Ecological Indicators 32 (2013) 1–8

Contents lists available at SciVerse ScienceDirect

Ecological Indicators

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

The water footprint of the EU for different diets

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ARTICLE INFO

Article history:
Received 19 July 2012
Received in revised form
17 December 2012
Accepted 15 February 2013

Keywords:
Water footprint
Virtual water
EU
Diets

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.

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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1470-160X/$ – see front matter
http://dx.doi.org/10.1016/j.ecolind.2013.02.020

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 $WF_{proc}[q]$ (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):

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

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

where C[p] is the consumption of agricultural product p by consumers within the EU28 (ton/yr) and $\mathrm{WF}^{*}_{\text{prod}}$[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 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' (FAO, 2001). For example, bread is converted into wheat equivalent. Total energy, 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
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 *Deutsche Gesellschaft für Ernährung (DGE)* – 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

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.

Table 2
Recommended intake amounts for product groups as recommended by the DGE.

Product group	Quantity chosen (g/d), based upon recommendations from the DGE	Data source/justification
Cereals, rice, potatoes	200 cereal eq. bread/cereal flakes + 200 potatoes/cereal products (e.g. pasta)	Elmadfa and Freisling (2007), Zessner et al. (2011)
Sugar	Max. 60 (most countries with a recommendation on sugar intake suggest that less than 10% of daily energy intake comes from sugar)	WHO (2003), based upon intake of 2200 kcal/d
Fruit	250 (2–3 portions) daily	Zessner et al. (2011), WHO (2003)
Vegetables	400 daily	Walter et al. (2007), Zessner et al. (2011)
Crop oils	10 (2 teaspoons) of high-quality plant-based oils such as rapeseed oil or olive oil and 10 (2 teaspoons) of plant-based oils for cooking	Walter et al. (2007), Zessner et al. (2011)
Animal fats	15 (3 teaspoons) of butter or margarine	Walter et al. (2007)
Meat	450 meat and 80 fish (substituted by meat) per week	Zessner et al. (2011)
Milk and milk products	200 milk/yoghurt and 50 cheese (400 milk eq.)	Zessner et al. (2011)
Eggs	Up to 3 eggs per week (1 egg 60 g)	Zessner et al. (2011)

In this paper, a population average energy intake of 2200 kcal/d is set as target, as also recommended by (WHO, 2007) for a healthy diet. The recommended values are 2500 kcal for young men and 2000 kcal for young women, and less for children and elderly people. A sex and age based analysis (with data from (EUROSTAT, 2012), Fig. 1) results in the average value of 2000 kcal (whole population average) for people with medium physical activities. For high physical activities energy requirements are higher. Therefore a EU28 average target value of 2200 kcal is appropriate. This results in a recommendation of 18–27 kg/yr protein intake (50–75 g/d) (Westhoek et al., 2011; WHO, 2007).

3. Results and discussion

3.1. WF reference situation

Fig. 2 shows the reference situation (1996–2005) EU28 WF of production (WF_{prod}) and WF of consumption (WF_{cons}) components for agricultural and industrial products as well as domestic water use. The total EU28 WF_{prod} is 609 km^3/yr or 3420 lcd. The total EU28 WF_{cons} is 857 km^3/yr or 4815 lcd. The WF of agricultural products represents by far the largest fraction in the total WF_{prod} and WF_{cons}. The WF of domestic water use only represents a minor fraction of the total WF. Green water represents by far the largest part of the WF of agricultural products. For agricultural products as well as industrial products the WF_{cons} is larger than the WF_{prod}. This means that for both product groups the EU28 is a net virtual water importer: it imports more virtual water than it exports (Vanham and Bidoglio, 2013; Hoekstra, 2011). Explanations are that 1) for some products the EU28 is not self-sufficient (although for many products it is) and 2) the production of agricultural/industrial goods is very water efficient as compared to other countries from which goods are imported (virtual water contents of goods are relatively low in the EU28).

