Journal of Cleaner Production 87 (2015) 666–674

Contents lists available at ScienceDirect

Journal of Cleaner Production

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

Comparing local and global water scarcity information in determining the water scarcity footprint of potato cultivation in Great Britain

T.M. Hess [a,*], A.T. Lennard [a,b], A. Daccache [a]

[a] Cranfield Water Science Institute, Cranfield University, Bedfordshire MK43 0AL, UK
[b] School of Environmental Sciences, University of Liverpool, Liverpool L69 7ZT, UK

ARTICLE INFO

Article history:
Received 15 May 2014
Received in revised form
29 September 2014
Accepted 24 October 2014
Available online 31 October 2014

Keywords:
Blue water
Impact assessment
Potato
Water footprint
Water risk
Water scarcity

ABSTRACT

In Great Britain (GB), more water is abstracted from surface and groundwater resources for the irrigation of potatoes than for any other crop. This abstraction occurs in the driest catchments and at the driest times of year, and therefore has the potential to exacerbate pressures on water supplies and aquatic ecology. The water scarcity footprint is a metric that describes the impact of an activity on the water scarcity in a locality. In this paper, we use the concept to estimate the volume of blue water consumed in potato production in an average year for the potato growing regions of GB. This has been contextualised by weighting the water consumption according to a global map of water scarcity (Ridoutt and Pfister, 2010) and a local assessment of water resource availability (Environment Agency, 2002). Average blue water consumption for the cultivation of potatoes in Great Britain is 61 Mm^3 per year, equivalent to 11 m^3/t. The global map of water scarcity was shown to be insufficient for identifying "hotspots", however the combination of water consumption estimates and local water resource availability assessments allowed the identification of catchments where potato production may be contributing to water scarcity. The East of England was identified as a "hotspot" of water related risk for potato production due to the large area of production, high irrigation need and the fact that many of the catchments are already over abstracted or over licenced.

© 2014 Elsevier Ltd. All rights reserved.

1. Introduction

Global supplies of freshwater are increasingly under pressure. Population growth, continuing industrialisation and the need for increased agricultural production all exacerbate stresses on this vital resource. The World Economic Forum identified water crises, resulting from mismanagement and increased competition, as the third highest risk of global concern (WEF, 2014). Given that agriculture accounts for >70% of global freshwater withdrawals, (Comprehensive Assessment of Water Management in Agriculture (2007)) the sustainable use of freshwater for food production is an increasing concern for governments, businesses and society. Water use for agriculture has the potential to cause environmental harm through the exploitation and potential pollution of water resources (Hess et al., 2014) whilst the security of water resources creates a risk for food supply chains (Kelly, 2014). It is therefore critical to examine water use, water availability and associated environmental impacts of agriculture to aid understanding for current and future resource management and to assess water related risk in food supply chains.

The term 'water footprint' was introduced by Hoekstra and Hung (2002) as an analogy to the 'ecological footprint' developed by Wackernagel and Rees (1996) and built on the concept of virtual water proposed by Allan (1998). It was defined as the life-cycle water consumption of a commodity or product, and was an indicator of the human appropriation of water associated with production. The concept has been applied to a range of commodities and products - for example, cotton (Chapagain et al., 2006); tea and coffee (Chapagain and Hoekstra, 2007); bio-energy (Gerbens-Leenes et al., 2009); food-waste (Ridoutt et al. 2010); and wheat (Mekonnen and Hoekstra, 2010). Whilst this provides an indication of the human appropriation of the global water resources, it reveals little on the impact on the environment or other water users, or the risk to agriculture associated with water availability. During the early phases of water footprinting, impact assessments were largely disregarded (Hoekstra et al., 2011) and water footprints based on total volume of water consumed have been criticised for being 'misleading and confusing' (Ridoutt and Pfister, 2010:117), lacking environmental relevance (Ridoutt and Huang, 2012) and

* Corresponding author. Tel.: +44 1234 750111.
E-mail address: t.hess@cranfield.ac.uk (T.M. Hess).

http://dx.doi.org/10.1016/j.jclepro.2014.10.075
0959-6526/© 2014 Elsevier Ltd. All rights reserved.

disregarding the impacts of water resources on livelihoods, other natural resources, or environmental amenities (Wilchens, 2011).

It is common to differentiate between water that is withdrawn from surface or groundwater resources (blue water) and rainfall that is used at the point where it falls (green water) (Falkenmark, 1995). This differentiation is important as, generally, green water has little, or no, alternative use except for environmental uses, whereas blue water use is in competition with other industrial, domestic and environmental uses. However, the blue water consumed in the production of a commodity may have come from different sources (rivers, groundwater and reservoirs); in different locations (regions, countries); and been withdrawn at different times (seasons). A total blue water consumption estimate would not distinguish between these different withdrawals and Pfister and Hellweg (2009) perceived the blue water footprint as simply a water "shoesize".

In order to evaluate the impact of production on water scarcity, the blue water consumption must be put into the context of the water resources at the place of withdrawal. For example, 100 m^3 of water taken from a water-stressed catchment is likely to have a higher impact on other water uses than an equivalent volume taken from a catchment where water is abundant. Reducing blue water consumption in areas of water scarcity will release water for other uses and understanding the volumes and sources of water consumed in the production of goods in relation to local water scarcity can help businesses mitigate the risks presented by water scarcity (Hoekstra, 2014).

