



The water footprint of the EU for different diets

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ABSTRACT

In this paper, the EU28 (EU27 and Croatia) water footprint of consumption (WF_{cons}) for different diets is analysed: the current diet (REF, period 1996–2005), a healthy diet (DGE), a vegetarian (VEG) and combined (COM) diet. By far the largest fraction of the total WF_{cons} (4815 lcd) relates to the consumption of edible agricultural goods (84%). The average EU28 diet is characterised by a too high energy intake and a too high ratio of animal to vegetal protein intake. For a healthy diet, the intake of some product groups should be reduced (sugar, crop oils, meat and animal fats) and of other product groups increased (vegetables and fruit). Especially the consumption of animal products accounts for high WF amounts. The three alternative diets result in a substantial reduction (–974 lcd or –23% for DGE, –1292 lcd or –30% for COM, –1611 lcd or –38% for VEG) of the WF_{cons} for agricultural products with respect to the existing situation (REF, 4265 lcd). The reduction in meat intake contributes most to the WF reduction. Each of the specific WF components (green, blue and grey) shows a reduction similar to the observed reduction in the total WF_{cons} . Regarding the total WF_{cons} (green, blue and grey WF_{cons}) as well as the WF_{cons} without the grey WF component (green + blue WF_{cons}) for agricultural products, the EU28 shifts from net virtual water (VW) importer for the REF and DGE diets to net exporter for the COM and VEG diets.

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1. Introduction

One of the key challenges of this century will be to provide a healthy diet to a growing world population equitably (by eradicating hunger and overweight/obesity) and sustainably. Today, hunger and famine coexist with overconsumption and associated health problems. By 2050, a projected 9.3 billion people need to be fed, which can only be addressed by a combination of improvements in agricultural production (e.g. closing the yield gap on existing agricultural lands by means of sustainable intensification (Foley et al., 2011; Beddington et al., 2012)) and changes in consumption behaviour. The EU28 (EU27 and Croatia) is an important global player regarding agricultural production and consumption. However, the EU28 as an entity is characterised by food overconsumption with a too high proportion of animal products in the current average diet (Westhoek et al., 2011). Due to the numerous negative impacts of an intensive livestock production system on the planet's resources and ecosystems as well as the growing demands of non-western countries for animal products, moving to

a more resource-efficient (and healthier) vegetable-rich diet in the EU28 is a necessity (Vanham and Bidoglio, 2013).

In order to produce agricultural products, the two elements land and water are essential. The water footprint (WF) and virtual water (VW) concepts provide the opportunity to link the use of water resources to the consumption of goods. These concepts have been brought into water management science in order to show the importance of consumption patterns and global dimensions in good water governance (Galli et al., 2012; Hoekstra and Chapagain, 2008). A review of the methodologies and applicability of these concepts for the EU28 can be found in (Vanham and Bidoglio, 2013). A global WF assessment was carried out by (Hoekstra and Mekonnen, 2012). Detailed national WF assessments have been done for several European countries, e.g. (Aldaya et al., 2008; Van Oel et al., 2009), and countries outside Europe, e.g. (Bulsink et al., 2010; Verma et al., 2009). Detailed WF analyses on a global level have been conducted for selected products, e.g. wheat (Mekonnen and Hoekstra, 2010) and rice (Chapagain and Hoekstra, 2011). Also for energy from biomass (bio-fuel) WF analyses have been carried out, e.g. (Gerbens-Leenes et al., 2012).

In this paper the WF of the EU28 is assessed for the current diet (reference period 1996–2005) as well as different scenarios: a healthy diet (as recommended by the German nutrition society), a vegetarian diet (including milk and milk products) and a combined diet between the latter two.

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2. Methodology

Regarding definitions of the WF, the Water Footprint Network's Global Water Footprint Standard is used (Hoekstra et al., 2011). An important distinction needs to be made between the WF of production (WF_{prod}) and WF of consumption (WF_{cons}). The EU28 WF_{prod} is the sum of water use of domestic (EU28) water resources. The EU28 WF_{cons} is defined as the total volume of freshwater that is used to produce the goods consumed by its inhabitants. It is the sum of direct and indirect water use of domestic and foreign water resources through domestic consumption. A balance between the two is reached by virtual water flows (import and export) (Vanham and Bidoglio, 2013). The WF consists of three (green, blue and grey water) components. The inclusion of a green WF component agrees with the fact that different authors (e.g. Falkenmark and Lannerstad, 2007; Falkenmark and Rockström, 2006; Hoff et al., 2010; Vanham, 2012) recommend to include green water in water management studies. Traditional water use statistics only account for blue water.

The geographical WF_{prod} (in m^3/yr) is the following (Hoekstra et al., 2011):

$$WF_{\text{prod}} = \sum_q WF_{\text{proc}}[q] \quad (1)$$

where $WF_{\text{proc}}[q]$ (in m^3/yr) refers to the water footprint of process q within the region that consumes or pollutes water.

