UNESCO-IHE
Institute for Water Education

M.M. Mekonnen
A.Y. Hoekstra

June 2011

The relation between national water management and international trade:

a case study for Kenya

Value of Water

Research Report Series No. 52

THE RELATION BETWEEN NATIONAL WATER MANAGEMENT AND INTERNATIONAL TRADE: A CASE STUDY FOR KENYA

M.M. MEKONNEN[1]
A.Y. HOEKSTRA[1,2]

JUNE 2011

VALUE OF WATER RESEARCH REPORT SERIES NO. 52

[1] Twente Water Centre, University of Twente, Enschede, The Netherlands
[2] Contact author: Arjen Y. Hoekstra, a.y.hoekstra@utwente.nl

Published by:
UNESCO-IHE Institute for Water Education
P.O. Box 3015
2601 DA Delft
The Netherlands

The Value of Water Research Report Series is published by UNESCO-IHE Institute for Water Education, in collaboration with University of Twente, Enschede, and Delft University of Technology, Delft.

Please cite this publication as follows:
Mekonnen, M.M. and Hoekstra, A.Y. (2011) The relation between national water management and international trade: A case study for Kenya, Value of Water Research Report Series No. 52, UNESCO-IHE, Delft, the Netherlands.

Content

Summary

This study quantifies and maps the water footprint of Kenya from both a production and consumption perspective and estimates virtual water import and export flows related to international trade. The study covers the period 1996-2005. Both water footprint and virtual water estimates are broken down into three components: green, blue and grey water. The main findings of the study are:

- The water footprint in Kenya related to crop production was 18.1 billion m^3/yr (17.6 green; 0.2 blue and 0.3 grey water).
- Kenya's virtual water export related to trade in agricultural products was 4.1 billion m^3/yr; its virtual water import was 4.0 billion m^3/yr. About 79% of the virtual water export was related to export of coffee, tea and cotton products. The water footprint in Kenya for producing cut flowers for export was 18 million m^3/yr.
- The average export earning per unit of water consumed or polluted for producing agricultural export products was 0.25 US$/$m^3$; the average expenditure on imported commodities per unit of virtual water imported was 0.10 US$/$m^3$.
- About 23% of the total water appropriated in the agricultural sector in Kenya was for producing export products, like coffee, tea, cotton, fruits, vegetables and cut flowers. The use of blue water resources for irrigation is strongly connected to export: more than half of the blue water footprint in the study period was related to production for export. On the other hand, Kenya imported many other water-intensive goods, primarily cereals and oil crops. Kenya was not self-sufficient with respect to its food supply: 10% of its maize (the major staple food), 63% of its wheat and 72% of its rice were imported.
- The total water footprint related to consumption of agricultural products was 34.5 billion m^3/yr, equivalent to 1080 m^3/yr per capita.

Next to increasing water productivities in crop production, part of a strategy to mitigate increasing water scarcity in Kenya can be to increase its import of water-intensive products such as cereals and enhance its export of high-value products such as cut flower, vegetables, spices and tea, with the aim of achieving net virtual water import. From a water resources point of view, particularly the production and export of green-water based tea and vegetables are positive: water productivities in terms of US$ per cubic metre are relatively high and the export values in absolute terms are very substantial.

1. Introduction

There are great disparities in water use and scarcity within and between countries because both people and water resources are unevenly distributed across the globe. Virtual water import in the form of import of agricultural goods is increasingly recognized as a mechanism to improve national water security (Allan, 2003; Hoekstra, 2003; De Fraiture et al., 2004; Oki and Kanae, 2004; Chapagain et al., 2006; Yang et al., 2006). Virtual water import enables nations to save scarce domestic water resources by importing water-intensive products and exporting commodities that require little water. On the other hand, water-abundant countries can profit by exporting water-intensive commodities (Hoekstra and Chapagain, 2008).

Kenya's internal renewable water resources are estimated at 20.7 Gm^3/yr. Most of this, 20.2 Gm^3/yr, is available as surface water. Renewable ground water resources are estimates to be 3.5 Gm^3/yr, of which 3.0 Gm^3/yr overlaps with the annual renewable surface water resources. It is estimated that 10 Gm^3/yr of river water flows into the country (FAO, 2005), which means that the total renewable water resources of Kenya are 30.7 Gm^3/yr.

According to Wong et al. (2005), the available renewable water resources are insufficient to meet Kenya's water needs. Kenya is generally characterized as a water-stressed country (Ohlsson and Appelgren, 1998; FAO, 2005; UNEP, 2006). This is also the starting point of Kenya's Vision 2030 (GoK, 2007).

The aim of this report is to assess the relation between national water resources use and international trade in a case study for Kenya. We quantify the water consumption and pollution related to the production of agricultural export commodities in the period 1996-2005 and put this in the context of export earnings. We also consider the import side by quantifying how much water is embedded in imported commodities.

2. Method and data

The water footprint is an indicator of human appropriation of freshwater resources. The term 'freshwater appropriation' refers to both consumptive water use (water evaporated or incorporated into the product) and water required to assimilate pollutants. The water footprint has three components: the green, blue and grey water footprint. The green water footprint is the volume of green water (rainwater) consumed. The blue water footprint refers to consumption of blue water resources (surface and ground water). The grey water footprint is an indicator of the degree of freshwater pollution and is defined as the volume of freshwater that is required to assimilate the load of pollutants based on existing ambient water quality standards.

Green, blue and grey water footprints have been estimated following the calculation framework as set out in *The Water Footprint Assessment Manual* developed by the Water Footprint Network (Hoekstra et al., 2011). We applied the national water footprint accounting scheme as shown in Figure 1. The water footprint within a nation is defined as the total freshwater volume consumed or polluted within the territory of the nation as a result of different economic activities. The water footprint of national consumption refers to the total amount of fresh water that is used to produce the goods and services consumed by the inhabitants of the nation. It includes an internal and external component. The external water footprint of national consumption refers to the volume of water consumed or polluted elsewhere to produce commodities imported by and consumed within the country. Data on water footprints of crop production in Kenya were taken from Mekonnen and Hoekstra (2010a).

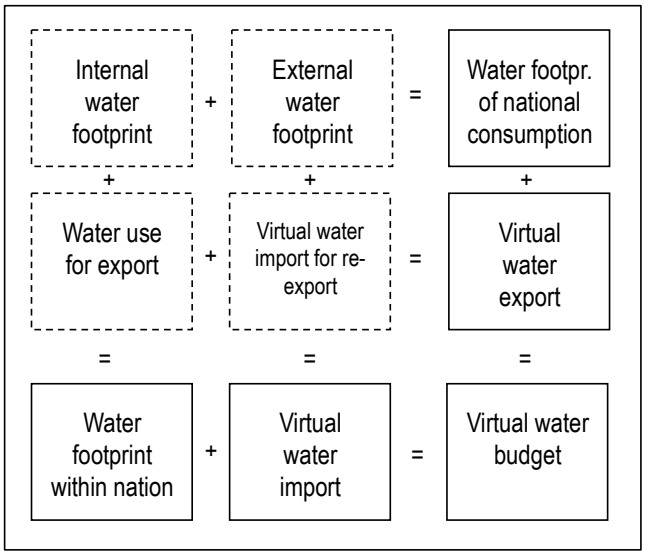

Figure 1. The national water footprint accounting scheme. Source: Hoekstra et al. (2011).

The virtual-water export from a nation is the sum of virtual water export from domestic water resources and re-exported virtual water of foreign origin. The gross virtual-water flow is calculated by multiplying the volume of trade by the water footprint per ton of product as in the exporting nation. We have taken the average product water footprint as in the exporting country and when a product is imported from a country that does not produce the product we have assumed the global average product water footprint for that import flow. Kenya's virtual water import and export related to trade in agricultural products was taken from Mekonnen and Hoekstra (2011).

The water footprint of national consumption is defined as the total volume of freshwater that is used to produce the goods and services consumed by the inhabitants of the nation. It consists of an internal and external component. The internal water footprint of national consumption refers to the use of domestic water resources to produce goods and services consumed by the national population. It is the difference between the water footprint within the nation and the volume of virtual-water export to other nations related to export of products produced with domestic water resources. The external water footprint of national consumption, on the other hand, is defined as the volume of water resources used in other nations to produce goods and services consumed by the population in the nation considered. It is the difference between the virtual-water import into the nation and the volume of virtual-water re-exported to other nations as a result of re-export of imported products.

The water footprint of national consumption is calculated by adding the direct and indirect water footprint of consumers within the nation. The direct water footprint of consumers refers to consumption and pollution of water related to domestic water supply. The indirect water footprint of consumers refers to the water use by others to make the commodities consumed, whereby we distinguish between agricultural and industrial commodities. The water footprint of national consumption of agricultural and industrial commodities can be calculated through either the top-down or the bottom-up approach (Hoekstra et al., 2011). In the top-down approach, the water footprint of national consumption is calculated as the water footprint within the nation plus the virtual-water import minus the virtual-water export. In the bottom-up approach, the water footprint of national consumption is calculated by adding the direct and indirect water footprints of consumers within the nation. The water footprint of national consumption was taken from Mekonnen and Hoekstra (2011), who used the bottom-up approach of calculation.

Water productivities of crops were calculated per crop, at national level, by dividing the crop value (US$/kg) by the water footprint of the crop (m^3/kg). Data on export and import values of agricultural products have been taken from the SITA database (Statistics for International Trade Analysis) available from the International Trade Centre (ITC, 2007).

3. Results

3.1 Water footprint of crop production

The total water footprint related to crop production in Kenya for the period 1996-2005 was 18.1 Gm^3/yr (97% green, 1% blue and 2% grey). The largest share of this water footprint was due to the production of maize, which accounted for about 38% of the total water footprint. Dry beans, coffee, tea and wheat together contributed 33% to the total water footprint (Table 1).

Table 1. The water footprint of crop production in Kenya (1996-2005).

Crop	Total water footprint (Mm^3/yr)				Water footprint per ton of crop (m^3/ton)			
	Green	Blue	Grey	Total	Green	Blue	Grey	Total
Maize	6688	11	96	6794	2703	4.4	39	2746
Beans, dry	2774	0.0	0.1	2774	8319	0.0	0.3	8319
Coffee	1426	51	35	1513	22222	802	549	23573
Tea	1131	1.0	25	1157	4061	3.6	89	4154
Wheat	439	0.0	20	460	1492	0.0	70	1562
Sorghum	453	0.0	0.0	453	4359	0.0	0.0	4359
Sugarcane	416	8.8	8.9	433	95	2.0	2.0	99
Potato	316	0.0	29	345	342	0.0	31	373
Banana	283	6.5	5.5	295	545	12	11	568
Plantains	284	0.0	5.5	289	546	0.0	11	556
Millet	260	0.0	0.0	260	5375	0.0	0.0	5375
Pigeon peas	240	0.0	0.0	240	3200	0.0	0.3	3200
Cassava	234	0.0	0.0	234	431	0.0	0.0	431
Other crops	2646	140	75	2861				
Total	17590	219	300	18109				

About 61% of the green water footprint was due to the production of maize, dry beans and coffee. The largest blue water footprint was estimated for growing coffee (51 Mm^3/yr) and rice (35 Mm^3/yr), which together accounted for 40% of the total blue water footprint related to crop production.

Although fertilizer application rates are relatively low by international standards, Kenya has among the highest fertilizer application rates within Sub-Saharan Africa, excluding South Africa. Fertilizer use has grown in the recent past and reached over 350 thousand metric ton in 2004/05 (Ariga et al., 2006). Not all fertilizer applied will be absorbed by the plant. A significant amount of nitrogen can remain in the soil and some of this will eventually leach into the groundwater or run off to surface water, causing water pollution. In this study, we have estimated that the grey water footprint due to nitrogen fertilizer leaching from crop fields was about 300 Mm^3/yr over the period 1996-2005. A little over half of this was related to the production of three crops – maize, coffee, and potato.

About 23% of the agricultural water footprint was due to producing export products. The remaining 77% of the water was used for producing products for domestic consumption. It is worth noting that the exported products yielded high foreign currency earnings per unit of water used (see Figure 10 for the water productivity of crops).

Among the major crops, the water footprint per ton of crop increases from sugar cane (roughly 100 m^3/ton), potato (~ 400 m^3/ton), maize (~ 2700 m^3/ton) to coffee (~ 24000 m^3/ton). The largest blue and grey water footprints per ton of crop were calculated for coffee (Table 1). The water footprint per ton of crop varies significantly across the country as shown Figure 2. While the total water footprint related to crop production is high in western Kenya, water footprints per ton of crop are highest in northern and eastern Kenya. The water footprint of maize, for example, varies from 1200 m^3/ton in some parts of the Rift Valley and Western provinces to as high as 6000 m^3/ton in the Eastern province. This variation can be partly explained by differences in the climatic conditions. The northern and eastern regions of Kenya are arid or semi-arid with annual precipitation as low as 200 mm, which affects crop yields. Appendix I shows the water footprint per ton of product per province.

The total water footprint of crop production in each province of Kenya is shown in Figure 3. The Rift Valley province accounts for about 39% of the total water footprint related to crop production. The larges blue water footprint is found in Rift Valley (25%) and Nyanza (20%) provinces. Rift Valley province alone accounts for 35% of the grey water footprint. Since most of Kenya's farming relies on rainfall, the croplands are concentrated in places where rainfall is most reliable, such as the highlands, the Lake Victoria basin, and the narrow coastal strip. The green water footprint dominates (>95%) in all provinces, reaching up to 98% in Rift Valley and Western provinces. Figure 4 shows the variation in the green, blue, grey and total water footprint of crop production within the country at a 5 by 5 arc minute grid. The pattern of the total water footprint is similar as the pattern of harvested crop area (Monfreda et al., 2008), which indicates that the water footprint per grid cell is largely determined by the fraction of harvested crop area per grid cell. Appendix II presents the total water footprint related to crop production per crop and per province.