Qualitative and quantitative water footprint impact assessment methods have been developed using various water stress or water scarcity indices to identify the vulnerability of the water sources where withdrawal is located. In a study of the water footprint of the Netherlands, van Oel et al. (2008) identified 'hotspots' where the volumetric water footprints were large and water scarcity was high. This comparison showed that the biggest impact of Dutch consumption was not necessarily in those countries where the water footprint was largest.

Pfister and Hellweg (2009) suggested that weighting is required to express volumes of water consumed in terms of potential impact on water scarcity and several studies have developed impact-orientated water footprints as part of Life Cycle Analysis (LCA) studies (Berger and Finkbeiner, 2010). Many indicators have been used to characterise volumetric water footprints based on human water requirements, water resources or environmental requirements (see Kounina et al., 2013; Brown and Matlock, 2011; White, 2012; UNEP, 2012; for reviews) and Jeswani and Azapagic (2011) showed how using different methods results in a huge variation in the interpretation of water footprints. Milà i Canals et al. (2009) developed Life Cycle Impact Assessment (LCIA) characterisation factors based on the environmental water stress indicator (EWSI) (Smakhtin et al., 2004) to estimate how consumptive water use can impact water availability and affect ecosystems. The freshwater ecosystem impact (FEI) is a measure of 'ecosystem-equivalent' water and is expressed in ecosystem equivalent volumes (Milà i Canals et al., 2009). The withdrawal-to-availability (WTA) ratio (Alcamo et al., 2003a) is a representative proxy for water scarcity (Kounina et al., 2013) and many studies (e.g. Ercin et al., 2011; Jefferies et al., 2012; Gerbens-Leenes and Hoekstra, 2012) have used global maps of WTA to compare alternative locations.

Ridoutt and Pfister (2010) developed a Water Stress Index (WSI) calculated using the WTA ratio from the Water GAP 2 model (Alcamo et al., 2003b). The WSI was calculated from the WTA ratio corrected by a variation factor that considers the variability of annual and monthly precipitation and how strongly flows are regulated in the basin (Pfister et al., 2009). The volume of blue water consumed was weighted by the WSI value of the basin where the consumption was located to produce an impact-orientated water footprint. The weighted consumption can also be normalised by the global average WSI (e.g. Ridoutt et al., 2010; De Boer et al., 2013) or the average WSI for the country of production (Page et al., 2012) to express the consumption as an H_2O equivalent (H_2Oeq) of freshwater water use at a global or national level respectively. A water footprint that considers only the impact of water consumption on water scarcity is known as a "water scarcity footprint" (ISO, 2014).

Although agriculture accounts for <2% of total freshwater withdrawals in Great Britain (GB, i.e., England, Wales & Scotland), irrigation potentially has a large impact on water resources. By definition, its use is restricted to a few months and the driest years when resources are most constrained; it is concentrated in the driest areas of the country; and it is a consumptive use – that is, water is not returned to the environment in the short term. As a result, irrigation can be the largest abstractor in some catchments in some dry summers. More water is used for the irrigation of potatoes than any other crop in GB and potatoes account for 43% of the total irrigated area and 54% of irrigation water use in England and Wales[1] (Defra, 2011). Potato production has the potential to contribute to local water scarcity more than any other crop. Nationally, 127,000 ha are planted with potatoes across mainland GB, with an average (2004–2013) annual production of 5.7 Mt and a yield of 44.6 t/ha (Potato Council, 2014). Although potatoes can be grown without irrigation in many regions of GB, supplementary irrigation is often used to ensure crop yield and particularly quality. As yield is a function of many agronomic factors including planting date, variety, soil type and location and there is no significant difference in the average yield between irrigated and non-irrigated potatoes in GB.

This paper aims to estimate the potential impact of potato production on water scarcity in GB and to identify the regions where water related risks are greatest. It will determine the total water consumption of ware potato cultivation in GB and compare impact assessment based on global water scarcity maps with local water resource assessment in order to test whether global water scarcity maps can adequately capture local water resource vulnerability.

2. Material and methods

2.1. Water consumption

Although potatoes are grown in all regions of GB, cultivation is concentrated in particular areas where soil and climate conditions are favourable (Daccache et al., 2012). Thirteen locations were identified in the areas where potato cultivation is concentrated (Fig. 1) and crop evapotranspiration for potatoes was estimated using the CROPWAT 8.0 software (FAO, 2009) and average (1981–2010) monthly climate data (Met Office, 2012) (Table 1). Average annual blue (BWC) and green (GWC) water consumption from evapotranspiration (m^3/t) were estimated for each location using the methods presented by Hoekstra et al. (2011) and recommended by Hess (2010) for temperate climates. Main crop potatoes in the UK are usually planted from mid-March to mid-May and are harvested from mid-August to mid-November; therefore a planting date of 1st April has been selected with a season length of 175 days. Crop development stages and crop parameters were estimated from FAO (2012). The dominant soil types across all the growing sites are either loamy, sandy loams or sandy soils,

[1] Comparable figures are not available for Scotland.

Download English Version:

https://daneshyari.com/en/article/8105357

Download Persian Version:

https://daneshyari.com/article/8105357

Daneshyari.com