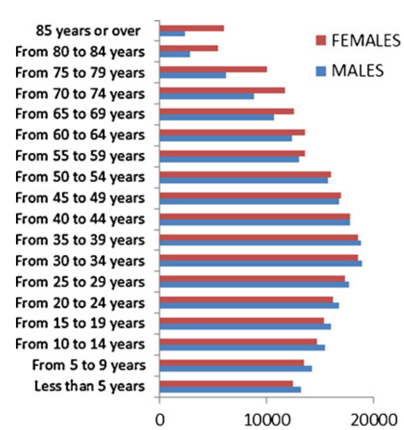

Fig. 1. The EU28 population pyramid for the year 2000 (population in 1000). Data source EUROSTAT (2012).

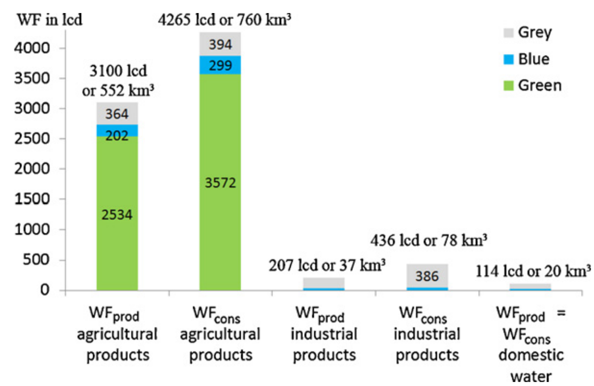

Fig. 2. The EU28 WF_{prod} and WF_{cons} components for agricultural and industrial products as well as domestic water use.

Data source Hoekstra and Mekonnen (2012).

Edible products account for the largest fraction of the total WF_{cons} (Fig. 3), i.e. 4032 lcd or 718 km^3/yr (84% of the total WF_{cons}). The WF_{cons} resulting from the consumption of edible animal products (2233 lcd or 397 km^3/yr) is larger than the one resulting from the consumption of crop products (1799 lcd or 320 km^3/yr), while the crop products provide more calories than the animal products.

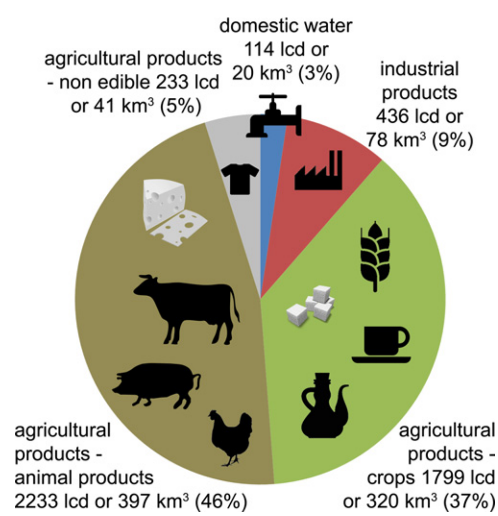

Fig. 3. The EU28 WF_{cons} for different product groups. Average for the period 1996–2005.

Data source Hoekstra and Mekonnen (2012).

