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P.R. van Oel
M.M. Mekonnen
A.Y. Hoekstra

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The external water footprint of the Netherlands: quantification and impact assessment

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THE EXTERNAL WATER FOOTPRINT OF THE NETHERLANDS:
QUANTIFICATION AND IMPACT ASSESSMENT

P.R. VAN OEL[1]

M.M. MEKONNEN[1]

A.Y. HOEKSTRA[1,2]

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[1] Dept. of Water Engineering and Management, University of Twente, Enschede, The Netherlands

[2] Contact author: Arjen Hoekstra, a.y.hoekstra@utwente.nl

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Contents

Summary

This study quantifies the external water footprint of the Netherlands by partner country and import product and assesses the impact of this footprint by contrasting the geographically explicit water footprint with water scarcity in the different parts of the world. Hotspots are identified as the places where the external water footprint of Dutch consumers is significant on the one hand and where water scarcity is serious on the other hand.

The main findings of this study are:

- The total water footprint of the Netherlands is estimated to be about 2300 m^3/yr/cap, of which 67% relates to the consumption of agricultural goods, 31% to the consumption of industrial goods, and 2% to domestic water use.
- The Dutch water footprint related to the consumption of agricultural goods, is composed as follows: 46% related to livestock products; 17% oil crops and oil from oil crops; 12% coffee, tea, cocoa and tobacco; 8% cereals and beer; 6 % cotton products; 5% fruits; and 6 % other agricultural products.
- About 11% of the water footprint of the Netherlands is internal and 89% is external. About 48% of the external water footprint of the Netherlands is located within European countries (mainly in Germany, France and Belgium) and 20% in Latin American countries (mainly in Brazil and Argentina). For industrial products 53% of the consumed products originates from European countries and about 33% originates from Asian countries (mainly China, Taiwan, Hong Kong and Viet Nam).
- As a trade nation, the Netherlands imports not only for the purpose of domestic consumption. Only 44% of the virtual-water import relates to products consumed in the Netherlands, thus constituting the external water footprint. For agricultural products this is 40% and for industrial products this is 60%. The remaining 56% of the virtual-water import to the Netherlands is re-exported. About 41% of the virtual-water import for re-export comes from Africa (mainly Cote d'Ivoire, Ghana, Cameroon and Nigeria) and mainly concerns the import of cocoa beans, most of which are processed in the Netherlands into cocoa butter, cocoa powder or cocoa paste and re-exported to other European countries (mainly Germany, United Kingdom, Belgium and Switzerland).
- The impact of the external water footprint of Dutch consumers is highest in countries that experience serious water scarcity. Based on indicators for water scarcity the following eight countries have been identified as hotspots: China; India; Spain; Turkey; Pakistan; Sudan; South Africa; and Mexico. Although these countries are not the largest contributors to the external water footprint of Dutch consumers in absolute terms, the impact of Dutch consumption in these countries deserves serious attention since in these countries the negative externalities of Dutch consumption are considered to be most serious.

The study shows that Dutch consumption implies the use of water resources throughout the world, with significant impacts at specified locations. This knowledge is relevant for consumers, government and businesses when addressing the sustainability of consumer behaviour and supply chains. The results of this study can be an input to bilateral cooperation between the Netherlands and the Dutch trade partners aimed at the reduction of the

negative impacts of Dutch consumption on foreign water resources. Dutch government can also engage with businesses in order to stimulate them to review the sustainability of their supply chains.

1. Introduction

The background of this study is the recognition that there is a relation between consumption by Dutch consumers and impacts on water systems elsewhere in the world. Many of the goods consumed in the Netherlands are not produced in the Netherlands, but abroad. Some goods, most in particular agriculture-based products, require a lot of water during production. These water-intensive production processes are accompanied by impacts on the water systems at the various locations where the production processes take place. The impacts vary from reduced river water flows, declined lake levels and declined ground water tables to increased salt intrusion in coastal areas and pollution of freshwater bodies. As an indicator of the water use related to consumption we use the water footprint concept.

The water footprint of a nation is defined as the total amount of water that is used to produce the goods and services consumed by the inhabitants of the nation (Hoekstra and Chapagain, 2007a, 2008). The total water footprint of a country includes two components: the part of the footprint that falls inside the country (internal water footprint) and the part of the footprint that presses on other countries in the world (external water footprint). In this report, we focus on the external water footprint of the Netherlands.

The external water footprint of the Netherlands is the volume of water used in other countries to produce goods and services imported and consumed by the inhabitants of the Netherlands. The water footprint is a quantitative measure of the amount of water consumed. It breaks down into three components: the blue, green and grey water footprint. The blue water footprint is the volume of freshwater that evaporated from the global blue water resources (surface water and ground water) to produce the goods and services consumed by the people in a nation. The green water footprint is the volume of water evaporated from the global green water resources (rainwater stored in the soil as soil moisture). The grey water footprint is the volume of polluted water that associates with the production of all goods consumed in the nation. The latter is calculated as the volume of water that is required to dilute pollutants to such an extent that the quality of the water remains below agreed water quality standards. Analysis of the grey water footprint of the Dutch community will be done in this study only in the last phase, when analyzing the impacts at hotspots.

We will specify the external water footprint of the Netherlands according to (i) partner countries and (ii) imported products. The results of the country and product analyses are confronted with water scarcity indicators. In this way, hotspots are identified where the external water footprint of the Netherlands expectedly has the largest impacts. For a number of selected hotspots the impact on the affected local water systems will be further analyzed.

The research is driven by the following research questions:

- What is the water use outside of the Dutch borders in effect of Dutch consumption?
- In which countries is the external footprint concentrated?
- What are the main products related to this external footprint?
- What is the external water use related to total import into the Netherlands?

- In which countries is the impact of the external water footprint most serious (hotspots)?
- What is the impact of the external water footprint on local water systems in the identified hotspots?

We have considered the period 1996-2005, which is long enough to get a good impression of average Dutch trade and its effects on the Dutch water footprint, excluding the effects of deviations in specific years, but which is not long enough to carry out trend-analyses, which was out of the scope of the current study. In quantifying the total external water footprint of the Netherlands it was not feasible to distinguish between the green, blue and grey components of the water footprint, but in the analysis of the identified hotspots, a specification of the green, blue and grey water footprint was made.

2. Method for calculating the external water footprint and its impacts

2.1 Definitions

As defined by Hoekstra and Chapagain (2007a, 2008), the water footprint (WF) of Dutch consumers has two components: the internal water footprint (WF_i) and the external water footprint (WF_e).

$$WF[NL] = WF_i[NL] + WF_e[NL]$$

The internal water footprint is defined as the annual use of domestic water sources to produce goods and services consumed by the Dutch population. It is the sum of the total water volume used from the domestic water resources in the national economy (WU) minus the volume of virtual-water export to other countries insofar as related to the export of products produced with domestic water resources ($V_{e,d}$):

$$WF_i[NL] = WU[NL] - V_{e,d}[NL]$$

The external water footprint is defined as the annual volume of water resources used in other countries to produce goods and services consumed by the population of these countries. It is equal to the virtual-water import into the country (V_i) minus the volume of virtual-water exported to other countries as a result of re-export of imported products ($V_{e,r}$):

$$WF_e[NL] = V_i[NL] - V_{e,r}[NL]$$

As Figure 2.1 shows, the virtual-water export (V_e) consists of exported water of domestic origin ($V_{e,d}$) and re-exported water of foreign origin ($V_{e,r}$):

$$V_e[NL] = V_{e,d}[NL] + V_{e,r}[NL]$$

The virtual-water import will partly be consumed, thus constituting the external water footprint of the country (WF_e), and partly be re-exported ($V_{e,r}$):

$$V_i[NL] = WF_e[NL] + V_{e,r}[NL]$$

Finally, we see in Figure 2.1 that the sum of V_i and WU is equal to the sum of V_e and WF. We call this sum the virtual-water budget (B_v) of a country (Ma et al., 2006; Hoekstra and Chapagain, 2008).

$$\begin{aligned} B_v[NL] &= V_i[NL] + WU[NL] \\ &= V_e[NL] + WF[NL] \end{aligned}$$

As will be discussed in the next two sections, one can estimate the water footprint (WF) of a country through a bottom-up or top-down approach. We will apply both approaches in this study in order to be able to compare the outcomes. As will become clear, however, the bottom-up approach gives more reliable results in the case of the Netherlands, so that in the rest of the study, after the comparison of the outcomes of both approaches, we will work with the outcomes of the bottom-up approach.

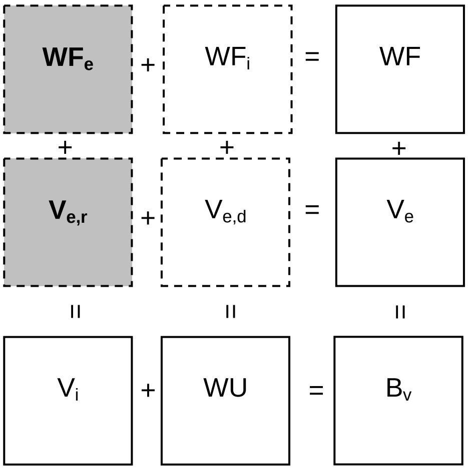


Figure 2.1. The relation between virtual-water import (V_i), virtual-water export (V_e), use of domestic water resources (WU) and the water footprint (WF) of a country. This study focuses on the grey-shaded boxes: the external water footprint (WF_e) and the import of virtual-water for re-export ($V_{e,r}$).

2.2 Bottom-up approach

In the bottom-up approach, the water footprint (WF) of the Netherlands (NL) is calculated by adding the direct water use by people and their indirect water use:

$$WF[NL] = WF_{direct}[NL] + WF_{indirect}[NL]$$

The direct water use refers to the water that people consume at home. The indirect water use of people refers to the water use by others to make the goods and services consumed. It refers to the water that was used to produce for example the food, clothes, paper, energy and industrial goods consumed. The indirect water use is calculated by multiplying all goods and services consumed by the inhabitants of the Netherlands by the respective water needs for those goods and services:

$$WF_{indirect}[NL,p] = \sum_{p=1}^{n}\left(C[NL,p]\cdot v^{*}[NL,p]\right)$$

C[NL,p] is Dutch consumption of product p (unit/yr) and $v^*[NL,p]$ the virtual-water content of this product (m^3/unit). The set of products considered refers to the full range of final consumer goods and services. The virtual-water content of a product is the volume of freshwater used to produce the product, measured at the place where the product was actually produced. The virtual-water content of a product thus varies as a function of place and conditions of production. It refers to the sum of the water use in the various steps of the production chain. The adjective 'virtual' refers to the fact that most of the water used to produce a product is not contained in the product. The real-water content of products is generally negligible if compared to the virtual-water content. The virtual water content of individual primary and processed products is calculated (per country) based on the method described in Hoekstra and Chapagain (2008).

In the case of agricultural products, the virtual-water content is expressed in terms of m^3/ton and consumption is expressed in ton/yr. In the case of industrial products, the virtual-water content is, for practical reasons, expressed in terms of m^3/US$ instead of m^3/ton. Industrial products show a relatively high heterogeneity and there are often different production methods for one type of product. As a result, the weight of an industrial product is not an as obvious indicator of underlying water use as in the case of an agricultural product. Since industrial production in a sector as a whole is generally expressed in monetary terms, it is easiest to consider water use in a sector per monetary unit as well.

The total volume of *p* consumed in a country will generally originate from different countries. The average virtual-water content of a product *p* consumed in the Netherlands is estimated by assuming that:

$$v^*[NL,p] = \frac{P[NL,p]\cdot v[NL,p] + \sum_{c=1}^{m}\left(I[c,p]\cdot v[c,p]\right)}{P[NL,p] + \sum_{c=1}^{m} I[c,p]}$$

The assumption here is that consumption originates from domestic production and imports according to their relative volumes.

2.3 Top-down approach

Another way of assessing the water footprint of a country (WF, m^3/yr) is the top-down approach, which takes the total water use (WU) in the country as starting point and then adds the incoming virtual-water flow (V_i) and subtracts the virtual-water export (V_e):

$$WF[NL] = WU[NL] + V_i[NL] - V_e[NL]$$

The water use in the Netherlands is calculated as follows:

$$WU[NL] = \sum_{p=1}^{n} P[NL,p]\cdot v[NL,p]$$

The gross virtual-water import is calculated as:

$$V_i[NL] = \sum_{p=1}^{n} \sum_{c=1}^{m} I[c,p] \cdot v[c,p]$$

The gross virtual-water export is calculated as:

$$V_e[NL] = \sum_{p=1}^{n} E[NL,p] \cdot v^*[NL,p]$$

The average virtual-water content of an exported product is estimated by applying the same assumption that was used in the bottom-up approach:

$$v^*[NL,p] = \frac{P[NL,p] \cdot v[NL,p] + \sum_{c=1}^{m} \left(I[c,p] \cdot v[c,p] \right)}{P[NL,p] + \sum_{c=1}^{m} I[c,p]}$$

2.4 The bottom-up versus the top-down approach

The bottom-up and top-down calculations of the water footprint of a country for a particular year theoretically result in the same figure, provided that there is no product stock change over a year. The top-down calculation can theoretically give a slightly higher (lower) figure if the stocks of water-intensive products increase (decrease) over the year. The reason is that the top-down approach presupposes a balance (V_i plus WU becomes WF and V_e) which is an approximation only (to be more precise: V_i plus WU becomes WF plus V_e plus virtual-water stock increase). Another drawback of the top-down approach is that there can be delays between the moment of water use for production and the moment of trade. When calculating the water footprint for year t, the variables V_i and V_e for year t may refer to actual water use in year t-1, t-2 or even t-3. For instance in the case of trade in livestock products this may happen: beef or leather products traded in one year originate from livestock raised and fed in previous years. Part of the water virtually embedded in beef or leather refers to water that was used to grow feed crops in previous years. As a result of this, the virtual-water balance presumed in the top-down approach ($WU[NL] + V_i[NL] = WF[NL] + V_e[NL]$) will hold over a period of a few years, but not necessarily over one year.

Next to theoretical differences between the two approaches, differences can result from the use of different types of data as inputs of the calculations. The bottom-up approach depends on the quality of consumption data, while the top-down-approach relies on the quality of trade data. When the different databases are not consistent with one another, the results of both approaches will differ.

In one particular type of case the outcome of the top-down can be very vulnerable to relatively small errors in the input data. This happens when the import and export of a country are large relative to its domestic production, which is typical for a trade nation as the Netherlands. In this case the water footprint, calculated in the top-down approach as the domestic water use plus the virtual-water import minus the virtual-water export, will be sensitive to the import and export data used. Relative small errors in the estimates of virtual-water import and export translate into a relatively large error in the water footprint estimate. In such a case, the bottom-up approach will yield a more reliable estimate than the top-down approach. In countries where trade is relatively small compared to domestic production, the reliability of the outcomes of both approaches will depend on the relative quality of the databases used for each approach. In the case of agricultural products, we carry out both calculations in this study. However, the water footprint outcomes from the bottom-up approach are used as a basis for further analysis. For industrial products we only carry out the top-down calculations. In the case of industrial products, we did not distinguish between different types of industrial commodities, thus effectively regarding industrial products as one homogeneous category with an average virtual-water content per dollar.

2.5 The external water footprint

In the present study we are interested in the external water footprint of Dutch consumers (WF_e) and the re-exported virtual-water ($V_{e,r}$). To determine these terms we use the following assumption, which we apply separately for the category of agricultural products and for the category of the industrial products:

$$WF_e[NL] = \frac{WF[NL]}{V_i[NL] + WU[NL]} \cdot V_i[NL]$$

This formula says that only a fraction of the gross virtual-water import can be said to be the external water footprint of the Dutch consumers and that this fraction is equal to the portion of virtual-water import plus use of domestic water that is to be attributed to consumption within the country[1].The other portion of virtual-water import plus use of domestic water is exported and is therefore not part of the Dutch footprint.

The term WF in above equation refers to the water footprint of the Dutch consumers. When calculating the external water footprint we have taken the total water footprint as earlier calculated with the bottom-up approach.

The external water footprint can be estimated for specific countries and products by assuming that the national ratio between the external water footprint and the total virtual-water import applies to all partner countries and imported products[2,3]:

$$WF_e[NL, c, p] = \frac{WF_e[NL]}{V_i[NL]} \cdot V_i[NL, c, p]$$

---

1 This assumption implies that $\frac{WF_e}{V_{e,r}} = \frac{WF_i}{V_{e,d}} = \frac{WF}{V_e}$ and that $\frac{WF_e}{WF_i} = \frac{V_{e,r}}{V_{e,d}} = \frac{V_i}{WU}$.