3.2 Virtual water flows related to trade in agricultural products

In the period 1996-2005, Kenya's virtual water export related to agricultural products was 4.1 Gm^3/yr (95% green, 3% blue and 2% grey). About 65% was related to export of coffee and tea. Cotton products, livestock products and products of oil crops were the other agricultural products responsible for significant virtual water export from Kenya (Table 2). Kenya's total export earning related to agricultural exports was US$ 1.02 billion. Given this export earning and the associated water use, we calculate an earning of about 0.25 US$/$m^3$.

Cut flowers generated the highest economic returns per unit of water exported, followed by vegetable products. The major destinations for Kenya's virtual water exports were the US, Germany, the UK, and Pakistan, which together accounted for about 45% of Kenya's virtual water exports. Appendix III presents Kenya's virtual water import and export related to trade in agricultural products per partner country.

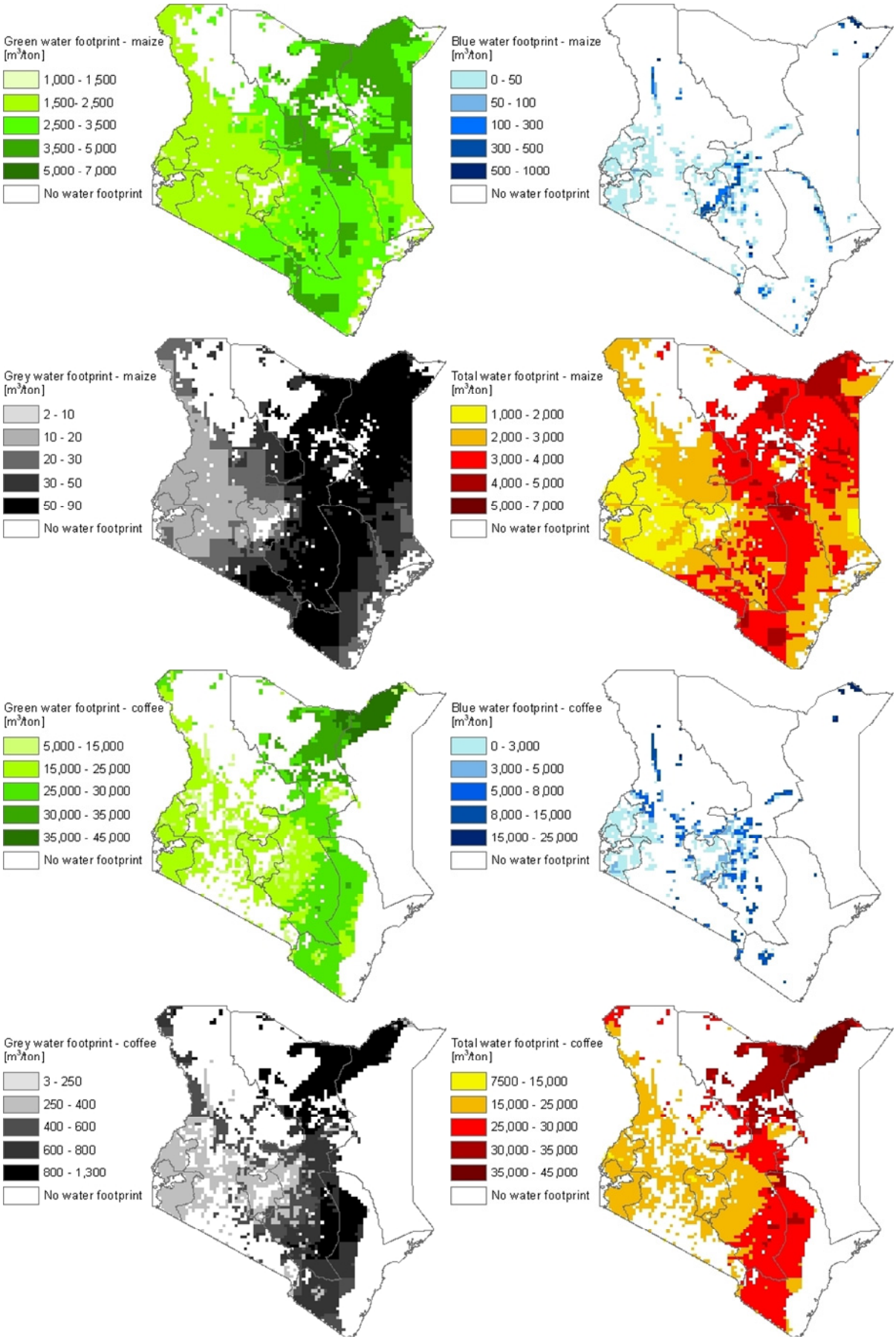

Figure 2. Green, blue, grey and total water footprint per ton of maize (top) and coffee (bottom). Period 1996-2005.

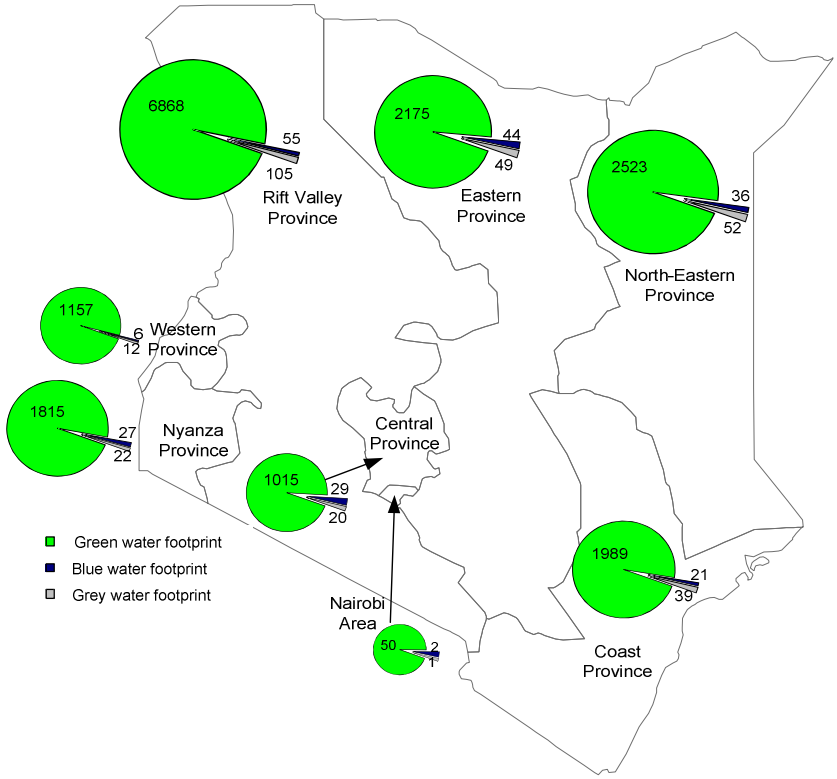

Figure 3. Green, blue and grey water footprint related to crop production per province. Values are given in million m^3/yr. Period 1996-2005.

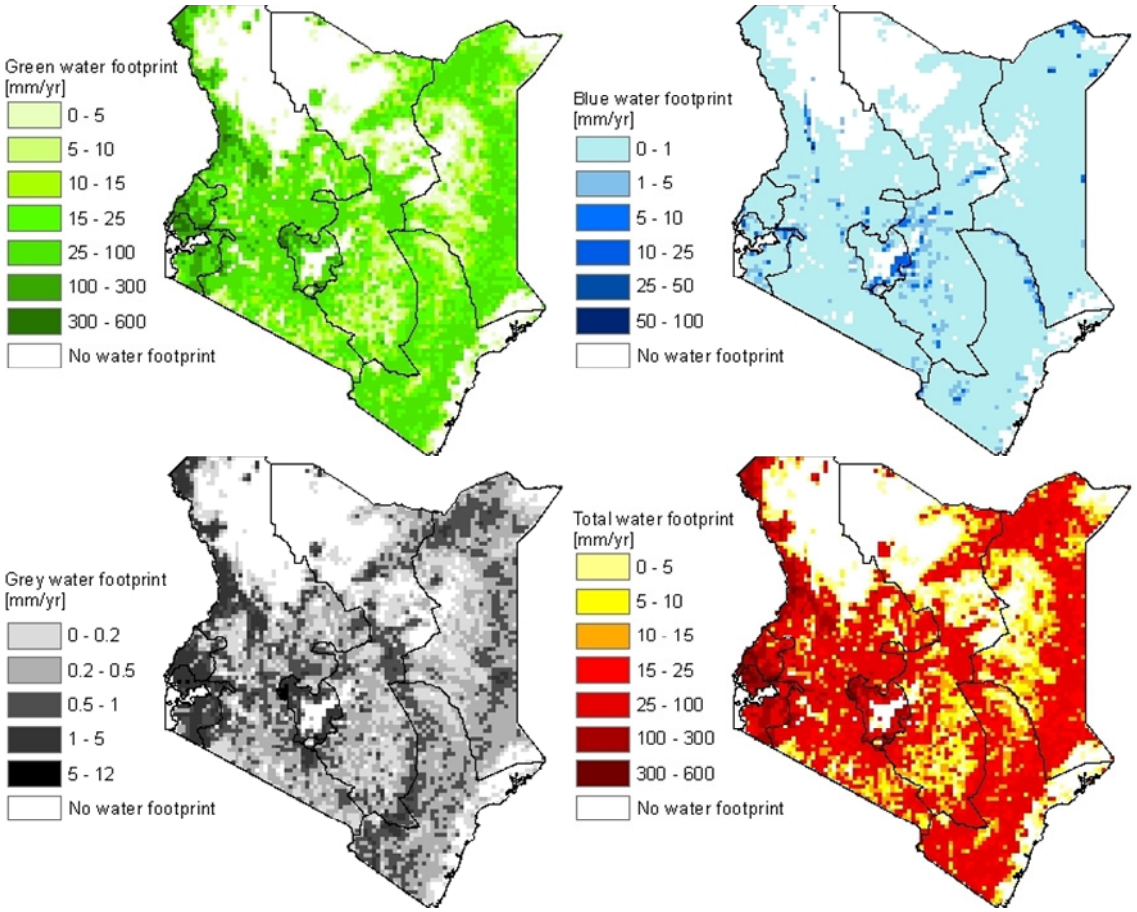

Figure 4. Green, blue, grey and total water footprint of crop production in Kenya. Period 1996-2005.

Table 2. Kenya's virtual water export by agricultural product, export earning and water productivity (1996-2005).

Products	Virtual water export (Mm^3/yr)				Export value (million US$/yr)	Water productivity (US$/$m^3$)*
	Green	Blue	Grey	Total		
Coffee	1568	57	37	1662	157	0.09
Tea	960	0.9	21	982	424	0.43
Cotton products	552	26	0.0	578	42	0.07
Livestock products	292	19	0.5	311	22	0.07
Oil crop products	138	2.0	1.3	142	25	0.17
Fibre products	99	1.1	0.2	100	11	0.11
Maize	84	0.1	1.2	86	7.6	0.09
Fruits	35	8.0	0.7	44	25	0.57
Pulses	38	0.2	2.9	41	2.0	0.05
Wheat	22	0.0	1.1	23	6.4	0.27
Spices	20	0.9	2.6	23	15	0.65
Vegetables	20	1.2	1.2	22	100	4.53
Other cereals	18	1.3	0.3	20	6.9	0.35
Cut flower	3.8	8.0	5.9	18	141	7.98
Other crops	43	0.5	0.9	44	34	0.77
Total**	3892	126	77	4095	1018	0.25

* Water productivity is calculated by dividing total export earning by the total virtual water export.

** Total export earning refers to export earning from the selected 302 crops and livestock products.

In the period 1996-2005, the virtual water export in relation to exports of coffee and tea was 2.6 Gm^3/yr (96% green, 2% blue and 2% grey). The main coffee growing regions include the region north of Nairobi, the high plateau surrounding Mount Kenya, and the Aberdare region. Tea growing regions in Kenya are located in the Great Rift Valley. To the east of the Rift Valley are the Aberdare highlands (Mt. Kenya and the Nyabene hills). To the west of the Rift Valley are the Nandi hills, and the highlands around Kericho, Mt. Elgon and the Kisii highlands. The rainfall in these regions ranges from 1200 mm to 2700 mm annually (EPZA, 2005). The water footprint for both coffee and tea is predominantly green water (96%). The contribution of coffee and tea towards Kenya's socio-economic development is vital. Coffee and tea cultivation provides direct and indirect employment to a large proportion of the population. In addition, the combined annual export revenue from coffee and tea accounted for US$ 581 million, a 57% share in the total revenue generated from exports of the selected crops and livestock products in the period 1996-2005.

Kenya's horticulture industry (vegetables, fruits and cut flowers) is the fastest growing agricultural sub-sector and has become the second largest export earner after tea, contributing 13% to the total export value in the period 1996-2005. Cut flowers export alone accounted for about 53% of Kenyan horticultural export value and its overall contribution to the country's export earnings is growing rapidly. In the period 1996-2005, the virtual water export in relation to the export of cut flowers was 18 Mm^3/yr (22% green, 45% blue and 33% grey). The virtual water export in relation to the export of cut flowers has grown significantly, from 14 Mm^3/yr in 1996 to

27 Mm^3/yr in 2005. Over 90% of this export went to just three countries: the Netherlands (69%), the UK (18%) and Germany (7%) (Mekonnen and Hoekstra, 2010b).