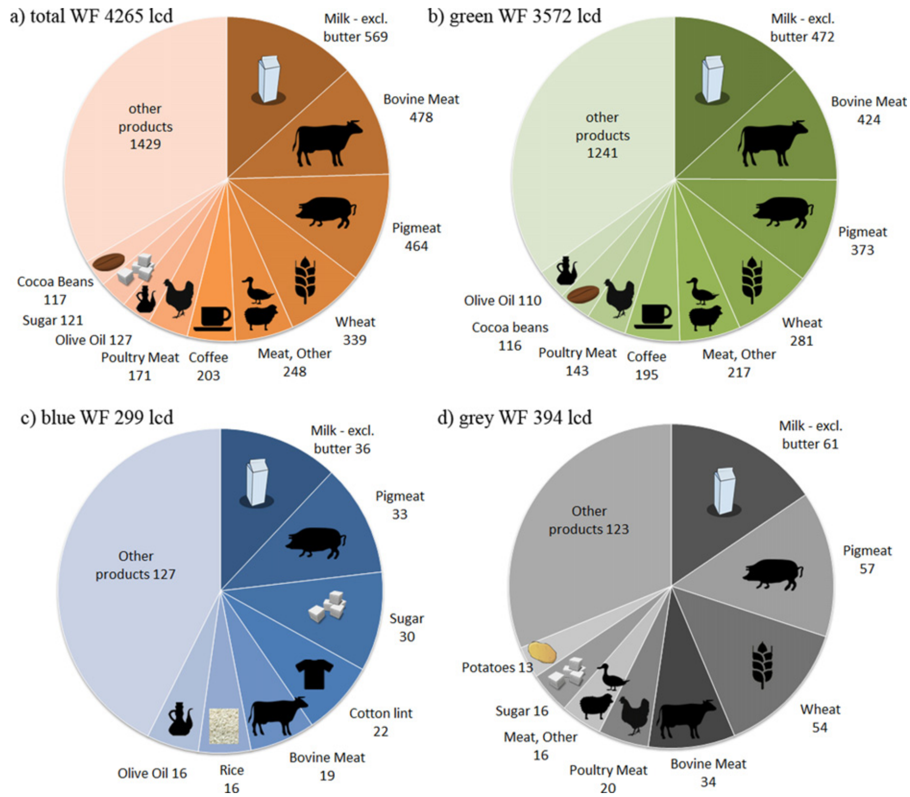

Fig. 4. The EU28 WF_{cons} (in lcd) for different products and WF components, sorted according to quantities. Averages for the period 1996–2005. Data source Hoekstra and Mekonnen (2012).

This shows that the largest reductions in the WF_{cons} can be made by changing diets.

Fig. 4 shows the products that contribute most to the total WF_{cons} as well as the products that contribute most to the green, blue, grey WF, respectively. Milk (including derived milk products like cheese and yoghurt) has the highest WF_{cons} value of all products, also for the different WF_{cons} components. All meat products have high WF_{cons} values. Some specific products have a relatively large contribution to green WF_{cons} (like coffee, cocoa and wheat), while other products, like cotton and rice, have a relatively large contribution to blue WF_{cons}.

3.2. Analysis of the different diets

Fig. 5 gives an overview of the intake amounts for the reference period and the DGE scenario. The current EU28 average intake of several product groups is near to the recommended amounts: cereals, rice and potatoes, milk including milk products and eggs. However the intake of some product groups should be reduced

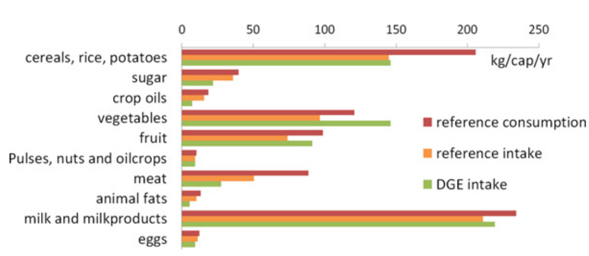

Fig. 5. Consumption and intake of product groups for the reference period and as recommended by the DGE. For some product groups, consumption values (from FAO FBS) are given in product equivalent (eq.) values (e.g. bread as wheat eq. and meat in carcass weight). Meat intake values are retail quantities. Milk and milk products are expressed as milk eq. (e.g. 8 l milk eq. for 1 kg of cheese). Pulses, nuts and oilcrops are not specifically recommended by the DGE.

(sugar, crop oils, meat and animal fats) and of other product groups increased (vegetables and fruit). It has to be stressed that these values are average EU28 intake values, and amongst nations, regions and individuals current intake amounts can be very different. As an example, current average intake amounts of meat (correlated with per capita GDP) are higher than the EU28 average in Austria or Spain but lower than average in Bulgaria or Romania (Westhoek et al., 2011; Vanham, 2013).