2 We have made an exception for cocoa products and derivates, because of the exceptionally high volumes that are imported and re-exported again. The national ratio between WF_e and V_i is not a good assumption here. Instead, we have applied a specific ratio of WF_e to V_i valid to the cocoa product category.

3 For cotton we applied the top-down approach for estimating the water footprint, because data on cotton product consumption are not available in the consumption database used in this study (FAO, 2007b). Because the Netherlands does not have cotton production, we could now assume that $WF_e = V_i - V_e$.

The external water footprint of Dutch consumers for an individual country and an individual product are respectively:

$$WF_e[NL,c] = \sum_{p=1}^{n} WF_e[NL,c,p]$$

$$WF_e[NL,p] = \sum_{c=1}^{m} WF_e[NL,c,p]$$

Many products are imported from countries in which they are not produced. Examples are cocoa products from Belgium and cotton products from Germany. For some product groups, world production is concentrated in specific regions. For these products we can estimate the ultimate place of origin based on world production data (FAO, 2007b). We do this for cotton, cocoa and coffee. For these products it is assumed that the water footprint in a non-producing country should be distributed over producing countries according to the same distribution of the world production. We only include producing countries from which the Netherlands is already importing directly.

2.6 Impact of the water footprint

In order to gather insight into the impacts of both Dutch consumption and re-exported virtual-water, both $WF_{e,}$ and V_i as a whole are compared to indicators of water scarcity or stress. Water-scarcity indicators are always based on two basic ingredients: a measure of water demand or use and a measure of water availability. We make use of three different indicators:

(1) water competition level;
(2) withdrawal-to-availability ratio; and
(3) withdrawal-to-availability ratio by accounting for the environmental water requirements.

The first commonly used indicator of water scarcity is population of an area divided by total runoff in that area, called the water competition level (Falkenmark, 1989) or water dependency (Kulshreshtha, 1993). Many authors take the inverse ratio, thus getting a measure of the per capita water availability. Falkenmark proposes to consider regions with more than 1700 m3 per capita per year as ‘water sufficient’, which means that only general water management problems occur. Between 1000-1700 m3/cap/yr would indicate ‘water stress’, 500-1000 m3/cap/yr ‘chronic water scarcity’ and less than 500 m3/cap/yr ‘absolute water scarcity’. This classification is based on the idea that 1700 m3 of water per capita per year is sufficient to produce the food and other goods and services consumed by one person. In Falkenmark’s indicator ‘runoff’ is taken as a measure of water availability. Runoff can refer to locally generated runoff (in FAO terminology then called the internal renewable water resources, IRWR), but it can also include inflows from other areas (in FAO terminology then called the total renewable water resources, TRWR).

A second common indicator of water scarcity is the ratio of water withdrawal in a certain area to total runoff in that area, called variously the water utilization level (Falkenmark, 1989; Falkenmark et al., 1989), the withdrawal-to-availability ratio (Alcamo et al., 2000, 2002) or the use-to-resource ratio (Raskin et al., 1996).

The third indicator has been proposed by Smakhtin et al. (2004a; 2004b), who have modified the withdrawal-to-availability ratio by accounting for the environmental water requirements, which are subtracted from runoff.

All three water scarcity indicators can be applied to either countries or river basins. The indicators of water scarcity enable us to estimate the Dutch share in the creation of water stress in a country. On weak soil the imprint of a footstep is deeper than that it is on solid ground, so the impact of a water footprint in a water-scarce area is larger than in an area where water is more abundant.

2.7 Green, blue and grey water footprint

For the products with the largest contribution to the external water footprint of the Netherlands in the identified hotspots we estimate the size of the green, blue and grey components in the total water footprint.

In the case of agricultural products, we estimate the volume of green water use by taking the minimum of the crop water requirement and the precipitation available to the crop over the cropping season. We assume that 60% of the rainfall in the cropping season is available to the crop. The difference between crop water requirement and the precipitation available to the crop over the cropping season gives an indication of the irrigation water requirement (i.e. blue water requirement). For the areas equipped for irrigation we assume that the irrigation water requirements were actually met. For estimating the green versus blue water footprint in agriculture, we use the following spatial-explicit data:

- The main locations where specific crops are cultivated (amongst others: Leff et al., 2004);
- The percentage of land equipped for irrigation (Döll and Siebert 2000);
- Crop water requirements (Chapagain and Hoekstra, 2004).
- Monthly precipitation at meteorological station (Müller and Hennings, 2000).

In the case of agricultural products, we estimate the grey water footprint as follows. We assume that the quantity of nitrogen that reaches free flowing water bodies is 10 percent of the applied fertilization rate (in kg/ha/yr), presuming a steady state balance at root zone in the long run (Hoekstra and Chapagain, 2008). The effect of the use of other nutrients, pesticides and herbicides to the environment has not been analyzed. The total volume of water required per ton N is calculated considering the volume of nitrogen leached (ton/ton) and the maximum allowable concentration in the free flowing surface water bodies. The standard recommended by EPA (2005) for nitrate in drinking water is 10 milligrams per litre (measured as nitrogen) and has been taken to calculate the necessary dilution water volume. This is a conservative approach, since natural background concentration of N in the water used for dilution has been assumed negligible. Data on the application of fertilizers has been obtained from the FERTISTAT database of FAO (FAO, 2007c).

In the case of industrial products, we have taken data on water withdrawals from FAO (2007a). Part of this volume evaporates (blue water footprint), while the other part generally returns as polluted water to the water system (grey water footprint). In the cases where industrial wastewater flows are partially treated, we have thus overestimated the grey water footprint. On the other hand, the effect of pollution has been underestimated, because one cubic meter of wastewater generally does not result in one cubic metre of polluted water, but much more (Postel et al., 1996). On average, ten percent of industrial water withdrawals are lost through evaporation (Shiklomanov and Rodda, 2003). In this report we assume that in the estimated water footprints related to industrial products, ten percent is a blue water footprint and ninety percent is a grey water footprint.

2.8 Methodological innovation

The calculation methods applied in this study are the same as in the world-wide study on virtual water trade and water footprints that was carried out earlier for the period 1997-2001 (Hoekstra and Chapagain, 2007a, 2008; Chapagain and Hoekstra, 2008) and that was also applied to the Netherlands in more specific terms (Hoekstra and Chapagain, 2007b). There are, however, two methodological improvements when compared to this earlier study:

- We applied the bottom-up approach to calculate the water footprint which is more accurate for a country as the Netherlands, where trade flows are large if compared domestic production. [We tested this approach earlier in a pre-study for the Netherlands, see Gerbens-Leenes and Hoekstra, 2007].
- The virtual water content of consumed and exported goods is calculated as a weighted average of domestically produced and imported products (the variable v^* in Section 2.2) instead of taking the virtual water content of the domestically produced products or the global average virtual water content in the case that there is no domestic production.

Apart from the methodological improvements, there are differences between the earlier study and the current one in terms of the data used. In the current study we analyse the ten-year period 1996-2005 instead of the five-year period 1997-2001. Besides, we apply more accurate data in the current study with respect to livestock feed composition (Appendix 6).

Finally, the current study extends the earlier study by making the step from water footprint estimation towards impact assessment (Section 2.6).

3. Data sources

The study is based on data for the period of 1996-2005. Most results are presented as 10-year averages, although in some cases specific annual data are shown. The product coverage of the study is comprehensive: the trade analysis covers all agricultural and industrial product categories as represented in the trade database of ITC (2006) and the consumption analysis covers all consumption categories available within the food balance sheets of the FAO (2007b). Table 3.1 gives an overview of all input sources used in this study.

Table 3.1. Overview of input variables and sources used.

Input variable	Source
Agricultural water use	
• Crop water requirement per crop per country	Hoekstra & Chapagain (2008)
• Agricultural yield per crop per country	FAOSTAT (FAO, 2007b)
• Livestock feed composition in the Netherlands	CBS (2007), Elferink et al. (2007), LEI (2007) PDV (2005)
• Livestock feed composition in other countries	Hoekstra & Chapagain (2008)
• Consumption per product	FAO's food balance sheets, which are part of FAOSTAT (FAO, 2007b); data available for 1996-2003; average for this period assumed for 2004-05.
• Agricultural production	FAO PRODSTAT (FAO, 2007b)
• Use of fertilizer for important crops in hotspots	FAO FERTISTAT (FAO, 2007c)
Domestic water use	
• Domestic water withdrawal in the Netherlands	AQUASTAT (FAO, 2007a); Vitens (2008)
Industrial water use	
• Industrial water withdrawal per country	AQUASTAT (FAO, 2007a)
• Added value in the industrial sector per country	UN Statistic Division (2007)
Import and export of agricultural and industrial products	ITC (2006)
Precipitation and renewable water resources per country	AQUASTAT (FAO, 2007a)

4. The water footprint of Dutch consumers

The total water footprint of Dutch consumers is about 2300 m^3 per capita per year for the period 1996-2005. Agricultural goods are responsible for the largest part of the footprint (67%), industrial goods are responsible for 31% and domestic water use accounts for about 2% (Figure 4.1).

The water footprint due to the consumption of agricultural products can be specified further into product categories (Figure 4.2). Livestock products make up 46% of the water footprint. Oil crops and oil from oil crops are large contributors as well (17%). The consumption of coffee, tea, cocoa and tobacco contributes another 12% and cereals and beer, which is made from barley, contribute 8%. Cotton products and fruit contribute 6% and 5% respectively. The remainder of the footprint is related to other agricultural products (6%). A more detailed overview of the individual contribution of product categories to the water footprint of Dutch consumers is given in Table 4.1.

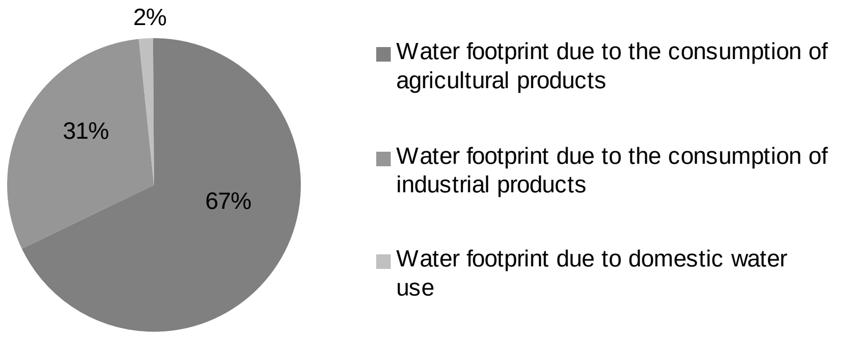


Figure 4.1. The water footprint of Dutch consumers. The total water footprint is 2300 m^3 per capita per year (population 16.3 million) for the period 1996-2005.

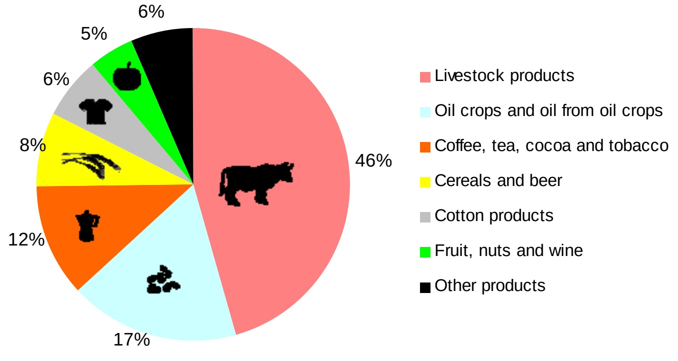


Figure 4.2. The total water footprint of the Dutch consumers related to consumption of agricultural products.

Table 4.1. Water footprint of the Dutch consumers related to consumption of agricultural products.

Product category	Water footprint (10^9 m^3)	
Livestock products	**11.58**	**45.6 %**
Pig meat	2.24	8.8%
Milk - excluding butter	2.10	8.3%
Bovine meat	1.88	7.4%
Fats, animals, raw	1.85	7.3%
Eggs	1.50	5.9%
Poultry meat	1.47	5.8%
Mutton & goat meat	0.14	0.5%
Offals, edible	0.13	0.5%
Butter, ghee	0.02	0.1%
Honey	0.00	< 0.1%
Cream	0.00	< 0.1%
Meat, other	0.24	1.0%
Oil from oil crops	**4.57**	**16.8 %**
Palm oil	1.04	4.1%
Coconut oil	0.48	1.9%
Sunflower seed oil	0.38	1.5%
Soya bean oil	0.19	0.8%
Palm kernel oil	0.15	0.6%
Rape and mustard oil	0.14	0.6%
Olive oil	0.12	0.5%
Groundnut oil	0.09	0.4%
Maize germ oil	0.09	0.3%
Cottonseed oil	0.01	< 0.1%
Sesame seed oil	0.01	< 0.1%
Oil crops oil, other	1.57	6.3%
Coffee, tea, cocoa beans	**2.98**	**11.7 %**
Coffee	2.38	9.4%
Tea	0.46	1.8%
Cocoa beans	0.14	0.5%
Cereals	**1.74**	**6.9 %**
Wheat	1.46	5.7%
Rice (milled equivalent)	0.15	0.6%
Maize	0.07	0.3%
Oats	0.02	0.1%
Barley	0.01	0.1%
Rye	0.01	< 0.1%
Cereals, Other	0.01	< 0.1%
Cotton products	**1.65**	**6.5 %**
Fruits	**1.03**	**4.0 %**
Oranges, Mandarins	0.36	1.4%
Apples	0.11	0.4%
Fruits continued		
Grapes	0.08	0.3%
Bananas	0.08	0.3%
Grapefruit	0.05	0.2%
Pineapples	0.03	0.1%
Lemons, limes	0.01	< 0.1%
Dates	0.00	< 0.1%
Plantains	0.00	< 0.1%
Citrus, other	0.00	< 0.1%
Fruits, other	0.31	1.2%
Sweeteners	**0.73**	**2.9%**
Sugar (raw equivalent)	0.32	1.2%
Sweeteners, other	0.42	1.6%
Beverages	**0.38**	**1.5 %**
Beer	0.22	0.9%
Wine	0.15	0.6%
Beverages, alcoholic	0.01	< 0.1%
Beverages, fermented	0.00	< 0.1%
Tree nuts	**0.30**	**1.2 %**
Roots and tubers	**0.24**	**1.0 %**
Potatoes	0.24	1.0%
Oil crops	**0.15**	**0.6 %**
Coconuts – incl. copra	0.08	0.3%
Olives	0.02	0.1%
Groundnuts (shelled eq.)	0.02	0.1%
Rape and mustard seed	0.01	< 0.1%
Soya beans	0.00	< 0.1%
Cottonseed	0.00	< 0.1%
Oil crops, other	0.02	0.1%
Vegetables	**0.14**	**0.6 %**
Onions	0.02	0.1%
Tomatoes	0.01	< 0.1%
Vegetables, other	0.12	0.5%
Spices	**0.14**	**0.6 %**
Pepper	0.04	0.2%
Cloves	0.04	0.1%
Pimento	0.03	0.1%
Spices, other	0.03	0.1%
Pulses	**0.05**	**0.2 %**
Beans	0.02	0.1%
Peas	0.02	0.1%
Pulses, other	0.02	0.1%

The water footprint of Dutch consumers is quite constant over time (Figure 4.3). The yearly amount of water used for the consumption of an average Dutch citizen is almost as high as the water volume of an Olympic swimming pool (2500 m^3). Figure 4.3 shows the result according to the bottom-up calculation. In Appendix 2 the results of both the bottom-up and the top-down approach for the water footprint due to the consumption of agricultural products are given.

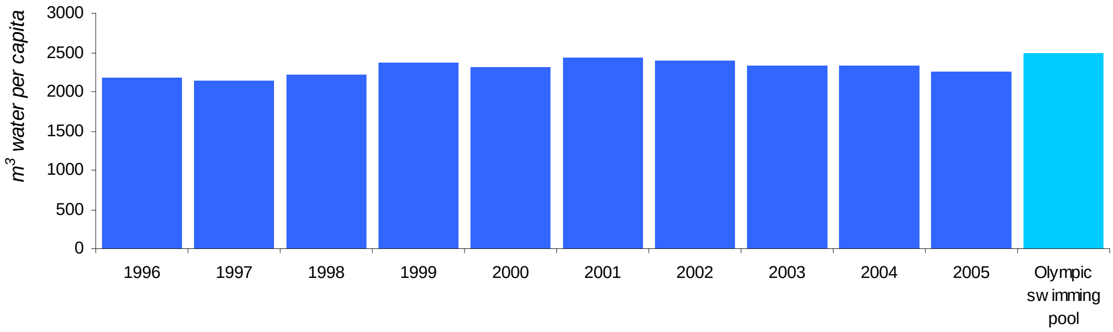


Figure 4.3. The total water footprint of the Dutch consumers per year (1996-2005).

