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Potential water saving through changes in European diets

D. Vanham [a,*], A.Y. Hoekstra [b], G. Bidoglio [a]

[a] European Commission, Joint Research Centre, Institute for Environment and Sustainability, Via E. Fermi 2749, 21027 Ispra, VA, Italy
[b] Department of Water Engineering and Management, University of Twente, Enschede, The Netherlands

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ABSTRACT

This study quantifies the water footprint of consumption (WF_{cons}) regarding agricultural products for three diets – the current diet (REF), a healthy diet (HEALTHY) and a vegetarian diet (VEG) – for the four EU zones WEST, NORTH, SOUTH and EAST. The WF_{cons} related to the consumption of agricultural products (4265 l per capita per day or lcd) accounts for 89% of the EU's total WF_{cons} (4815 lcd). The effect of diet has therefore an essential impact on the total WF_{cons}. The current zonal WF_{cons} regarding agricultural products is: 5875 lcd (SOUTH), 4053 lcd (EAST), 3761 lcd (WEST) and 3197 lcd (NORTH). These differences are the result of different consumption behaviours as well as different agricultural production methods and conditions. From the perspective of a healthy diet based on regional dietary guidelines, the intake of several product groups (sugar, crop oils, animal fats and meat) should be decreased and increased for others (vegetables, fruit). The WF_{cons} regarding agricultural products for the alternative diets are the following: HEALTHY 4110 lcd (−30%) and VEG 3476 lcd (−41%) for SOUTH; HEALTHY 3606 lcd (−11%) and VEG 2956 lcd (−27%) for EAST; HEALTHY 2766 lcd (−26%) and VEG 2208 lcd (−41%) for WEST; HEALTHY 3091 lcd (−3%) and VEG 2166 lcd (−32%) for NORTH. Both the healthy and vegetarian diets thus result – consistent for all zones – in substantial WF_{cons} reductions. The largest reduction takes place for the vegetarian diet. Indeed, a lot of water can be saved by EU citizens by a change in their diet.

1. Introduction

The water footprint (WF) concept has 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 Mekonnen, 2012). It is an indicator of direct and indirect water use. An assessment of the WF of all nations has recently been conducted (Hoekstra and Mekonnen, 2012). The distinction between the WF of production (WF_{prod}) and the WF of consumption (WF_{cons}) of a geographical region is an important factor in WF analyses (Hoekstra et al., 2011; Vanham and Bidoglio, 2013). The first refers to the total use of domestic water resources within the region for producing goods and services for either domestic consumption or for export. The second refers to the use of domestic and foreign water resources behind all goods and services consumed domestically. A balance between the two is reached by virtual water flows (import and export) (Hoekstra et al., 2011; Vanham and Bidoglio, 2013).

A review on the WF for the EU (Vanham and Bidoglio, 2013) quantifies its WF_{prod} and WF_{cons}. The WF of agricultural products contributes by far the largest fraction of the total EU WF, i.e. 91% (3100 l per capita per day or lcd) of the total WF_{prod} (3420 lcd) and 89% (4265 lcd) of the total WF_{cons} (4815 lcd). A reduction in the consumption of water intensive agricultural products (e.g. animal products, sugar) by EU citizens is identified as a way to reduce the WF_{cons}. In the framework of feeding a growing global population in a sustainable way, with existing agricultural land and water resources, both changes in production processes and consumption behaviour need to take place (Ehrlich and Ehrlich, 2013; Foley et al., 2011; Godfray et al., 2010; Licker et al., 2010; Tilman et al., 2011). Today, hunger and famine coexist with overconsumption and associated health problems (James, 2008). Assessments of the influence of diets on the WF_{cons} have been carried out for China (Liu and Savenije, 2008), Austria (Vanham, 2013a) and the EU as one entity (Vanham et al., 2013).

This study assesses the WF_{cons} for three diets for the four EU regions (Fig. 1). It includes the current diet (REF), a healthy diet (HEALTHY) based on Food-Based Dietary Guidelines (FBDG) and a vegetarian diet (VEG). The study improves on a previous analysis for the EU (Vanham et al., 2013) in a number of aspects. First, the study distinguishes four regions across which diets differ considerably. Within each of the four zones there are similarities regarding the per capita values and characteristics of the WF_{cons} (Vanham and Bidoglio, 2013), due to similar climatological conditions for agricultural production and similar consumption behaviour for important product groups (e.g. meat). Second, for the healthy diet scenario, the study applies recommendations from different regional institutions, assuming that those regional recommendations better link up with regional practices and traditions. It is also anticipated that recommendations on a healthy diet will be better accepted by the

* Corresponding author.
E-mail addresses: davy.vanham@jrc.ec.europa.eu, davy.vanham@yahoo.de (D. Vanham).

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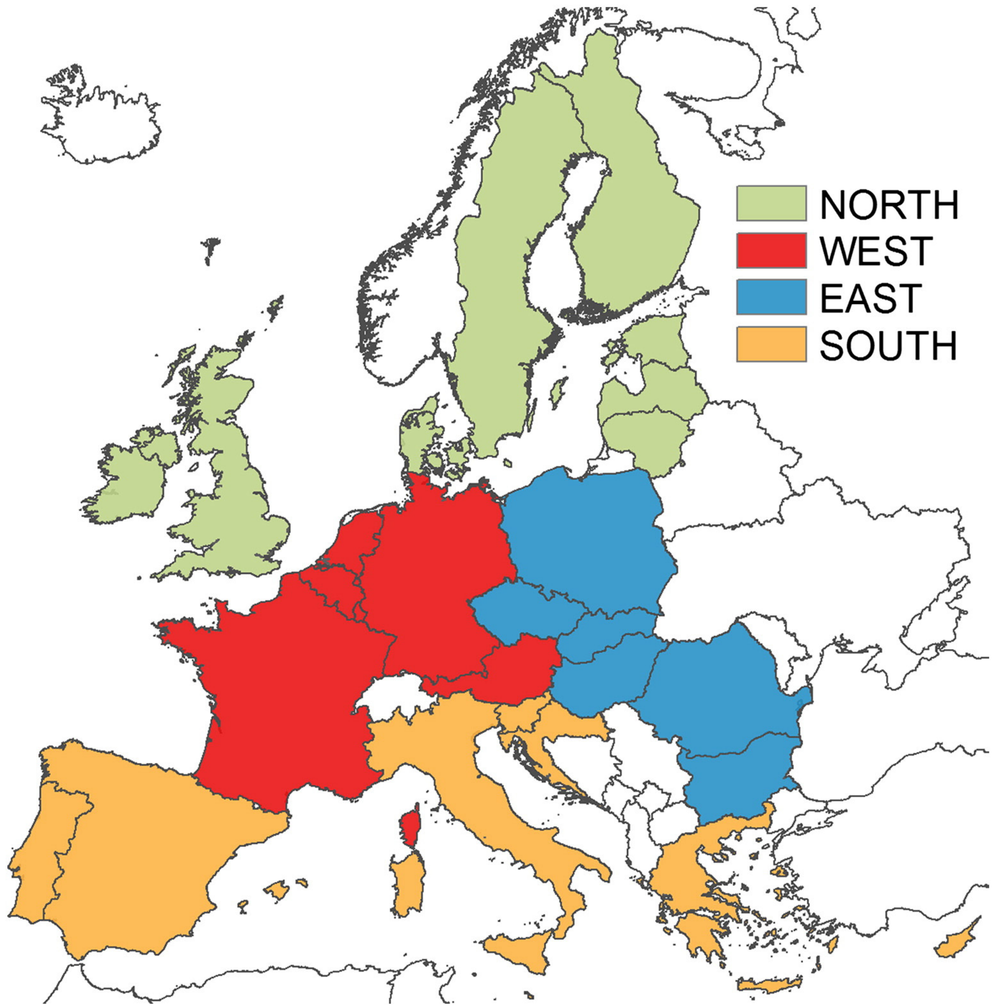

Fig. 1. The four different zones of the EU28 (EU and Croatia). The countries are divided in 4 geographical zones (according to the UN standard country or area codes and geographical regions): NORTH (Ireland, UK, Sweden, Finland, Denmark, Estonia, Latvia, Lithuania), WEST (Germany, Belgium, The Netherlands, Luxembourg, France, Austria), EAST (Poland, Czech Republic, Slovakia, Hungary, Romania, Bulgaria) and SOUTH (Portugal, Spain, Italy, Slovenia, Croatia, Greece, Malta, Cyprus).

population and policy makers within a specific region when these come from regional institutions.

2. Methodology

2.1. Accounting framework

Fig. 2 presents the workflow of the methodology used in this study. We follow the Global Water Footprint Standard developed by the Water Footprint Network (Hoekstra et al., 2011). The total WF consists of a blue, a green and a grey component. Following the definition of Rockström et al. (2009), green water is the soil water held in the unsaturated zone, formed by precipitation and available to plants, while blue water refers to liquid water in rivers, lakes, wetlands and aquifers. Irrigated agriculture receives blue water (from irrigation) as well as green water (from precipitation), while rainfed agriculture only receives green water. The green WF is thus the rainwater consumed by crops. The inclusion of a green WF component agrees with the fact that different authors – e.g. Editorial (2008), Falkenmark and Rockström (2006), Hoff et al. (2010), Vanham (2012), Karimi et al. (2013) – recommend including green water in water management studies. Traditional water use statistics only account for blue water. The blue WF refers to the volume of surface and groundwater consumed to produce a product. The grey WF is the volume of water needed to dilute a certain amount of pollution such that it needs ambient water quality standards (Hoekstra et al., 2011). It is an indicator of the degree of water pollution.