The intakes for the different scenarios in terms of weight (kg/yr), energy (kcal/d) and protein (g/d) are shown in Table 3. For the VEG and COM diets, all respectively half of the meat intake is substituted by a slightly larger amount of pulses and oilcrops (no nuts are added). The amount equals an intake of 30.6 kg/yr (existing 9.3 + 21.3) for the VEG scenario. For the COM scenario an amount of 19.9 kg/yr (existing 9.3 + 10.6) is chosen. These amounts are chosen because they result in no change in total energy and protein intake for the VEG and COM scenarios as compared to the DGE scenario (Total 1 in Table 3: 2171 kcal/d and 70.8 g/d protein). Although the total energy intake (2171 kcal/d) for the assessed products is slightly below the targeted 2200 kcal/d, this poses no problem because the additional consumed products (stimulants, alcoholic beverages, spices) result in total energy intake values (Totals 2 and 3 in Table 3) larger than this value. For the product groups assessed by the DGE (Total 1 in Table 3), the percentage of total energy intake from animal products ranges from 29% (REF) to 20% (VEG). The percentage of total protein intake from animal products ranges from 59% (REF) to 31% (VEG).

3.3. WF_{cons} of the different diets

Fig. 6 shows a substantial decrease in the total WF_{cons} for agricultural products (−974 lcd or −23% DGE, −1292 lcd or −30% COM, −1611 lcd or −38% VEG) for the alternative diets relative to the existing situation (REF, 4265 lcd). The reduction in meat intake has

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.

Product group	Weight (kg/yr)		Energy (kcal/d)		Protein(g/d)	
	REF	Scenario	REF	Scenario	REF	Scenario
Cereals, rice, potatoes	145.1	146.0	880	886	25.8	26.0
Sugar	35.7	21.9	341	209	0.0	0.0
Crop oils	15.7	7.3	380	177	0.1	0.0
Vegetables	96.6	146.0	66	99	3.1	4.7
Fruit	74.1	91.3	86	106	1.0	1.2
Pulses, nuts, oilcrops	9.3	9.3* (DGE), 30.6 (VEG), 19.9 (COM)	71	71* (DGE), 264 (VEG), 167 (COM)	3.2	3.2 (DGE), 17.1 (VEG), 10.1 (COM)
Meat	50.5	27.6 (DGE), 0 (VEG), 13.8 (COM)	354	193 (DGE), 0 (VEG), 97 (COM)	25.5	13.9 (DGE), 0 (VEG), 7.0 (COM)
Animal fats	10.2	5.5	189	101	0.4	0.2
Milk and milk products	210.7	219.0	282	293	18.0	18.7
Eggs	11.2	9.4	43	36	3.5	2.9
Total 1	659.1	683.1 (DGE), 676.9 (VEG), 680.0 (COM)	2692	2171 (DGE, VEG, COM)	80.5	70.8 (DGE, VEG, COM)
Stimulants	6.7	6.7**	20	20	1.2	1.2
Alcoholic beverages	98.4	63.5***	170	110	0.9	0.6
Total 2	764.2	750.5 (DGE), 742.5 (VEG), 745.1 (COM)	2882	2301 (DGE, VEG, COM)	82.6	72.6 (DGE, VEG, COM)
Spices	0.5	0.5*	4	4	0.1	0.1
Fish, seafood	19.1	0****	40	0	5.6	0.0
Miscellaneous	0.0	0.0	3	3	0.0	0.0
Total 3	783.8	753.9	2929	2308 (DGE, VEG, COM)	88.3	72.7 (DGE, VEG, COM)

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

the largest impact on the WF reduction, due to the relatively high WF of meat products (Fig. 4). But also the reduction in oil and sugar intake has an important impact. In the VEG diet, WF is the lowest (2655 lcd). A large fraction of the WF in this diet relates to the consumption of milk and milk products.