5. The external water footprint of Dutch consumers

About 11% of the water footprint of the Netherlands is internal and 89% is external. For the water footprint due to the consumption of agricultural products the external part is even 97%. For agricultural products, about 48% of the external water footprint is located within Europe (mainly in Germany, France and Belgium) and 20% in Latin America (mainly in Brazil and Argentina). For industrial products, 53% of the external water footprint is in Europe and about 33% in Asia (mainly China, Taiwan, Hong Kong and Viet Nam). Figure 5.1 summarizes the results per continent, where Latin America includes Mexico, and Europe includes Turkey and the Russian Federation. Figure 5.2 shows how the external water footprint related to the consumption of agricultural products developed over time. During the period 1996-2005, the external water footprint in Latin America steadily increased, while the external water footprint in North America decreased.

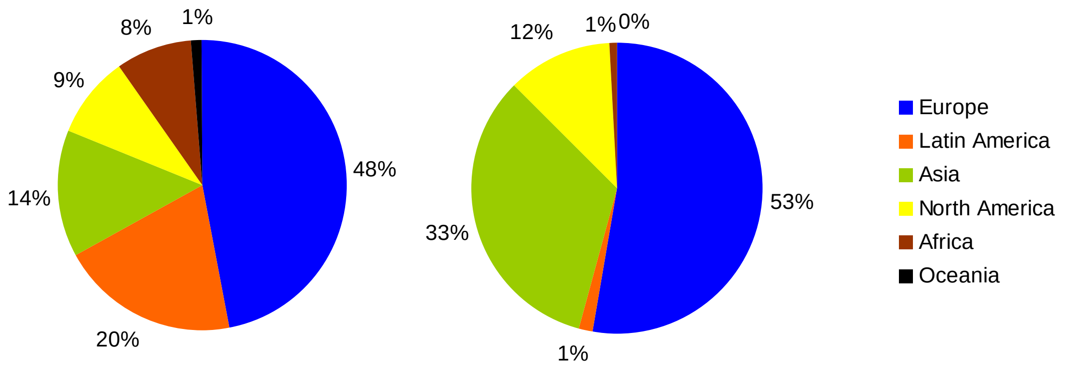


Figure 5.1. Distribution of the external water footprint of Dutch consumption due to the consumption of agricultural products (left) and industrial products (right).

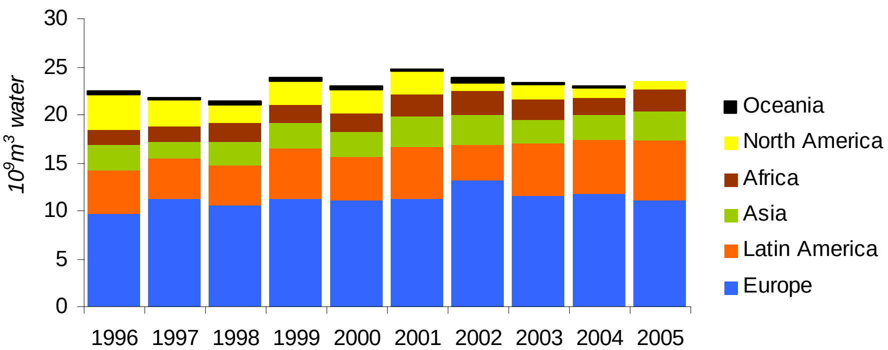


Figure 5.2. The external footprint of Dutch consumers due to the consumption of agricultural products, specified per year over the period 1996-2005.

Figure 5.3 shows the external water footprint of the Dutch consumers per agricultural product category. The product categories and the percentages refer to products as imported, not as consumed. This partly explains the difference with Figure 4.2, which shows the total water footprint (internal + external) by product as consumed. For instance, the product categories of 'cereals' and 'oil crops' in Figure 5.3 include imported feed for the Dutch livestock sector. The Dutch livestock sector produces livestock products for consumption, which is shown in Figure 4.2.

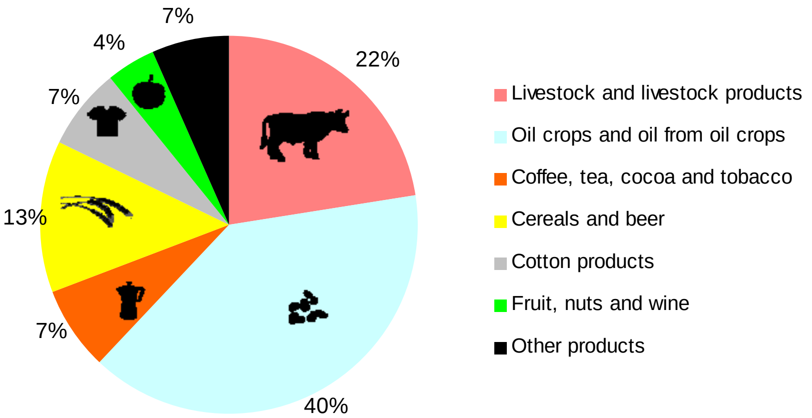


Figure 5.3. The external water footprint of Dutch consumers due to the consumption of agricultural products. The product categories and the percentages refer to products as imported, not as consumed.

The water footprint of Dutch consumers is one variable out of a set of nine variables that together give an overview of the Dutch water accounts. As can be seen from the numbers in Figure 5.4, the Netherlands, as a trade nation, imports not only for the purpose of domestic consumption. More than half of the virtual water import is re-exported again. Part of the re-export of virtual-water is done after having processed imported raw materials. An example of such processing is related to the Dutch livestock sector. Crops are imported from Asia and Latin America to be used as feed for Dutch livestock, while large volumes of cheese, eggs and meat are exported.

The sector-specific water accounts are given in Table 5.1. The geographical spreading of the external water footprint in so far related to the consumption of industrial products differs considerably from the geographical distribution of the external water footprint related to the consumption of agricultural products. Tables 5.2 and 5.3 show the ten largest contributors to the external footprint of agricultural and industrial products respectively. In Appendices 3 and 4, country-specific contributions for more countries are given. In Figure 5.5 and 5.6 country-specific contributions to the external footprint are presented geographically.

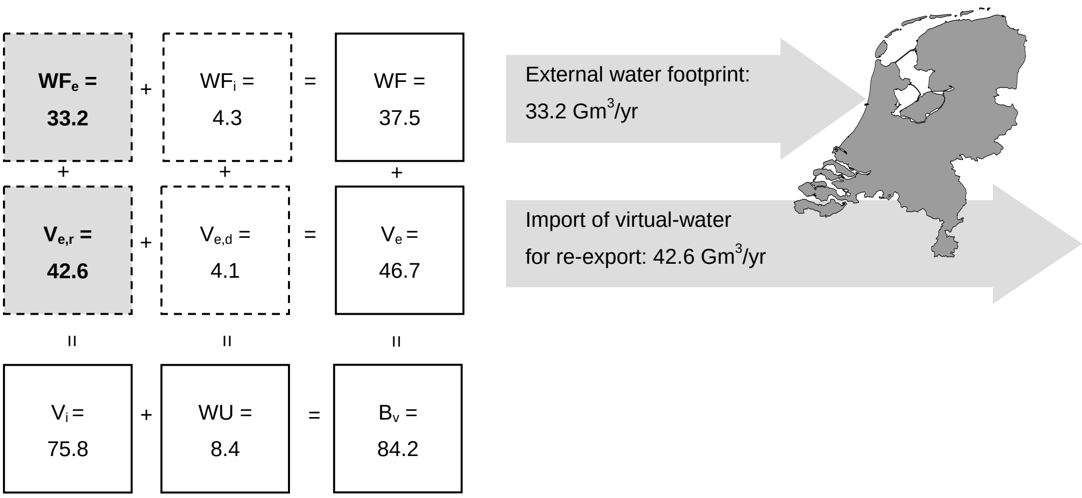


Figure 5.4. The Dutch water accounts. All data are in Gm^3/yr.

Table 5.1. The Dutch water accounts specified by consumption category. Period 1996-2005.

	Related to domestic water use (Gm^3/yr)	Related to agricultural products (Gm^3/yr)	Related to industrial products (Gm^3/yr)	Total (Gm^3/yr)
Use of domestic water resources (WU)	**0.6**	**3.0**	**4.8**	**8.4**
Virtual-water import (V_i)	**-**	**61.5**	**14.3**	**75.8**
Virtual-water export (V_e)	**-**	**39.1**	**7.6**	**46.7**
• related to export of domestically produced products ($V_{e,d}$)	-	2.2	1.9	4.1
• related to re-export of imported products ($V_{e,r}$)	-	36.9	5.7	42.6
Water footprint (WF)	**0.6**	**25.4**	**11.5**	**37.5**
• internal water footprint (WF_i)	0.6	0.8	2.9	4.3
• external water footprint (WF_e)	-	24.6	8.6	33.2

Table 5.2. The largest contributors to the external water footprint related to Dutch consumption of agricultural products.

Country	Part of external water footprint (related to the consumption of agricultural products)
Germany	18.3%
Brazil	9.7%
France	8.7%
United States	8.6%
Belgium-Luxembourg	8.2%
Argentina	5.4%
Indonesia	4.1%
Malaysia	2.5%
India	2.2%
Thailand	1.9%

Table 4.3. The largest contributors to the external water footprint related to Dutch consumption of industrial products.

Country	Part of external water footprint (related to the consumption of industrial products)
China	15.2%
United States	11.0%
Germany	10.6%
Russian Federation	10.6%
Belgium-Luxembourg	9.9%
Taiwan (POC)	6.6%
France	5.6%
Hong Kong	3.3%
Viet Nam	2.4%
Poland	2.1%

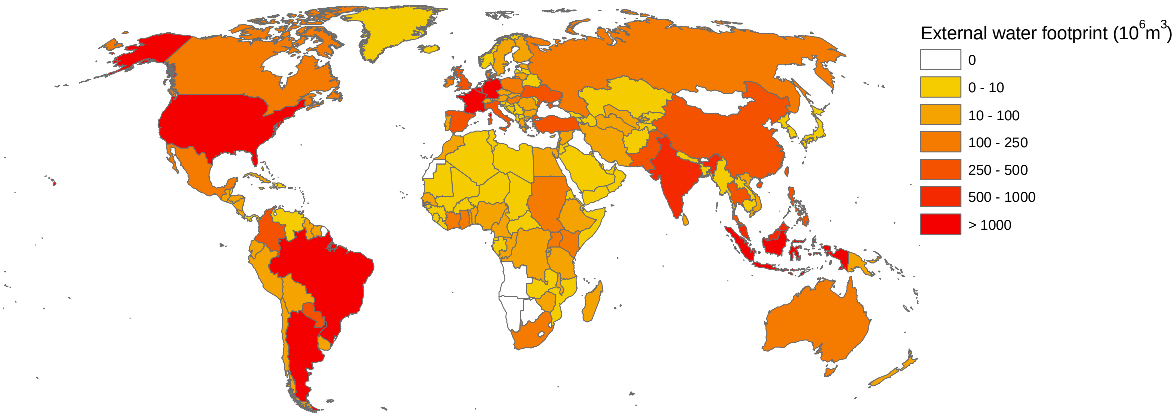


Figure 5.5. Geographical distribution of the external water footprint related to Dutch consumption of agricultural products.

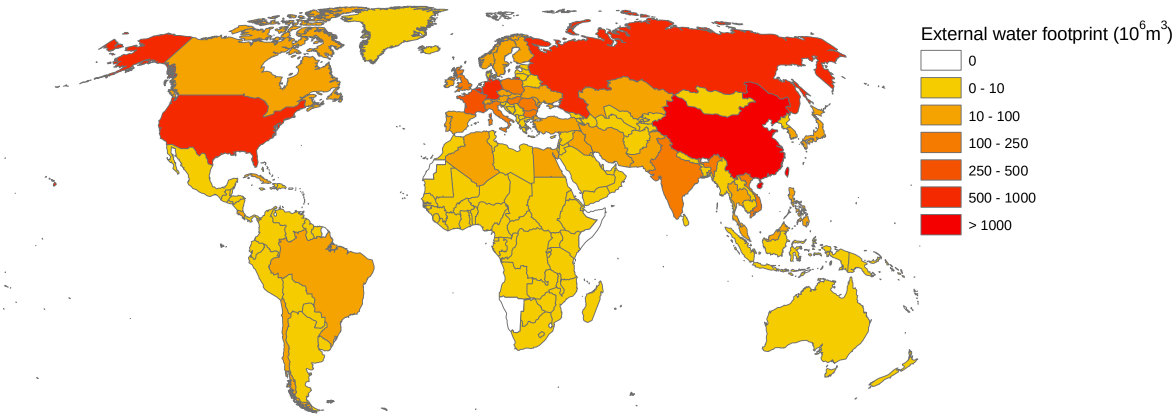


Figure 5.6. Geographical distribution of the external water footprint related to Dutch consumption of industrial products.

Figures 5.7 to 5.13 show the external water footprint for a number of specific products or product categories: feed for livestock products (Figure 5.7); oil crops and oil from oil crops (Figure 5.8); coffee (Figure 5.9); cocoa (Figure 5.10); cereals and beer (Figure 5.11); cotton products (Figure 5.12); and fruit, nuts and wine (Figure 5.13). To show the external water footprint due to the consumption of livestock products we analyzed the origin of crops used for feeding livestock in the Netherlands. Therefore, we aggregated the foreign water use for a number of these crops and derivates, including soybeans, soybean scrap, cassava, sugar cane molasses, and citrus pulp. For a complete list of included ingredients we refer to Table A6.4 in Appendix 6. For coffee, cocoa and cotton products we have redistributed virtual-water imports from non-producing countries over producing countries taking into account the share of these producing countries in world production of these products.

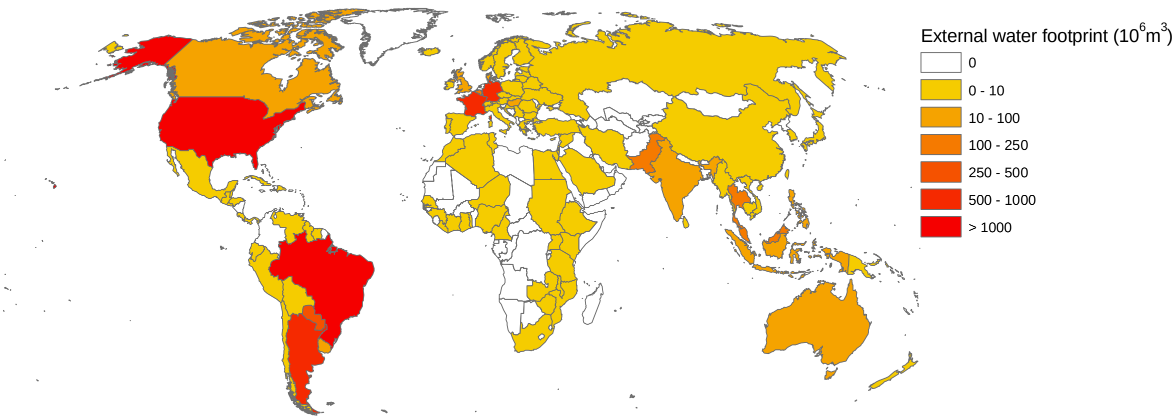


Figure 5.7. Geographical distribution of the external water footprint related to feed for livestock.

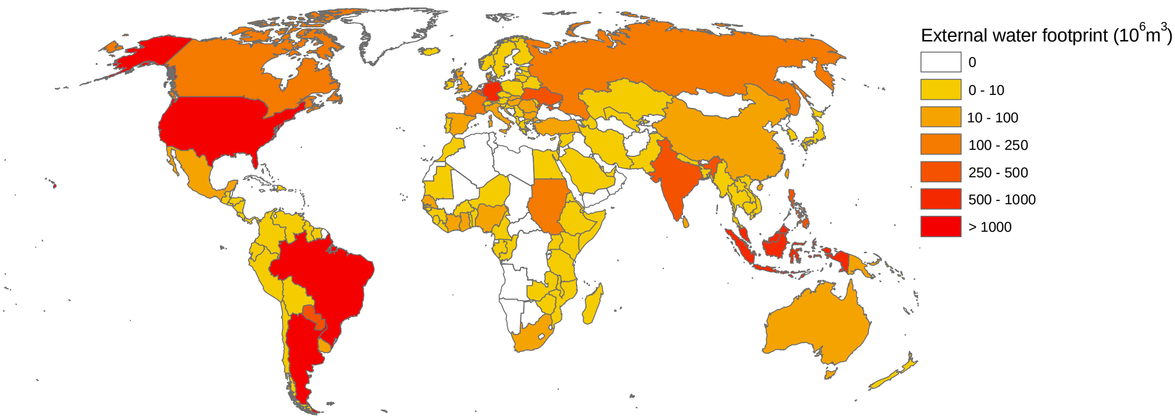


Figure 5.8. Geographical distribution of the external water footprint related to oil crops and oil from oil crops.