Data on the green, blue and grey water footprint of production (WF_{prod}) and consumption (WF_{cons}) for agricultural products for each EU nation are obtained from Hoekstra and Mekonnen (2012) and Mekonnen and Hoekstra (2011b). The WF_{cons} can be calculated by means of the top-down or bottom-up approach (Hoekstra et al., 2011; Vanham and Bidoglio, 2013). Within the top-down approach, the WF_{cons} equals the WF_{prod} within a nation/region plus the virtual water import (VW_i) minus the virtual water export (VW_e). The bottom-up approach is based upon direct underlying data on consumption. It is calculated by multiplying all agricultural products consumed by the inhabitants of the nation by their respective product water footprint. The WF_{cons} of agricultural products is in this paper calculated with the bottom-up approach, based upon direct underlying national data on consumption from FAO Food Balance Sheets (FBS) (Food and Agriculture Organization, 2013). The bottom-up approach enables also to assess the WF_{cons} in a detailed way per commodity or product category (Hoekstra et al., 2011; Vanham and Bidoglio, 2013). The period for which the analyses were made is 1996–2005. This period is therefore identified as the reference period within this study. Within the paper WF amounts are listed in lcd (l per capita per day).

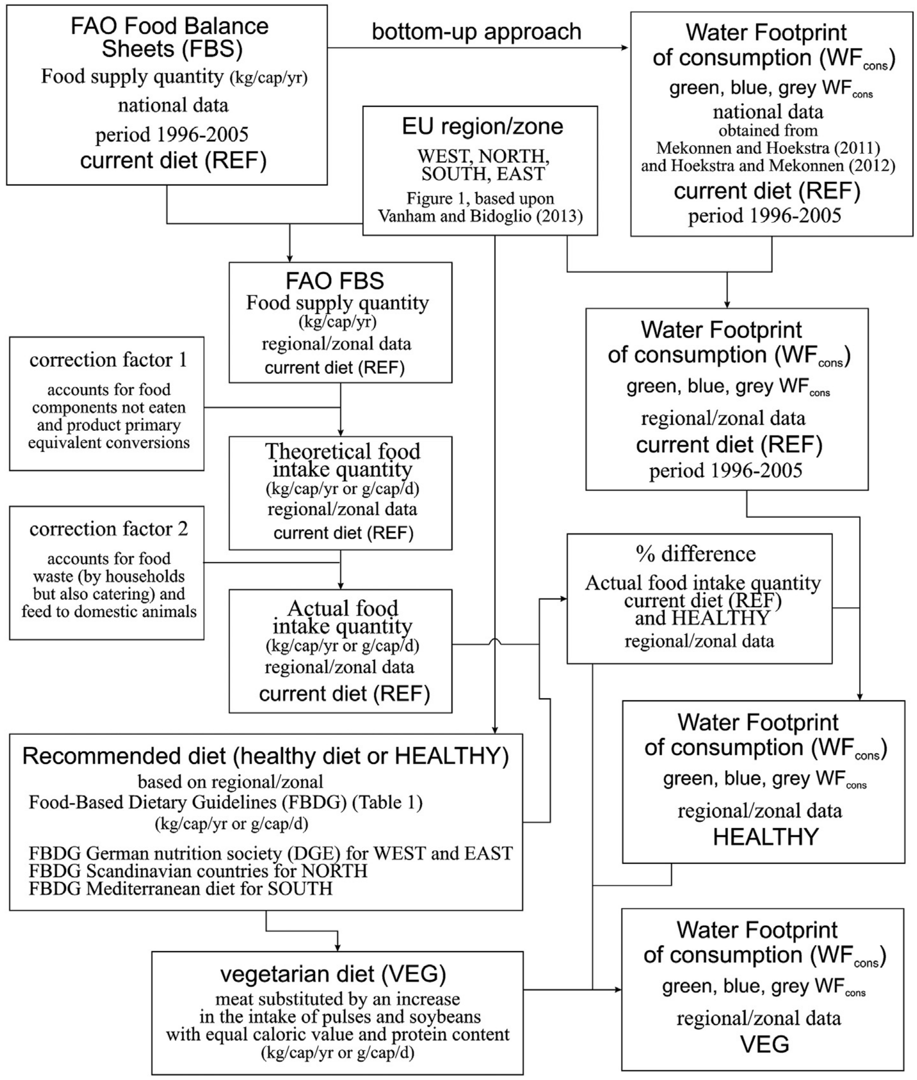

Fig. 2. Workflow of the methodology.

2.2. Diets

In this study three diets – the current diet (REF), a healthy diet (HEALTHY) based on regional Food-Based Dietary Guidelines (FBDG) (Table 1) and a vegetarian diet (VEG) – for the four EU regions are assessed. In Europe, many different FBDG exist, some on a national basis and some for a group of countries like those of the German nutrition society (DGE — Deutsche Gesellschaft für Ernährung) (Elmadfa et al., 2009; WHO, 2003). The latter are used within the German-speaking countries of Europe (Elmadfa and Freisling, 2007; Walter et al., 2007) and also applied in some eastern countries like Hungary and the Czech Republic (Elmadfa et al., 2009). Therefore, for the EU zones WEST and EAST these FBDG were chosen for a healthy diet. The actual product group amounts chosen are based upon Vanham et al. (2013).

For the zone SOUTH the recommendations for a Mediterranean diet were chosen, based upon Willett et al. (1995), Bach-Faig et al. (2011) and Aranceta and Serra-Majem (2001). For the zone NORTH the recommendations of Scandinavian countries were chosen (Astrup et al., 2005; Barbieri and Lindvall, 2005). Some input was taken from the new Nordic diet (Mithril et al., 2013). The recommended intake of meat is high for both Swedish (Barbieri and Lindvall, 2005) and Danish (Mithril et al., 2013) FBDG. In the UK, the National Health Service (NHS, 2013) recommends cutting down red and processed meat to 70 g daily, giving no indication about white meat or fish. In Ireland, the intake of 4 oz (113 g) of meat and fish daily is recommended (Food Safety Authority of Ireland, 2011). Therefore, it is justified to choose a high intake of meat for the zone NORTH. The amounts of fish recommended by the respective FBDG are substituted by meat. The reason for this is that no WF data for fish have been published thus far. Table 1 shows an overview on healthy diet intake amounts for different product groups for the four zones.

In this paper, a vegetarian diet includes the intake of milk and milk products (cheese, butter, yoghurt, etc.). All meat is substituted by the group pulses, nuts and oilcrops, by an increase in the intake of pulses and soybeans (consumed e.g. in the form of soy burger or tofu), with equal caloric value and protein content.

For the product groups as defined by the FBDG of a healthy diet, a daily energy requirement of 2200 kcal for the WEST, EAST (Walter et al., 2007) and SOUTH is set as target, as also recommended by WHO (2007). A sex and age based analysis – with data from EUROSTAT (2012b) – results in whole population average values (for people with medium physical activities) of 1996 kcal (WEST), 2015 kcal (EAST) and 1992 kcal (SOUTH). For the zone NORTH, traditional FBDG require an average daily energy intake of 2450 kcal for a healthy diet (Barbieri and Lindvall, 2005). Regarding protein intake, recommendations range between 50 and 75 g daily (Westhoek et al., 2011; WHO, 2007). For

Table 1
Recommended intake amounts for product groups as recommended for a healthy diet.

Product group	Quantity chosen, based upon healthy diet recommendations		
Zone	WEST and EAST	SOUTH	NORTH
Cereals, rice, potatoes	200 g/d cereal eq. bread/cereal flakes + 200 g/d potatoes/cereal products (e.g. pasta)	4–6 servings daily (400 g/d chosen)	230 g/d cereal eq. bread/cereal flakes + 250 g/d potatoes/cereal products (e.g. pasta)
Sugar	Max. 60 g/d (most countries with a recommendation on sugar intake suggest that less than 10% of daily energy intake comes from sugar)		
Pulses, nuts and oilcrops	No recommendation	Olives and nuts 1–2 servings daily; legumes ≥2 servings weekly as alternative for meat; total 45 g/d chosen	30 g/d
Fruit	250 g/d (2–3 portions)	3–6 servings daily (300 g/d chosen)	300 g/d
Vegetables	400 g/d	6 servings daily (400 g/d chosen)	300 g/d
Crop oils	10 g/d (2 teaspoons) of high-quality plant-based oils such as rapeseed oil or olive oil and 10 g/d (2 teaspoons) of plant-based oils for cooking	Main source of dietary fat is olive oil, which replaces solid fats (butter and margarine); 3–5 servings daily (40 g/d chosen for eating and cooking)	15 g/d (3 teaspoons) of high-quality plant-based oils such as rapeseed oil
Animal fats	15 g/d (3 teaspoons) of butter or margarine	Restrict intake; substituted by olive oil; 0 g/d chosen	10 g/d (2 teaspoons) of butter or margarine and 10 g/d cream
Meat	450 g meat and 80 g fish (substituted by meat) per week	200 g meat and 200 g fish (substituted by meat) per week	100 g/d meat and 35 g/d fish (substituted by meat)
Milk and milk products	200 g/d milk/yoghurt and 50 g/d cheese (400 g milk eq.) = total 600 g/d	2 servings daily = 150 g/d milk/yoghurt and 40 g/d cheese (320 g milk eq.) = total 470 g/d	350 g/d milk and 25 g/d cheese (200 g milk eq.) = total 550 g/d
Eggs	Up to 3 eggs per week (1 egg 60 g)	2–4 eggs per week (1 egg 60 g)(3 eggs chosen)	Up to 3 eggs per week (1 egg 60 g)
Stimulants	No specific recommendations		
Alcoholic beverages	Thresholds 20 g/d for men and 10 g/d for women (minimum age 16)		

the vegetarian diets, the extra intake of products from the group pulses, nuts and oilcrops was chosen in such a way that the amounts of kcal and protein intake equal those for the healthy diet.