For the REF (4265 lcd) and DGE (3291 lcd) diets, WF_{cons} is larger than WF_{prod} (3100 lcd, see also Fig. 2) of agricultural goods (edible and non-edible). This means that the EU28 imports more VW than it exports, resulting in a net VW import. However, for the COM (2973 lcd) and VEG (2655 lcd) diets, WF_{cons} is smaller than WF_{prod}. For these diets, the EU28 thus changes to a net VW exporter: it exports more VW than it imports. There is even more potential for reducing the WF_{cons}, namely by reducing the consumption of stimulants (especially coffee and cocoa) and non-edible agricultural products (e.g. cotton, leather or rubber).

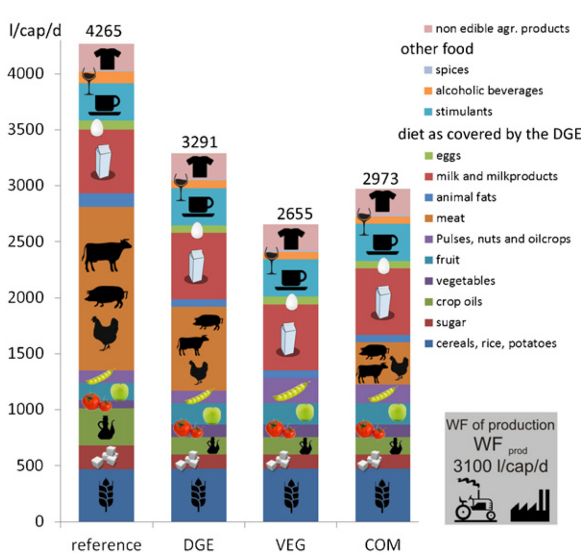

Fig. 6. The EU28 WF_{cons} regarding agricultural products for different diet scenarios.

The reduction patterns for the green, blue and grey WF_{cons} in the three alternative diets are similar to the reduction pattern for the total WF_{cons} (Fig. 7). The green WF_{cons} shows a decrease for all diets (−838 lcd or −23% DGE, −1112 lcd or −31% COM, −1385 lcd or −39% VEG) with respect to the existing situation (REF, 3572 lcd). Also the blue WF_{cons} shows a decrease for all diets (−54 lcd or −18% DGE, −73 lcd or −25% COM, −93 lcd or −31% VEG) with respect to the existing situation (REF, 299 lcd). Finally, the grey WF_{cons} shows a decrease for all diets (−82 lcd or −21% DGE, −107 lcd or −27% COM, −133 lcd or −34% VEG) with respect to the existing situation (REF, 394 lcd).

Regarding the green WF, the EU28 is a net VW importer for the REF and DGE scenarios, but becomes a net VW exporter for the COM and VEG scenarios. For the blue WF, the EU28 is a net VW importer for all scenarios. However, for the VEG scenario the difference is very small (WF_{prod} = 202 lcd and WF_{cons} = 206 lcd). Regarding the grey WF, the EU28 is a net VW importer for the reference period, but becomes a net VW exporter for the DGE, COM and VEG scenarios.

The EU28 green + blue WF_{cons} (without the grey WF_{cons} component) is shown in Fig. 8a. The same observations are made as in Fig. 6. The EU28 blue WF_{cons} for the different diet scenarios is presented in Fig. 8b. The figure shows that the relative proportions of product groups for the blue WF_{cons} are different to those of the total WF_{cons} (Fig. 6) and the green + blue WF_{cons} (Fig. 8a). With respect to the reference situation, the blue WF_{cons} decreases substantially for the product groups meat, crop oils and sugar. However, a substantial increase is observed for the product groups fruit and vegetables. It is to be noted, however, that the composition of single fruit and vegetable products within their groups for REF has been extrapolated to the other 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. Overall, the total blue WF_{cons} of the EU28 decreases for the different diet scenarios. With the appropriate water resources management decisions, this could contribute to relieve water stress in EU28 river basins. In several EU28 river basins, this stress is significant, as shown by (Hoekstra et al., 2012). They estimate blue water scarcity by comparing total blue WF_{prod} to ecological available blue water, whereby the latter