The import of virtual water to Kenya in the study period, in so far related to the import of agricultural goods, was 4.0 Gm^3/yr, about the same volume as the virtual water export (Table 3). The virtual water trade balance of the country was about zero, but the monetary trade balance was positive: the export value of the exported agricultural commodities was 2.5 times bigger than the total cost of the imported agricultural commodities. The total value of the agricultural products imported by Kenya was 412 million US$/yr. The average cost of imported commodities per unit of virtual water imported was 0.10 US$/$m^3$. Thus, in average, Kenya received 0.25 US$ per m^3 of water exported and paid 0.10 US$ per m^3 of water imported.

Table 3. Kenya's virtual water import and import expenditure related import of agricultural products (1996-2005).

Products	Virtual water import (Mm^3/yr)				Import value (million US$/yr)	Import cost per unit of virtual water imported (US$/$m^3$)
	Green	Blue	Grey	Total		
Cereals	1423	407	174	2005	167	0.08
Oil crops	1083	4	58	1145	121	0.11
Sugar products	114	83	13	210	44	0.21
Cotton products	181	16	9	206	37	0.18
Cocoa products	149	0	7	156	1.8	0.01
Pulses	48	1	32	81	6.9	0.09
Other products	133	19.6	5.6	158	36	0.23
Total	3132	531	298	3961	412	0.10

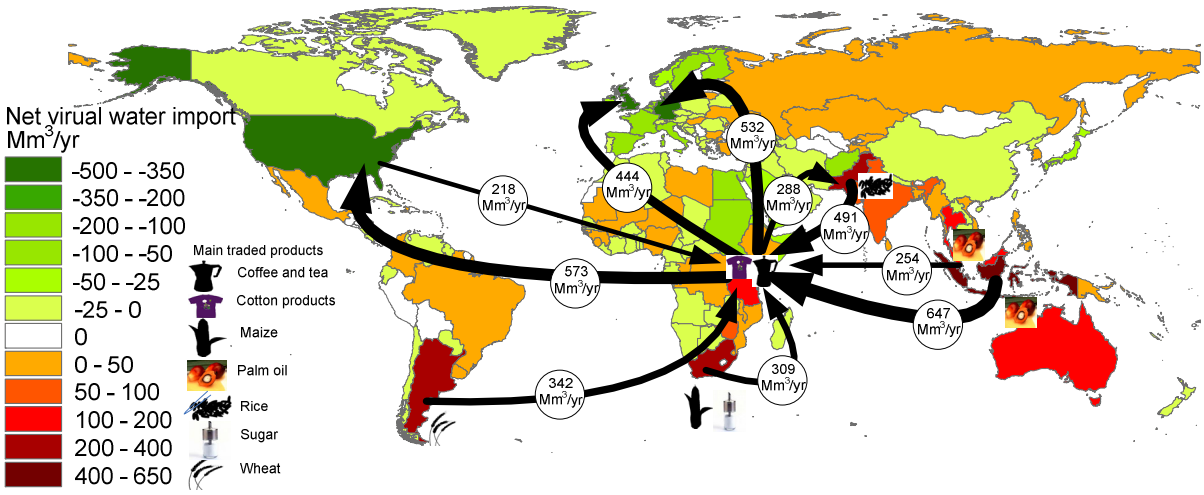

Figure 5. Global map showing countries with net virtual water import because of agricultural products imported from Kenya (green) and countries with net virtual water export because of agricultural products exported to Kenya. The arrows represent the biggest gross virtual water flows from and to Kenya (> 200 Mm^3/yr). Period 1996-2005.

Imports of cereal products (mainly from Pakistan and South Africa) and palm oil products (mainly from Indonesia and Singapore) were responsible for 2.0 Gm^3/yr and 1.1 Gm^3/yr, respectively (Figure 5). Other key agricultural products responsible for Kenya's virtual water import were sugar products (0.21 Gm^3/yr) and cotton

products (0.21 Gm^3/yr). Kenya is not self-sufficient in water for its own food supply: 10% of its maize (the major staple food), 63% of its wheat and 72% of its rice is imported. Although the level of domestic cereal production has remained high, imports have shown significant growth. In the period 1996-2005, the share of imports was significant – reaching over 25% of the total supply of the main cereal products (maize, rice and wheat). At the same time, Kenya's exports of coffee and tea have enjoyed significant growth (Figure 6). This is an evidence of the shift in the agricultural sector towards the export of high-value crops (tea, coffee and horticulture) and import of low-value crops such as cereals.

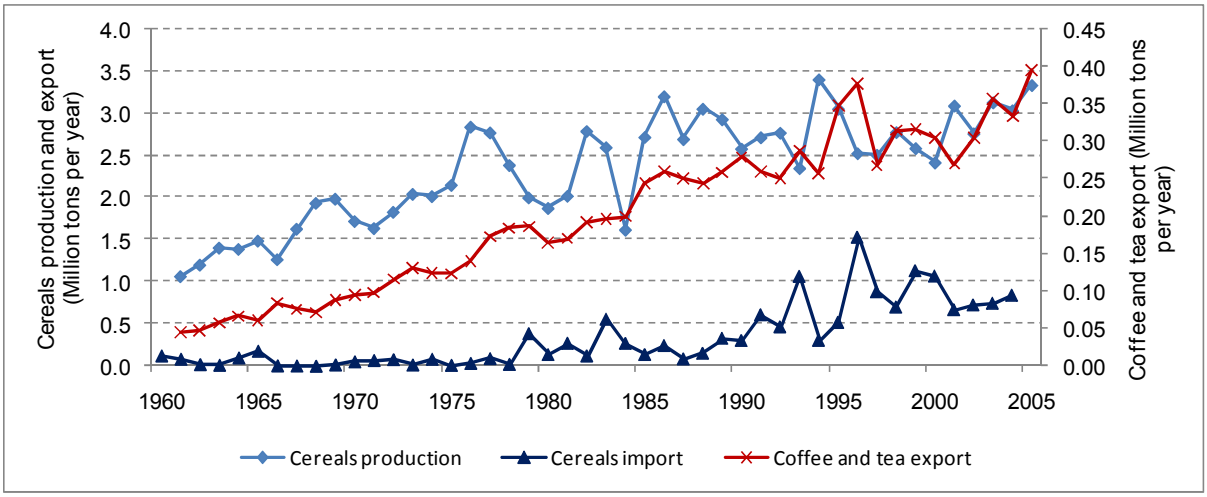

Figure 6. Kenya's production and import of cereals (maize, rice and wheat) and export of coffee and tea. Data source: FAO (2010).

3.3 The water footprint of national consumption

In the period 1996-2005, the total water footprint related to Kenyan consumption of agricultural products was 34.5 billion m^3/yr, equivalent to 1080 m^3/yr per capita (Table 4). When we include the water footprint related to the consumption of industrial products and domestic water, we find a total water footprint of Kenyan consumption of 35.2 billion m^3/yr, which means that Kenyan citizens had a water footprint of 1100 m^3/yr per capita on average (94% green, 3% blue and 3% grey). This is twenty per cent less than the global average (Mekonnen and Hoekstra, 2011).

The water footprint of Kenyan consumption is largely determined by the consumption of agricultural goods, contributing 98% to the total water footprint. When we look at the level of product categories, consumption of meat products gives the largest contribution to the total water footprint (30%), followed by cereal products (29%) and pulses (12%). The consumption of maize products contributes the largest proportion (74%) to the cereal-related water footprint of Kenyan consumers, which is no surprise given the fact that Kenya's food staple is *ugali* made from cornmeal.

When we look at the breakdown of the water footprint into internal and external, the external water footprint constitutes 17% of the total water footprint, a bit lower than the global average of 22% (Mekonnen and Hoekstra, 2011).

Table 4. The water footprint of Kenyan national consumption.

Product category	Water footprint of national consumption (Mm^3/yr)			Water footprint per capita (m^3/yr/cap)			
	Green	Blue	Grey	Green	Blue	Grey	Total
Cereals	9371	523	317	293.5	16.4	9.9	320
Starchy roots	744	5	28	23.3	0.2	0.9	24
Sugar crops	32	6	1	1.0	0.2	0.0	1.2
Sugar & sweeteners	443	81	20	13.9	2.5	0.6	17
Pulses	4139	2	64	130	0.1	2.0	132
Nuts	18	0	0	0.5	0.0	0.0	0.6
Oil crops	161	2	1	5.1	0.1	0.0	5.2
Vegetable oils	1119	9	48	35	0.3	1.5	37
Vegetables	409	51	22	13	1.6	0.7	15
Fruits	1052	20	21	33	0.6	0.6	34
Stimulants	252	6	7	7.9	0.2	0.2	8.3
Spices	54	2	0	1.7	0.1	0.0	1.7
Alcoholic beverages	73	1	3	2.3	0.0	0.1	2.4
Fibres	178	9	3	5.6	0.3	0.1	5.9
Tobacco	43	0	1	1.4	0.0	0.0	1.4
Rubber	50	1	2	1.6	0.0	0.1	1.7
Meat	10345	149	7	324	4.7	0.2	329
Offals	956	12	0	30	0.4	0.0	30
Animal fats	73	4	0	2.3	0.1	0.0	2.4
Milk	2833	144	3	89	4.5	0.1	93
Eggs	125	5	2	3.9	0.1	0.1	4.1
Hides & skins	455	8	0	14	0.3	0.0	14
Total agricultural products	32924	1040	550	1031	32	17	1080
Industrial products	0	12	177	0.0	0.4	5.5	5.9
Domestic water supply	0	47	419	0.0	1.5	13.1	15
Total	32924	1100	1146	1031	34	36	1101

4. Water conservation in Kenya – the role of virtual water trade

Water scarcity is becoming an increasingly significant problem for Kenya (GoK, 2007; UNEP, 2006). Kenya's total renewable blue water resources are estimated at 30.7 Gm^3/yr (FAO, 2005). Using the 2005 population of 35.6 million (UNSD, 2010), this comes down to 862 m^3/yr per capita. According to the UN medium variant projection, Kenya's population will grow towards 97 million in the year 2050 and on to 160 million in 2100 (UN, 2011). This means that the renewable blue water resources will drop towards 316 m^3 per capita in 2050 and 192 m^3 per capita in 2100. This is extremely little when compared with the 1000 m^3 per capita per year roughly needed for an adequate diet and often used as a threshold for chronic water shortage (Falkenmark et al., 2009). One should realize, though, that Kenya mainly draws on *green* water resources (rain-fed agriculture). Even in irrigated agriculture, green water resources are an important component in the total water supply. Much of the world's food is grown not from blue but from green water (Falkenmark and Röckstrom, 2004). This is certainly the case in Kenya, where agriculture is mainly rain-fed and about 97% of the water footprint related to crop production is a green water footprint. Therefore, it is quite important to consider the level of green water scarcity as well.

The average annual rainfall in Kenya is approximately 630 mm. There is a significant variation across the country, from less than 200 mm in northern Kenya to over 1800 mm on the slopes of Mt. Kenya (FAO, 2005). More than 80% of the country, including the northern and eastern regions, is arid or semi-arid, and only 17% of the country is considered to be land with high agricultural potential (FAO, 2005; WRI, 2007). The annual rainfall amount does not show the existing pattern of dry and wet seasons within the year, the differences between drier and wetter years, or the variations across the country. Figure 7 shows the temporal and spatial variability of Kenya's rainfall, with long-term statistics for the months of February, April, and July and for the annual average. East of the Rift Valley, "long" rains fall from March to May and "short" rains from October to November (WRI, 2007). The western part of the country bordering Lake Victoria generally experiences only one long rainy season from March to September. For most of the country, the "long" rains account for much of the annual rainfall, but the "short" rains also play a crucial role in many areas (WRI, 2007). There is also great variation in the rainfall amount and distribution from year to year (Figure 8).

The temporal and spatial variability of rainfall, combined with high levels of crop water requirements typical in the semi-arid and arid parts of the country, precludes much of the country from being suitable for the growth of rain-fed crops. Thus, policy makers should take effective measures to use the limited water resources wisely, in order to avoid future problems with the country's food production and economic development.

Managing water scarcity entails either supply-side or demand-side management or a combination of the two. Since the available water supply is limited in many areas and increasing it is usually costly or simply impossible, there is a growing emphasis on increasing water use efficiency (Falkenmark, et al. 2007; Gleick, 1998; Postel, 2000; Wallace and Gregory, 2002). According to Hoekstra and Hung (2005), there are three levels at which water use efficiency can be increased: the level of the water user, the level at which water allocation takes place (usually the catchment level), and the international level, at which virtual water trade takes place.