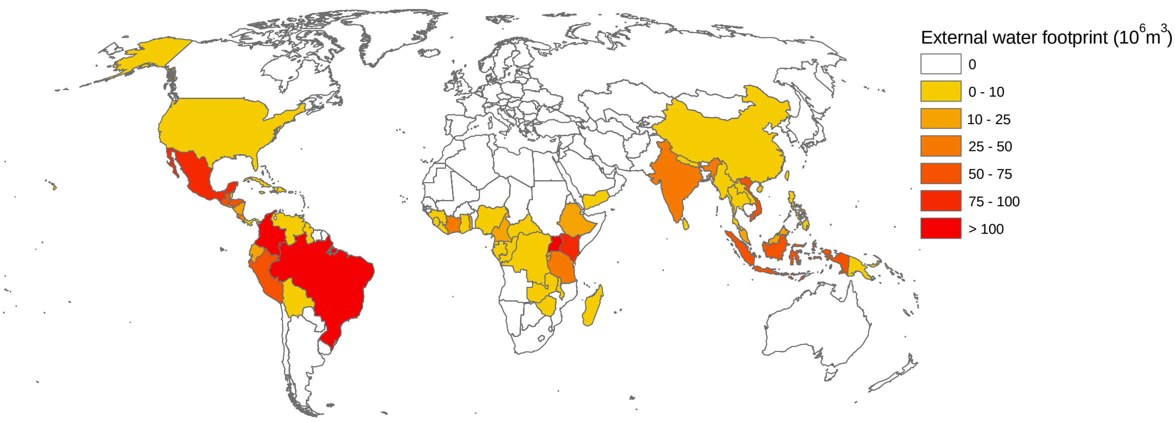


Figure 5.9. Geographical distribution of the external water footprint related to Dutch coffee consumption.

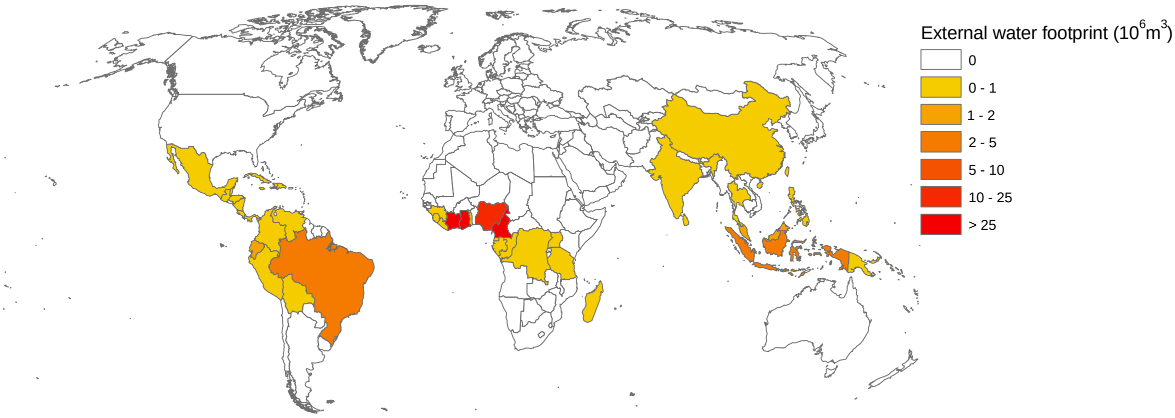


Figure 5.10. Geographical distribution of the external water footprint related to Dutch cocoa consumption.

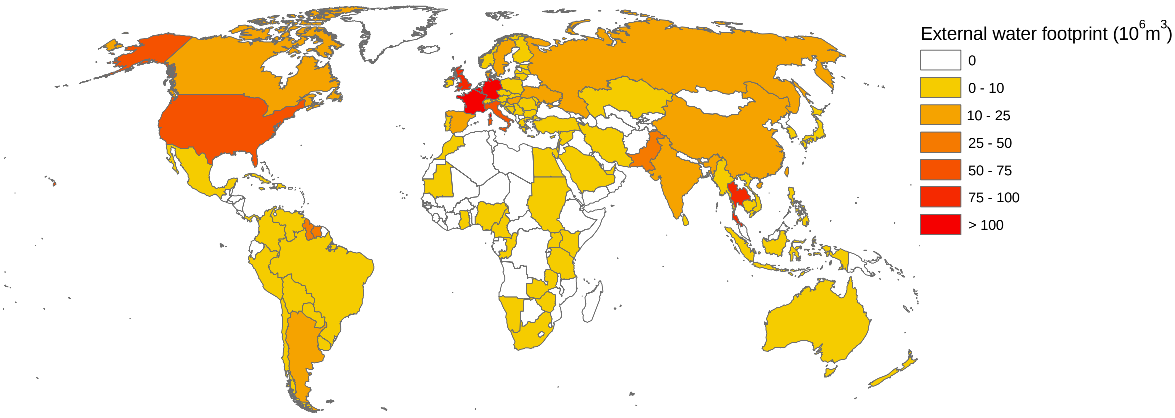


Figure 5.11. Geographical distribution of the external water footprint related to Dutch consumption of cereals and beer.

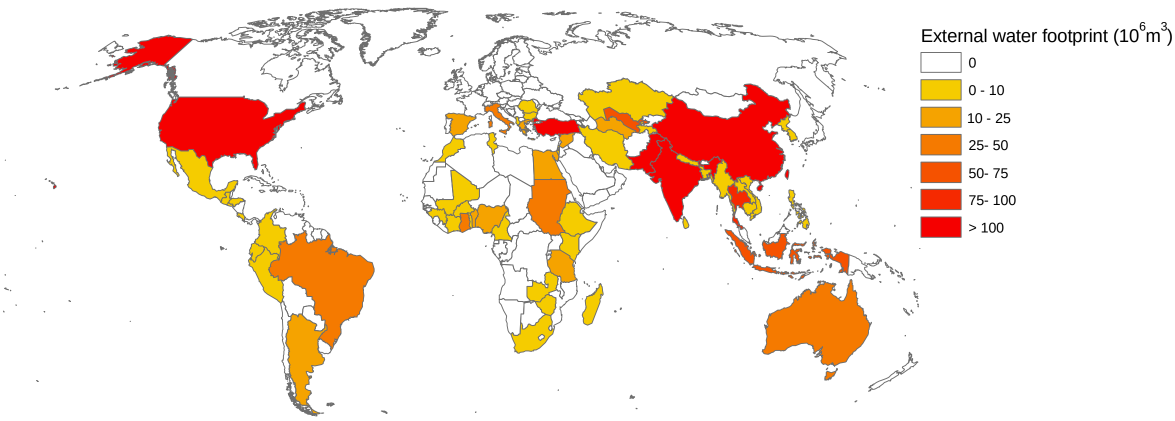


Figure 5.12. Geographical distribution of the external water footprint of the Dutch related to the consumption of cotton products.

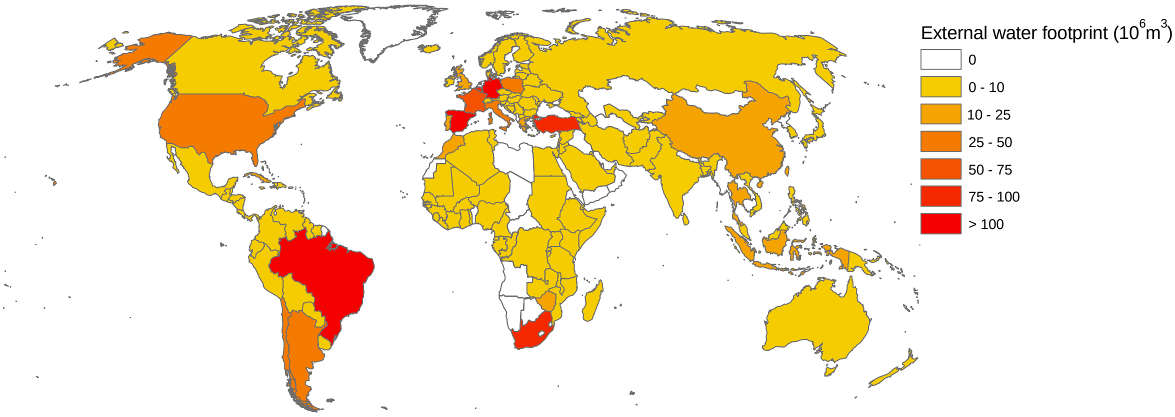


Figure 5.13. Geographical distribution of the external water footprint of the Dutch related to the consumption of fruit, nuts and wine.

6. The total virtual-water import to the Netherlands

About 44% of the virtual-water import to the Netherlands relates to products consumed in the Netherlands, thus constituting the external water footprint. This means that the other 56% of the virtual-water imported to the Netherlands is re-exported (60% in the case of agricultural products and 40% in the case of industrial products). Figure 6.1 shows, for agricultural products, the distribution of virtual-water import and virtual-water re-export over the six continents. For these products, about 41% of the virtual-water import for re-export comes from Africa (mainly Cote d'Ivoire, Ghana, Cameroon and Nigeria) and mainly concerns the import of cocoa beans, most of which are processed in the Netherlands into cocoa butter, cocoa powder or cocoa paste and re-exported to other European countries (mainly Germany, the United Kingdom, Belgium and Switzerland).

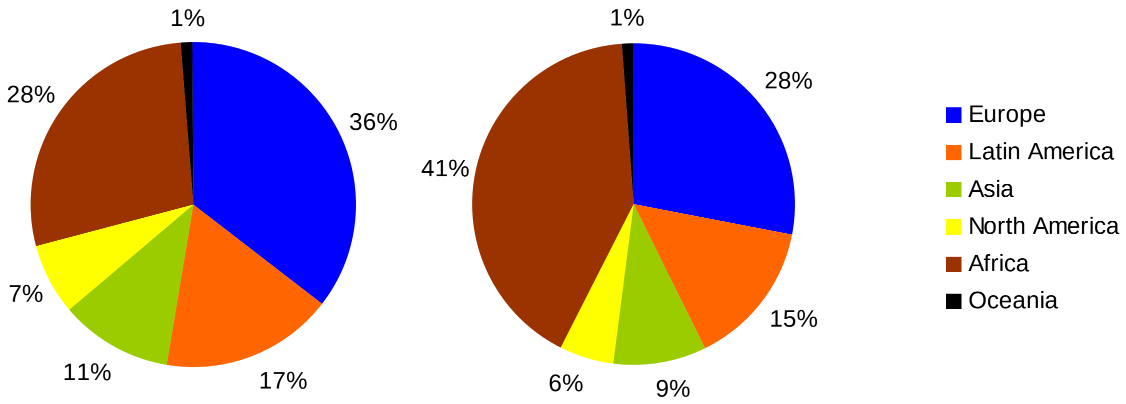


Figure 6.1. Geographical distribution of virtual-water import (left) and imported virtual-water for re-export (right) for agricultural products.

When we compare the water footprint of the Netherlands over time (previous section) with the virtual-water import to the country, we see that the latter is much more variable over time. Where consumption over time is rather constant, the trade balance, domestic production and over-year storage vary more significantly. Figure 6.2 shows that the virtual-water import was incidentally low in the year 2002, which is mainly due to a low import volume for various water-intensive products in that particular year.

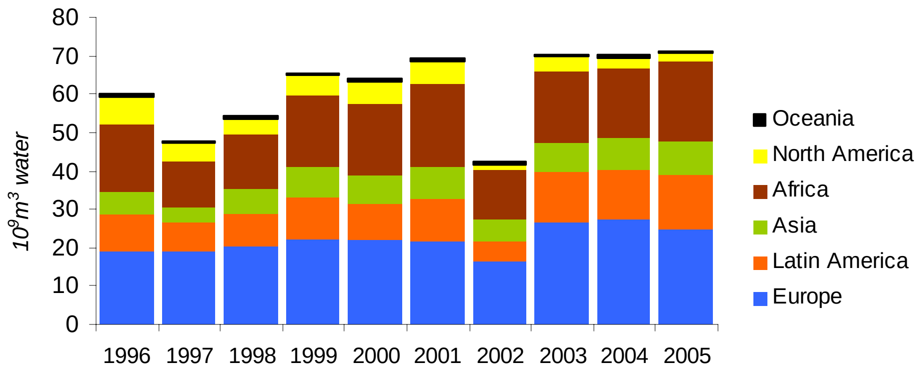


Figure 6.2. The virtual-water import in so far related to the import of agricultural products, specified per year over the period 1996-2005.

Appendix 5 gives an overview of the countries from where virtual water is imported (in so far related to the import of agricultural goods) that later on is re-exported. For industrial products it was assumed that the country-specific contributions to the imported virtual-water for re-export correspond to the distribution of the external water footprint and is given in Appendix 4.

7. Hotspots

In this section we compare the external water footprint of Dutch consumers as quantified in the previous section with water scarcity in the countries where the water footprint is located. Figures 7.1 to 7.3 present three different indicators of water scarcity as described in Section 2.6. Figure 7.1 shows the water competition level per country; Figure 7.2 shows withdrawal-to-availability per country; and Figure 7.3 shows withdrawal-to-availability per river basin, taking into account environmental water requirements. The exact values of water scarcity indicators per country are given in Appendices 3 and 5. The water scarcity data per river basin as shown in Figure 7.3 have been translated into country-information by overlaying countries and basins.

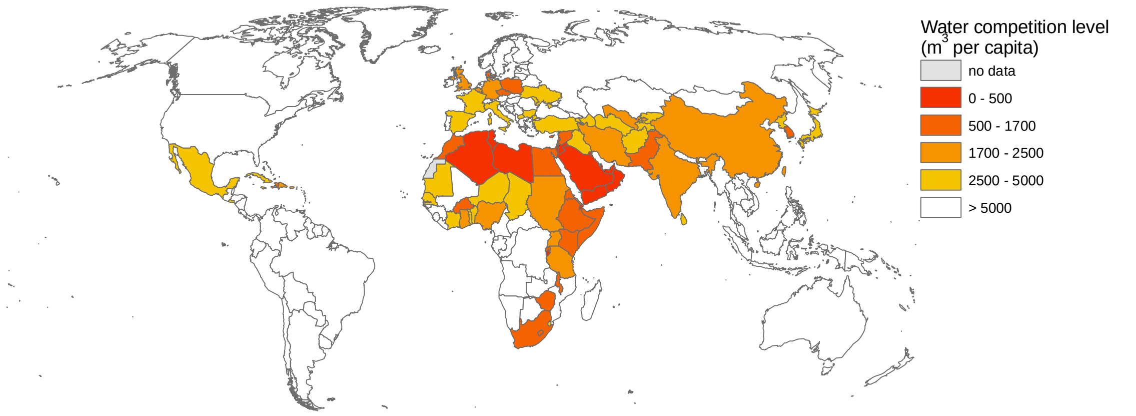


Figure 7.1. Water competition level by country expressed as the total renewable water resources per capita (data from FAO, 2007a).

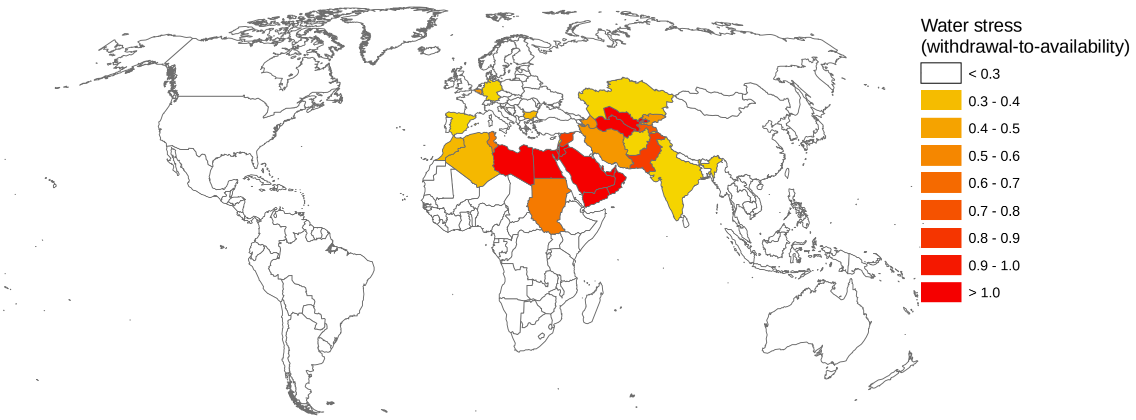


Figure 7.2. Water scarcity level by country expressed as the ratio of the withdrawal to the total renewable water resources (data from FAO, 2007a).