National data on food consumption (period 1996–2005) – on which basis the WF_{cons} is calculated – were taken from the FAO Food Balance Sheets (FBS) (Food and Agriculture Organization, 2013). These are data on food supply (tons and kg/cap/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". Important in the assessment is the conversion of these food product supply values to actual intake values (as given in the FBDG). This conversion implies two correction factors. The first factor accounts for food components not eaten and product primary 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. These factors were quantified as described in Vanham et al. (2013) and presented in Table 2. For the different zones the same values are used. For the first factor, specifications from Westhoek et al. (2011) and 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.

3. Results

3.1. Diets

Fig. 3 gives an overview of the intake amounts for the reference period (REF) and the healthy diet scenario (HEALTHY). Within all four zones it is observed that the intake of some product groups should be reduced (sugar, crop oils and animal fats) and of other product groups increased (vegetables and fruit). Apart from the NORTH, where traditional FBDG recommend a high intake of meat (49.3 kg/cap/yr), the intake of meat should drastically be reduced. There is especially a high discrepancy between current meat intake in the SOUTH (58.9 kg/cap/yr) and the recommended value (20.8 kg/cap/yr). Current meat intake (57.2 kg/cap/yr) is also more than double of the recommended value (27.6 kg/cap/yr) in WEST. The current meat intake (43.3 kg/cap/yr) in EAST is the lowest, but still higher than recommended (27.6 kg/cap/yr). EAST differs from the three other zones regarding the intake of cereals, rice and potatoes as well as milk and milk products. Regarding cereals, rice, and potatoes

Table 2
Correction factors for the different products in the FAO FBS to compute intake values from food supply quantity values.

Product group	Correction factor 1	Correction factor 2
Cereals, rice, potatoes	Wheat 0.8; rice (milled equivalent) 1.0; barley 0.75; maize 0.63; rye and oats 0.75; others 1.0	Wheat 0.8; others 0.85
Sugar and sweeteners	1.0	0.9
Crop oils	1.0	0.85
Vegetables	1.0	0.8
Fruit	1.0	0.75
Pulses, nuts, oilcrops	1.0	0.9
Meat	Bovine meat 0.65; mutton & goat meat 0.667; pig meat 0.705; poultry meat 0.7; other meat 0.675; offals 0.258	0.9
Animal fats	Butter, ghee, cream 1.0; fats, animals, raw 0.65	0.9
Milk and milk products	1.0	0.9
Eggs	1.0	0.9
Stimulants	1.0 (with 8 l milk equivalent for 1 kg of cheese)	0.9
Alcoholic beverages	1.0	0.9
Spices	1.0	0.9
Fish, seafood	0.4	0.9
Miscellaneous	1.0	0.9

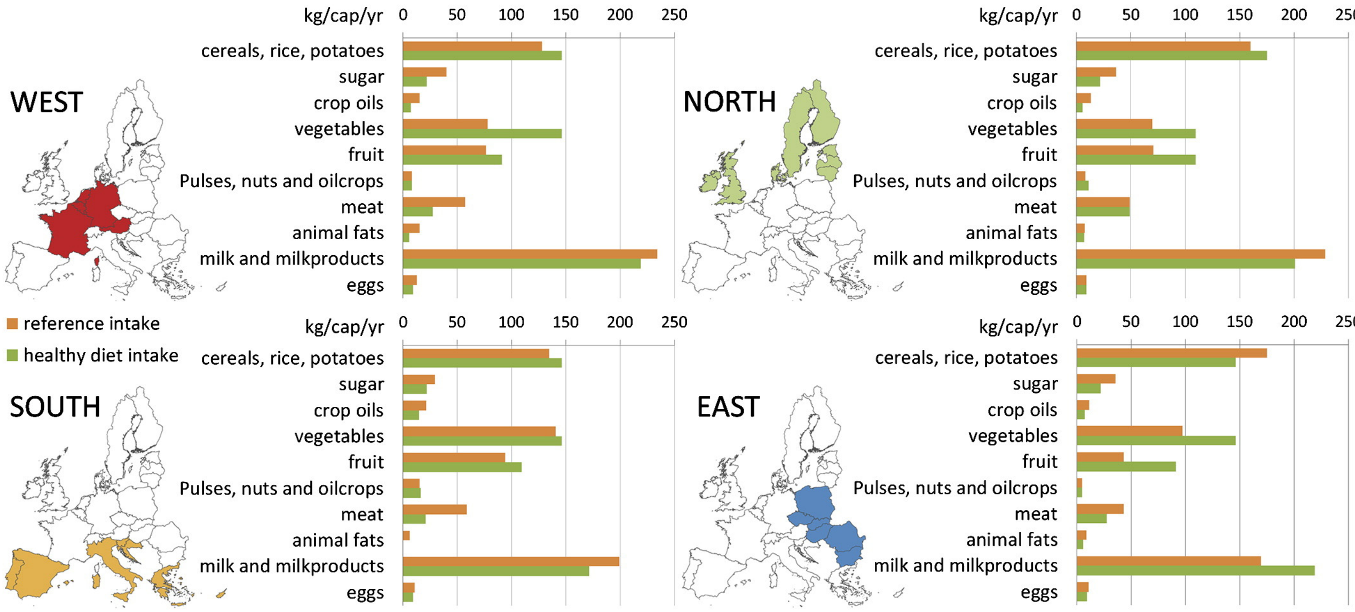

Fig. 3. Intake of product groups (in kg/cap/yr) for the reference period (1996–2005) and as recommended for a healthy diet for the four EU zones. For some product groups, intake values are given in product equivalent (eq.) values (e.g. bread as wheat eq. and meat in carcass weight). Meat intake values are retail quantities. Milk and milk products are expressed as milk eq. (e.g. 8 l milk eq. for 1 kg of cheese).

the intake in EAST should be reduced, but increased in the three other zones. Regarding milk and milk products the intake in EAST should be increased, but reduced in the three other zones. For eggs the current intake approximately equals the recommended value in all four zones.

For all four zones current energy and protein intake are higher than recommended (Table 3). For the product groups covered by FBDG (Total 1 in Table 3), current energy intake (WEST 2730 kcal/d, EAST 2577 kcal/d, SOUTH 2744 kcal/d, NORTH 2614 kcal/d) are approximately reduced to the target energy intake (WEST, EAST, SOUTH 2200 kcal/d and NORTH 2450 kcal/d) within the healthy and vegetarian diet scenarios. The total energy intake in all scenarios is slightly higher when product groups not covered by FBDG are included.

3.2. The WF_{cons} for different diets

The current WF_{cons} for agricultural products and the impact of a healthy and vegetarian diet on it for the four EU zones is shown in Fig. 4. There are substantial differences in the current WF_{cons} between the four zones due to 1) different consumption behaviour and 2) different agricultural production methods (like irrigation and fertilization practices) and environmental conditions (like climate, soil) (Vanham and Bidoglio, 2013).

The high value of the current WF_{cons} for SOUTH (5875 lcd) can be explained by its high meat intake and the fact that the water footprint in litre/kg of many domestically produced products is higher than in other zones, especially due to climatological conditions (drier and hotter) (Vanham and Bidoglio, 2013). The latter means that generally for many main products it requires more water (WF_{prod} is higher) to produce the same amount of product in SOUTH as compared to other zones, especially WEST and NORTH. This is shown for a selection of main crops in Table 4. Of a total agricultural WF_{prod} in the EU of 3100 lcd or 552 km^3 (Vanham and Bidoglio, 2013), the crops presented in this table (used as food and feed) represent 50%. For e.g. wheat (representing 24% of the total EU agricultural WF_{prod}) the WF_{prod} for SOUTH (1516 m^3/ton) is substantially higher than the WF_{prod} for WEST (656 m^3/ton) and NORTH (512 m^3/ton). This is also true for other main cereals like maize and barley or potatoes. For tomatoes the WF_{prod} for SOUTH (224 m^3/ton) is substantially higher than the WF_{prod} for WEST (29 m^3/ton) and NORTH (41 m^3/ton). For many main products the WF_{prod} of EAST is more in the range of SOUTH, e.g. wheat (EAST 1499 m^3/ton and SOUTH 1516 m^3/ton), maize (EAST 916 m^3/ton and SOUTH 794 m^3/ton), potatoes (EAST 283 m^3/ton and SOUTH 276 m^3/ton), grapes (EAST 882 m^3/ton and SOUTH 725 m^3/ton) or sunflower (EAST 2922 m^3/ton and SOUTH 3074 m^3/ton).

