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The impact of healthier dietary scenarios on the global blue water scarcity footprint of food consumption in the UK

Tim Hess [a,*], Ulrika Andersson [a], Carlos Mena [b], Adrian Williams [a]

[a] School of Energy, Environment and Agrifood, Cranfield University, Cranfield, Bedford MK43 0AL, UK
[b] School of Management, Cranfield University, Cranfield, Bedford MK43 0AL, UK

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ABSTRACT

Large quantities of water are required to produce the food for a nation, some of which is derived within the country and some associated with imported food commodities. In this study, we consider the spatially explicit potential impact of alternative healthier eating scenarios for the UK on global blue water scarcity using the concept of a water scarcity footprint. The water required to produce the food consumed by the UK was estimated at 52.6 Gm^3/y of which 93% is from rainfall at the point where it falls and 7% is "blue" water withdrawn from surface and ground water resources. Five alternative healthier diets were considered and the impact on the blue water scarcity footprint was modest (ranging from −3% to +2% compared to baseline). However more significant impacts were projected on the geographical distribution of the blue water scarcity footprint. This study has shown that if current trade patterns continue, policies to promote healthier eating in the UK may contribute to increased blue water scarcity at home and in other parts of the world. The use of virtual water estimates and global datasets of water scarcity can help to understand the potential environmental impacts of alternative diets.

Introduction

In a time when the obese and undernourished are living side by side, the world is faced with the long-term challenge to provide the growing population with healthy and sustainable food products. In the UK, the number of overweight and obese men, women and children is currently increasing and 61% of the adults in England are overweight or obese (HSCIC, 2013; DH, 2011). This trend is driven by a low consumption of fruit and vegetables, a high consumption of energy dense foods and drinks, in combination with a low activity level (HSCIC, 2013; Defra, 2011). From a governmental perspective, this development has both economic and public health implications since it is linked with lifestyle related health problems such as diabetes and heart disease.

Dietary advice directed towards healthy eating for populations was pioneered by the United States Department of Agriculture (USDA) in the beginning of the 1900's (Falbe and Nestle, 2008). Within the UK, the four administrative areas have developed their own nutritional strategies and each country has several (Caraher et al., 2009). *Health of the Nation* (DH, 1992, cited in Caraher et al. (2009)) was the first strategy in England dealing with healthy consumption. The aim was to reduce the proportion of energy derived from saturated fatty acids and total fat in order to reduce the prevalence of obesity (DH, 1992, cited in Harland et al. (2012)). The *eatwell plate* was constructed to encourage the population to eat according to the target consumption of major food groups set out in this strategy document (Harland et al., 2012; NHS, 2013).

The UK government has shown interest in the environmental aspects of UK diet since the early 2000s and several projects have been launched to evaluate the environmental impacts of the UK diet. *Food Matters* (Cabinet Office, 2008) set out to understand the link between the environment, health, nutrition and behavioural aspects of food consumption, which resulted in the strategy *Food 2030* (Defra, 2010a). One of the priority areas was to define and inform the population about what is a healthy and sustainable diet. Even though the explicit goal in the strategy was to promote sustainable eating, no definition was suggested. Evidence from various aspects such as greenhouse gas emissions and water use relating to food consumption is currently gathered, but the full picture is yet to be understood (MacDiarmid, 2013). Since the freshwater resources of the world are currently under pressure, water consumption is an important area to address in order to achieve a sustainable diet (FAO, 2011; MEA, 2005).

Water consumed during the production of a commodity or a service is known as the virtual, or embedded, water (VW) content

* Corresponding author.
E-mail address: t.hess@cranfield.ac.uk (T. Hess).

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of this product (Allan, 1996). It represents the total amount of freshwater consumed, expressed as volume per unit commodity (e.g. m^3/t). The virtual water concept was developed to draw attention to the link between trade, food and water (Allan, 2003). This is achieved by quantifying the VW flows for nations by the use of international trade statistics, consumption levels and estimates of the VW content of different products.

The VW used to produce the goods and services consumed by a nation can be divided into the internal VW (water used from domestic water resources) and the external VW (water used in other countries to produce imported goods) (Hoekstra and Chapagain, 2007). This division enables an analysis of the spatial distribution of a nation's impact on water resources and forms the baseline for initiatives dealing with water management on a global scale.

Depending on food consumption habits and sourcing, national and individual diets have dissimilar impacts on the world's water resources. A number of studies have compared the virtual water consumption of alternative diets at the scale of the individual.[1] Due to the high virtual water consumption associated with meat production (Gerbens-Leenes et al., 2013) many have compared the impacts of reducing, or removing, meat from the diet. These have all shown that considerably less water is required to support a vegetarian diet than a non-vegetarian diet (Table 1). Vanham et al. (2013a,b) estimated the impact of a change to a more healthy diet on virtual water consumption. They showed for the EU28 that a diet following the German Nutrition Society (DGE) recommendations requires 77% of the virtual water of the reference diet, although, a "healthy" diet (based on regional food based dietary guidelines) for the UK was estimated to require 97% of the virtual water of the reference diet (Vanham and Bidoglio, 2014).