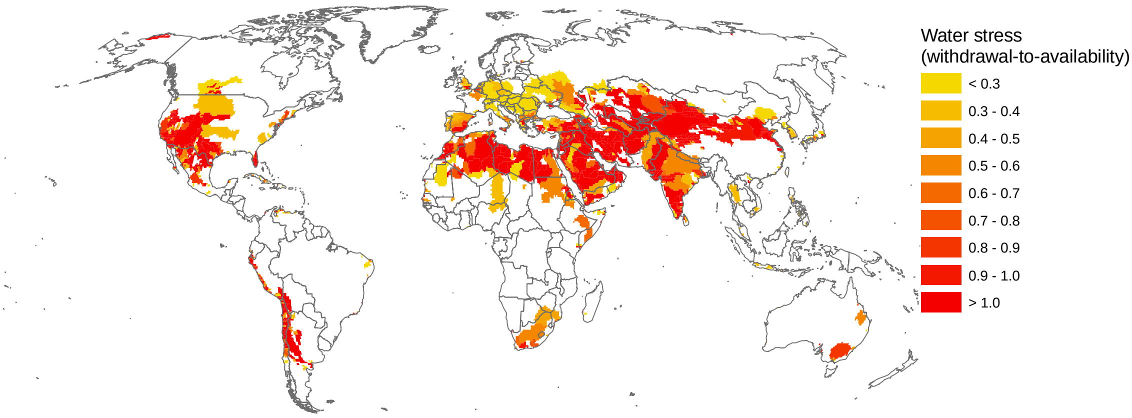


Figure 7.3 Water scarcity level by basin taking into account environmental water requirements (Smakhtin et al., 2004a,b).

Hotspots – i.e. countries where the impact of the Dutch external water footprint is relatively large – have been selected based on a country's share in the total external water footprint of Dutch consumers and the three indicators of water scarcity (Appendix 3)[4]. The impact is obviously larger when the footprint is relatively large in a place where water scarcity is relatively large as well. The countries that have been selected as hotspots are: China; India; Spain; Turkey; Pakistan; Sudan; South Africa; and Mexico. With the exception of China, the external water footprint in these countries is mainly due to the consumption of agricultural products (Figure 7.4). In China, the water footprint is too a large extent related to the production of industrial goods for the Dutch consumer market. The water footprint related to industrial goods consists mostly (90%) of a grey water footprint (pollution), the remainder (10%) being a blue water footprint (evaporation of ground and surface water). In the other hotspots, the water footprint is dominated by agricultural products. The ratio of the blue to the green water footprint per hotspot depends on the degree of irrigation at these hotspots (Figure 7.5). The type of agricultural products in the hotspots vary greatly as is shown in Figure 7.6.

Table 7.1 summarizes the most important findings with respect to the selected hotspots. Figure 7.7 maps the global water footprint of Dutch consumers in so far related to the consumption of agricultural goods and shows the countries considered as hotspots with the water-intensive products originating from these hotspots.

[4] The selection of hotspots has been done at country level. In Chapter 8 we analyse where within the selected hotspot-countries the impacts are located. The study has ignored local hotspots within other countries, where impacts at national level are not among the most significant, but where nevertheless significant local impacts can exist.

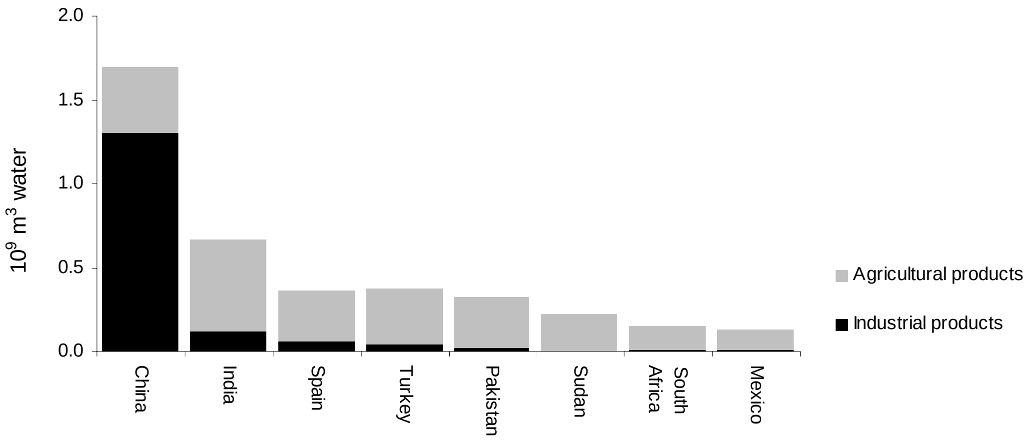


Figure 7.4. Composition of the external water footprint of Dutch consumers at the selected hotspots specified by product category.

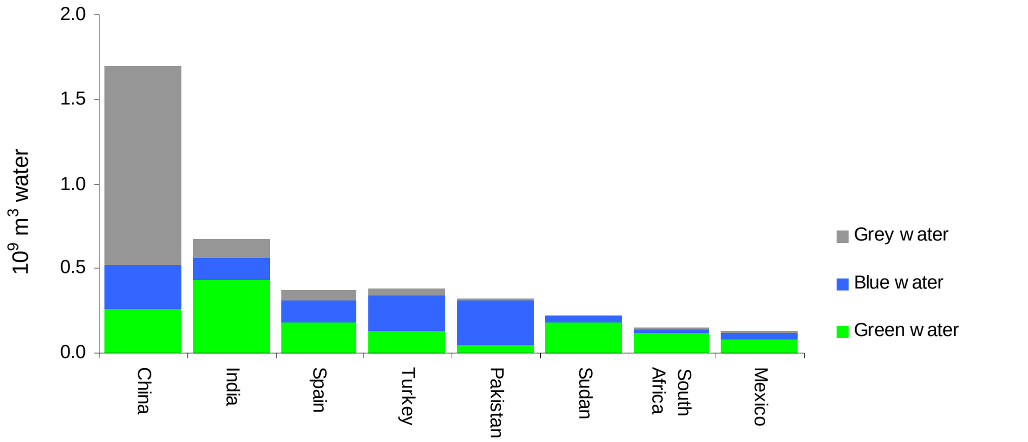


Figure 7.5. Composition of the external water footprint of Dutch consumers at the selected hotspots specified by its grey, green and blue component.

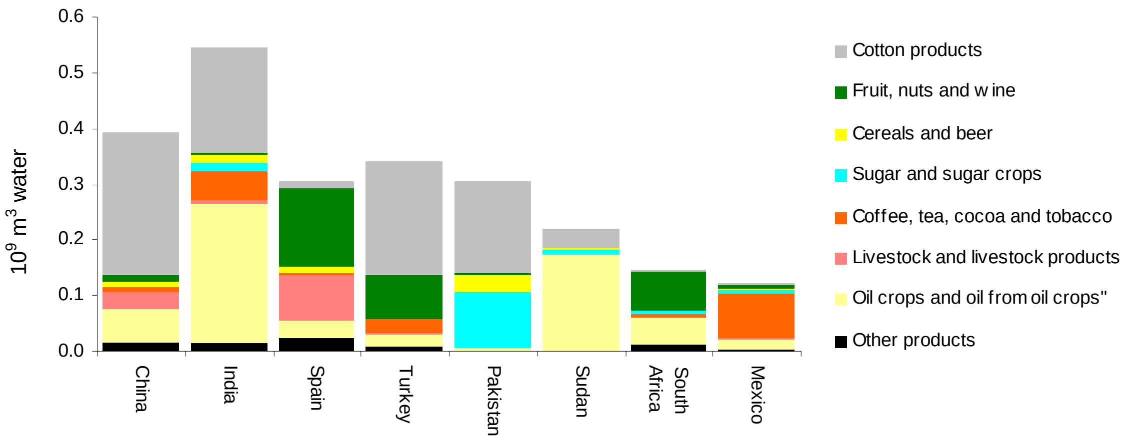


Figure 7.6. Composition of the external water footprint of Dutch consumers (in so far related to the consumption of agricultural products), per hotspot and specified by product category.

Table 7.1. Hotspots and the products contributing to the external water footprint of Dutch consumers.

Country	External water footprint related to industrial products (10^6 m^3/yr) [a]	External water footprint related to agricultural products (m^3/yr)					
		Total (10^6 m^3/yr)	Product category with largest contribution	Contribution of the product category	Main product within product category	Green	Blue
China	1307	393	Fibres (including cotton)	65%	Cotton (100%)	62%	38%[b]
			Oil crops and oil from oil crops	16%	Groundnuts (74%)	90%	10%
			Livestock products	7%	Skin and hair of pigs (90%)		
India	123	547	Oil crops and oil from oil crops	46%	Castor oil seed (72%)	82%	18%
			Fibres (including cotton)	35%	Cotton (100%)	75%	25%[b]
			Coffee, tea, cocoa and tobacco	10%	Coffee (72%)	79%	21%
Spain	63	305	Fruits (including wine)	46%	Citrus fruit (36%), wine, grapes, raisins (28%)	60%	40%
			Livestock products	27%	Cattle (42%), pig (27%) and goat (20%)		
Turkey	39	340	Fibres (including cotton)	60%	Cotton (99%)	9%	91%[b]
			Fruits (including wine)	23%	Raisins (81%)	91%	9%
			Coffee, tea, cocoa and tobacco	7%	Tobacco (84%)	93%	7%
Pakistan	17	305	Fibres (including cotton)	54%	Cotton (100%)	21%	79%[b]
			Sugar (including sugar crops)	33%	Cane molasses (100%)	8%	92%
Sudan	<1	218	Oil crops and oil from oil crops	79%	Sesame seed (89%)	81%	19%
South Africa	6	145	Fruits (including wine)	49%	Citrus fruit (35%), grapes, wine, raisins (29%)	80%	20%
			Oil crops and oil from oil crops	34%	Groundnut/oil (56%), sunflower seed (40%)	81%	19%
Mexico	7	123	Coffee, tea, cocoa and tobacco	66%	Coffee (100%)	57%	43%
			Oil crops and oil from oil crops	16%	Sunflower oil (75%)	100%	0%

[a] Industrial water footprints estimated to be 10% blue and 90% grey.

[b] Based on Chapagain et al. (2006).

Table 7.2. Estimated grey water footprint for specific crops at the hotspots.

		Area (km^2)[a]	Area with fertilizer (%)[a]	Rate N (kg/ha) [a]	Rate P (kg/ha) [a]	Rate K (kg/ha) [a]	Grey water footprint (m^3/ha)[b]
China, Mainland (1997)	Cotton	5528	100	120	70	25	1200
	Oil crops	668	95	65	40	30	618
India (2003/2004)	Cotton	8500	6	90	23	5	54
	Other crops	60400	22	35	19	7	77
Spain (1999/2000)	Fruits	4975	n.a.	57	24	26	n.a.
Turkey (1999)	Cotton	718	99	127	39	4	1257
	Fruits	1240	70	< 0.1	< 0.1	< 0.1	0.4
	Tobacco	289	68	3	1	6	20
Pakistan (2001/2002)	Cotton	n.a.	n.a.	120	50	0.1	n.a.
	Sugar cane	n.a.	n.a.	125	56	0.3	n.a.
Sudan[a]		n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
South Africa (2004)	Citrus fruits	64	100	80	35	60	800
	Sunflower	640	85	15	21	2	128
Mexico (1998)	Coffee	679	60	60	40	15	360
	Sunflower	123	80	75	10	0	600

[a] Source: FAO (2007c). For Sudan, no data on fertiliser use are available.

[b] Assumptions: nitrogen is the critical factor; 10% of the nitrogen leaches to the water system; nitrogen water standard 10 mg/litre (Hoekstra and Chapagain, 2008).

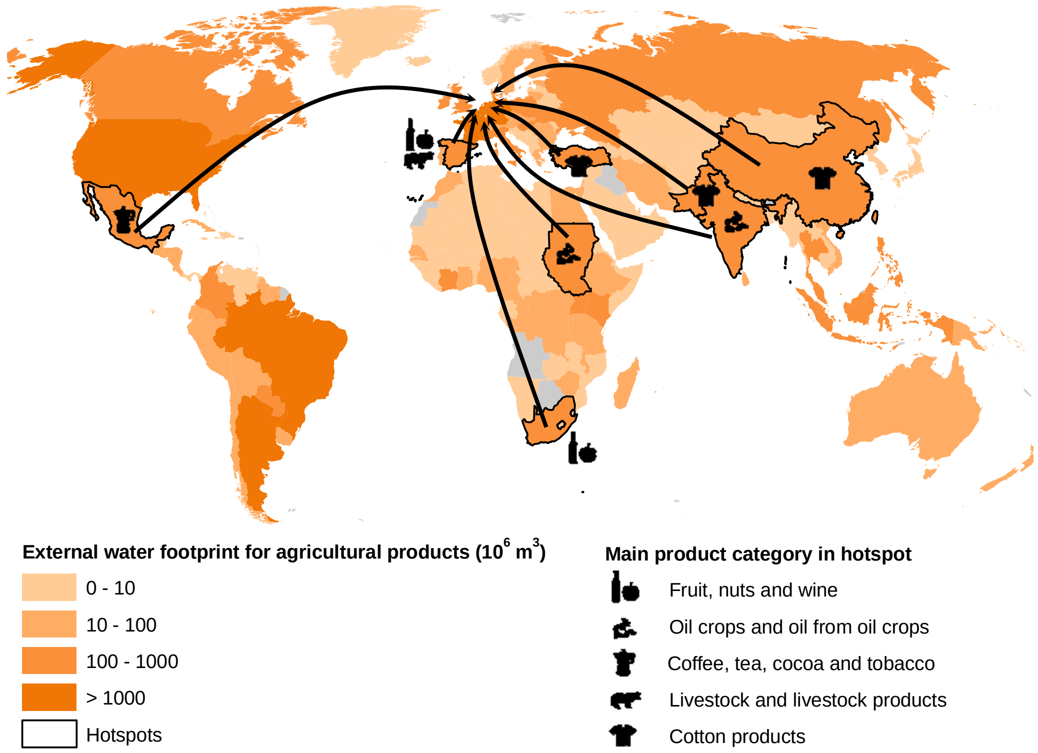


Figure 7.7. The external water footprint for agricultural products consumed in the Netherlands and the countries considered as hotspots, i.e. the countries where the external water footprint of the Netherlands has a relatively high environmental impact.

8. Impact assessment

In this section we discuss in more detail the impacts of the external water footprint in the hotspots identified in the previous section.

8.1. China

In 2004, the BBC reported on China as being one of the world's water hotspots (BBC, 2004). Water related problems are mainly concentrated in the northern part of China. Rivers are polluted, are a threat to human health and limit irrigation (Economy, 2004). As mentioned in the previous section, the largest part of the external water footprint of the Netherlands in China is related to industrial products. We focus in this study however on the agricultural products. The lower reaches of the Yellow River, which feeds China's most important farming region, run dry for at least 200 days every year. Furthermore, in the north China plain, 30 Gm^3 more ground water is pumped to the surface each year by farmers than is replaced by rain. As groundwater is used to produce 40% of the country's cereals, experts warn that water shortages could make the country dependent on cereal imports. They fear that further development of irrigation in China is hampered by increasing water shortages in the whole country, especially the north. Most irrigation projects constructed in the 1950s and 1960s can no longer be operated effectively. This results in a continuous decline in irrigation benefits and has a direct impact on the stability of agricultural development and on the economy (FAO, 2007b).

The main agricultural product contributing to the external water footprint of the Netherlands in China is cotton. For cotton products like manufactured clothing it is very hard to determine the specific place of origin (Rivoli, 2005). It is hard to tell whether a t-shirt bought by Dutch consumers is made of cotton from China. However, China has a 24 % share in the world cotton production. Chinese cotton production is concentrated in the east of the country (Leff et al., 2004), partly in the Huang He (Yellow river) delta (Figure 8.1).

Another important contributing crop is groundnuts. Like for cotton production, the Chinese production of groundnuts is concentrated for a large part in the east of the country (Leff et al., 2004; Figure 8.2).

The most important basin impacted by the production of cotton and groundnut is the basin of the Huang He (Yellow river). This river basin has a withdrawal-to-availability ratio of 94% (Smakhtin et al., 2004a). Land cover in the basin is shown in Figure 8.3.