As shown in Fig. 4, the WF_{cons} for EAST (4053 lcd) is higher than the ones for WEST (3761 lcd) and NORTH (3197 lcd) due to higher water footprints per kg for many domestically produced products, predominately as a result of lower yields of many crops (Vanham and Bidoglio, 2013). This is again shown in Table 4. As an example, yields of the following products are the lowest in EAST: maize, potatoes, tomatoes, apples (when the Baltic states are not included in NORTH) and grapes. For these crops the WF_{prod} of EAST is the highest amongst all zones. For the remaining crops (wheat, barley, sunflower) the yield is slightly higher than SOUTH but clearly lower than WEST and NORTH.

Predominately due to a higher meat intake, the WF_{cons} of WEST (3761 lcd) is higher than the WF_{cons} of NORTH (3197 lcd). In general these two zones are otherwise characterised by similar consumption behaviour as well as agricultural production methods and conditions.

Fig. 4 shows – consistently for all four zones – a decrease in the WF_{cons} for agricultural products for the alternative diets relative to the existing situation. The largest decrease takes place for the vegetarian diet. For WEST, the current WF_{cons} decreases with 26% (−995 lcd) for the healthy diet and 41% (−1553 lcd) for the vegetarian diet. For NORTH, the current WF_{cons} decreases with 3% (−106 lcd) for the healthy diet and 32% (−1031 lcd) for the vegetarian diet. For the healthy diet the reduction is low because the traditional Nordic FBDG recommend a high meat intake. The highest reductions are observed for SOUTH: 30% (−1765 lcd) for the healthy diet and 41% (−2399 lcd) for the vegetarian diet. For EAST, the current WF_{cons} decreases with 11% (−447 lcd) for the healthy diet and 27% (−1097 lcd) for the vegetarian diet. Relevant for all four zones, the reduction in meat intake has the largest effect on the decrease in WF_{cons}. Also the reduction in oil and sugar intake has an important impact.

Fig. 4 also shows the WF_{prod} for agricultural products within each zone. When the WF_{cons} is larger than the WF_{prod}, a zone is characterised as net virtual water importer regarding agricultural products. This means it imports more virtual water than it exports through the trade

Table 3
Reference and scenario intake values per product groups in terms of weight (kg/yr), energy (kcal/d) and protein (g/d). All values per capita; WEST (W), EAST (E), SOUTH (S), NORTH (N).

Product group	Weight (kg/yr)			Energy (kcal/d)			Protein (g/d)		
	REF	HEA	VEG	REF	HEA	VEG	REF	HEA	VEG
Cereals, rice, potatoes	128.1 (W); 175.1 (E); 134.8 (S); 160.1 (N)	146.0 (W, E, S); 175.2 (N)		770 (W); 1071 (E); 880 (S); 849 (N)	877 (W); 893 (E); 953 (S); 929 (N)		22.5 (W); 31.2 (E); 26.2 (S); 25.1 (N)	25.7 (W); 26.0 (E); 28.4 (S); 27.4 (N)	
Sugar	39.8 (W); 35.5 (E); 29.5 (S); 36.6 (N)	21.9 (W, E, S, N)		383 (W); 341 (E); 278 (S); 347 (N)	211 (W, E); 206 (S); 208 (N)		0.0 (W, E, S, N)	0.0 (W, E, S, N)	
Crop oils	15.1 (W); 11.1 (E); 21.4 (S); 13.0 (N)	7.3 (W, E); 14.6 (S); 5.5 (N)		366 (W); 271 (E); 518 (S); 325 (N)	177 (W); 178 (E); 354 (S); 137 (N)		0.1 (W, E, S); 0.0 (N)	0.0 (W, S, N); 0.1 (E)	
Vegetables	78.0 (W); 97.3 (E); 140.9 (S); 69.7 (N)	146.0 (W, E, S); 109.5 (N)		58 (W); 65 (E); 87 (S); 51 (N)	109 (W); 98 (E); 91 (S); 80 (N)		2.8 (W); 3.0 (E); 4.3 (S); 2.4 (N)	5.2 (W); 4.5 (E, S); 3.7 (N)	
Fruit	76.6 (W); 43.1 (E); 94.4 (S); 70.7 (N)	91.3 (W, E); 109.5 (S, N);		85 (W); 55 (E); 116 (S); 76 (N)	101 (W); 117 (E); 134 (S); 118 (N)		0.9 (W, N); 0.6 (E); 1.5 (S);	1.1 (W); 1.3 (E, N); 1.7 (S);	
Pulses, nuts, oilcrops	8.4 (W); 4.6 (E); 15.1 (S); 8.2 (N)	8.4 (W)[a]; 4.6 (E)[a]; 16.4 (S); 11.0 (N)	28.8 (W); 23.6 (E); 29.8 (S); 49.2 (N)	65 (W); 40 (E); 102 (S); 72 (N)	65 (W)[a]; 40 (E)[a]; 111 (S); 97 (N)	249 (W); 215 (E); 237 (S); 479 (N)	2.7 (W); 2.0 (E); 4.4 (S); 3.6 (N)	2.7 (W)[a]; 2.0 (E)[a]; 4.4 (S); 3.6 (N)	15.7(W); 15.0 (E); 14.4 (S); 28.9 (N)
Meat	57.2 (W); 43.3 (E); 58.9 (S); 49.0 (N)	27.6 (W, E); 20.8 (S); 49.3 (N)	0.0 (W, E, S, N)	379 (W); 275 (E); 358 (S); 380 (N)	183 (W); 175 (E); 126 (S); 382 (N)	0 (W, E, S, N)	27.0 (W); 20.4 (E); 28.3 (S); 24.1 (N)	13.0 (W, E); 10.0 (S); 24.3 (N)	0.0 (W, E, S, N)
Animal fats	15.2 (W); 8.6 (E); 6.2 (S); 7.7 (N)	5.5 (W, E); 0.0 (S); 7.3 (N)		271 (W); 170 (E); 112 (S); 157 (N)	98 (W); 109 (E); 0 (S); 149 (N)		0.5 (W); 0.3 (E, N); 0.2 (S);	0.2 (W, E, N); 0.0 (S);	
Milk and milk products	234.2 (W); 169.7 (E); 199.1 (S); 228.3 (N)	219.0 (W, E); 171.6 (S); 200.8 (N)		303 (W); 246 (E); 251 (S); 321 (N)	283 (W); 318 (E); 216 (S); 282 (N)		21.0 (W); 14.8 (E); 15.5 (S); 18.9 (N)	19.6 (W); 19.1 (E); 13.3 (S); 16.6 (N)	
Eggs	12.5 (W); 10.8 (E); 10.9 (S); 9.4 (N)	9.4 (W, E, S, N)		49 (W); 42 (E, S); 36 (N)	36 (W, E, S, N)		3.9 (W); 3.4 (E, S); 2.9 (N)	2.9 (W, E, S, N)	
Total 1	665.3 (W); 599.0 (E); 711.2 (S); 652.5 (N)	682.3 (W); 678.4 (E); 656.1 (S); 699.2 (N)	675.1 (W); 669.9 (E); 648.7 (S); 688.2 (N)	2730 (W); 2577 (E); 2744 (S); 2614 (N)	2141 (W); 2174 (E); 2227 (S); 2419 (N)		81.4 (W); 75.8 (E); 83.8 (S); 78.1 (N)	70.4 (W); 69.1 (E); 65.2 (S); 80.2 (N)	
Stimulants	8.4 (W); 4.1 (E); 5.9 (S); 7.6 (N)	8.4 (W)[b]; 4.1 (E)[b]; 5.9 (S)[b]; 7.6 (N)[b]		27 (W); 11 (E); 16 (S); 21 (N)	27 (W)[b]; 11 (E)[b]; 16 (S)[b]; 21 (N)[b]		1.5 (W, N); 0.7 (E); 1.0 (S);	1.5 (W, N)[b]; 0.7 (E)[b]; 1.0 (S)[b];	
Alcoholic beverages	113.5 (W); 84.2 (E); 84.0 (S); 103.8 (N)	61.2 (W)[c]; 61.1 (E)[c]; 58.5 (S)[c]; 80.0 (N)[c]		196 (W); 149 (E, S); 169 (N)	106 (W)[c]; 108 (E)[c]; 104 (S)[c]; 130 (N)[c]		1.0 (W); 0.9 (E); 0.6 (S); 1.2 (N)	0.6 (W)[c]; 0.7 (E)[c]; 0.4 (S)[c]; 0.9 (N)[c]	
Total 2	787.2 (W); 687.3 (E); 801.0 (S); 763.9 (N)	751.9 (W); 743.6 (E); 720.5 (S); 786.7 (N)	744.7 (W); 735.1 (E); 713.1 (S); 775.7 (N)	2953 (W); 2737 (E); 2909 (S); 2805 (N)	2274 (W); 2294 (E); 2347 (S); 2570 (N)		83.9 (W); 77.5 (E); 85.4 (S); 80.8 (N)	72.4 (W); 70.5 (E); 66.7 (S); 82.5 (N)	
Spices	0.5 (W); 1.0 (E); 0.2 (S); 4.8 (N)	0.5 (W)[a]; 1.0 (E)[a]; 0.2 (S)[a]; 4.8 (N)[a]		4 (W); 6 (E); 2 (S); 0 (N)	4 (W)[a]; 6 (E)[a]; 2 (S)[a]; 0 (N)[a]		0.2 (W, E, N); 0.1 (S);	0.2 (W, N)[a]; 0.1 (E, S)[a]	
Fish, seafood	19.0 (W); 6.2 (E); 28.3 (S); 20.0 (N)	0.0 (W, E, S, N)[d]		44 (W); 16 (E); 53 (S); 39 (N)	0 (W, E, S, N)[d]		5.4 (W); 2.4 (E); 8.2 (S); 5.6 (N)	0.0 (W, E, S, N)[d]	
Miscellaneous	0.0 (W, E, S, N);	0.0 (W, E, S, N)		1 (W); 2 (E); 4 (S); 7 (N)	1 (W); 2 (E); 4 (S); 7 (N)		0.0 (W); 0.1 (E); 0.2 (S, N);	0.0 (W, E, S, N)	
Total 3	806.7 (W); 694.4 (E); 829.5 (S); 788.7 (N)	752.4 (W); 744.6 (E); 720.7 (S); 791.5 (N)	745.2 (W); 736.1 (E); 713.3 (S); 780.5 (N)	3002 (W); 2761 (E); 2968 (S); 2851 (N)	2279 (W); 2301 (E); 2353 (S); 2578 (N)		89.5 (W); 80.2 (E); 93.8 (S); 86.8 (N)	72.6 (W); 70.6 (E); 66.8 (S); 82.7 (N)	