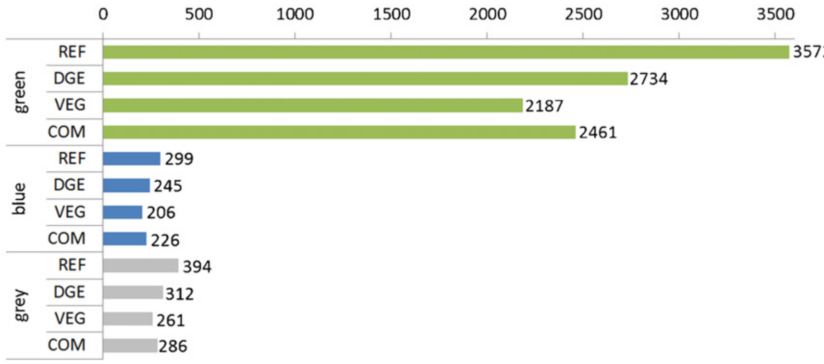

Fig. 7. The EU28 green, blue and grey WF_{cons} regarding agricultural products for different diet scenarios. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.)

is taken as the hydrological available blue water minus ecological flow requirements.

3.4. Implications for EU28 agricultural production: potential scenarios

Within a global context, with finite land and freshwater resources, one of the key issues to address is global sustainable agriculture that is able to feed the whole world population. Within the recent final Rio + 20 text, there is reaffirmation of the necessity to promote, enhance and support more sustainable agriculture, that improves food security, eradicates hunger and is economically viable, while conserving land, water, plant and animal genetic resources, biodiversity and ecosystems and enhancing resilience to climate change and natural disasters. Current EU28 agricultural production systems contribute to the depletion (Hoekstra et al., 2012) and contamination of domestic water resources. Current EU28 consumption also contributes to depletion and contamination of foreign water resources, due to its substantial external WF_{cons}. With increasing competition over scarce global freshwater resources it is doubtful whether the EU28 can continue to rely on external water resources to the same extent as today (Hoekstra, 2011). Increasing food demands in countries like China and India, depletion of water resources for export products in countries like Australia and the US, deforestation for livestock feed production in Brazil, climate change and other global developments, imply that the EU28 will – apart from modifying its consumption diet – have to optimise the use of its own water resources for domestic production (Hoekstra, 2011; Vanham and Bidoglio, 2013). The latter needs to be done by means of sustainable intensification, with lessons from organic farming.

There is a difference in agricultural production outputs between different EU28 zones (Vanham and Bidoglio, 2013). The southern EU zone is a net exporter of vegetables and fruit but a net importer for cereals, meat and milk. The western and northern zones are net exporters for cereals, meat and milk and net importers for vegetables and fruit. According to (Ciscar et al., 2011), agricultural yields in northern Europe will increase as a result of climate change, but in southern Europe they will decrease. In the western EU zone, moderate yield changes are predicted. In order to achieve the same