The WF_{cons} (in m^3/yr), as calculated with the bottom-up approach (based upon consumption data), is the following (Hoekstra et al., 2011):

$$WF_{\text{cons}} = WF_{\text{cons,dir}} + WF_{\text{cons,indir}}(\text{agricultural commodities}) + WF_{\text{cons,indir}}(\text{industrial commodities}) \quad (2)$$

$$\text{with } WF_{\text{cons,indir}}(\text{agricultural commodities}) = \sum_p (C[p] \times WF_{\text{prod}}^*[p]) \quad (3)$$

where $C[p]$ is the consumption of agricultural product p by consumers within the EU28 (ton/yr) and $WF_{\text{prod}}^*[p]$ the average water footprint of this product (m^3/ton). The set of products considered refers to the full range of final agricultural goods.

For the assessment, which is primarily a statistical data analysis, the following data sources are used:

- Data on WFs (period 1996–2005) of specific products from (Mekonnen and Hoekstra, 2012; Mekonnen and Hoekstra, 2011)
- Data on food consumption (period 1996–2005) from the Food Balance Sheets (FBS) of the FAO (FAOSTAT, 2012)
- Data and specifications to convert FBS food consumption data into actual food intake amounts from different sources (Westhoek et al., 2011; EC, 2010; Zessner et al., 2011)

In (Mekonnen and Hoekstra, 2012; Mekonnen and Hoekstra, 2011), separate amounts for the green, blue and grey WF of agricultural products are listed. The period for which the analyses were made is 1996–2005. Therefore all analyses within this paper relate to this period. Within the paper different units for water use will be listed: km^3 and lcd (l per capita per day).

Data on food consumption were obtained from the Food Balance Sheets (FBS) of the FAO (FAOSTAT, 2012). These are data on food supply (tonnes and $\text{kg}/\text{cap}/\text{yr}$), i.e. food reaching the consumer. They are on an "as purchased" basis, i.e. as the food leaves the retail shop or otherwise enters the household. The quantities are provided on the basis of 'primary equivalents' (FAO, 2001). For example, bread is converted into wheat equivalent. Total energy,

Table 1
Specification of the different diets.

Diet	Specification
Current or reference diet (REF)	The average EU28 diet for the reference period 1996–2005
Healthy diet (DGE)	Based upon the dietary recommendations issued by the <i>Deutsche Gesellschaft für Ernährung (DGE)</i> – German nutrition society
Vegetarian diet (VEG)	Same as the healthy diet, but all meat products are substituted by pulses and oilcrops. Dairy products are still of animal origin
Combination diet (COM)	Diet between a healthy and vegetarian diet: half of the meat products is replaced by pulses and oilcrops

fat and protein contents are computed from the original processed commodities, aggregated and presented alongside primary equivalents for the edible food parts (Srinivasan et al., 2006).

Table 1 gives an overview of the different assessed diets. The specification of these diets is based upon food-based dietary guidelines (Elmadfa and Freisling, 2007; Elmadfa, 2009). In Europe, many different reference values exist, some on a national basis and some for a group of countries like those of the German nutrition society (DGE) (Elmadfa, 2009; WHO, 2003). The latter is used within the German-speaking countries, e.g. resulting in the Swiss food pyramid (Walter et al., 2007). These guidelines are applied also in Hungary, Slovenia and the Czech Republic (Elmadfa, 2009). In this paper, the DGE recommendations for a healthy diet are used. The amounts of fish recommended by the DGE are however substituted by meat. The reason for this is that WF analyses do not account for fish and that a shift from the terrestrial to river, lake and marine systems for human consumption would have dramatic effects on already stressed fish ecosystems. The intake amounts for the DGE diet are based upon (Elmadfa and Freisling, 2007) and (Zessner et al., 2011) and shown in Table 2. Vegetarian diets do not contain meat, poultry or fish; vegan diets further exclude dairy products and eggs (Key et al., 2006). Pesco-vegetarian diets include fish and shellfish. In this paper, a vegetarian diet (VEG) including the consumption of milk and milk products (cheese, butter, yoghurt, etc.) is chosen. This is an assumption made due to the economic and ecological importance of dairy production on the grasslands and meadows of many EU regions. In practice, these products could be substituted by vegetal products (e.g. soy milk). All meat is substituted by the group pulses, nuts and oilcrops, by an increase in the consumption of pulses and soybeans (consumed e.g. in the form of soy burger or tofu). This is a simplification; in practice, meat can of course also be substituted by other protein-rich products like cereals. The combination diet (COM) combines the two latter diets (DGE and VEG).

Important in the assessment is the conversion of food product supply values (as given by the FAO FBS) to actual consumption or intake values (as given in the food-based dietary guidelines). This conversion implies two correction factors as described in (Zessner et al., 2011). The first factor accounts for food components not eaten and product equivalent conversions (e.g. bones in meat – meat supply in the FBS is given in carcass weight – or wheat equivalent to flour of wheat or bread) and the second for food waste (by households but also catering) and feed to domestic animals. For the first factor, specifications from (Westhoek et al., 2011; Zessner et al., 2011) were used. For the second factor, product group specifications from different sources (Westhoek et al., 2011; Zessner et al., 2011; EC, 2010; WRAP, 2009; Gustavsson et al., 2011; Parfitt et al., 2010) were used. The foods that EU28 households waste the most are fresh vegetables and fruit as well as bakery items (product group cereals) such as bread and cakes.

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