[a] For pulses, nuts and oilcrops, as well as spices, the DGE (W and E) gives no recommendation; for the scenarios the same existing amount plus the meat substitution amount is assumed.
[b] For stimulant (coffee, tea, cocoa) no diet recommendations are available, the same amount is assumed.
[c] For alcoholic beverages the thresholds 20 g/d for men and 10 g/d for women (minimum age 16, population data from (EUROSTAT, 2012a)) are used.
[d] For fish and seafood, the healthy diets give recommendations, however for the scenarios no consumption is assumed.

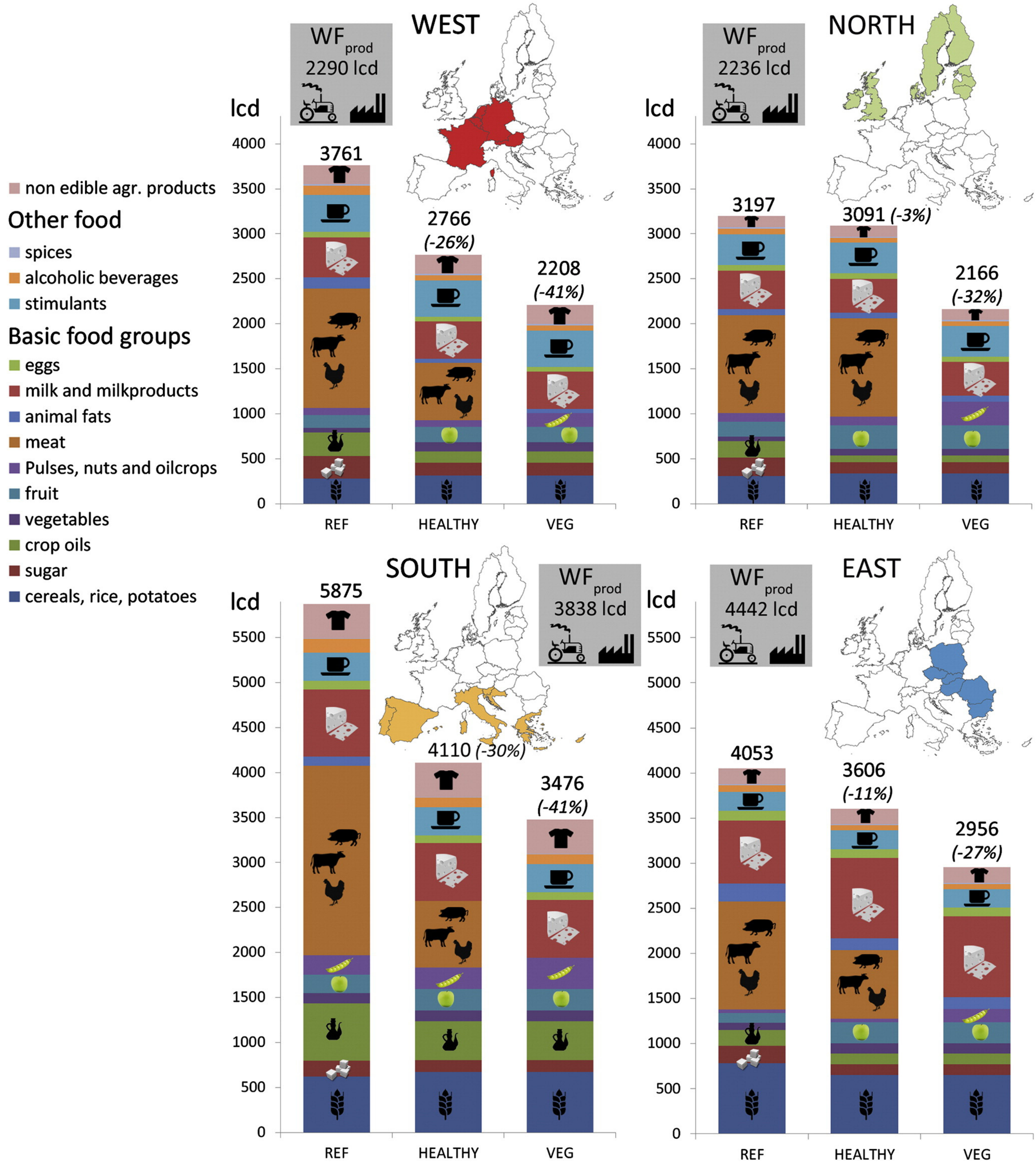

Fig. 4. The water footprint of consumption (WF_{cons}) regarding agricultural products for different diet scenarios for the four EU zones (in lcd). Also the water footprint of production (WF_{prod}) for agricultural products is shown.

of agricultural products. When the WF_{cons} is smaller than the WF_{prod}, a zone is characterised as net virtual water exporter. The zone EAST is for all diet scenarios a net virtual water exporter, as its WF_{prod} (4442 lcd) is larger than even its current WF_{cons} (4053 lcd). The three other zones shift from net virtual water importer for the current and healthy diet scenarios to net virtual water exporter for the vegetarian diet scenario.

The green + blue WF_{cons} (without the grey WF_{cons} component) is shown in Fig. 5. Compared to the current green + blue WF_{cons}, the following water savings are made: 27% (HEALTHY) and 42% (VEG) for WEST, 3% (HEALTHY) and 33% (VEG) for NORTH, 30% (HEALTHY) and 41% (VEG) for SOUTH, 10% (HEALTHY) and 27% (VEG) for EAST.

The blue WF_{cons} for the different diet scenarios is presented in Fig. 6. The blue WF_{cons} of SOUTH exceeds those of the other zones substantially, as agricultural production within this zone is strongly dependent on irrigation. In the other zones most agricultural production is rain-fed. The figure shows that the relative proportions of product groups for the blue WF_{cons} are slightly different from those of the total WF_{cons}

Table 4
Production, yield and WF_{prod} of selected major crops in the four EU zones (average annual values for 1996–2005).

Product	Zone	Production (1000 ton)	Yield (ton/ha)	WF_{prod} (m^3/ton)			
				Green	Blue	Grey	Total
Wheat	W	61,627	7.1	579	1	76	656
	E	27,365	3.4	1170	10	319	1499
	S	16,582	2.8	1273	30	213	1516
	N	24,962	6.6	400	0	112	512
Maize	W	21,254	8.7	420	67	139	626
	E	20,304	4.1	852	13	51	916
	S	19,758	8.4	425	212	157	794
	N	5	*	*	*	*	*
Barley	W	24,115	6.0	502	2	170	674
	E	9305	3.1	841	1	114	956
	S	10,544	2.7	953	69	224	1246
	N	16,644	4.5	381	0	70	451
Potatoes	W	29,468	41.2	78	8	31	117
	E	25,961	17.4	202	2	78	283
	S	7745	20.4	139	78	59	276
	N	13,049	27.9	103	9	22	134
Tomatoes	W	1701	177.2	19	6	5	29
	E	1779	18.5	192	26	5	224
	S	13,690	53.6	52	26	18	96
	N	199	102.3	34	2	5	41
Apples	W	4475	35.0	188	15	8	211
	E	3617	11.8	454	3	12	468
	S	3732	24.0	226	87	34	347
	N	418	6.9	680	1	26	707
	N without Baltic states	265	17.1	269	1	19	289
Grapes	W	8887	8.8	468	3	15	485
	E	2311	4.9	830	6	46	882
	S	17,287	7.1	526	73	125	725
	N	2	*	*	*	*	*
Sunflower	W	1836	2.3	1257	10	552	1819
	E	2783	1.4	2617	52	253	2922
	S	1384	1.2	2229	664	181	3074
	N	0					

Data sources: Food and Agriculture Organization (2013) for production and yield and Mekonnen and Hoekstra (2010) for WF_{prod}. *No data are given as the small existing production quantity is not representative for a whole zone.