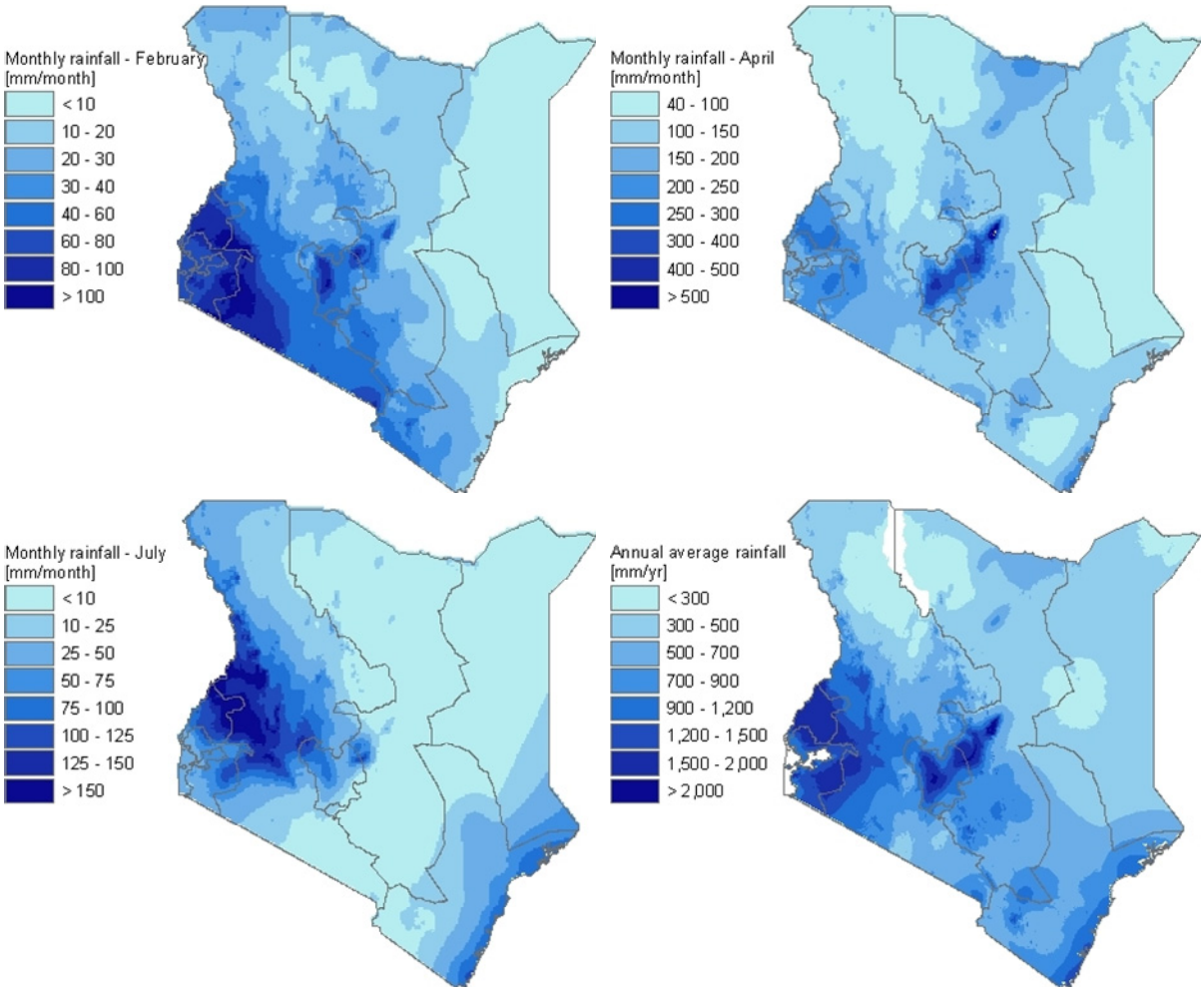

Figure 7. Temporal and spatial rainfall variability in Kenya. Source: WRI (2007).

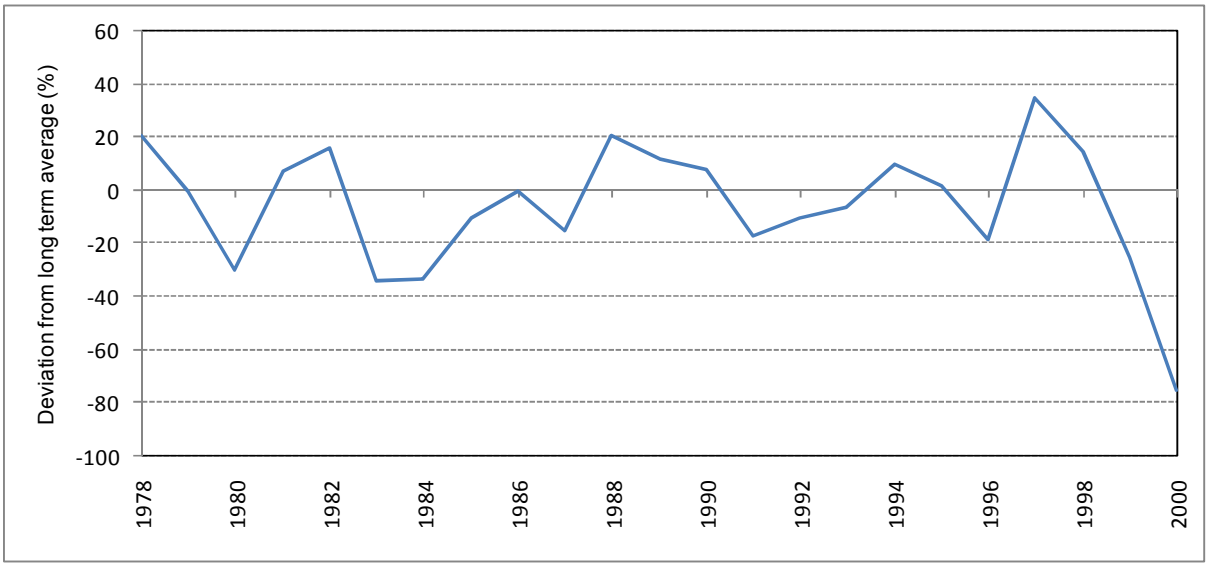

Figure 8. Kenya's year to year rainfall variability (adopted from Mogaka et al., 2006).

At the user level, water use efficiency can be increased by enlarging water productivity (more crop per drop), both in rain-fed and irrigated agriculture. Green water productivity can often be increased by better soil management, so that the soil better holds rainwater, which improves water availability to the plants and thus helps to increase yields. One could also look at the possibilities of introducing high yielding and drought resistant crops, and smart ways of crop rotation. The key is here to reduce unproductive evaporation and increase yields. Blue water productivity can be increased by better irrigation technology and practices (e.g. deficit irrigation). Indirect instruments to stimulate farmers to increase blue water productivity are charging water prices based on full marginal cost, assisting with making necessary investments and creating awareness on the detrimental impacts of excessive water abstractions.

Most of Kenya's irrigation systems suffer from poor irrigation efficiency. About 60% of the irrigated land is irrigated by sprinklers and about 38% by surface irrigation (FAO, 2005). Although the potential for water saving through increased efficiency is high, it is not as large as one may think. This is because the classical definition of irrigation efficiency ignores the value of return flows, i.e. irrigation water runoff and seepage that re-enters the surface-groundwater system (Keller and Keller 1995; Seckler et al. 2003). When the return flow is reused, the overall efficiency increases. Thus, while individual systems could have low levels of efficiency, the basin-wide efficiencies can be much higher. Therefore, taking steps to increase water use efficiency at the local level based on the classical efficiency calculations often will not result in genuine water savings. The key in blue water footprint reduction is to reduce non-productive evaporation losses and increase yields.

Figure 9 shows that the maize yield in Kenya has shown no improvement over the years. Although Kenya's maize yield is slightly above the African average, it is much below the yields obtained in Egypt and South Africa and the average yield at global level. This low yield level is an indication that there is still much room for improvement in Kenya's agriculture productivity.

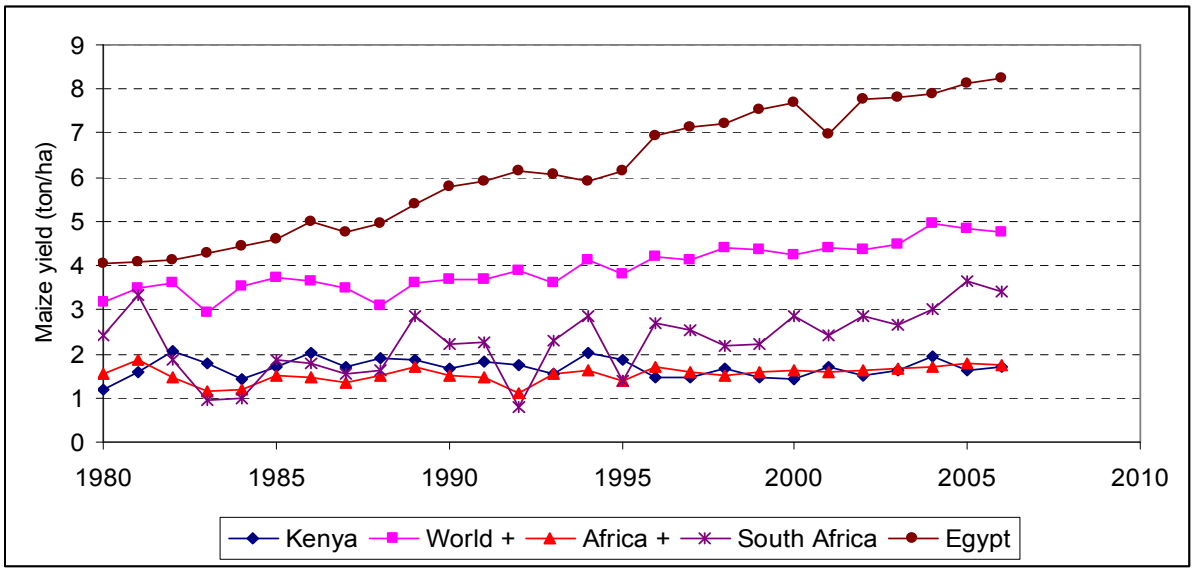

Figure 9. Kenya's maize yield compared to maize yields in Egypt, South Africa, the continent of Africa and the world. Source: FAO (2010).

At the catchment level, water use efficiency can be improved by re-allocating the limited water resources to those purposes with the highest marginal benefits. At this level, we speak of 'allocative efficiency' (Allan, 1999; Dinar, 1998). Figure 10 shows economic water productivities of selected crops in Kenya. Cut flowers have the highest productivity per unit of water, 250 times higher than pulses and 120 times higher than maize. Vegetables have high water productivity as well, close to that of cut flower. Spices, fruits and tea also produce more value per unit of water as compared to most other crops. This analysis is consistent with results obtained by other researchers. Owuor (1998), for example, showed that horticultural crops are more productive compared to cereal crops such as maize. The high productivity in the cut flower and vegetable sectors are partly due to irrigation, so the blue water footprint is relatively large here. This is a concern in the sense that blue water resources in Kenya are much scarcer than green water resources.

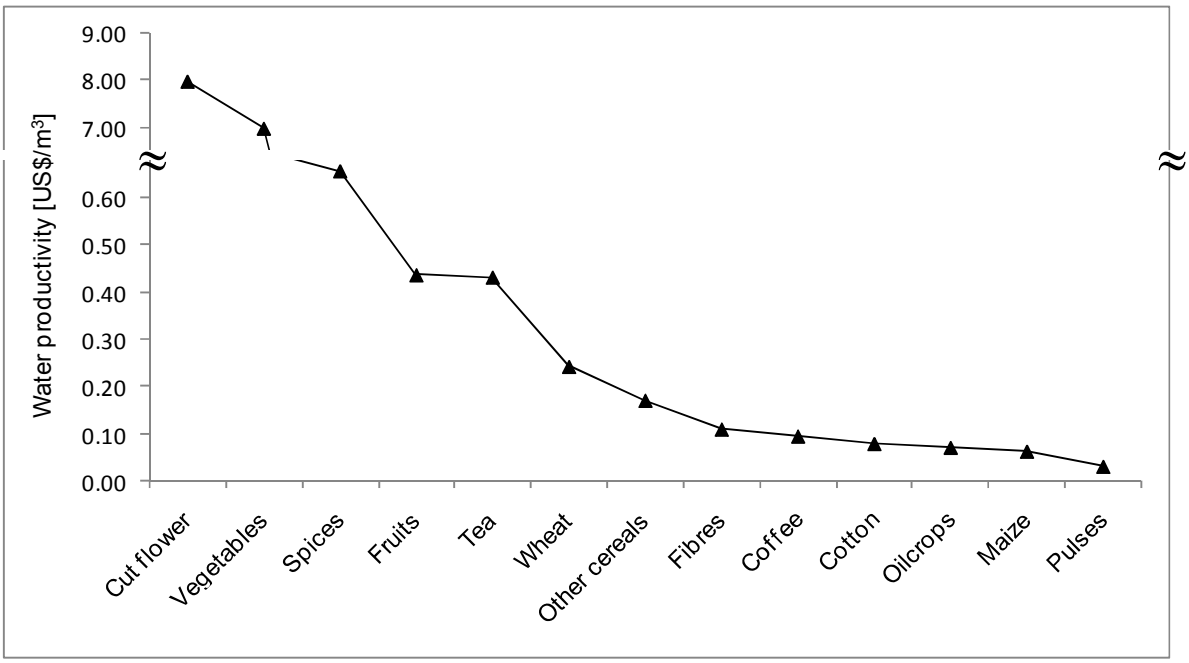

Figure 10. Economic water productivity for selected crops in Kenya for the period 1996-2005.

At the international level, water use efficiency can be increased if nations use their relative water abundance or scarcity to either encourage or discourage the use of domestic water resources for producing export commodities (Hoekstra and Chapagain, 2008). In the case of Kenya, this implies that the country could best seek to achieve a positive net virtual water import balance. It does not mean that it should stop using domestic water resources for producing export products, but it should do so wisely, to make sure that only crops are produced for export that generate a high value per drop of water used and to find a balance between production for export and production for domestic food security. Kenya's current virtual water export is based mainly on high-value crops such as coffee, tea and horticultural crops, which generate indeed a high return per unit of water consumed, higher than in the case of water use for cereal crops like maize. Kenya's imports, on the other hand, are mainly low-value but water-intensive cereal products. The net effect of Kenya's virtual water exports and imports related to agricultural trade is more or less neutral.