To estimate the green and blue components of the external water footprint related to cotton and groundnuts we used meteorological data from the following meteorological station: Xuzhou: 20237, Lat: 34.28 N, Lon: 117.17 E (Müller and Hennings, 2000). Related to grey water, information on the application of fertilizers in China is given in Table 7.2.

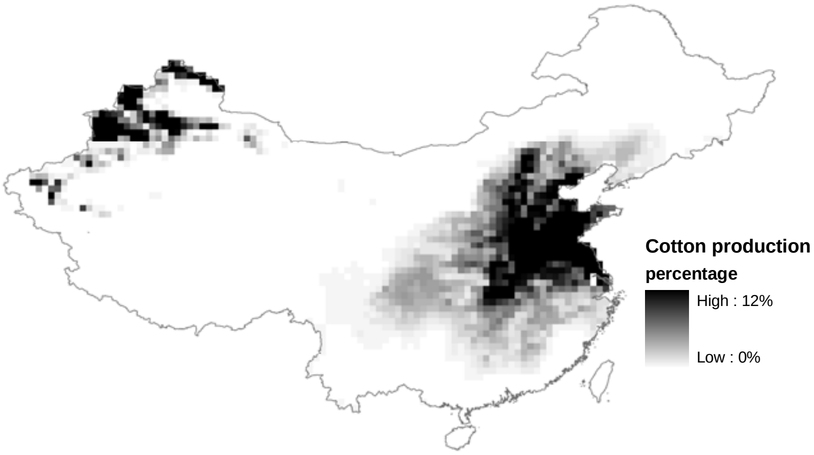


Figure 8.1. Distribution of cotton production in China.

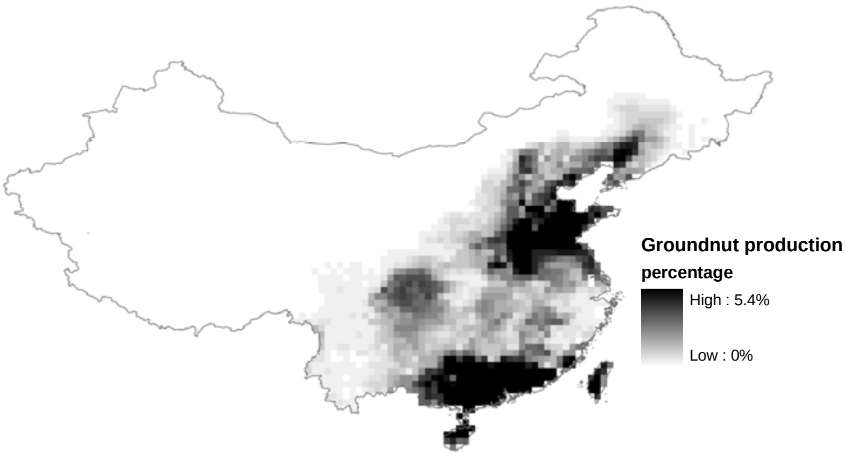


Figure 8.2. Distribution of groundnut production in China.

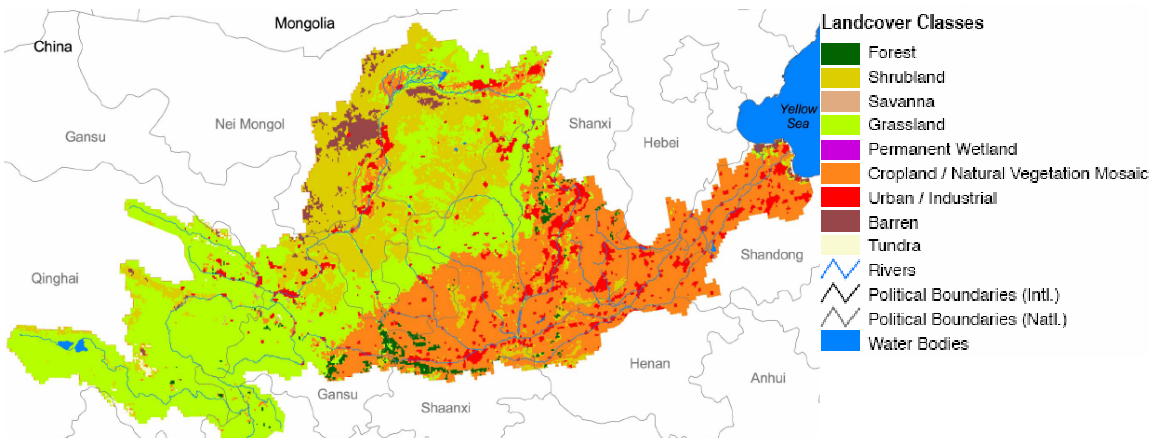


Figure 8.3. Land cover in the basin of the Huang He (Yellow river) (Bos and Chabloz, 2003).

8.2. India

An important issue related to agriculture and water in India is the inequitable allocation of water and the deteriorating of irrigation infrastructure. There is a growing incidence and severity of water conflicts between states, between cities and farmers, between industries and villagers, between farmers and the environment, and within irrigated areas. In a growing number of areas, high-value crops are now displacing low-value food grains. Strategic challenges include adaptation to increasing water scarcity and to climate change, which could impact India more than most other countries (World Bank, 2007).

The largest part of the external water footprint of the Netherlands in India is related to oil crops (46%). Within this category, castor oil seeds are responsible for the largest share. Other important contributors are cotton (35%) and coffee (7%). All these crops are important cash crops. Oil crops increasingly compete with food crops for fertile soils. In this context, India is expected to experience an increasing number of problems in the near future (Fraiture et al., 2008). Related research focuses on water-food-energy-environment tradeoffs (McCornick et al., 2008). Castor oil and its derivatives have applications in the manufacturing of soaps, lubricants, hydraulic and brake fluids, paints, dyes, coatings, inks, cold resistant plastics, waxes and polishes, nylon, pharmaceuticals and perfumes (Linnaeus, 2008; WHC, 2008). India is the world's major producer, followed by China and Brazil at considerable distance. India holds a share of 70% in the total exports. Castor oil beans are mainly grown in the state of Gujarat. Gujarat contributes 86% to the total castor seeds produced in India (Crnindia, 2008). Important producing districts in Gujarat are Mehsana, Banaskantha, Sabarkantha, Gandhinagar and Ahmedabad. These districts are indicated in Figure 8.4.

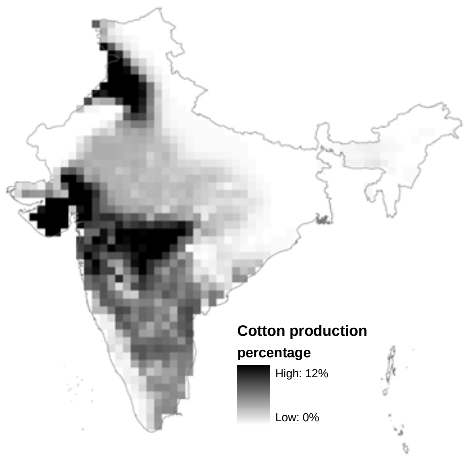
Cultivation of cotton is also practised in specific parts of the Indian subcontinent. According to Leff et al. (2004), cotton production is mainly concentrated in the north and central west of India (Figure 8.5). Coffee production is mainly concentrated in the southern part of India, more specifically in the states of Karnataka, Kerala and Tamilnadu (Figure 8.6).

All important crops studied are located in water scarce regions. To give insight in the water related problems in these areas, we focus on three large basins. Using information on these basins (Bos and Chabloz, 2003) enables us to estimate the use of green and blue water. For castor oil production, the Tapti basin can be regarded as representative. The withdrawal-to-availability ratio for this basin is 128%. For cotton we also refer to the Tapti basin, but a considerable part of cotton production is encountered in the Indian part of the Indus basin. The Indus basin has a withdrawal-to-availability ratio of 1292% (Smakhtin et al., 2004a). For coffee, the Krishna basin is regarded as representative. Water scarcity in the Krishna basin is also severe (157%), leading to increasing tensions between the three states that share the basin (IWMI, 2008). A recent publication on the influence of water scarcity on land use and equitable water distribution illustrates the severity of problems in the Krishna basin (Gaur et al., 2008). In Figure 8.7, the locations of the three basins are shown.

To estimate the green and blue components of the external water footprint related to castor oil, cotton and coffee (as shown in Table 7.1), we used meteorological data from the following meteorological stations (Müller and

Hennings, 2000): Ahmadabad for castor oil (20167, Lat: 23.03 N, Lon: 72.58 E); Sholapur for cotton (20173, Lat: 17.67 N, Lon: 75.90 E); Bangalore for coffee (20190, Lat: 12.95 N, Lon: 77.62 E). Related to grey water, information on the application of fertilizers in India is given in Table 7.2.

Figure 8.4. Gujarat, the centre of Indian castor bean production (Crnindia, 2008).



Fugure 8.5. Distribution of the cultivation of cotton in India (Leff et al., 2004).

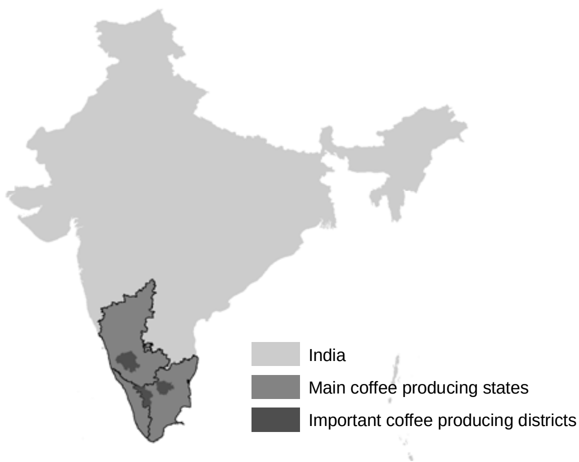


Figure 8.6. South India, the centre of Indian coffee production (Indiacoffee, 2008)

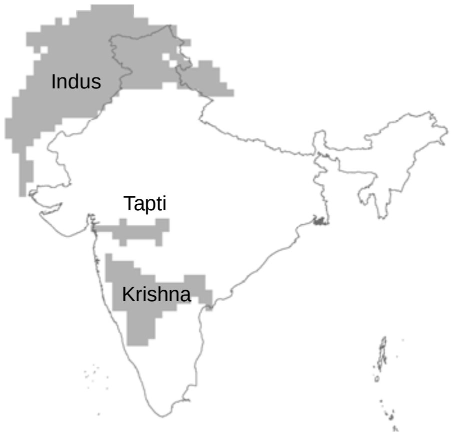


Figure 8.7. The three representative basins in India.

8.3. Spain

Spain increasingly experiences serious water scarcity. Various facilities for water transfer between basins have been constructed over the years in response to increasing demands and problems related to water scarcity (Wikipedia, 2008).

The products contributing to the external water footprint of the Netherlands in Spain are diverse: citrus fruit (13%); almonds (11%) grapes and wine (10%); olive oil (8%); and various livestock products (27%). We will not go into depth with respect to the livestock products, because it seems impossible to trace the origin and type of feed for the various animals involved. Citrus fruits include oranges, tangerines, mandarins, clementines, lemons and limes. Oranges are the most important contributor. Most citrus fruit is grown in the states of Valencia (65%), Andalucía (18%) and Murcia (13%). Within the state of Valencia, the capital district (Figure 8.8) accounts for 58% of the states production (INE, 2008).

Spain accounted for about 16% of world almond production in the nineties (FAO, 2007b). Production is quite evenly spread across the country. The most important areas where almond is produced are the provinces of the Balearic Islands, Zaragoza, Tarragona, Lleida, Granada, Almeria, Málaga, Alicante, Castellon de la Plana, Valencia, Murcia and Albacete. Grapes (for wine) are mainly cultivated in Castilla-La Mancha (51%) and olives are mainly produced in Andalucía (63%). All these data are derived from the National Statistics Institute of Spain (INE, 2008).

The most seriously influenced river basins are the Segura, Jucar, Guadiana and Gualdaquivir (Figure 8.9). In all these basins (environmental) water scarcity is serious (Smakhtin et al. 2004a).

About 40% of the Dutch fruit-related water footprint in Spain is blue; the remainder is green (Table 7.1). This estimate is based on meteorological data from the following meteorological stations (Müller and Hennings, 2000): Valencia for citrus fruits (10309, Lat: 39.48 N, Lon: 0.38 W); Ciudad Real for grapes (10310, Lat: 38.98 N, Lon: 3.93 W); and Granada for almonds and olive oil (10316, Lat: 37.15 N, Lon: 3.58 W). Related to grey water, information on the application of fertilizers in Spain is given in Table 7.2.

Figure 8.8. Valencia, the centre of citrus fruit production in Spain.

Figure 8.9. Main river basins in Spain (Wikipedia, 2008).

8.4. Turkey

According to the BBC (2004), Turkey is one of the world's water hotspots. Turkey is vulnerable to shortages and has recently spent billions of dollars in the past decades building dams to increase its water reserves and boost its hydroelectric capabilities. A system of 22 dams on the Tigris and Euphrates rivers has provoked criticism from downstream neighbours Iraq and Syria. In particular there is current concern about the use of polluted water resources to irrigate agricultural lands, especially in western Turkey, which has been experiencing water shortages on a regular basis in recent years (FAO, 2007a).

Cotton products (60%) and fruits (23%), in particular raisins (19%) contribute greatly to the external water footprint of the Netherlands in Turkey. Tobacco contributes another 6%. Most cotton production is found in the west of Turkey. Near the border of Syria a considerable amount of cotton producing lands can be found as well (Figure 8.10).

As for cotton, most grape production is found in the west of Turkey (Figure 8.11). In Turkey, production of grapes for raisins is mainly done in the western provinces of Turkey, like Izmir and Manisa. According to FAO (FAO, 2007b) Turkey is responsible for 32% of world exports of raisins.

Figure 8.10. Distribution of cotton production in Turkey (Leff et al, 2004).

Figure 8.11. Manisa amd Izmir, two provinces in the raisin producing region in the west of Turkey.

The Manisa province is also important for tobacco production. The Manisa province accounts for about 23% of the nation's tobacco output and value (FAO, 2007b).

Small basins flowing towards the Mediterranean Sea are mostly influenced. Withdrawal-to-availability is considerably high, with values just below and well above 100%. To estimate the green and blue components of the external water footprint we used meteorological data from the following meteorological station (Müller and Hennings, 2000): Usak for all crops (20322, Lat: 38.67 N, Lon: 29.75 E). Hundred percent of the cotton production in Turkey is estimated to be under irrigation, so that most of the cotton-related water footprint refers to blue water (Chapagain et al., 2006). Related to grey water, information on the application of fertilizers in Turkey is given in Table 7.2.

8.5. Pakistan

Most water related issues in Pakistan relate to the Indus basin. With water rather than land being the main constraint, irrigation systems are generally designed to use the available river supplies quite efficiently, with minimum water provided to bring the crops to maturity. With almost 14 million ha, the Indus basin irrigation system is the largest contiguous irrigation system in the world. Over the past 20 years, groundwater use has become a major factor in increasing agricultural production. However, because of uncontrolled and rapid private sector development of ground water, there is a danger of excessive lowering of ground water tables and intrusion of saline water into freshwater aquifers (FAO, 2007a).

Cotton products (54%) and cane sugar molasses (33%) contribute the most the external water footprint of the Netherlands in Pakistan. Sugar cane molasses are an important feed ingredient for the Dutch livestock sector. The distribution of crop production for both products is shown in Figure 8.12.

Withdrawal-to-availability in the Indus basin is 1292% (Smakhtin et al., 2004a). Both cotton and sugar cane are mostly irrigated. To estimate the green and blue components of the external water footprint we used meteorological data from the following meteorological station (Müller and Hennings, 2000): Multan for all crops (20158, Lat: 30.20 N, Lon: 71.52 E). Related to grey water, information on the application of fertilizers in Pakistan is given in Table 7.2.