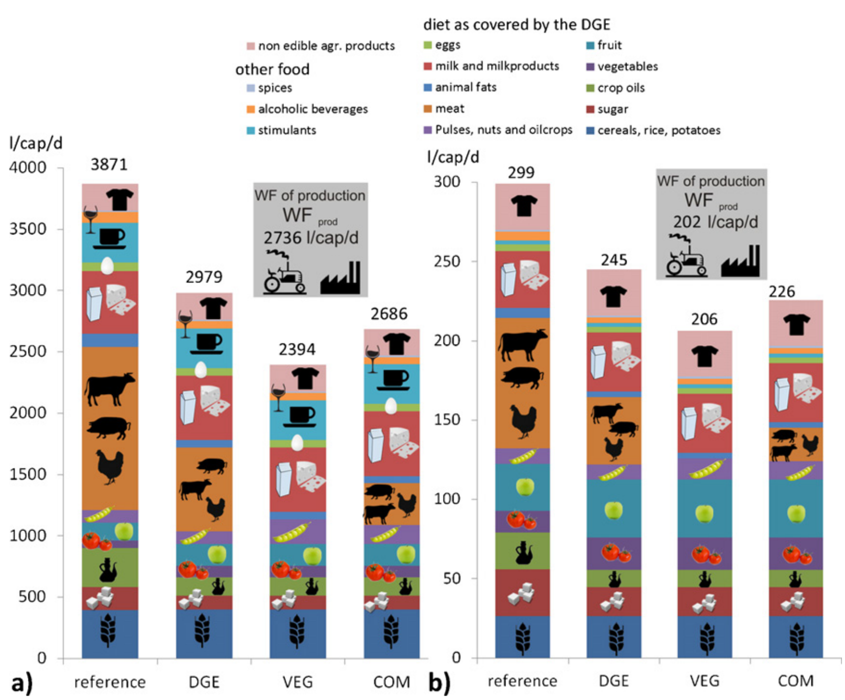

Fig. 8. The EU28 (a) green + blue WF_{cons} and (b) blue WF_{cons} regarding agricultural products for different diet scenarios. Also the WF_{prod} regarding agricultural products is shown. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.)

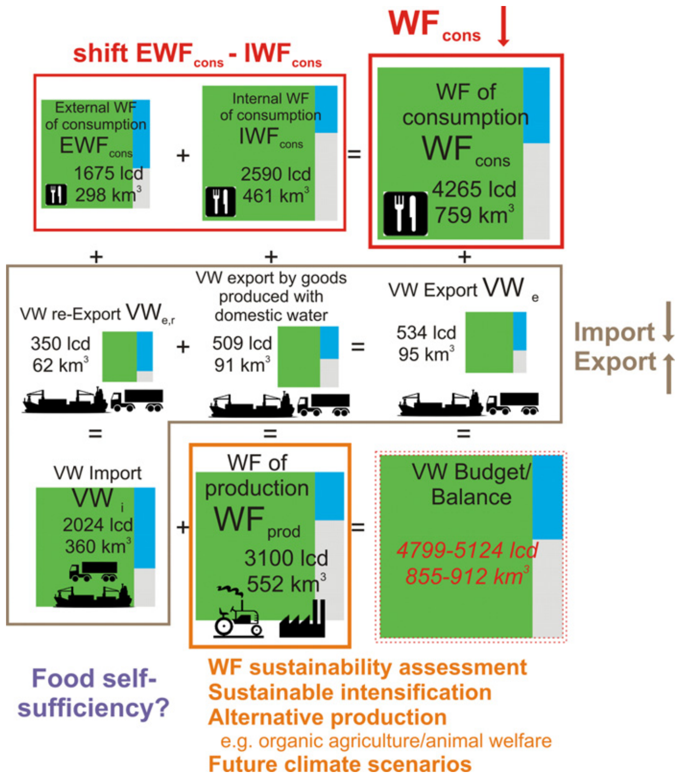

Fig. 9. WF accounting scheme for agricultural products for the EU28. Indication of possible scenarios for the EU28 VW flows and WF_{prod}, in case of a reduction in the EU28 WF_{cons} due to other diets.

production levels, climate change will result in increased irrigation requirements, especially in the Mediterranean zone but also in other parts of the EU28 for supplementary irrigation during summer (Wriedt et al., 2009). The overall picture is that there will be a gradual shift of water-demanding activities from other parts of the world to Europe and, within Europe, from Southern to Northern Europe (Hoekstra, 2011).