Nyoro et al. (2001) showed that Kenya is less competitive compared to its neighbours, Uganda and Tanzania, in producing the major cereals crops, in particular maize. The local production cost of maize, sugar (and in some cases wheat) is much higher than the import parity price. According to Nyoro et al. (2001), the production cost of coffee is among the highest in the world. Under such conditions, a rational economic decision would be to produce and export crops in which the country has comparative economic advantage and import crops where its comparative advantage is minimal or negative. However, such policy decisions are never straightforward. It requires a policy shift from national food self-sufficiency to food security. Such a policy pre-supposes a strong and diversified economy, which provides enough income to pay for the virtual water import in a sustainable manner. Unless there is enough foreign currency earning from the export of high productive crops, from the industry and the service sectors, virtual water import may result in the depletion of the country's foreign currency reserve. In addition, the domestic agricultural sector needs to become more competitive, otherwise it will be damaged due to the availability of cheaper agricultural goods from outside the country. The other important factor that must be addressed is the maintenance of employment for the rural population. In a country such as Kenya where the great majority of the population relies on the agricultural sector for their livelihood, a policy shift in the direction of virtual water import may create great social stress (Allan, 1999; Turton and Ohlsson, 1999). Thus, a careful analysis of all available options for water management must be made before embracing virtual water trade as a strategy.

5. Conclusion

In the period 1996-2005, Kenya's imports contributed 25% to its total supply of the main cereals (maize, wheat and rice). In this way, Kenya is relying significantly on freshwater resources elsewhere. On the other hand, a substantial part (23%) of the freshwater appropriation in Kenya is for producing export products. About 42% of Kenya's total foreign exchange earnings come from the export of coffee, tea and horticultural products. These products contributed about 66% toward the virtual water export related to export of agricultural commodities. Currently, the water use within Kenya for producing export products is more or less in balance with the water use elsewhere for making products for consumption in Kenya. However, given Kenya's growing population, the increase in the use of scarce water resource for export products may, in the long run, conflict with water use for domestic food supply. The dilemma will be to increase water use for high-value export commodities in order to be able to import more food, or to reserve increasing amounts of water resources for domestic food production at the cost of water for producing export products. As long as water productivities can be increased (producing more with the same water), making this trade-off between water-for-export versus water for domestic consumption can be postponed, but the moment will inevitably come, because of Kenya's growing population and changing consumption pattern (more animal products, which are more water-intensive per kcal than crop products).

The production and export of cash crops from Kenya positively impacts on the socio-economic development of the country. The water use for coffee and tea production is mainly positive: the impacts on the water system are limited because water use mostly involves the use of rainwater, while the export revenues amount to US$ 581 million per year, which is 29% of Kenya's total export value. The water use for cut flower production near Lake Naivasha contributes to water scarcity (declining lake level) and pollution problems, but the cut flower export sector is a vital one, contributing US$ 141 million per year in foreign currency, which is 7% of Kenya's export value.

In order to address its water scarcity problem, Kenya must implement policy measures at different levels. Such policy measures include: the improvement of water use efficiency at the user level by charging prices based on full marginal cost, stimulating water-saving technologies, and creating awareness among the water users on the detrimental impacts of excessive water abstraction. Charging prices on full marginal cost, besides its positive effect on raising water use efficiency, will force farmers to use water more efficiently and reallocate the limited water to crops which can generate high economic return per unit of water. Kenya's crop yields are among the lowest in the world. Raising yields through growing selected seeds and utilization of the available soil moisture through integrated soil and water management will be essential. At the river basin level, water use efficiency can be improved by re-allocating water to those purposes with the highest marginal benefits. Finally, Kenya can use virtual water import and export as a strategy to address its water problem by discouraging the use of domestic water resources for producing export commodities that are highly water intensive and have low economic return per unit of water. Production of cash crops with high economic return per unit of water that are less water intensive and produced from rainwater can be encouraged, although Kenya's challenge will be to maintain national food security at the same time.

References

Allan, J.A. (1999) Productive efficiency and allocative efficiency: Why better water management may not solve the problem, Agricultural Water Management, 40: 71-75.

Allan, J.A. (2003) Virtual water — the water, food, and trade nexus: Useful concept or misleading metaphor? Water International, 28(1): 106-113.

Ariga, J., Jayne, T.S., and Nyoro, J. (2006) Factors driving the growth in fertilizer consumption in Kenya, 1990-2005: Sustaining the momentum in Kenya and lessons for broader replicability in Sub-Saharan Africa, Tegemeo Working Paper 24, Tegemeo Institute of Agricultural Policy and Development, Egerton University, Nairobi, Kenya.

Chapagain, A.K., Hoekstra, A.Y., and Savenije, H.H.G. (2006) Water saving through international trade of agricultural products, Hydrology and Earth System Sciences, 10(3): 455-468.

De Fraiture, C., Cai, X., Amarasinghe, U., Rosegrant, M., and Molden, D. (2004) Does international cereal trade save water? The impact of virtual water trade on global water use, Comprehensive Assessment Research Report, Vol. 4, IWMI, Colombo, Sri Lanka.

Dinar, A. (1998) Water policy reforms: information needs and implementation obstacles, Water Policy, 1(4): 367-382

EPZA (2005) Tea and coffee industry in Kenya, Export Processing Zones Authority, Nairobi, Kenya.

Falkenmark, M., Berntell, A., Jägerskog, A., Lundqvist, J., Matz, M. and Tropp, H. (2007). On the verge of a new water scarcity: A call for good governance and human ingenuity, SIWI Policy Brief, Stockholm International Water Institute, Stockholm, Sweden.

Falkenmark, M. and Rockström, J. (2004) Balancing water for humans and nature: the new approach in ecohydrology, Earthscan, London, UK.

Falkenmark, M., Rockström, J. and Karlberg, L. (2009) Present and future water requirements for feeding humanity, Food Security, 1(1): 59-69.

FAO (2005) Kenya country report, In: Irrigation in Africa in figures, AQUASTAT Survey 2005, Food and Agriculture Organization Rome, Italy.

FAO (2010) FAOSTAT on-line database, Food and Agriculture Organization, Rome, http://faostat.fao.org.

Gleick, P.H. (1998) Water in crisis: Paths to sustainable water use, Ecological Applications, 8(3): 571-579.

GoK (2007) Vision 2030: A competitive and prosperous Kenya, Government of the Republic of Kenya, Nairobi, Kenya.

Hoekstra, A.Y. (ed.) (2003) Virtual water trade: Proceedings of the International Expert Meeting on Virtual Water Trade, Delft, The Netherlands, 12-13 December 2002, Value of Water Research Report Series No. 12, UNESCO-IHE, Delft, the Netherlands.

Hoekstra, A.Y. and Chapagain, A.K. (2008) Globalization of water: Sharing the planet's freshwater resources, Blackwell, Oxford, UK.

Hoekstra, A.Y., Chapagain, A.K., Aldaya, M.M. and Mekonnen, M.M. (2011) The water footprint assessment manual: Setting the global standard, Earthscan, London, UK.

Hoekstra, A.Y. and Mekonnen, M.M. (2011) Global water scarcity: monthly blue water footprint compared to blue water availability for the world's major river basins, Value of Water Research Report Series No. 51, UNESCO-IHE, Delft, the Netherlands.

Hoekstra, A. Y. and Hung, P. Q. (2005) Globalisation of water resources: international virtual water flows in relation to crop trade, Global Environmental Change, 15(1): 45-56.

ITC (2007) SITA version 1996–2005 in SITC, [DVD-ROM]. International Trade Centre, Geneva, Switzerland.

Keller, A.A. and Keller, J. (1995) Effective efficiency: A water use efficiency concept for allocating freshwater resources, Discussion Paper 22, Centre for Economic Policy Studies, Winrock International, Arlington, USA.

Mekonnen, M.M. and Hoekstra, A.Y. (2010a) The green, blue and grey water footprint of crops and derived crop products, Value of Water Research Report Series No. 47, UNESCO-IHE, Delft, the Netherlands.

Mekonnen, M.M. and Hoekstra, A.Y. (2010b) Mitigating the water footprint of export cut flowers from the Lake Naivasha Basin, Kenya, Value of Water Research Report Series No.45, UNESCO-IHE, Delft, the Netherlands.

Mekonnen, M.M. and Hoekstra, A.Y. (2011) National water footprint accounts: The green, blue and grey water footprint of production and consumption, Value of Water Research Report Series No. 50, UNESCO-IHE, Delft, the Netherlands.

Mogaka, H., Gichere, S., Davis, R., and Hirji, R. (2006) Climate variability and water resources degradation in Kenya: Improving water resources development and management, World Bank Working Paper, No. 69, Washington, D.C., USA.

Monfreda, C., Ramankutty, N., and Foley, J.A. (2008) Farming the planet: 2. Geographic distribution of crop areas, yields, physiological types, and net primary production in the year 2000, Global Biogeochemical Cycles, 22: GB1022. Data available at http://www.geog.mcgill.ca/landuse/pub/Data/175crops2000.

Nyoro, J. K., Wanzala, M. and Awour, T. (2001) Increasing Kenya's agricultural competitiveness: farm level issues, Tegemeo Working Paper No. 4, Tegemeo Institute of Agricultural Policy and Development, Egerton University, Nairobi, Kenya.

Ohlsson, L. and Appelgren, B. (1998) Water and social resource scarcity: Alternative socially based approaches to assessment and management of water scarcity, The Water Page, http://www.africanwater.org/SoicalResourceScarcity.htm.

Oki, T. and Kanae, S. (2004) Virtual water trade and world water resources, Water Science and Technology, 49(7): 203-209.

Owuor, P.O. (1998) Determinants of agricultural productivity in Kenya, Kenya Agricultural Marketing and Policy Analysis Project, Tegemeo Institute of Agricultural Policy and Development. Egerton University, Nairobi, Kenya & Agricultural Research Institute, Michigan State University, USA.

Postel, S.L. (2000) Entering an era of water scarcity: The challenges ahead, Ecological Applications, 10(4): 941-948.

Seckler, D., Molden, D. and Sakthivadivel, R. (2003) The concept of efficiency in water resources management and policy, In: Kijne, J.W., Barker, R. and Molden, D. (eds.) Water productivity in agriculture: limits and opportunities for improvement, Comprehensive Assessment of Water Management in Agriculture Series, No. 1, CAB International, Wallingford, UK.

Turton, A.R. and Ohlsson, L. (1999) Water scarcity and social stability: towards a deeper understanding of the key concepts needed to manage water scarcity in developing countries, 9th Stockholm Water Symposium, 9-12 August 1999, Stockholm, Sweden.

UN (2011) World population prospects: The 2010 revision, Population Division, Department of Economic and Social Affairs, United Nations, New York, USA.

UNEP (2006) Africa environment outlook-2: Our environment, our wealth, Nairobi, Kenya.

UNSD (2010) Nationals accounts main aggregates database, UN Statistic Division, http://unstats.un.org/unsd/snaama/selectionbasicFast.asp.

Wallace, J.S. and Gregory, P.J. (2002) Water resources and their use in food production systems, Aquatic Sciences, 64(4): 363-375.

Wong, C., Roy, M. and Duraiappah, A.K. (2005) Connecting poverty and ecosystem services: A series of seven country scoping studies, focuses on Kenya, published for UNEP and IISD, Nairobi, Kenya.

WRI (2007) Nature's benefits in Kenya: An atlas of ecosystems and human well-being, World Resources Institute, Washington, D.C., USA.

Yang, H., Wang, L., Abbaspour, K.C. and Zehnder, J.B. (2006) Virtual water trade: an assessment of water efficiency use efficiency in the international food trade, Hydrology and Earth System Sciences, 10: 443-454.

Appendix I: The average water footprint per ton of crop at national and provincial level (m^3/ton).