(Fig. 4) and the green + blue WF_{cons} (Fig. 5). The relative proportion of fruit in the blue WF_{cons} is relatively high in WEST and NORTH, which relates to the fact that many of the fruits consumed in these zones are imported from SOUTH, where they are produced under irrigation (Hoekstra and Mekonnen, 2012; Mekonnen and Hoekstra, 2011b). With respect to the reference diet situation, the blue WF_{cons} decreases substantially for the product groups meat, crop oils and sugar. Regarding the product groups fruits and vegetables the WF_{cons} however increases for the healthy and vegetarian diet scenarios, as an increased intake of fruit and vegetables is recommended by regional zone FBDG. It is to be noted, however, that the composition of single fruit and vegetable products within the current diets has been extrapolated to the healthy and vegetarian diets. The preferred intake of seasonal vegetable and fruit products is not taken into account, which could lead to a reduced blue WF but also increased green WF (Vanham and Bidoglio, 2013). Overall, the total blue WF_{cons} for each zone decreases for the different diet scenarios. Only in NORTH the WF_{cons} for a healthy diet is higher than the current WF_{cons}, due to an increased WF_{cons} related to more fruit intake.

4. Discussion

This paper shows that the regional aspect is very important. In the zone WEST, agricultural production of many basic crops consumed as food and feed in the EU is already today very water efficient, as yields are amongst the highest in the world (Table 4, Mekonnen and Hoekstra, 2011a; Mueller et al., 2012) and climatological conditions and soil productivity are very good for crops like wheat (Olesen et al., 2011). The WF_{prod} of many main crops like wheat, barley, potatoes, tomatoes or apples is amongst the lowest in the world (Mekonnen and Hoekstra, 2010; Mekonnen and Hoekstra, 2011a). Also NORTH is characterised by a very low WF_{prod} of many main crops consumed in the EU like wheat, barley or potatoes (Table 4, Mekonnen and Hoekstra (2010), Mekonnen and Hoekstra (2011a)). Yields of main crops like wheat, barley or potatoes are higher than in SOUTH and EAST, but lower than in WEST due to climatological conditions (limited by cooler temperatures — shorter growing seasons) (Olesen et al., 2011). In EAST, focus should be put on agricultural yield increase (Mueller et al., 2012; Neumann et al., 2010) by sustainable intensification (Beddington et al., 2012; Foley et al., 2011; Godfray et al., 2010; Tilman et al., 2011; Vanham and Bidoglio, 2013), to acquire more "crop per drop" for the WF_{prod}. In SOUTH, climatological conditions lead to a higher water footprint in litre/kg for certain basic crops consumed in the EU (Table 4; Mekonnen and Hoekstra, 2011a), resulting in high overall WF_{prod} and WF_{cons} (Figs. 4–6) values. Yields of e.g. wheat in SOUTH are limited by higher temperatures and lower rainfall than in other zones (Olesen et al., 2011). This zone is also characterised by irrigated agriculture (Wriedt et al., 2009), leading to high blue WF_{cons} values (Fig. 6), e.g. for maize (Table 4). Due to climate change, decreases in yield and water availability are projected in this zone (Ciscar et al., 2011). Adaptation options for the WF_{prod} include efficiency increase in irrigation and the replacement of current crops to others better fitting climate conditions (Hoekstra et al., 2011; Vanham and Bidoglio, 2013). Olives are e.g. a regional crop well adapted for the climate in SOUTH. Olive oil is identified as a principal source of fat in the Mediterranean FBDG, stressing the importance of applying regional FBDG for healthy diet identifications.

As a next step the sustainability of the current WF_{prod} should be assessed, with the relevant blue, green and grey WF sustainability indicators (Vanham and Bidoglio, 2013). Already today several EU and non-EU river basins experience water stress (Hoekstra et al., 2012). The maximum sustainable WF_{prod} should be addressed per river basin. When such maximum sustainable WF_{prod} would be implemented and/or WF_{cons} would change due to different diets, it is anticipated that the current distribution of net virtual water importer/exporter river basins in the EU (Vanham, 2013) will change.

There is in this study off course a certain sensitivity of the results to uncertainties in assumptions and used data. WF_{cons} used in this study (Mekonnen and Hoekstra, 2011b) were computed with the bottom-up approach and not the top-down approach. The bottom-up approach for the WF_{prod}, WF_{cons} and VW flows depends on the quality of production, consumption and trade data, whereas the top-down approach relies on the quality of production and trade data (Hoekstra et al., 2011). The bottom-up approach for the WF_{cons} is however generally recognized as more stable (Hoekstra et al., 2011; Van Oel et al., 2009). A more detailed discussion on this can be found in Hoekstra et al. (2011) and Vanham and Bidoglio (2013). The grey WF methodology needs to be further standardized (Thaler et al., 2012; Vanham and Bidoglio, 2013). For the diets of the different zones, average values were chosen from selected FBDG (Table 1), although recommendations for specific product groups often indicate a range of intake. Correction factors as displayed in Table 2 are based upon a list of publications but were not available on a zonal/regional level. An important limitation is also the fact that WF values for fish (and seafood) have not been published yet, although regional FBDG include fish. In our analyses these recommended amounts were substituted by meat. The WF_{cons} for the HEALTHY and VEG diets thus include the protein and energy intake of fish (substituted by meat), but in the REF diet the current intake of fish (and seafood) is not represented at all in the REF WF_{cons}. Fig. 7 shows the REF and recommended intake values for meat (including offals) and fish (with seafood) for the four zones. Indeed, substantial

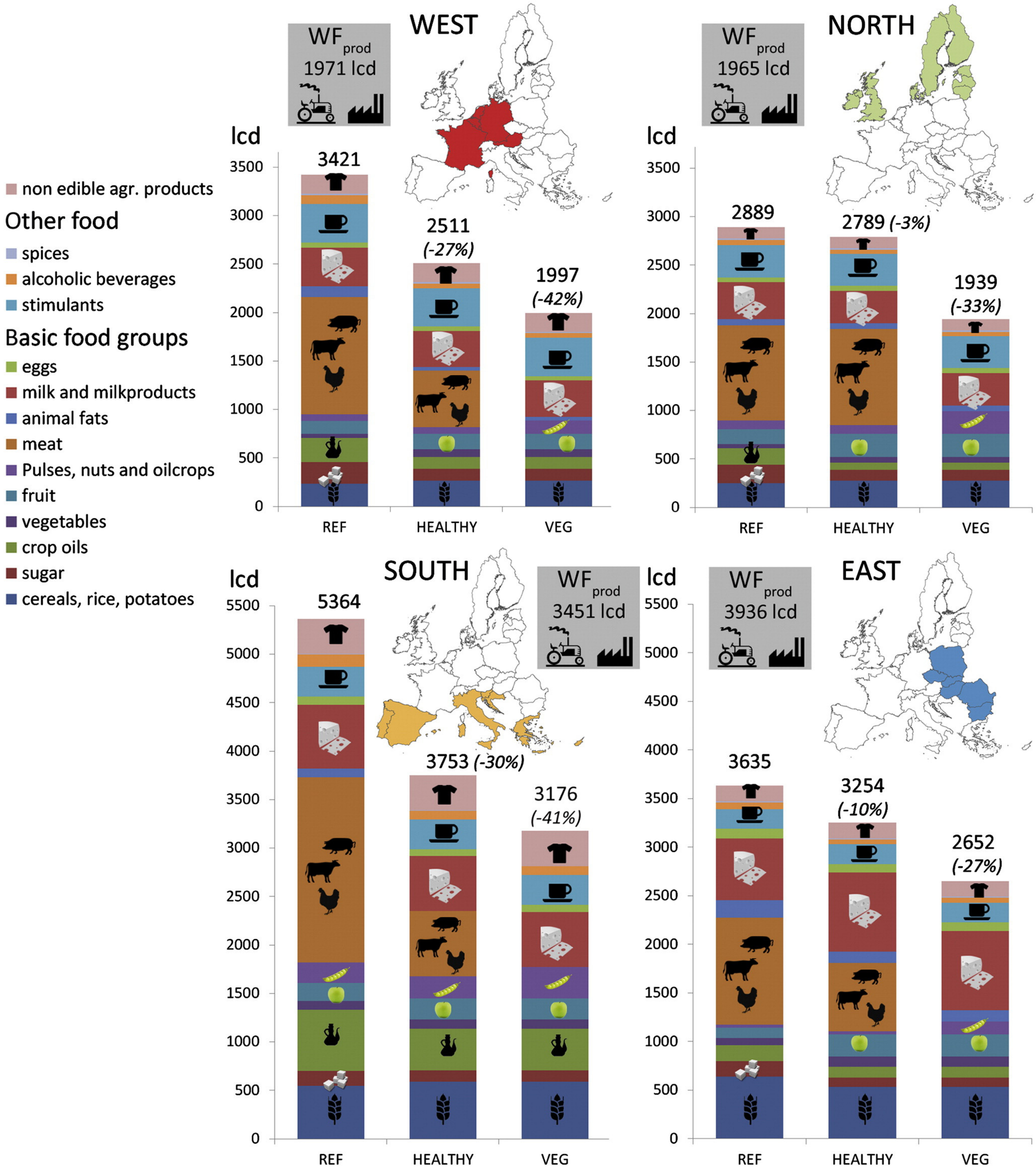

Fig. 5. The green + blue WF_{cons} regarding agricultural products for different diet scenarios for the four EU zones (in lcd). Also the green + blue WF_{prod} for agricultural products is shown.

fish (and seafood) amounts are part of the REF diet in all zones. By not incorporating these values, the current WF_{cons} is in fact underestimated. For NORTH, the recommended intake of meat including fish (49.3 kg/cap/yr) is about the same as the REF intake of meat. However, when the REF intake of fish and seafood is added to the REF meat intake (resulting in a REF intake of 57.0 kg/cap/yr), this exceeds the recommended intake by 7.7 kg/cap/yr.