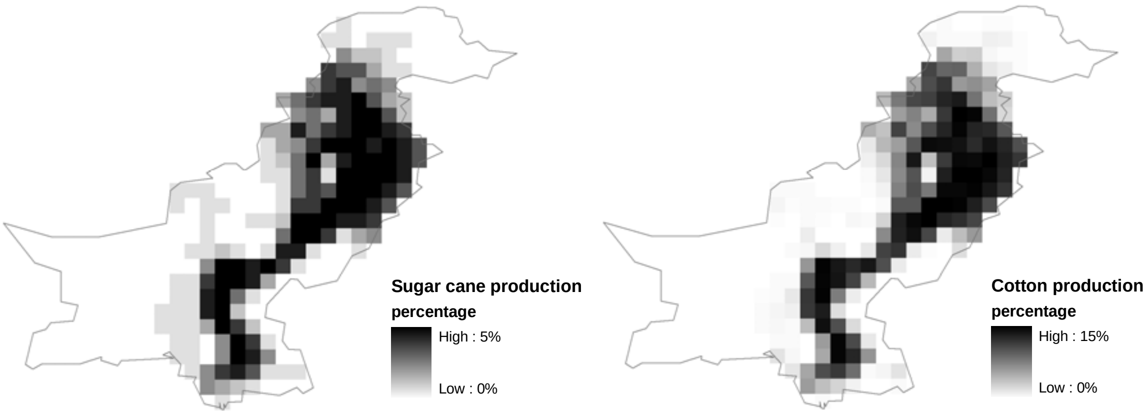


Figure 8.12. Distribution of sugar cane production (left) and cotton production (right) (Bos and Chabloz 2003).

8.6. Sudan

Internally produced water resources in Sudan are rather limited. Available water in Sudan mainly comes from the Nile river system. About 64% of the Nile basin lies within Sudan, while about 80% of Sudan lies in the Nile basin. According to FAO estimates, the traditional rain-fed farming sector contributes all the production of millet, 11 percent of sorghum, 48 percent of groundnuts and 28 percent of sesame production of the country. (FAO, 2007a). Sudan has the second largest irrigated area in Africa, after Egypt. The irrigated sub-sector plays a very important role in the country’s agricultural production. Although the irrigated area constitutes only about 11 percent of the total cultivated land in Sudan, it contributes more than half of the total volume of the agricultural production. Irrigated agriculture has become more and more important over the past few decades as a result of drought and rainfall variability and uncertainty (FAO, 2007a). Sudan is generally self-sufficient in basic foods, but there are geographical differences. Among the high-risk areas are Northern Kordofan and Northern Darfur (FAO, 2007a).

In relation to Dutch imports and consumption, there is one crop particularly worth mentioning for Sudan: sesame seed. It is important as a food crop, a raw material for industry, as a feed ingredient for livestock as well as a leading export crop. Sudan has an impressive record with respect to sesame, cultivating 80% of all sesame area in the Arab World and 40% of all sesame area in the African Continent. The most important area for sesame production is Northern Kordofan State (Figure 8.13). Other production areas include the Gadarif and Damazine clay plains and scattered areas in the States of Southern Kordofan, Southern Darfur and Northern Upper Nile.

As for most agricultural activity in Sudan, the Nile river basin is the most important basin for sesame production. Recently, sesame has been introduced in the crop rotation of the irrigated schemes in the Nile State as a winter crop with much success (Sudagric, 2008). Information on the relationship between rainfall and sesame cultivation inn Sudan can be found in Larsson et al. (1996). As can be seen in Figure 8.14, the sesame production in Northern Kordofan is situated in a part of the Nile basin where land use is barren and grassland. For high production volumes irrigation is a necessity here. Consumptive water use for sesame production goes at the cost of inflow into the lake Nasser that provides Egypt with a secure water supply.

To estimate the green and blue components of the external water footprint we used meteorological data from the following meteorological stations (Müller and Hennings, 2000): Al-Ubayyid for sesame (30046, Lat: 13.18 N, Lon: 30.23 E). With respect to grey water, no information on the application of fertilizers for sesame cultivation in Sudan was found.

Figure 8.13. The state of Northern Kordofan in Sudan

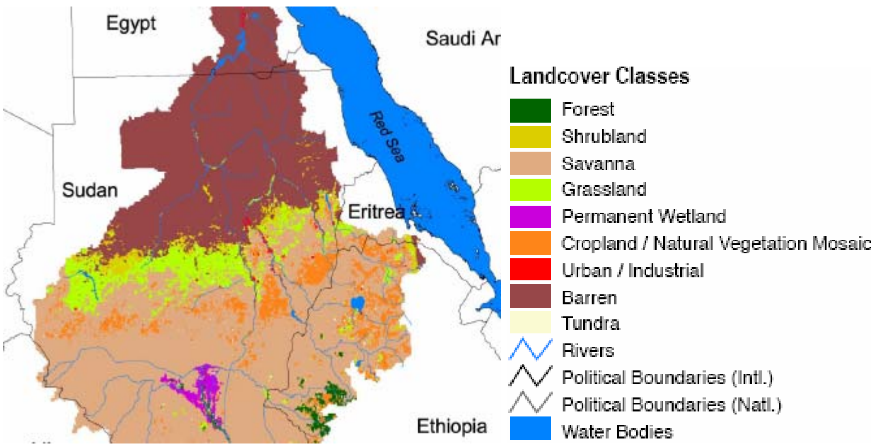


Figure 8.14. Land cover in the Nile basin in Sudan (Bos and Chabloz 2003)

8.7. South Africa

In South Africa, especially in the northern parts of the country, both surface water and groundwater resources are nearly fully developed and in some cased over-exploited, with little undeveloped resource potential remaining. In the well-watered south-eastern part of the country significant undeveloped and little-used resources still exist. It is estimated that South Africa will run out of surplus usable water by 2025, or soon thereafter. It is foreseen that in the future the irrigation sector must sacrifice some of its water for public and industrial usage. Inter-basin transfers are in place and more are planned, but due to the high cost of this development, such water will rather be used for industrial and public needs than for irrigation. New large-scale irrigation development is not possible because of the limited water availability and the shortage of good irrigable soils within economic distance of water sources. Intergovernmental discussions and studies are underway on the sharing of Orange River water between South Africa and Namibia, as well as on the sharing of Limpopo River water between South Africa and the other three countries in the Limpopo River Basin: Botswana, Zimbabwe and Mozambique (FAO, 2007a).

Although fruit accounts for almost half of the external water footprint of the Netherlands in South Africa, groundnuts (19%) and sunflower seeds (13%) are the most important individual crops. Data on the whereabouts of the cultivation of these crops (Leff et al., 2004) point to a evenly distributed spread over the country. The two largest basins in the country are the Limpopo and the Orange basin with a withdrawal-to-availability ratio of 45% and 56% respectively (Smakhtin et al., 2004a). Land cover in both basins is shown in Figure 8.15.

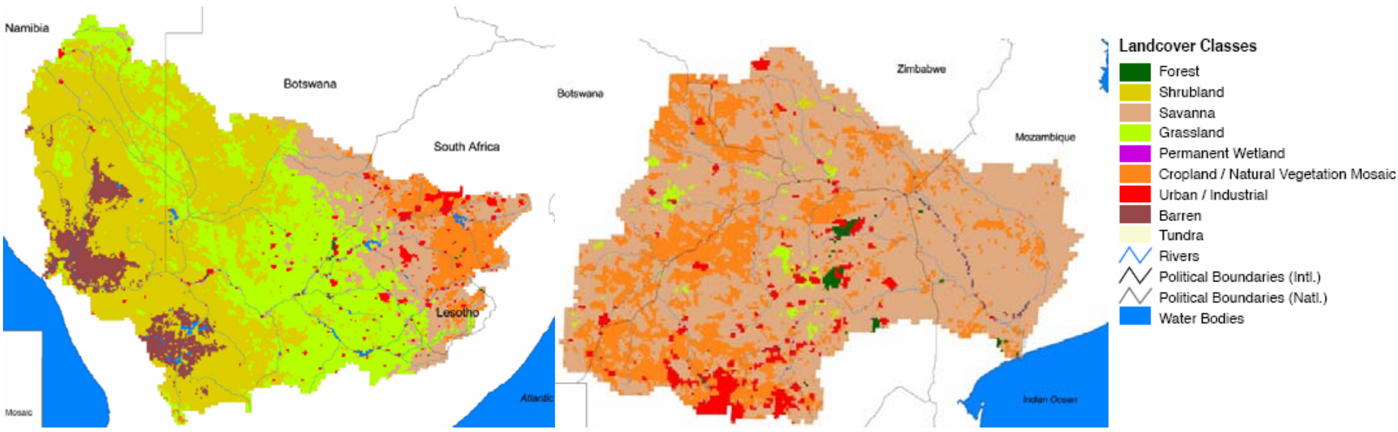


Figure 8.15. The Orange basin (left) and the Limpopo basin (right) (Bos and Chabloz, 2003).

To estimate the green and blue components of the Dutch external water footprint in South Africa (as shown in Table 7.1) we used meteorological data from the following meteorological station (Müller and Hennings, 2000): Kimberley for all crops (30153, Lat: 28.80 S, Lon: 24.77 E). Related to grey water, information on the application of fertilizers in South Africa is given in Table 7.2.

8.8. Mexico

Mexico experiences large water problems, particularly in Mexico City. The city is sinking because of the amount of water being pumped out from beneath its foundations. The city draws 80% of its water from aquifers below it, and has sunk an estimated nine metres into the soft, drained lake bed since the 1900s. It already buys in a third of its water from surrounding areas, and an estimated million people are dependent on water trucks.

By far the most important contributor to the external water footprint of the Netherlands in Mexico is coffee (66%). Sunflower seeds and oil are secondly important (12%). About 99% of all coffee production in Mexico in located in only eight states (Figure 8.16), the most important of which are: Chiapas (29%); Oaxaca (24%) and Veracruz (18%).

Figure 8.16. Mexican coffee production is concentrated in the south of the country.

No basins with severe water scarcity are impacted by coffee production. However, one could argue that the production of coffee limits the production of other crops. To estimate the green and blue components of the Dutch external water footprint in Mexico we used meteorological data from the following meteorological station (Müller and Hennings, 2000): Salina Cruz for both coffee and sunflower (70144, Lat: 16.20 N, Lon: 95.20 W). Related to grey water, information on the application of fertilizers in Mexico is given in Table 7.2.

9. Conclusion

The total water footprint of the Netherlands is estimated to be about 2300 m^3/yr/cap, which is nearly double the water footprint of an average world citizen. About 67% of the Dutch water footprint relates to the consumption of agricultural goods, 31% to the consumption of industrial goods, and 2% to domestic water use. The Dutch water footprint related to the consumption of agricultural goods, is composed as follows: 46% related to livestock products; 17% oil crops and oil from oil crops; 12% coffee, tea, cocoa and tobacco; 8% cereals and beer; 6 % cotton products; 5% fruits; and 6 % other agricultural products. Most agricultural products are related to food consumption, most important exceptions being cotton for textiles and oil crops for cosmetics, pharmaceuticals, soaps, lubricants, paints and bio-energy.[5]

About 89% of the water footprint of the Netherlands is external. About 48% of this external footprint is located within European countries (mainly in Germany, France and Belgium) and 20% in Latin American countries (mainly in Brazil and Argentina). For industrial products 53% of the consumed products originates from European countries and about 33% originates from Asian countries (mainly China, Taiwan, Hong Kong and Viet Nam).

As a trade nation, the Netherlands imports not only for the purpose of domestic consumption. Only 44% of the virtual-water import relates to products consumed in the Netherlands, thus constituting the external water footprint. For agricultural products this is 40% and for industrial products this is 60%. The remaining 56% of the virtual-water import to the Netherlands is re-exported. About 41% of the virtual-water import for re-export comes from Africa (mainly Cote d'Ivoire, Ghana, Cameroon and Nigeria) and mainly concerns the import of cocoa beans, most of which are processed in the Netherlands into cocoa butter, cocoa powder or cocoa paste and re-exported to other European countries (mainly Germany, United Kingdom, Belgium and Switzerland).

The impact of the external water footprint of Dutch consumers is highest in countries that experience serious water scarcity. Based on indicators for water scarcity the following eight countries have been identified as hotspots: China; India; Spain; Turkey; Pakistan; Sudan; South Africa; and Mexico. Although these countries are not the largest contributors to the external water footprint of Dutch consumers in absolute terms, the impact of Dutch consumption in these countries deserves serious attention since in these countries the negative externalities of Dutch consumption are considered to be most serious.

The study shows that Dutch consumption implies the use of water resources throughout the world, with significant impacts at specified locations. This knowledge is relevant for consumers, government and businesses when addressing the sustainability of consumer behaviour and supply chains. The results of this study can be an input to bilateral cooperation between the Netherlands and the Dutch trade partners aimed at the reduction of the negative impacts of Dutch consumption on foreign water resources. Dutch government can also engage with businesses in order to stimulate them to review the sustainability of their supply chains.

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[5] Wood products such as paper and furniture and flowers were excluded in this study.

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http://es.wikipedia.org/wiki/Trasvase_Talave-Cenajo

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Appendix 1. List of symbols

Symbol	Unit	Explanation
$B_v[NL]$	m^3/yr	virtual-water budget of the Netherlands
$E[NL,p]$	ton/yr	quantity of product *p* exported from the Netherlands
$I[c,p]$	ton/yr	imported quantity of product *p* from country *c*
$I[c,p]$	ton/yr	imported quantity of product *p* from country *c*
$P[NL,p]$	ton/yr	quantity of product *p* produced in the Netherlands
$v[NL,p]$	m^3/ton	virtual-water content of product *p* when produced in the Netherlands
$v[c,p]$	m^3/ton	virtual-water content of product *p* when produced in country *c*
$v^*[NL,p]$	m^3/ton	average virtual-water content of product *p* as available in the Netherlands, i.e. the virtual-water content of product *p* averaged over the domestically produced quantity and imported quantities of product *p*
$V_e[NL]$	m^3/yr	gross virtual-water export from the Netherlands
$V_{e,d}[NL]$	m^3/yr	the part of the gross virtual-water export that concerns export of domestically produced products
$V_{e,r}[NL]$	m^3/yr	the part of the gross virtual-water export that concerns re-export of imported products
$V_i[NL]$	m^3/yr	gross virtual-water import into the Netherlands
$WF[NL]$	m^3/yr	water footprint of the people living in the Netherlands
$WF_{direct}[NL]$	m^3/yr	direct water use of the people living in the Netherlands (domestic water use)
$WF_{indirect}[NL]$	m^3/yr	indirect water use of the people living in the Netherlands (water use behind products being consumed)
$WF_i[NL]$	m^3/yr	internal water footprint of the people living in the Netherlands
$WF_e[NL]$	m^3/yr	external water footprint of the people living in the Netherlands
$WU[NL]$	m^3/yr	water use in the Netherlands

Appendix 2. Comparison of the results from the top-down and bottom-up approach

This appendix shows the results of the water footprint of the Dutch consumers related to consumption of agricultural products estimated with both the top-down and the bottom-up approach. The difference between the outcomes of the two approaches is mainly explained by the high variability in traded quantities from year to year. Consumption quantities are much more stable (FAO, 2007b). Especially since the Netherlands imports and exports large quantities relative to domestic production, this influences outcomes for the water footprint of Dutch consumption in the top-down approach.

Water footprint of Dutch consumers related to consumption of agricultural products, estimated according to the top-down and bottom-up approach.

	Top-down approach (water footprint as the closing entry)				Bottom-up approach (virtual-water export as the closing entry)			
	A	B	C	D=A+B-C	A	B	E=A+B-F	F
Year	Virtual-water import (Gm^3/yr)	Water use (Gm^3/yr)	Virtual-water export (Gm^3/yr)	Water footprint (Gm^3/yr)	Virtual-water import (Gm^3/yr)	Water use (Gm^3/yr)	Virtual-water export (Gm^3/yr)	Water footprint (Gm^3/yr)
1996	60.1	3.1	34.5	28.7	60.1	3.1	39.7	23.5
1997	47.7	3.1	39.9	10.9	47.7	3.1	28.0	22.8
1998	54.4	2.9	38.1	19.2	54.4	2.9	33.3	23.9
1999	65.6	3.0	41.5	27.2	65.6	3.0	42.0	26.7
2000	64.1	3.1	42.3	24.8	64.1	3.1	41.5	25.7
2001	69.3	3.0	43.2	29.2	69.3	3.0	44.8	27.5
2002	42.4	3.1	34.7	10.7	42.4	3.1	18.5	27.0
2003	70.5	3.0	40.2	33.3	70.5	3.0	47.5	26.0
2004	70.1	3.1	44.1	29.1	70.1	3.1	47.3	25.9
2005	71.2	3.0	45.4	28.8	71.2	3.0	49.4	24.8
Average	61.5	3.0	40.4	24.2	61.5	3.0	39.1	25.4

Period: 1996-2005. Original data from this study.