An overview of implications and future scenarios related to a reduction in the WF_{cons} as observed for the different diets is shown in Fig. 9. This figure displays the WF accounting scheme for agricultural products for the EU28. The total EU28 WF accounting scheme was already displayed in (Vanham and Bidoglio, 2013). Theoretically the sum of $WF_{prod} + VW_i$ should equal the sum of $WF_{cons} + VW_e$. The figure shows that this does not hold. The reason is that the WF_{cons} is assessed by means of the bottom-up approach and that the different WF accounting components are assessed with different underlying data.

A key question in the definition of scenarios is to what extent the EU28 can become self-sufficient (apart from certain commodities which cannot be grown domestically like coffee or cocoa). With a reduction in the WF_{cons} (assuming the WF_{prod} remains the same), the EU28 can choose to reduce its imports (decrease of VW_i) and/or increase its exports (increase of VW_e), or a combination of both. This is consistent with a shift between IWF_{cons} and EWF_{cons} (Fig. 9).

Possible implications/scenarios for EU28 agricultural production are also displayed in Fig. 9:

- A key issue is whether the current WF_{prod} for agricultural products is sustainable. An overview on WF sustainability assessment indicators to be used is listed in (Vanham and Bidoglio, 2013). The blue water scarcity indicator, accounting for environmental flow requirements over the year, has already been analysed for major EU river basins (Hoekstra and Mekonnen, 2011).
- Within the global setting described before, there is a need for sustainable intensification (without simplification, i.e. without the loss of diversity) of the EU28 agricultural production system. Especially in eastern European member states yields can still be increased. With this respect an analysis of potential increases in water productivity at farm level (yield increase, precision irrigation, shift to less thirsty crops) should be conducted (Vanham and Bidoglio, 2013). Also the potential of organic farming production – a procedure which can significantly reduce grey WF_{prod} – and livestock production systems that account for animal welfare should be studied.
- An analysis of the maximum sustainable WF_{prod} per catchment for EU28 river basins should be conducted.
- Analyses for the current and future climate scenarios.

To formulate integrated policy options, there needs to be an integration with other factors (apart from water) like land resources, greenhouse gas emissions and (fossil) energy use, because the WF is a partial indicator (Vanham and Bidoglio, 2013).

4. Conclusions

The WF concept provides the unique opportunity to link the use of water resources to the consumption of goods. It also shows the global dimension of water as a resource. The total current EU28 WF_{prod} is 3420 lcd and its WF_{cons} is 4815 lcd. The EU28 is a net virtual water importer regarding its total WF as well as its WF for agricultural products. This paper has shown that different EU28 diets – a healthy (DGE), vegetarian (VEG) and combined (COM) diet – as compared to the current average diet (REF) would result in a substantial reduction of the EU28 WF_{cons} for agricultural products. The latter is by far the most dominant part of the total WF. The current EU28 diet consists of recommended (healthy diet) amounts for the product groups cereals, rice and potatoes, milk including milk products and eggs. However, in order to have 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).

Of the diets analysed, the VEG diet would result in the lowest WF_{cons}. The reduction in meat intake has the largest impact on the WF reduction, due to the high WF per caloric value of meat products. Regarding the total WF for agricultural products, the EU28 shifts from net VW importer for the REF and DGE diets to net exporter for the COM and VEG diets (for the current production system). The same observations are made for the green + blue WF_{cons} (without the grey WF_{cons} component). Regarding the green WF, this shift occurs for the same diets. Regarding the blue WF, the EU28 is a net VW importer for all scenarios. For the VEG scenario the difference is however very small. Regarding the grey WF, the EU28 is a net VW importer for the REF diet, but becomes a net VW exporter for the DGE, COM and VEG diets.

The paper concludes with the implications these reduced WF_{cons} values can have for EU28 agricultural production, VW imports and exports (Fig. 9).

5. Disclaimer

The conclusions and statements presented are those of the authors and may not in any circumstances be regarded as stating an official position of the European Commission.

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