspots and suggesting mitigation strategies to reduce the impact of anthropogenic productions on the environment.

Human impact on the environment has grown much more and faster than what was expected, and humanity consumes more resources (e.g., land, water) than what Earth is capable of regenerating (Galli et al., 2012; Hoekstra and Chapagain, 2008; IPCC, 2006). Immediate policies to limit the drawbacks and to restore a sustainable condition are needed, and stakeholders and decision makers are aware of this (Roelich et al., 2014; Wang et al., 2015). For example, more than 20% of Italian agricultural area is irrigated, but climate change is exposing the country to a deep change in precipitation trends (Natali et al., 2009). Thus the sector must adapt.

The most spread methodology to quantify the environmental impacts is the Life Cycle Assessment — LCA (ISO 14040, 2006) (Bacenetti et al., 2015a, 2015b; Bacenetti and Fusi, 2015; González-García et al., 2012; Ingrao et al., 2015a, 2015b; Rinaldi et al., 2014). Indicators such as Carbon Footprint, Ecological Footprint and Water Footprint have also developed to fulfil similar evaluations (Galli et al., 2012; Steen-Olsen et al., 2012) for specific environmental issues.

With regard to water, all over the world, the freshwater natural resource is getting precious, since scarcity and overexploitation are undeniable issues (Van Oel and Hoekstra, 2012; Zhang et al., 2013) that lead to social, environmental and economic problems (Ridoutt and Pfister, 2010). In more details, freshwater is a resource necessary not only for human and health concerns but also for productions and industrial processes; hence, its use must be distributed among different opportunities (e.g., Cazcarro et al., 2014; Lee, 2015). Because water is becoming scarcer and scarcer, mitigation strategies and a conscious use are key concerns.

In this context, a methodology was developed to analyse and quantify water use and to better understand the linkages between humanity's productive activities and the growing pressure on water directly and indirectly embedded in products and services (Hoekstra, 2010). This methodology is the “Water Footprint” (WF) and was introduced by Hoekstra and Hung (2002). Since then several studies have been carried out considering both the agricultural field production and the processing phases till the reach of consumers and waste disposal. Moreover, legislation to safeguard water has spread. WF was recently standardised by the ISO Standard 14,046 (ISO, 2014) and the EU defined the Water Framework Directive (WFD) (European Commission, 2010) to improve water quality, scarcity and productivity across Member States.

The aim of this paper is to carry out a literature review on the Water Footprint (WF) indicator, with focus on the WF of agricultural productions, and in particular of crops for food and energy purposes. The reason is that agricultural productions are the major responsible for water use and water stress (Hoekstra and Hung, 2002; Ridoutt and Pfister, 2010) and the availability of many studies inserted in different productive contexts needs clarity. In addition, even if WF has spread only in recent times, the concept upon which it grounds has gone through a constant progress; therefore, it is interesting to understand the aim and the development steps to comprehend its evolution.

The questions to which the present review aims to answer are:

(i) How did the concept of Water Footprint develop in the 10–15 years in which it started being used worldwide?
(ii) Is it a reliable indicator? Are there any limits to its application?
(iii) What are the limits of studies carried out till present?
(iv) How can its application and reliability be improved?

The outcomes of the present review can be helpful for policy makers and stakeholders in particular, in order to understand the usefulness of WF indicator and to develop policies and/or global decisions able to improve the freshwater use and to draft legislation on its sustainable consumption.

The paper is divided in five parts. In Section 2, WF approach and the definition of its components is given and in Section 3 the literature review of selected products is fulfilled. Finally, in Sections 4 and 5 WF limits and recommendations are analysed and conclusions are drawn.

2. Methods

2.1. Water Footprint definition

The concept of Virtual Water (VW) and the indicator of Water Footprint (WF) were developed over many years, and defined concepts and idea already clear in the 1990s. VW was first introduced by Allan (1997, 1998, 2001). It was defined as the water volume required to produce products or services during the production processes and not only the volume directly present in products (it is a “virtual” content). The concept got more precise and practical with Hoekstra and Hung (2002), Chapagain and Hoekstra (2003b), Hoekstra (2003), Oki et al. (2003), Zimmer and Renault (2003) and