5. Conclusions

This study shows that different diets have a crucial effect on the water footprint of European consumption. As indicated in Vanham and Bidoglio (2013), there are strong similarities regarding the per capita values and characteristics of the WF_{cons} between the nations within each of the four EU zones. This requires a regional WF_{cons}

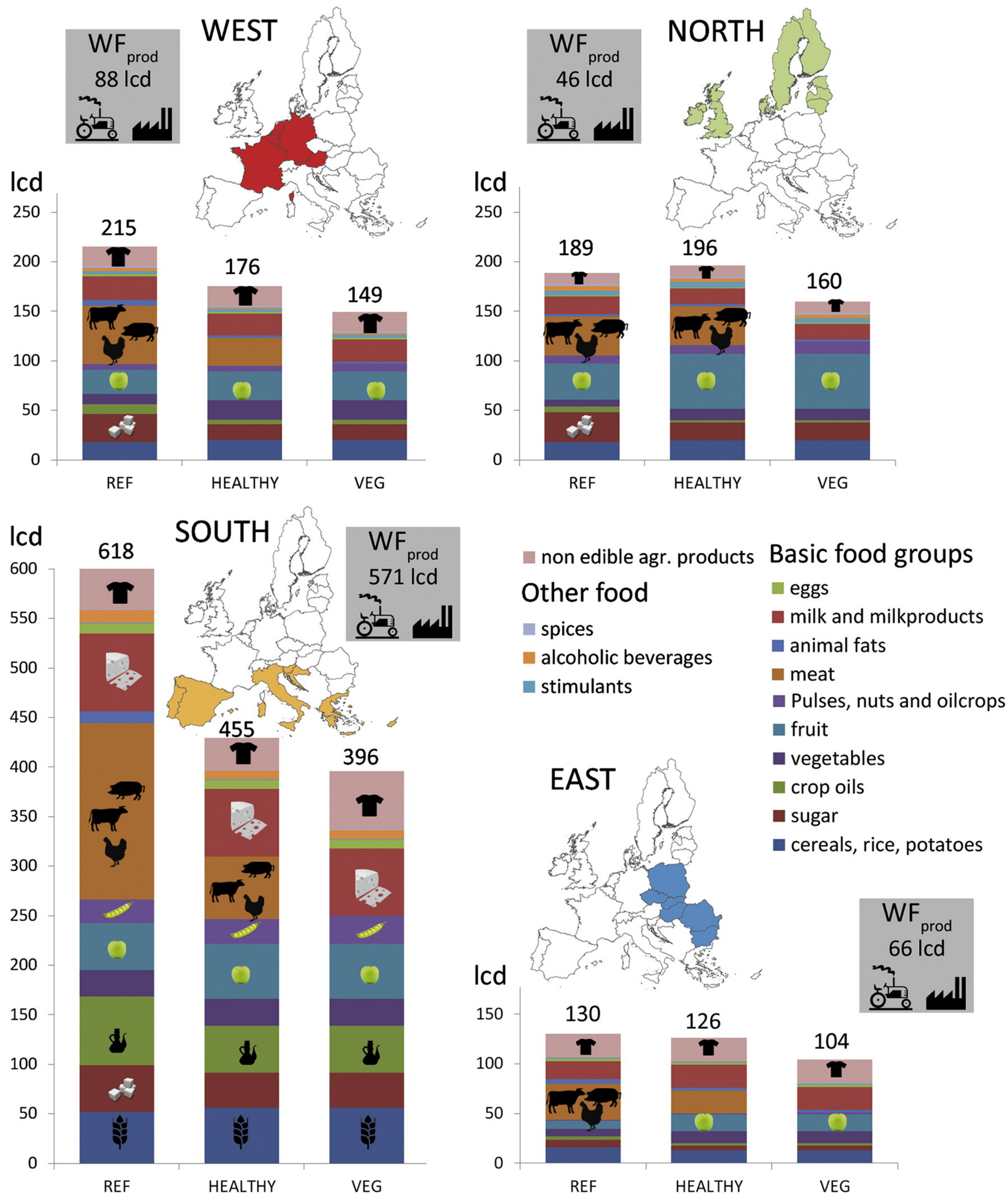

Fig. 6. The blue WF_{cons} regarding agricultural products for different diet scenarios for the four EU zones (in lcd). Also the blue WF_{prod} for agricultural products is shown.

analysis in order to identify potential policy options. The current EU WF_{cons} regarding agricultural products is 4265 lcd, but zonal values differ substantially from this average. The current WF_{cons} regarding agricultural products is the highest in SOUTH (5875 lcd), followed by EAST (4053 lcd), WEST (3761 lcd) and NORTH (3197 lcd). These differences are due to different consumption behaviour and differences in agricultural production methods and conditions. Currently EAST is a net virtual water exporter for agricultural products. The three other zones are net virtual water importers.

To assess a healthy diet, regional Food-Based Dietary Guidelines (FBDG) were applied for the four zones. The current diets in all zones are characterised by an overconsumption of several product groups (sugar, crop oils and animal fats). Also the meat intake is too high within all zones but NORTH (according to traditional Nordic FBDG). The intake of vegetables and fruit should be increased. For all zones, a reduction in the WF_{cons} was observed for a healthy and a vegetarian diet compared to the current diet. The vegetarian diets have the lowest WF_{cons}. Especially the decrease in meat intake accounts for a substantial WF_{cons} reduction. For the latter diet, all zones shift to virtual water exporters regarding agricultural products.

Such reduced WF_{cons} in the four EU zones can contribute to sustainable water management both within the EU and outside its borders. They could help to reduce the dependency of EU consumption on domestic and foreign water resources or even increase virtual water exports from the EU to other regions, in this way contributing to the mitigation of the growing water scarcity in other parts of the world (Vanham et al., 2013). As global land and water resources are both finite, both adaptations in production and consumption need to be made.

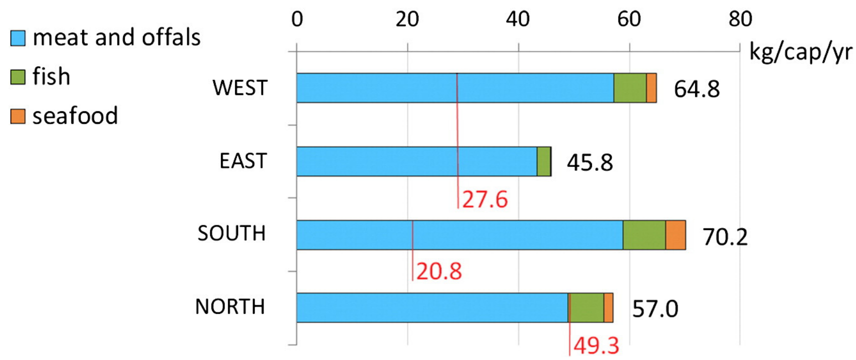

Fig. 7. Reference and recommended (in red) intake values for meat (including offals) and fish (with seafood). (For interpretation of the reference to colour in this figure legend, the reader is referred to the web version of this article.)

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References

Aranceta J, Serra-Majem L. Dietary guidelines for the Spanish population. Public Health Nutr 2001;4:1403–8. http://dx.doi.org/10.1079/PHN2001228.

Astrup A, Andersen NL, Stender S, Trolle E. Kostrådene 2005. Danmarks Fødevareforskning; 2005.

Bach-Faig A, Berry EM, Lairon D, Reguant J, Trichopoulou A, Dernini S, et al. Mediterranean diet pyramid today. Science and cultural updates. Public Health Nutr 2011;14: 2274–84. http://dx.doi.org/10.1017/S1368980011002515.

Barbieri HE, Lindvall C. Swedish Nutrition Recommendations Objectified (SNO). Sweden: National Food Administration; 2005.

Beddington J, Asaduzzaman M, Clark M, Fernández A, Guillou M, Jahn M, et al. Achieving food security in the face of climate change: final report from the Commission on Sustainable Agriculture and Climate Change. Copenhagen, Denmark: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS); 2012.

Ciscar J-C, Iglesias A, Feyen L, Szabó L, Van Regemorter D, Amelung B, et al. Physical and economic consequences of climate change in Europe. Proc Natl Acad Sci U S A 2011;108:2678–83. http://dx.doi.org/10.1073/pnas.1011612108.