The VW can be partitioned into blue (VWb) and green water (VWg) components that are differentiated by the source (Falkenmark and Rockström, 2004; Mekonnen and Hoekstra, 2011). Blue water is taken from ground or surface water while green water refers to rainwater used by the vegetation at the point where it falls. In the case of agricultural production, blue water is mainly used for irrigating crops and supporting livestock. Green water is only accessible through access to, and occupation of, land (Ridoutt and Pfister, 2010) and as such, has a low opportunity cost since it does not have competing uses. Only if a change of land use results in a change in annual evapotranspiration or runoff generation, does it impact local water scarcity. Blue water, on the other hand, is associated with a high opportunity cost as upstream uses impact the availability of water for other users or the environment downstream. Several studies (e.g. Chapagain and Orr, 2008; Yu et al., 2010; Hunt et al., 2014) have demonstrate the reliance of UK food consumption on global water. Hunt et al. (2014) for example, identified the importance of bovine meat imports from Ireland in the total VW of the UK. However, as Irish beef is mainly raised on rain-fed grazing and feeds (Hess et al., 2012) consumption of Irish beef in the UK diet contributes little to blue water scarcity in Ireland. Therefore, VWb is a more meaningful indicator of the potential contribution of consumption to blue water scarcity (Ridoutt and Pfister, 2010).

Estimates of VWb are very sensitive to assumptions about the composition of the diet. Vanham et al. (2013a,b) estimated a reduction in VWb of 31% for a vegetarian diet compared to the reference EU diet, assuming the meat was replaced by pulses and soybeans. In contrast, Meier and Christen (2013) estimated increases of 7% for a vegan diet and 84% for a vegetarian diet compared to the baseline German consumption, mainly due to increased consumption of fruit, nuts and seeds.

[1] As this paper is concerned with physical water scarcity, virtual water required to dilute pollutants generated in production ("grey virtual water") has been excluded from these estimates.

Table 1
Relative virtual water consumption of vegetarian diets compared to reference, non-vegetarian diets.

Reference diet	Vegetarian diet (%)	Source
California	50	Renault and Wallender (2000)
California	34	Marlow et al. (2009)
Europe[a]	66	After Vanham and Bidoglio (2014)
EU28	62	After Vanham et al. (2013b)
EU North	67	Vanham et al. (2013a)

[a] Weighted average of 22 European river basins.

VWb alone does not provide information on the impact of water consumption on water scarcity, unless it is related to blue water scarcity in the region of production. The concept of water footprinting has been developed to account for the environmental impacts of water consumption (Pfister et al., 2009; Milà et al., 2009). This has been further revised to take blue water scarcity in the place of production into account by weighting the VWb use according to local characterisation factors (Pfister et al., 2009; Ridoutt and Pfister, 2010; Hanafiah et al., 2011). A water footprint assessment in which environmental impacts related solely to water quantity can be referred to as a water scarcity footprint (WSF) (ISO, 2014). Comparing the WSF of alternative dietary scenarios provides an indication of the potential contribution to global blue water scarcity and is a measure of one aspect of the sustainability of each.

This study aims to assess the effect of five dietary scenarios – designed to promote healthier and more sustainable eating – on the blue water scarcity footprint of UK food consumption. The objectives are to estimate the total blue water consumed in the production of food commodities consumed in the UK; the contribution, and geographical concentration, to global blue water scarcity; and the potential impact of alternative healthy eating scenarios on global blue water scarcity.

Methodology

The method for estimating water scarcity footprint of consumption by source for alternative dietary scenarios is shown in Fig. 1.

UK consumption and import data

Estimates of the net domestic and overseas production of food commodities required to support UK food consumption were taken from Audsley et al. (2009) (Appendix A). These estimates are for the least processed commodity and take account of the loss in weight during production and wastage in the food supply chain. So, for example, 24.4 Mt of milk must be produced in order to support the annual UK consumption of dairy products (including cheese, cream, yoghurt, fresh and powdered milk). UK trade data (HMRC, 2013) for arrival (movement of goods within the EU) and imports (non-EU goods movement) were used to map the origin of the imported commodities for 2012. In cases where the product was not produced in the country of export (e.g., bananas imported from the Netherlands), import statistics from the International Trade Centre (INTRACEN, 2013) for the exporting country were used to estimate the origin of the commodity. Data for countries with $\geqslant$3% share of the import to the UK have been used and the volume for each commodity was later adjusted to account for the remaining proportion. By using this bottom-up approach it was possible to calculate the imported proportion from each country per commodity and weight the impact on the total WSF of these countries.