Period 1996-2005

Product code (FAOSTAT)	Product description (FAOSTAT)	Central			Coast			Eastern			Nairobi Area			North-Eastern			Nyanza			Rift Valley			Western			Kenya average		
		Green	Blue	Grey	Green	Blue	Grey	Green	Blue	Grey	Green	Blue	Grey	Green	Blue	Grey	Green	Blue	Grey	Green	Blue	Grey	Green	Blue	Grey	Green	Blue	Grey
15	Wheat	1081	0	34	1844	0	96	1790	0	97	1242	0	46	1793	0	101	1053	0	31	1218	0	42	965	0	29	1492	0	70
27	Rice, paddy							669	1302	0							1068	735	0	995	792	0	1206	594	0	1065	732	0
44	Barley	1307	0	24	1645	0	50	1673	0	59	1398	0	35	1915	0	65	1364	0	25	1426	0	30	1278	0	22	1578	0	43
56	Maize	1919	30	20	3183	6	50	3230	14	55	2246	28	29	3348	6	55	1890	4	18	2210	2	25	1727	0	15	2703	4	39
75	Oats	2750	553	0	3297	257	0	3019	420	0	2764	496	0	3613	309	0	3051	54	0	3307	74	0	3174	1	0	3310	176	0
79	Millet	4655	0	0	5335	0	0	5551	0	0	4780	0	0	6465	0	0	4716	0	0	4936	0	0	4069	0	0	5375	0	0
83	Sorghum	3917	0	0	4297	0	0	4404	0	0	4009	0	0	4971	0	0	3999	0	0	4151	0	0	3722	0	0	4359	0	0
116	Potatoes	295	0	18	401	0	38	360	0	44	340	0	30	363	0	43	289	0	14	322	0	22	274	0	12	342	0	31
122	Sweet potatoes	301	29	0	402	19	0	399	33	0	314	30	0	510	28	0	311	1	0	358	3	0	517	0	0	398	12	0
125	Cassava	418	0	0	465	0	0	442	0	0	408	0	0	410	0	0	446	0	0	425	0	0	431	0	0	431	0	0
137	Yams	283	62	0	446	8	0	454	21	0	287	74	0	562	7	0	321	3	0	373	3	0	325	0	0	427	8	0
149	Roots and tubers not elsewhere specified	230	12	0	284	8	0	302	12	0	233	9	0	372	12	0	238	1	0	264	3	0	237	0	0	291	6	0
156	Sugar cane	68	0	1	111	0	2	115	0	3	73	0	1	98	14	3	68	0	1	83	0	1	63	0	1	95	2	2
176	Beans, dry	6766	0	0	9502	0	0	9435	0	0	7773	0	0	9620	0	0	6123	0	0	7417	0	0	5980	0	0	8319	0	0
191	Chick peas	2783	0	0	3937	0	0	4182	0	0	3052	0	0	4387	0	1	2499	0	0	3000	0	0	2529	0	0	3548	0	0
195	Cow peas, dry	3444	0	0	5037	0	0	5000	0	1	3864	0	0	4828	0	1	3080	0	0	3704	0	0	3074	0	0	4248	0	0
197	Pigeon peas	2915	0	0	3824	0	0	3315	0	0	3440	0	0	3240	0	0	2618	0	0	3098	0	0	2595	0	0	3200	0	0
201	Lentils	2746	0	0	4586	0	0	4452	0	0	3111	0	0	4519	0	0	2531	0	0	3127	0	0	2510	0	0	3757	0	0
211	Pulses not elsewhere specified	4200	0	831	6468	0	1587	6498	0	1432	4051	0	678	6066	0	2052	3953	0	634	5312	0	1206	4162	0	763	5646	0	1412
217	Cashew nuts	1042	143	0	1182	21	0	1103	33	0	993	154	0	1090	18	0	1142	5	0	1145	13	0	1172	0	0	1130	20	0
234	Nuts, not elsewhere specified	1489	176	0	2072	40	0	2107	57	0	1473	204	0	2431	41	0	1597	10	0	1812	21	0	1627	0	0	1976	33	0
236	Soybeans							4057	0	0													2371	0	1	3733	0	2
242	Groundnuts in shell	2371	0	43	2136	0	70	1979	0	71	2192	0	56	2078	0	75	2479	0	43	2431	0	48	3027	0	32	2318	0	54
249	Coconuts	1879	0	0	2074	0	0	2045	0	0	1868	0	0	2047	0	0	1855	0	0	1954	0	0	1900	0	0	1994	0	0
265	Castor oil seed	24829	2698	0	29362	521	0	28159	764	0	24055	3178	0	29217	476	0	26426	125	0	27674	288	0	27042	2	0	28096	453	0
267	Sunflower seed	3680	0	0	4592	0	0	4300	0	0				4459	0	0	3753	0	0	3886	0	0	3548	0	0	3912	0	0
289	Sesame seed	6707	570	0	6934	300	0	6702	505	0	6594	561	0	7686	409	0	6811	15	0	7371	51	0	6990	0	0	7222	204	0
328	Seed cotton	5227	418	0	5603	413	0	6025	727	0	6772	697	0	8816	324	0	6166	384	0	6490	206	0	6482	35	1	6747	320	0
333	Linseed	2657	209	0	2743	119	0	3126	178	0	2613	214	0	3092	154	0	2701	4	0	2912	20	0	2765	0	0	2876	77	0
339	Oilseeds, not elsewhere specified	5196	1336	0	6519	656	0	5923	902	0	5322	1158	0	6970	682	0	5860	194	0	6442	198	0	6196	11	0	6445	422	0
358	Cabbages and other brassicas	173	43	6	228	44	11	212	36	10	162	53	7	240	51	14	196	8	6	210	16	8	207	0	6	218	26	10
367	Asparagus	884	165	16	1184	87	25	1096	122	25	818	233	16	1347	92	35	992	14	15	1084	41	20	1021	0	16	1122	69	23
372	Lettuce and chicory	186	17	10	218	9	15	217	14	17	190	12	11	262	13	20	197	2	10	213	4	12	199	0	10	223	7	15
373	Spinach	149	15	8	175	8	13	174	12	14	153	10	9	210	11	16	158	2	8	171	4	10	160	0	8	179	7	12
388	Tomatoes	174	3	6	228	0	10	231	1	9	174	0	6	275	21	13	172	6	5	180	19	7	175	1	6	206	12	8
393	Cauliflowers and broccoli	118	9	6	138	5	9	137	8	10	120	7	7	166	8	12	125	1	6	135	2	7	125	0	6	141	4	9
397	Cucumbers and gherkins	252	71	15	348	80	34	293	90	31	242	91	19	372	95	42	287	9	14	326	14	20	300	0	14	338	40	28
401	Chillies and peppers, green	406	119	18	661	123	36	649	85	29	452	75	19	790	173	52	485	40	19	571	70	31	540	6	24	628	87	34
403	Onions, dry	239	79	7	392	69	13	373	54	11	271	48	7	479	107	21	296	24	7	357	48	12	359	4	8	378	55	13
406	Garlic	333	101	10	530	94	18	505	71	15	370	64	10	649	150	29	402	32	10	466	65	17	441	5	12	512	75	18

Product code (FAOSTAT)	Product description (FAOSTAT)	Central			Coast			Eastern			Nairobi Area			North-Eastern			Nyanza			Rift Valley			Western			Kenya average		
		Green	Blue	Grey	Green	Blue	Grey	Green	Blue	Grey	Green	Blue	Grey	Green	Blue	Grey	Green	Blue	Grey	Green	Blue	Grey	Green	Blue	Grey	Green	Blue	Grey
414	Beans, green	339	5	22	421	10	33	438	10	34	336	5	22	565	15	42	346	0	21	386	4	26	342	0	22	432	7	31
417	Peas, green	393	35	20	524	20	35	536	33	37	409	27	22	712	31	47	416	4	19	472	8	25	416	0	19	534	16	32
426	Carrots and turnips	127	48	7	211	46	14	199	38	12	148	27	7	216	74	20	160	13	7	189	27	12	180	2	9	197	34	13
430	Okra	373	12	19	436	11	26	447	14	27	375	10	19	544	17	32	381	1	18	417	3	21	379	0	19	446	8	25
463	Vegetables fresh not elsewhere specified	171	65	9	294	60	17	275	45	14	197	40	9	335	83	26	214	21	9	253	39	16	243	3	11	274	45	17
486	Bananas	283	83	4	689	14	13	605	20	12	321	77	5	560	10	14	364	6	4	558	9	9	408	1	4	545	12	11
489	Plantains	401	0	6	684	0	13	623	0	13	435	0	7	544	0	14	357	0	4	704	0	9	584	0	3	546	0	11
490	Oranges	1007	60	16	1248	120	24	1157	138	23	963	119	17	1478	127	36	1031	17	15	1137	36	19	1050	6	16	1201	66	22
497	Lemons and limes	1225	73	20	1519	146	29	1407	168	28	1171	144	20	1798	154	43	1255	21	18	1383	43	23	1277	8	19	1460	80	27
507	Grapefruit (inc. pomelos)	690	41	11	859	83	16	792	95	16	657	81	11	1020	88	25	710	12	10	783	24	13	725	4	11	826	45	15
512	Citrus fruit, not elsewhere specified	690	48	11	869	80	16	808	100	16	653	96	11	1029	81	25	710	14	10	791	25	13	725	4	11	839	47	16
515	Apples	942	0	13	1209	0	21	1199	0	22	958	0	15	1398	0	32	913	0	12	1040	0	16	923	0	12	1150	0	21
521	Pears	676	0	10	867	0	15	860	0	16	688	0	11	1003	0	23	655	0	8	747	0	12	663	0	8	722	0	13
526	Apricots	979	0	14	1255	0	23	1245	0	24	996	0	17	1452	0	33	948	0	13	1081	0	18	959	0	13	1195	0	22
534	Peaches and nectarines	868	0	13	1113	0	20	1104	0	21	884	0	15	1288	0	29	841	0	11	958	0	16	851	0	11	1060	0	20
536	Plums and sloes	910	0	13	1167	0	21	1158	0	22	925	0	15	1350	0	30	881	0	11	1005	0	16	892	0	11	983	0	18
544	Strawberries	1026	453	29	915	1029	34	684	1187	31	736	785	29	716	1496	35	1111	310	28	936	668	30	1226	208	30	336	356	12
558	Berries not elsewhere specified	570	0	26	777	0	42	832	0	46	558	0	24	1176	0	72	564	0	23	686	0	35	558	0	24	812	0	45
567	Watermelons	238	0	9	307	0	17	323	0	18	253	0	11	380	0	20	224	0	8	258	0	10	224	0	7	297	0	14
571	Mangoes, mangosteens, guavas	744	0	10	957	0	17	950	0	17	756	0	11	1102	0	26	721	0	8	824	0	13	730	0	8	910	0	16
572	Avocados	399	59	6	576	9	11	560	14	11	397	64	7	669	9	17	439	2	6	498	5	8	447	0	6	544	8	10
574	Pineapples	75	4	2	104	1	3	104	1	3	76	4	2	130	1	4	77	0	2	89	0	2	81	0	2	100	1	3
577	Dates	2398	0	30	2667	0	44	2628	0	44	2384	0	32	2649	0	55	2365	0	27	2504	0	36	2398	0	27	2561	0	41
600	Papayas	488	72	8	705	11	13	685	17	14	486	79	9	819	11	20	538	2	7	610	6	10	547	0	7	666	10	13
603	Fruit, tropical fresh not elsewhere specified	724	0	9	931	0	16	924	0	17	736	0	11	1072	0	25	702	0	8	802	0	12	711	0	8	886	0	16
619	Fruit Fresh not elsewhere specified	471	0	7	604	0	11	600	0	11	479	0	8	699	0	16	456	0	6	523	0	8	472	0	6	705	0	13
656	Coffee, green	17583	756	350	26424	408	738	24715	1224	672	17610	1151	395	35504	1432	1109	18039	678	310	19895	518	443	17198	112	296	22222	802	549
667	Tea	3721	3	72	4822	3	134	4769	8	129	3735	7	81	5808	34	184	3623	1	60	4117	5	94	3654	0	59	4061	4	89
687	Pepper (Piper spp.)	3464	517	0	4775	268	0	4759	448	0	3697	436	0	6166	366	0	3752	51	0	4279	81	0	3799	3	0	4779	189	0
689	Chillies and peppers, dry	4506	1188	0	8181	218	0	8421	330	0	4651	1175	0	9255	207	0	5464	104	0	6694	147	0	5626	12	0	7394	216	0
692	Vanilla	36706	21182	1	28145	45030	1	30699	31523	1	32256	25592	1	20903	68736	1	41796	13212	1	36230	25123	1	46257	8701	1	35248	26299	1
698	Cloves																									28953	545	0
702	Nutmeg, mace and cardamoms	12307	3767	0	23033	641	0	22556	1008	0	12866	3556	0	26243	603	1	15399	322	0	18848	449	0	15789	41	0	20864	657	0
711	Anise, badian, fennel, corian.	4091	610	0	5632	316	0	5605	528	0	4357	513	0	7294	433	0	4424	61	0	5040	96	0	4474	3	0	5646	223	0
720	Ginger	729	125	0	1054	71	0	1027	133	0	785	118	0	1236	100	0	800	14	0	931	23	0	814	1	0	1023	50	0
723	Spices, not elsewhere specified	2983	513	0	4310	290	0	4163	543	0	3215	484	0	5000	405	0	3271	57	0	3802	94	0	3312	3	0	4170	205	0
789	Sisal	4865	529	0	6198	68	0	5924	113	0	4639	658	0	6338	55	0	5190	9	0	5642	31	0	5299	0	0	5835	63	0
826	Tobacco, unmanufactured	1761		35	2146		48	2209		44	1792		30	2400		67	1790		28	1963		41	1780		31	2098		47
29271	Cut flowers,flower buds	95	197	121																79	164	121				79	165	121

Appendix II: Total water footprint of crop production at at national and provincial level (Mm^3/year).