Appendix 3. The external water footprint of Dutch consumers due to the consumption of agricultural products, specified by country of origin

Country	Part of external water footprint[a]	Water competition level (m^3/yr/capita)[b]	Withdrawal-to-availability ratio (%)[c]	Part of country with serious water stress (%)[d]
Germany	18.3%	1865	31	1
Brazil	9.7%	45039	1	0
France	8.7%	3355	20	19
United States	8.6%	6902	24	23
Belgium-Luxembourg	8.2%	1767	52	93
Argentina	5.4%	20707	4	19
Indonesia	4.1%	12596	3	1
Malaysia	2.5%	22902	2	1
India	2.2%	1729	37	80
Thailand	1.9%	6397	22	1
United Kingdom	1.6%	2457	7	15
China	1.6%	2128	23	41
Philippines	1.6%	5784	7	8
Turkey	1.4%	3128	18	56
Ukraine	1.3%	2921	26	16
Pakistan	1.2%	1382	86	77
Spain	1.2%	2707	32	71
Colombia	1.1%	46754	1	0
Italy	1.1%	3341	23	24
Paraguay	1.1%	54545	0	0
Sudan	0.9%	1841	62	32
Denmark	0.8%	1114	21	0
Ireland	0.8%	12871	2	0
Hungary	0.7%	10630	7	0
Poland	0.6%	1599	26	0
Uganda	0.6%	2389	1	0
Canada	0.6%	90767	2	1
South Africa	0.6%	1103	25	64
Cote d'Ivoire	0.5%	4719	1	0
Russian Federation	0.5%	31841	2	2
Mexico	0.5%	4298	18	42
Australia	0.5%	24487	5	7
Kenya	0.4%	919	6	1
Ghana	0.4%	2437	2	0
Cameroon	0.3%	17236	0	0
Viet Nam	0.3%	10662	9	5
Papua New Guinea	0.3%	134419	0	0
Uruguay	0.3%	40139	2	0
Tanzania	0.3%	2372	6	0
Guatemala	0.3%	8574	2	0
Honduras	0.3%	13219	1	0
Nigeria	0.3%	2198	3	0
Costa Rica	0.3%	25976	3	0
Peru	0.3%	68400	1	19
Romania	0.2%	9534	11	2
Greece	0.2%	6764	10	42
Austria	0.2%	9569	3	0
Uzbekistan	0.2%	1876	126	69
Total		95.1%		

[a] The numbers refer to external water footprint in so far related to import of agricultural goods only. Calculated in this study. Period: 1996-2005.
[b] Based on total renewable water resources per country (FAO, 2007a) and population numbers (UN Statistic Division, 2007).
[c] Based on water withdrawal per country (FAO, 2007a) and total renewable water resources per country (FAO, 2007a).
[d] Based on basin-specific data from Smakhtin et al. (2004a,b), which have been translated to country-level.

Appendix 4. The external water footprint of Dutch consumers due to the consumption industrial products, specified by country of origin

Country	Part of external water footprint and virtual-water import for re-export[a]	Average water withdrawal per unit value added in the industrial sector (m^3/US$)[b]
China	15.2%	0.256
USA	11.0%	0.098
Germany	10.6%	0.052
Russian Federation	10.6%	0.373
Belgium-Luxembourg	9.9%	0.097
Taiwan (POC)	6.6%	0.083
France	5.6%	0.091
Hong Kong	3.3%	0.083
Viet Nam	2.4%	1.349
Poland	2.1%	0.233
Hungary	1.9%	0.258
United Kingdom	1.8%	0.018
Italy	1.5%	0.048
India	1.4%	0.275
Bulgaria	1.3%	1.957
Romania	1.2%	0.490
Philippines	0.9%	0.107
Canada	0.8%	0.141
Ukraine	0.7%	0.885
Spain	0.7%	0.034
Kazakhstan	0.6%	0.612
Sweden	0.6%	0.024
Malaysia	0.6%	0.041
Finland	0.6%	0.051
Norway	0.6%	0.022
Japan	0.6%	0.012
Turkey	0.4%	0.064
Iraq	0.4%	0.133
Ireland	0.4%	0.021
Switzerland	0.4%	0.024
Total	95.0%	

[a] The numbers refer to the external water footprint and virtual water import in so far related to import of industrial goods only. Calculated in this study. Period: 1996-2005.

[b] Based on industrial water withdrawal per country (FAO, 2007a) and the value added in the industrial sector (UN Statistic Division, 2007).

Appendix 5. Imported virtual water for re-export, specified by country of origin

Country	Part of virtual-water import for re-export [a]	Water competition level (m^3/yr/capita)[b]	Withdrawal-to-availability ratio (%)[c]	Part of country with serious water stress (%)[d]
Cote d'Ivoire	12.7%	4719	1	0
Germany	11.0%	1865	31	1
Ghana	10.1%	2437	2	0
Cameroon	7.5%	17236	0	0
Brazil	7.3%	45039	1	0
Nigeria	5.8%	2198	3	0
France	5.4%	3355	20	19
United States	5.2%	6902	24	23
Belgium-Luxembourg	4.8%	1767	52	93
Argentina	3.5%	20707	4	19
Indonesia	3.1%	12596	3	1
Malaysia	2.0%	22902	2	1
India	1.3%	1729	37	80
Thailand	1.1%	6397	22	1
China	1.0%	2128	23	41
Philippines	1.0%	5784	7	8
United Kingdom	0.9%	2457	7	15
Turkey	0.8%	3128	18	56
Spain	0.7%	2707	32	71
Colombia	0.7%	46754	1	0
Ukraine	0.7%	2921	26	16
Pakistan	0.7%	1382	86	77
Paraguay	0.7%	54545	0	0
Italy	0.6%	3341	23	24
Denmark	0.5%	1114	21	0
Ireland	0.5%	12871	2	0
Ecuador	0.5%	32289	4	10
Sudan	0.5%	1841	62	32
Uganda	0.4%	2389	1	0
Hungary	0.4%	10630	7	0
Aruba	0.4%	-	-	-
Poland	0.4%	1599	26	0
Mexico	0.3%	4298	18	42
Russian Federation	0.3%	31841	2	2
Canada	0.3%	90767	2	1
Papua New Guinea	0.3%	134419	0	0
South Africa	0.3%	1103	25	64
Kenya	0.3%	919	6	1
Australia	0.3%	24487	5	7
Equatorial Guinea	0.2%	49904	0	0
Peru	0.2%	68400	1	19
Total		95.0%		

[a] The numbers refer to virtual water import in so far related to import of agricultural goods only. Calculated in this study. Period: 1996-2005.
[b] Based on total renewable water resources per country (FAO, 2007a) and population numbers (UN Statistic Division, 2007).
[c] Based on water withdrawal per country (FAO, 2007a) and total renewable water resources per country (FAO, 2007a).
[d] Based on basin-specific data from Smakhtin et al. (2004a,b), which have been translated to country-level.

Appendix 6. Livestock

The main products produced by Dutch livestock are: beef, chicken, pork, milk, cheese, condense butter and eggs. To estimate the virtual water content of these individual products the following issues have to be taken into account:

- Animal products are imported, produced and exported;
- Live animals are imported, produced and exported;
- Feed ingredients are imported, produced and exported;
- Different animals have different diets.[6]

To deal with these issues, we have taken the following consecutive steps:

1. We categorised the livestock products by animal of origin.
2. We estimated the composition and amounts of feed per type of animal.
3. Per feed ingredient we identified the countries of origin.

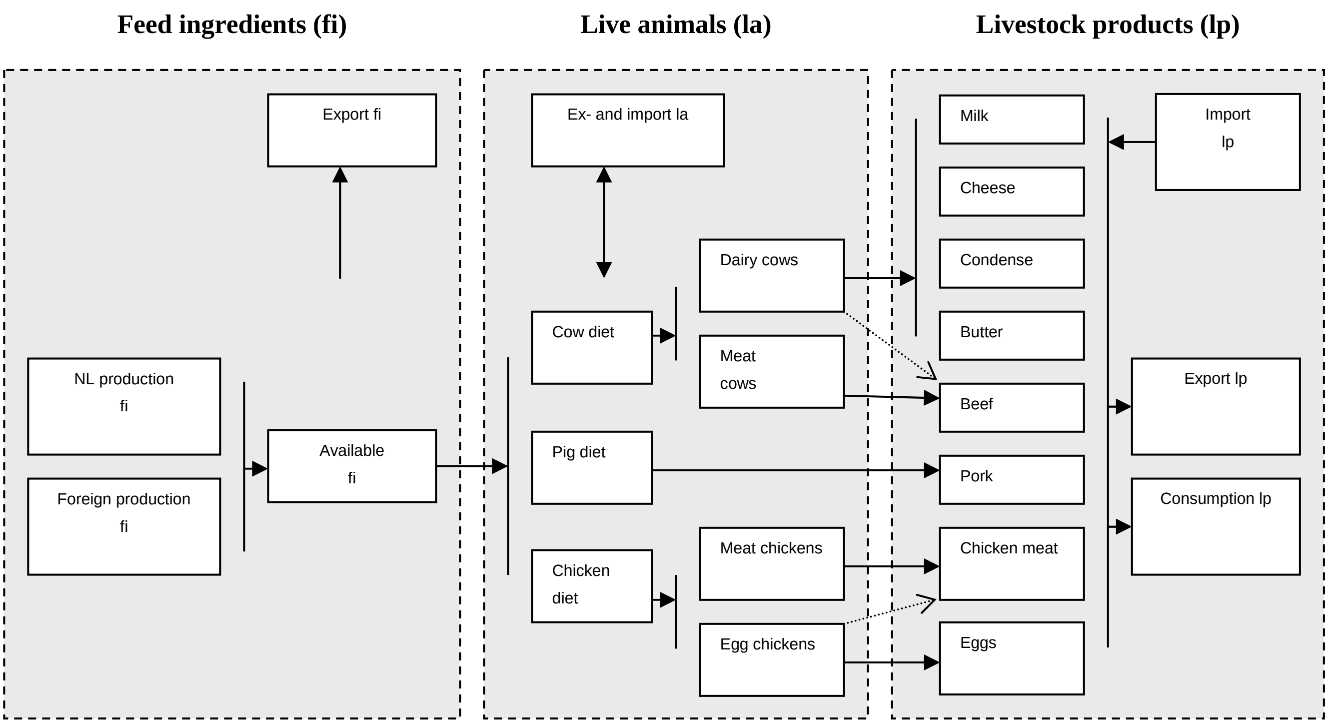

Figure A6.1. A schematization of the Dutch livestock sector. To derive the external water footprint of a livestock product consumed in the Netherlands, one has to take into account the flows of goods in three stages of product development, since during this the development there are two product transformations.

[6] We did not differentiate between the diets for dairy cattle and beef cattle.

Table A6.1 gives a summary of livestock products in the Netherlands. The numbers are based on studies by CBS (2007) and represent values for 2003-2005. Dutch livestock that should be associated with the production of these products is represented in Table A6.2. The animals represented in Table A6.2 are taken as annual averages. Live animals are traded. From trade statistics, it is however unclear what the age of these animals is. For pigs, for instance, some animals are exported just after birth and others just before slaughter. The numbers of traded animals are given in Table A6.3.

Table A6.1. Import, export, production and consumption of livestock products.

Product	SITC code	Unit	Import 2006 (LEI, 2007)	Production 2006 (LEI, 2007)	Total consumption (CBS, 2006)	Export (LEI, 2007)
Beef products	011, 01251/2, 01681/2, 0176	10^3 kg	331000	179000	305600	223000
Chicken meat	0123	10^3 kg	399000	665000	350400	715000
Pork products	01221/2, 01253/4, 01611/2/9, 0175	10^3 kg	239000	1270000	664000	833000
Milk products	022	10^3 kg	359000	1475000	1598400	449000
Butter products	023	10^3 kg	32000	149000	187200	126000
Cheese	024	10^3 kg	157000	715000	267200	496000
Condense	-	10^3 kg	214000	310000	83200	227000
Egg products	025	mln. units	2102	9160	2912	8202

Table A6.2. Livestock numbers in the Netherlands. Counting Nov/Dec 2006 (CBS, 2007).

Type of animal	Number	
Meat cows	1124000	
Dairy cows	1397000	
Breeding cows	1153000	(partly attributed to meat cows and partly to dairy cows)
Pigs	11220000	
Meat chickens	48760000	
Egg chickens	41642000	

Table A6.3. Import, export and production of live animals (LEI 2007)

Animal	Unit	Import	Produced	Export	Animals for production in NL
Cows	number	23000	596000	38000	581000
Pigs	number	861000	20738000	7499000	14100000
Chickens	10^3 kg slaughtered weight	122000	613000	71000	664000

For feed consumption we take into account the feed ingredients as used by CBS (2007). Import, export and production statistics are derived from PDV (2005), ITC (2006) and CBS (2007). These ingredients are represented in Table A6.4. This table shows the amounts of these ingredients that were available for Dutch cattle (PDV, 2005) and the diets of the different species, as derived from Elferink and Nonhebel (2007).

For livestock products we have chosen to take into account only the most recent data available. Depending on source of the data this can mean data from 2003 up to 2006 and in some case averages of these years.

There is a large inconsistency between the diet constraints of Elferink and Nonhebel (2007) and the statistics on available feed ingredients (PDV, 2005). In order to deal with this inconsistency we have redistributed feed ingredients to animal types in order to fit feed ingredient availability to diet constraints as good as possible. In Table 4 the outcome is shown.

Statistics Netherlands (CBS, 2007) reports on place of origin of available feed ingredients (CBS, 2007). Roughly 60% of the feed ingredients are imported. However, many of the domestically originated feed ingredients originate from abroad as well (by-products of grains and oilcakes for instance). An analysis of production data for the Netherlands (FAO, 2007) and trade data (ITC, 2006) results in a rough estimate that around 90% of the virtual water of feed ingredients for Dutch livestock, originates abroad.

There are many factors influencing the uncertainty in determining virtual water content of livestock and livestock products:

- Diet of animals differs from year to year. How is unclear. Misfit between diets and available feed ingredients.
- Not all feed ingredients are represented in the SITC database as referred to by PDV.
- Dairy cows produce meat and male calves for meat production.
- The age of exported pigs is unclear.
- The ITC database does not include poultry meat, butter and condense

Table A6.4. Feed ingredients and feed consumption by Dutch livestock

Feed ingredients		Feed consumption per animal type according to Elferink and Nonhebel (2007)						Available amount (PDV, 2005)	Feed consumption per animal type after adjustment to fit the availability per feed ingredient		
		Cattle[a]	Pigs[a]	Chickens[a]	Cattle[b]	Pigs[b]	Chickens[b]		Cattle	Pigs	Chickens
Product	SITC code	%	%	%	10^3 tons	10^3 tons	10^3 tons	10^3 tons	10^3 tons	10^3 tons	10^3 tons
Wheat	0411	2	8	35	95	647	1661	1811	72	488	1252
Barley	0430	0	10	1	0	809	47	432	0	408	24
Maize	0449	0	0	11	0	0	522	1470	0	0	1470
Peas	05421	0	4	2	0	323	95	187	0	145	42
Lupines	05484	2	0	0	95	0	0	48	48	0	0
Wheat pellets	0462	1	10	0	47	809	0	698	39	659	0
Maize pellets	04721	2	1	0	95	81	0	152	82	70	0
Maize gluten pellets	04721	24	1	0	1139	81	0	867	809	57	0
Dried potato fibre	59213	4	0	0	190	0	0	2023	2023	0	0
Dried beet pulp	05487	7	0	0	332	0	0	234	234	0	0
Molasses	06151/9	4	5	0	190	404	0	417	133	284	0
Citrus pulp/pellets	05822	12	0	0	570	0	0	535	535	0	0
Cassava pellets	05481	0	20	1	0	1617	47	749	0	728	21
Soybeans	2222	0	1	7	0	81	332	1848	0	362	1486
Rapeseed	22261	0	0	1	0	0	47		0	0	0
Soybean scrap	08131	9	15	23	427	1213	1092	2521	394	1119	1008
Rapeseed scrap	08136	2	4	1	95	323	47	562	115	390	57
Sunflower scrap	08135	3	6	1	142	485	47	350	74	251	25
Palm seed scrap	08138	12	2	0	570	162	0	707	550	156	0
Cocos scrap	08137	6	0	0	285	0	0	95	95	0	0
Linseed scrap	08134	1	0	0	47	0	0		0	0	0
Grass lucerne meal	08112	3	0	0	142	0	0	117	117	0	0
Waste-streams and rest	?	6	13	17	285	1051	807	1758	234	862	662
Consumption of total available feed		**27**	**46**	**27**	4747	8087	4747	17580	5553	5979	6047

[a] Source: Elferink and Nonhebel (2007).

[b] Calculated based on data from Elferink and Nonhebel (2007) and total available feed from PDV (2005).

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The Netherlands

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