EC. Preparatory study on food waste across EU 27. European Commission, Technical Report 2010-054 2010.

Editorial. A fresh approach to water. Nature 2008;452:253-253.

Ehrlich PR, Ehrlich AH. Can a collapse of global civilization be avoided? Proc R Soc Lond B Biol Sci 2013;280. http://dx.doi.org/10.1098/rspb.2012.2845.

Elmadfa I, Freisling H. Food-based dietary guidelines in Austria. Ann Nutr Metab 2007;51: 8–14.

Elmadfa I, Meyer A, Nowak V, Hasenegger V, Putz P, Verstraeten R, et al. European Nutrition and Health Report 2009. Basel: Forum of Nutrition; 2009.

EUROSTAT. http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home/, 2012. [access: 16.04.2012].

EUROSTAT. on-line database:http://epp.eurostat.ec.europa.eu, 2012.

Falkenmark M, Rockström J. The new blue and green water paradigm: breaking new ground for water resources planning and management. J Water Resour Plann Manage 2006;132:129–32.

Foley JA, Ramankutty N, Brauman KA, Cassidy ES, Gerber JS, Johnston M, et al. Solutions for a cultivated planet. Nature 2011;478:337–42. http://dx.doi.org/10.1038/nature10452.

Food Safety Authority of Ireland. Scientific Recommendations for Healthy Eating Guidelines in Ireland, Dublin; 2011.

Food and Agriculture Organization. FAOSTAT On-line Database. Rome: FAO; 2013 [http://faostat.fao.org].

Galli A, Wiedmann T, Ercin E, Knoblauch D, Ewing B, Giljum S. Integrating ecological, carbon and water footprint into a "footprint family" of indicators: definition and role in tracking human pressure on the planet. Ecol Indic 2012;16:100–12. http://dx.doi.org/10.1016/j.ecolind.2011.06.017.

Godfray HCJ, Beddington JR, Crute IR, Haddad L, Lawrence D, Muir JF, et al. Food security: the challenge of feeding 9 billion people. Science 2010;327:812–8.

Gustavsson J, Cederberg C, Sonesson U, van Otterdijk R, Meybeck A. Global Food Losses and Food Waste – Extent, Causes and Prevention. Gothenburg, Rome: Swedish Institute for Food and Biotechnology (SIK), FAO; 2011.

Hoekstra AY, Mekonnen MM. The water footprint of humanity. Proc Natl Acad Sci U S A 2012;109:3232–7.

Hoekstra AY, Chapagain AK, Aldaya MM, Mekonnen MM. The Water Footprint Assessment Manual: Setting the Global Standard. London, UK: Earthscan; 2011.

Hoekstra AY, Mekonnen MM, Chapagain AK, Mathews RE, Richter BD. Global monthly water scarcity: blue water footprints versus blue water availability. PLoS One 2012;7:e32688. http://dx.doi.org/10.1371/journal.pone.0032688.

Hoff H, Falkenmark M, Gerten D, Gordon L, Karlberg L, Rockström J. Greening the global water system. J Hydrol 2010;384:177–86. http://dx.doi.org/10.1016/j.jhydrol.2009.06.026.

James WPT. The epidemiology of obesity: the size of the problem. J Intern Med 2008;263: 336–52. http://dx.doi.org/10.1111/j.1365-2796.2008.01922.x.

Karimi P, Bastiaanssen WGM, Molden D, Cheema MJM. Basin-wide water accounting based on remote sensing data: an application for the Indus Basin. Hydrol Earth Syst Sci 2013;17:2473–86. http://dx.doi.org/10.5194/hess-17-2473-2013.

Licker R, Johnston M, Foley JA, Barford C, Kucharik CJ, Monfreda C, et al. Mind the gap: how do climate and agricultural management explain the 'yield gap' of croplands around the world? Glob Ecol Biogeogr 2010;19.

Liu J, Savenije HHG. Food consumption patterns and their effect on water requirement in China. Hydrol Earth Syst Sci 2008;12:887–98.

Mekonnen MM, Hoekstra AY. The green, blue and grey water footprint of crops and derived crop products. Value of Water Research Report Series No.47. Delft, the Netherlands: UNESCO-IHE; 2010.

Mekonnen MM, Hoekstra AY. The green, blue and grey water footprint of crops and derived crop products. Hydrol Earth Syst Sci 2011a;15:1577–600.

Mekonnen MM, Hoekstra AY. National water footprint accounts: the green, blue and grey water footprint of production and consumption. Value of Water Research Report Series No.50. Delft, the Netherlands: UNESCO-IHE; 2011b.

Mithril C, Dragsted LO, Meyer C, Tetens I, Biltoft-Jensen A, Astrup A. Dietary composition and nutrient content of the New Nordic Diet. Public Health Nutr 2013;16:777–85. http://dx.doi.org/10.1017/S1368980012004521.

Mueller ND, Gerber JS, Johnston M, Ray DK, Ramankutty N, Foley JA. Closing yield gaps through nutrient and water management. Nature 2012;490:254–7. [http://www.nature.com/nature/journal/v490/n7419/abs/nature11420.html#supplementary-information].

Neumann K, Verburg PH, Stehfest E, Müller C. The yield gap of global grain production: a spatial analysis. Agr Syst 2010;103:316–26. http://dx.doi.org/10.1016/j.agsy.2010.02.004.

NHS. Meat in your diet. National Health Service; 2013. www.nhs.uk/Livewell/Goodfood/Pages/meat.aspx (access: 03.06.2013).

Olesen JE, Trnka M, Kersebaum KC, Skjelvåg AO, Seguin B, Peltonen-Sainio P, et al. Impacts and adaptation of European crop production systems to climate change. Eur J Agron 2011;34:96–112. http://dx.doi.org/10.1016/j.eja.2010.11.003.

Parfitt J, Barthel M, Macnaughton S. Food waste within food supply chains: quantification and potential for change to 2050. Phil. Trans. R. Soc. B 2010;365:3065–81.

Rockström J, Falkenmark M, Karlberg L, Hoff H, Rost S, Gerten D. Future water availability for global food production: the potential of green water for increasing resilience to global change. Water Resour Res 2009;45:W00A12. http://dx.doi.org/10.1029/2007WR006767.

Thaler S, Zessner M, Bertran De Lis F, Kreuzinger N, Fehringer R. Considerations on methodological challenges for water footprint calculations. Water Sci Technol 2012;65: 1258–64. http://dx.doi.org/10.2166/wst.2012.006.

Tilman D, Balzer C, Hill J, Befort BL. Global food demand and the sustainable intensification of agriculture. Proc Natl Acad Sci U S A 2011;108:20260–4.

Van Oel P, Mekonnen M, Hoekstra A. The external water footprint of The Netherlands: geographically-explicit quantification and impact assessment. Ecol Econ 2009;69: 82–92.

Vanham D. A holistic water balance of Austria — how does the quantitative proportion of urban water requirements relate to other users? Water Sci Technol 2012;66:549–55. http://dx.doi.org/10.2166/wst.2012.201.

Vanham D. The water footprint of Austria for different diets. Water Sci Technol 2013;67: 824–30. http://dx.doi.org/10.2166/wst.2012.623.

Vanham D. An assessment of the virtual water balance for agricultural products in EU river basins. Water Resour Ind 2013;1–2:49–59. http://dx.doi.org/10.1016/j.wri.2013.03.002.

Vanham D, Bidoglio G. A review on the indicator water footprint for the EU28. Ecol Indic 2013;26:61–75. http://dx.doi.org/10.1016/j.ecolind.2012.10.021.

Vanham D, Mekonnen MM, Hoekstra AY. The water footprint of the EU for different diets. Ecol Indic 2013;32:1–8. http://dx.doi.org/10.1016/j.ecolind.2013.02.020.

Walter P, Infanger E, Mühlemann P. Food pyramid of the Swiss Society for Nutrition. Ann Nutr Metab 2007;51:15–20.

Westhoek H, Rood T, van den Berg M, Nijdam D, Reudink M, Stehfest E. The protein puzzle. The Consumption and Production of Meat, Dairy and Fish in the European Union. The Hague: PBL Netherlands Environmental Assessment Agency; 2011.
WHO. Food Based Dietary Guidelines in the WHO European Region. Copenhagen: WHO Regional Office for Europe; 2003.
WHO. Protein and amino acid requirements in human nutrition. Report of a Joint WHO/FAO/UNU Expert Consultation, World Health Organisation, Geneva WHO Technical Report Series 935; 2007.
Willett WC, Sacks F, Trichopoulou A, Drescher G, Ferro-Luzzi A, Helsing E, et al. Mediterranean diet pyramid: a cultural model for healthy eating. Am J Clin Nutr 1995;61:1402S–6S.
WRAP. Household Food and Drink Waste in the UK, United Kingdom; 2009.
Wriedt G, Van der Velde M, Aloe A, Bouraoui F. Estimating irrigation water requirements in Europe. J Hydrol 2009;373:527–44. http://dx.doi.org/10.1016/j.jhydrol.2009.05.018.
Zessner M, Helmich K, Thaler S, Weigl M, Wagner KH, Haider T, et al. Nutrition and land use in Austria. Oesterr Wasser — Abfallwirtsch 2011;63:95–104.