Period 1996-2005

Product code (FAOSTAT)	Central			Coast			Eastern			Nairobi Area			North-Eastern			Nyanza			Rift Valley			Western			Kenya total			
	Green	Blue	Grey	Green	Blue	Grey	Green	Blue	Grey	Green	Blue	Grey	Green	Blue	Grey	Green	Blue	Grey	Green	Blue	Grey	Green	Blue	Grey	Green	Blue	Grey	Total
15	6.14	0.00	0.22	48.21	0.00	2.82	48.48	0.00	2.97	0.59	0.00	0.02	68.40	0.00	4.34	41.49	0.00	1.38	198.67	0.00	7.80	27.43	0.00	0.91	439.4	0.00	20.47	459.9
27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	23.64	16.29	0.00	17.38	13.86	0.00	10.20	5.04	0.00	51.23	35.20	0.00	86.43
44	0.49	0.00	0.01	9.35	0.00	0.31	6.17	0.00	0.24	0.11	0.00	0.00	14.12	0.00	0.52	9.17	0.00	0.18	35.54	0.00	0.83	5.85	0.00	0.11	80.80	0.00	2.20	83.00
56	88.39	1.28	1.03	772.7	1.37	13.51	717.3	2.86	13.59	7.84	0.09	0.11	1128	1.95	20.55	626.8	1.19	6.48	2931	2.01	36.53	415.6	0.08	3.88	6688	10.82	95.68	6794
75	0.23	0.05	0.00	1.48	0.11	0.00	1.33	0.18	0.00	0.02	0.00	0.00	2.07	0.18	0.00	1.24	0.02	0.00	5.37	0.12	0.00	0.77	0.00	0.00	12.51	0.66	0.00	13.18
79	2.77	0.00	0.00	30.38	0.00	0.00	31.70	0.00	0.00	0.35	0.00	0.00	52.87	0.00	0.00	21.77	0.00	0.00	101.30	0.00	0.00	18.78	0.00	0.00	259.9	0.00	0.00	259.9
83	5.41	0.00	0.00	53.94	0.00	0.00	53.94	0.00	0.00	0.65	0.00	0.00	88.34	0.00	0.00	41.18	0.00	0.00	183.27	0.00	0.00	26.21	0.00	0.00	452.9	0.00	0.00	452.9
116	4.36	0.00	0.31	36.91	0.00	4.01	28.83	0.00	4.06	0.34	0.00	0.03	45.36	0.00	6.12	34.70	0.00	1.98	142.03	0.00	11.21	23.66	0.00	1.17	316.2	0.00	28.89	345.1
122	3.01	0.30	0.00	19.52	0.95	0.00	18.60	1.58	0.00	0.24	0.02	0.00	30.48	1.71	0.00	15.10	0.05	0.00	69.69	0.67	0.00	23.22	0.00	0.00	179.9	5.29	0.01	185.1
125	2.73	0.00	0.00	30.23	0.00	0.00	29.07	0.00	0.00	0.30	0.00	0.00	33.66	0.00	0.00	27.31	0.00	0.00	86.48	0.00	0.00	24.71	0.00	0.00	234.5	0.00	0.01	234.5
137	0.08	0.02	0.00	0.36	0.01	0.00	0.33	0.01	0.00	0.01	0.00	0.00	0.56	0.01	0.00	0.27	0.00	0.00	1.27	0.01	0.00	0.18	0.00	0.00	3.05	0.06	0.00	3.11
149	0.10	0.01	0.00	0.75	0.02	0.00	0.85	0.03	0.00	0.01	0.00	0.00	1.26	0.04	0.00	0.48	0.00	0.00	2.20	0.03	0.00	0.28	0.00	0.00	5.92	0.13	0.00	6.05
156	5.10	0.00	0.08	53.02	0.00	1.27	51.19	0.00	1.29	0.51	0.00	0.01	66.06	8.84	1.96	42.62	0.00	0.60	170.0	0.00	3.27	27.13	0.00	0.37	415.6	8.84	8.86	433.3
176	37.57	0.00	0.00	336.7	0.00	0.01	260.7	0.00	0.01	3.02	0.00	0.00	449.5	0.00	0.02	261.5	0.00	0.01	1229	0.00	0.04	195.9	0.00	0.01	2774	0.00	0.11	2774
191	0.49	0.00	0.00	4.95	0.00	0.00	3.83	0.00	0.00	0.05	0.00	0.00	6.56	0.00	0.00	3.39	0.00	0.00	16.83	0.00	0.00	2.29	0.00	0.00	38.40	0.00	0.00	38.40
195	2.59	0.00	0.00	19.93	0.00	0.00	17.21	0.00	0.00	0.24	0.00	0.00	26.22	0.00	0.00	16.47	0.00	0.00	84.53	0.00	0.01	11.75	0.00	0.00	178.9	0.00	0.02	178.9
197	3.70	0.00	0.00	26.02	0.00	0.00	19.72	0.00	0.00	0.30	0.00	0.00	30.29	0.00	0.00	24.20	0.00	0.00	118.43	0.00	0.01	17.58	0.00	0.00	240.2	0.00	0.02	240.3
201	0.11	0.00	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.01	0.00	0.00	1.34	0.00	0.00	0.75	0.00	0.00	3.32	0.00	0.00	0.52	0.00	0.00	8.04	0.00	0.00	8.04
211	1.59	0.00	0.33	17.81	0.00	4.65	20.70	0.00	4.85	0.22	0.00	0.04	18.65	0.00	6.71	12.27	0.00	2.09	53.04	0.00	12.80	7.24	0.00	1.41	131.5	0.00	32.89	164.4
217	0.34	0.05	0.00	1.68	0.03	0.00	1.61	0.05	0.00	0.03	0.00	0.00	1.98	0.03	0.00	1.26	0.01	0.00	4.85	0.05	0.00	0.77	0.00	0.00	12.50	0.22	0.00	12.72
234	0.58	0.07	0.00	2.71	0.05	0.00	2.97	0.08	0.00	0.05	0.01	0.00	3.51	0.06	0.00	2.03	0.01	0.00	8.24	0.09	0.00	1.26	0.00	0.00	21.36	0.36	0.00	21.72
236	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.47	0.00	0.00	7.47	0.00	0.00	7.47
242	0.37	0.00	0.01	2.74	0.00	0.10	2.05	0.00	0.08	0.09	0.00	0.00	4.42	0.00	0.18	7.80	0.00	0.16	24.01	0.00	0.54	9.27	0.00	0.11	50.75	0.00	1.19	51.94
249	1.61	0.00	0.00	16.14	0.00	0.00	16.80	0.00	0.00	0.18	0.00	0.00	20.49	0.00	0.00	11.59	0.00	0.00	47.78	0.00	0.00	7.61	0.00	0.00	122.2	0.00	0.00	122.2
265	2.61	0.28	0.00	12.51	0.22	0.00	12.61	0.34	0.00	0.20	0.03	0.00	15.50	0.25	0.00	9.27	0.04	0.00	37.05	0.38	0.00	5.77	0.00	0.00	95.53	1.54	0.00	97.07
267	0.20	0.00	0.00	1.25	0.00	0.00	1.19	0.00	0.00	0.00	0.00	0.00	1.76	0.00	0.00	8.59	0.00	0.00	23.05	0.00	0.00	5.54	0.00	0.00	41.58	0.00	0.00	41.58
289	1.41	0.12	0.00	9.01	0.39	0.00	8.95	0.68	0.00	0.11	0.01	0.00	13.83	0.74	0.00	7.04	0.02	0.00	32.73	0.23	0.00	4.19	0.00	0.00	77.27	2.18	0.00	79.46
328	1.46	0.12	0.00	14.12	1.04	0.00	15.16	1.83	0.00	0.29	0.03	0.00	35.55	1.31	0.00	14.74	0.92	0.00	62.04	1.98	0.00	10.08	0.05	0.00	153.4	7.28	0.00	160.7
333	0.04	0.00	0.00	0.27	0.01	0.00	0.36	0.02	0.00	0.00	0.00	0.00	0.46	0.02	0.00	0.21	0.00	0.00	0.95	0.01	0.00	0.12	0.00	0.00	2.42	0.06	0.00	2.48
339	3.81	0.97	0.00	23.88	2.39	0.00	23.25	3.52	0.00	0.29	0.06	0.00	33.81	3.29	0.00	20.49	0.67	0.00	91.17	2.79	0.00	12.77	0.02	0.00	209.5	13.71	0.00	223.2
358	3.21	0.80	0.12	15.64	2.99	0.77	17.99	3.04	0.88	0.20	0.06	0.01	18.88	3.96	1.20	13.54	0.56	0.43	48.98	3.69	2.04	7.13	0.01	0.22	125.6	15.12	5.65	146.3
367	0.01	0.00	0.00	0.02	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.02	0.00	0.00	0.06	0.00	0.00	0.01	0.00	0.00	0.16	0.01	0.00	0.18
372	0.00	0.00	0.00	0.03	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.02	0.00	0.00	0.08	0.00	0.00	0.01	0.00	0.00	0.21	0.01	0.01	0.23
373	0.06	0.01	0.00	0.46	0.02	0.03	0.45	0.03	0.04	0.01	0.00	0.00	0.68	0.04	0.05	0.33	0.01	0.02	1.38	0.03	0.08	0.19	0.00	0.01	3.56	0.13	0.24	3.94
388	0.52	0.01	0.02	6.12	0.00	0.26	7.00	0.02	0.28	0.07	0.00	0.00	8.78	0.65	0.43	7.52	0.24	0.24	22.36	2.29	0.89	2.90	0.02	0.10	55.26	3.24	2.22	60.73
393	0.00	0.00	0.00	0.02	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.02	0.00	0.00	0.07	0.00	0.00	0.01	0.00	0.00	0.18	0.00	0.01	0.19
397	0.01	0.00	0.00	0.02	0.00	0.00	0.02	0.01	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.02	0.00	0.00	0.08	0.00	0.01	0.01	0.00	0.00	0.18	0.02	0.02	0.22
401	0.05	0.01	0.00	0.29	0.05	0.02	0.39	0.05	0.02	0.00	0.00	0.00	0.35	0.07	0.02	0.21	0.02	0.01	0.79	0.09	0.04	0.10	0.00	0.00	2.19	0.30	0.12	2.62
403	0.52	0.17	0.02	3.20	0.55	0.11	3.89	0.55	0.12	0.04	0.01	0.00	3.51	0.77	0.16	2.36	0.19	0.06	8.37	1.12	0.30	1.21	0.01	0.03	23.11	3.37	0.81	27.29
406	0.03	0.01	0.00	0.15	0.02	0.01	0.18	0.02	0.01	0.00	0.00	0.00	0.16	0.04	0.01	0.11	0.01	0.00	0.37	0.05	0.01	0.05	0.00	0.00	1.04	0.15	0.04	1.23
414	0.21	0.00	0.01	1.68	0.04	0.13	1.79	0.04	0.14	0.02	0.00	0.00	2.83	0.08	0.21	1.07	0.00	0.06	4.67	0.05	0.32	0.59	0.00	0.04	12.86	0.20	0.93	13.99
417	0.29	0.02	0.01	2.15	0.08	0.15	2.14	0.13	0.15	0.03	0.00	0.00	3.51	0.15	0.24	1.45	0.01	0.07	6.39	0.11	0.35	0.85	0.00	0.04	16.80	0.50	1.01	18.31
426	0.23	0.08	0.01	1.30	0.27	0.09	1.59	0.29	0.10	0.02	0.00	0.00	1.22	0.41	0.12	1.03	0.08	0.05	3.65	0.50	0.24	0.46	0.00	0.02	9.51	1.65	0.64	11.79

Product code (FAOSTAT)	Central			Coast			Eastern			Nairobi Area			North-Eastern			Nyanza			Rift Valley			Western			Kenya total			
	Green	Blue	Grey	Green	Blue	Grey	Green	Blue	Grey	Green	Blue	Grey	Green	Blue	Grey	Green	Blue	Grey	Green	Blue	Grey	Green	Blue	Grey	Green	Blue	Grey	Total
430	0.03	0.00	0.00	0.23	0.01	0.01	0.25	0.01	0.02	0.00	0.00	0.00	0.38	0.01	0.02	0.15	0.00	0.01	0.70	0.01	0.04	0.08	0.00	0.00	1.83	0.03	0.10	1.96
463	3.75	1.39	0.20	21.72	4.33	1.33	27.89	4.43	1.49	0.32	0.06	0.02	24.21	5.84	1.93	16.38	1.60	0.71	57.45	8.59	3.70	7.56	0.10	0.37	159.3	26.34	9.74	195.4
486	5.46	1.55	0.08	36.43	0.70	0.74	36.19	1.16	0.79	0.48	0.11	0.01	41.03	0.68	1.14	27.13	0.44	0.36	116.0	1.82	2.12	20.09	0.03	0.23	282.8	6.47	5.47	294.8
489	3.14	0.00	0.06	31.42	0.00	0.77	31.30	0.00	0.83	0.33	0.00	0.01	35.38	0.00	1.18	23.40	0.00	0.37	130.5	0.00	2.08	28.01	0.00	0.21	283.5	0.00	5.51	289.0
490	0.57	0.03	0.01	3.94	0.37	0.08	4.56	0.52	0.09	0.07	0.01	0.00	4.59	0.38	0.11	4.52	0.07	0.07	11.91	0.36	0.21	1.67	0.01	0.03	31.83	1.75	0.59	34.17
497	0.01	0.00	0.00	0.05	0.00	0.00	0.06	0.01	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.05	0.00	0.00	0.14	0.00	0.00	0.02	0.00	0.00	0.39	0.02	0.01	0.41
507	0.21	0.01	0.00	1.44	0.13	0.03	1.67	0.19	0.03	0.02	0.00	0.00	1.68	0.14	0.04	1.65	0.03	0.02	4.36	0.13	0.08	0.61	0.00	0.01	11.65	0.64	0.22	12.50
512	1.78	0.12	0.03	15.01	1.34	0.29	16.14	1.92	0.33	0.20	0.03	0.00	18.43	1.39	0.46	13.62	0.27	0.20	44.05	1.32	0.77	6.19	0.04	0.10	115.4	6.42	2.18	124.0
515	0.02	0.00	0.00	0.18	0.00	0.00	0.18	0.00	0.00	0.00	0.00	0.00	0.24	0.00	0.01	0.12	0.00	0.00	0.52	0.00	0.01	0.08	0.00	0.00	1.35	0.00	0.02	1.37
521	0.06	0.00	0.00	0.67	0.00	0.01	0.68	0.00	0.01	0.01	0.00	0.00	0.88	0.00	0.02	0.45	0.00	0.01	1.95	0.00	0.03	0.30	0.00	0.00	5.00	0.00	0.09	5.09
526	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.05
534	0.01	0.00	0.00	0.05	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.04	0.00	0.00	0.16	0.00	0.00	0.02	0.00	0.00	0.40	0.00	0.01	0.41
536	0.07	0.00	0.00	0.72	0.00	0.01	0.73	0.00	0.01	0.01	0.00	0.00	0.95	0.00	0.02	0.48	0.00	0.01	2.08	0.00	0.03	0.32	0.00	0.00	5.35	0.00	0.10	5.45
544	0.00	0.00	0.00	0.03	0.03	0.00	0.03	0.04	0.00	0.00	0.00	0.00	0.04	0.08	0.00	0.02	0.01	0.00	0.09	0.06	0.00	0.01	0.00	0.00	0.22	0.23	0.01	0.46
558	0.01	0.00	0.00	0.06	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.01	0.04	0.00	0.00	0.16	0.00	0.01	0.02	0.00	0.00	0.44	0.00	0.02	0.47
567	0.02	0.00	0.00	0.16	0.00	0.01	0.15	0.00	0.01	0.00	0.00	0.00	0.27	0.00	0.01	0.11	0.00	0.00	0.55	0.00	0.02	0.08	0.00	0.00	1.33	0.00	0.06	1.39
571	1.64	0.00	0.02	16.54	0.00	0.31	16.76	0.00	0.33	0.18	0.00	0.00	20.41	0.00	0.51	12.11	0.00	0.15	48.46	0.00	0.80	8.02	0.00	0.10	124.11	0.00	2.22	126.3
572	0.78	0.11	0.01	4.13	0.06	0.08	4.15	0.10	0.09	0.06	0.01	0.00	5.10	0.06	0.13	2.95	0.01	0.04	12.06	0.12	0.21	1.80	0.00	0.03	31.04	0.48	0.60	32.12
574	1.20	0.07	0.04	7.66	0.06	0.22	7.48	0.10	0.24	0.10	0.01	0.00	10.70	0.08	0.36	4.27	0.00	0.11	20.04	0.08	0.56	2.59	0.00	0.07	54.06	0.39	1.59	56.04
577	0.04	0.00	0.00	0.37	0.00	0.01	0.38	0.00	0.01	0.00	0.00	0.00	0.47	0.00	0.01	0.26	0.00	0.00	1.08	0.00	0.02	0.17	0.00	0.00	2.77	0.00	0.04	2.81
600	1.24	0.18	0.02	6.54	0.10	0.13	6.57	0.16	0.14	0.09	0.01	0.00	8.06	0.10	0.21	4.66	0.02	0.06	19.08	0.18	0.34	2.85	0.00	0.04	49.08	0.76	0.95	50.78
603	0.35	0.00	0.00	3.52	0.00	0.07	3.57	0.00	0.07	0.04	0.00	0.00	4.34	0.00	0.11	2.58	0.00	0.03	10.31	0.00	0.17	1.71	0.00	0.02	26.41	0.00	0.47	26.88
619	0.66	0.00	0.01	7.03	0.00	0.13	7.12	0.00	0.14	0.07	0.00	0.00	9.22	0.00	0.22	4.70	0.00	0.06	20.43	0.00	0.34	3.20	0.00	0.04	52.44	0.00	0.94	53.38
656	505.6	20.24	10.72	165.6	2.38	4.92	411.1	18.97	11.90	19.32	1.18	0.46	53.18	2.00	1.77	115.7	4.05	2.12	93.87	2.28	2.23	61.90	0.37	1.13	1426	51.46	35.25	1513
667	301.5	0.27	6.12	57.31	0.04	1.67	135.7	0.21	3.87	11.54	0.02	0.26	10.81	0.06	0.36	244.8	0.07	4.24	289.8	0.33	6.94	79.69	0.01	1.34	1131	1.01	24.81	1157
687	0.03	0.00	0.00	0.18	0.01	0.00	0.18	0.02	0.00	0.00	0.00	0.00	0.29	0.02	0.00	0.14	0.00	0.00	0.63	0.01	0.00	0.09	0.00	0.00	1.53	0.06	0.00	1.59
689	1.00	0.25	0.00	4.86	0.12	0.00	5.37	0.20	0.00	0.08	0.02	0.00	5.71	0.12	0.00	3.68	0.07	0.00	14.32	0.30	0.00	2.32	0.00	0.00	37.34	1.09	0.00	38.43
692	0.10	0.06	0.00	0.02	0.03	0.00	0.04	0.04	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.05	0.01	0.00	0.09	0.06	0.00	0.01	0.00	0.00	0.31	0.23	0.00	0.54
698	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.75	0.30	0.00	16.05
702	0.02	0.01	0.00	0.12	0.00	0.00	0.12	0.01	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.09	0.00	0.00	0.34	0.01	0.00	0.05	0.00	0.00	0.88	0.03	0.00	0.90
711	0.01	0.00	0.00	0.07	0.00	0.00	0.07	0.01	0.00	0.00	0.00	0.00	0.11	0.01	0.00	0.05	0.00	0.00	0.23	0.00	0.00	0.03	0.00	0.00	0.56	0.02	0.00	0.58
720	0.00	0.00	0.00	0.02	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.02	0.00	0.00	0.07	0.00	0.00	0.01	0.00	0.00	0.17	0.01	0.00	0.18
723	0.09	0.01	0.00	0.60	0.04	0.00	0.50	0.06	0.00	0.01	0.00	0.00	0.79	0.06	0.00	0.48	0.01	0.00	2.00	0.05	0.00	0.29	0.00	0.00	4.75	0.23	0.00	4.99
789	3.10	0.34	0.00	17.92	0.20	0.00	17.89	0.34	0.00	0.23	0.03	0.00	23.56	0.20	0.00	11.40	0.02	0.00	50.37	0.28	0.00	6.88	0.00	0.00	131.4	1.42	0.00	132.8
826	0.46	0.00	0.01	5.51	0.00	0.13	6.29	0.00	0.13	0.06	0.00	0.00	6.73	0.00	0.20	3.67	0.00	0.06	14.97	0.00	0.32	2.21	0.00	0.04	39.89	0.00	0.89	40.78
29271																									4.04	8.40	6.17	18.61
Total	1015	29.02	19.53	1989	20.58	39.22	2175	43.89	49.37	49.66	1.83	1.01	2523	35.87	51.71	1815	27.04	22.46	6848	46.14	98.39	1157	5.81	12.23	17590	219	300	18109

Appendix III: Virtual water import and export related to trade in agricultural products (Mm^3/yr).

Period 1996-2005

Country	Virtual water import			Virtual water export			Net virtual water import			
	Green	Blue	Grey	Green	Blue	Grey	Green	Blue	Grey	Total
Afghanistan	0.02	0.07	0.00	51.2	0.06	1.12	-51.2	0.02	-1.12	-52.3
Albania	0.00	0.00	0.00	0.32	0.01	0.01	-0.32	-0.01	-0.01	-0.33
Algeria	0.00	0.00	0.00	0.70	0.01	0.01	-0.70	-0.01	-0.01	-0.71
Angola	0.00	0.00	0.00	1.22	0.00	0.04	-1.22	0.00	-0.04	-1.27
Antigua and Barbuda	1.87	0.46	0.28	0.09	0.00	0.00	1.78	0.46	0.28	2.52
Argentina	320	3.17	18.78	0.39	0.00	0.02	320	3.16	18.8	342
Australia	175	1.46	8.98	16.7	0.46	0.39	159	1.00	8.6	168
Austria	3.42	0.00	0.64	23.0	0.84	0.49	-19.6	-0.84	0.14	-20.2
Azerbaijan, Republic	0.00	0.00	0.00	0.11	0.00	0.00	-0.11	0.00	0.00	-0.11
Bahamas	0.01	0.00	0.00	0.17	0.01	0.00	-0.16	-0.01	0.00	-0.17
Bahrain	0.00	0.00	0.00	0.40	0.08	0.01	-0.40	-0.07	-0.01	-0.48
Belgium	4.03	0.82	0.54	119	4.07	2.69	-115	-3.25	-2.15	-120
Brazil	12.2	0.49	0.82	1.16	0.03	0.00	11.08	0.45	0.81	12.3
Burundi	0.12	0.01	0.00	7.42	0.25	0.01	-7.30	-0.25	-0.01	-7.56
Cameroon	0.00	0.00	0.00	0.13	0.00	0.00	-0.13	0.00	0.00	-0.13
Canada	37.2	0.17	7.33	44.9	1.36	1.01	-7.70	-1.19	6.33	-2.57
Cayman Islands	0.00	0.00	0.00	0.09	0.00	0.00	-0.09	0.00	0.00	-0.10
Chile	0.00	0.00	0.00	0.19	0.00	0.00	-0.18	0.00	0.00	-0.19
China	16.3	2.66	5.69	29.5	0.68	0.72	-13.2	1.98	4.97	-6.29
Colombia	1.73	0.12	0.01	0.77	0.00	0.02	0.97	0.12	-0.01	1.08
Comoros	0.00	0.00	0.00	0.27	0.03	0.00	-0.27	-0.03	0.00	-0.30
Congo, Republic	5.31	0.00	0.00	0.31	0.00	0.01	5.00	0.00	0.00	4.99
Congo, Dem Republic	13.4	0.00	0.00	5.50	0.18	0.14	7.89	-0.18	-0.14	7.56
Côte d'Ivoire	0.00	0.00	0.00	0.82	0.01	0.01	-0.82	-0.01	-0.01	-0.83
Croatia	0.00	0.00	0.00	0.14	0.01	0.00	-0.14	-0.01	0.00	-0.15
Czech Republic	0.07	0.03	0.01	1.99	0.08	0.05	-1.92	-0.05	-0.04	-2.01
Denmark	0.75	0.01	0.05	15.5	0.57	0.35	-14.7	-0.56	-0.30	-15.6
Djibouti	0.05	0.00	0.00	6.36	0.29	0.14	-6.30	-0.28	-0.14	-6.72
Ecuador	0.00	0.00	0.00	0.53	0.02	0.01	-0.53	-0.02	-0.01	-0.56
Egypt	3.23	32.5	5.79	122	0.26	2.90	-119	32.2	2.88	-84.0
Equatorial Guinea	0.00	0.00	0.00	0.36	0.00	0.01	-0.36	0.00	-0.01	-0.37
Eritrea	0.01	0.00	0.00	28.00	1.01	0.56	-28.0	-1.01	-0.56	-29.6
Ethiopia	26.5	0.53	0.24	5.63	0.10	0.13	20.9	0.43	0.10	21.4
Finland	1.04	0.14	0.04	76.0	2.75	1.78	-75.0	-2.61	-1.74	-79.4
France	14.2	0.57	0.69	60.4	6.56	1.48	-46.1	-6.00	-0.80	-52.9
Gabon	0.00	0.00	0.00	0.20	0.00	0.01	-0.20	0.00	-0.01	-0.20

Country	Virtual water import			Virtual water export			Net virtual water import			
	Green	Blue	Grey	Green	Blue	Grey	Green	Blue	Grey	Total
Georgia	0.00	0.00	0.00	0.26	0.00	0.01	-0.26	0.00	-0.01	-0.27
Germany	3.71	0.47	0.61	500	18.8	12.3	-497	-18.4	-11.7	-527
Ghana	0.00	0.00	0.00	0.56	0.01	0.00	-0.56	-0.01	0.00	-0.57
Greece	0.02	0.01	0.00	3.35	0.11	0.04	-3.33	-0.10	-0.04	-3.47
Hong Kong	1.99	0.35	0.91	165	13.93	0.46	-163	-13.57	0.45	-176
Hungary	5.88	0.01	2.06	1.50	0.04	0.03	4.37	-0.03	2.02	6.37
Iceland	0.12	0.03	0.01	0.35	0.01	0.01	-0.23	0.01	0.00	-0.21
India	83.0	33.8	12.2	35.8	0.63	1.04	47.1	33.1	11.1	91.4
Indonesia	605	0.59	41.6	11.3	0.40	0.06	594	0.18	41.5	635
Iran	0.50	2.31	0.12	6.94	0.01	0.15	-6.43	2.31	-0.03	-4.16
Ireland	0.63	0.22	0.10	33.1	0.34	0.74	-32.4	-0.12	-0.64	-33.2
Israel	0.96	0.81	0.22	6.57	0.23	0.18	-5.61	0.58	0.03	-5.01
Italy	17.1	2.89	4.17	82.2	3.22	0.76	-65.0	-0.33	3.41	-62.0
Japan	3.17	0.12	1.05	41.0	1.14	0.73	-37.8	-1.03	0.32	-38.5
Jordan	0.00	0.00	0.00	17.2	0.68	0.37	-17.2	-0.68	-0.37	-18.2
Kazakhstan	6.53	0.05	0.00	2.30	0.00	0.05	4.23	0.04	-0.05	4.23
Korea, Republic	3.78	0.22	0.20	1.47	0.03	0.01	2.31	0.19	0.19	2.69
Kuwait	0.00	0.00	0.00	0.12	0.04	0.01	-0.12	-0.04	-0.01	-0.16
Lebanon	0.00	0.00	0.00	0.86	0.05	0.02	-0.86	-0.05	-0.02	-0.93
Luxembourg	0.00	0.00	0.00	0.15	0.00	0.01	-0.15	0.00	-0.01	-0.16
Madagascar	0.29	0.01	0.00	4.41	0.00	0.01	-4.12	0.01	-0.01	-4.12
Malawi	26.0	9.25	1.29	6.63	0.13	0.09	19.4	9.12	1.20	29.7
Malaysia	170	0.14	6.71	52.3	2.46	0.01	118	-2.31	6.70	122
Mali	0.87	2.13	0.00	0.29	0.00	0.00	0.59	2.13	0.00	2.71
Mexico	25.3	2.14	4.39	2.05	0.04	0.00	23.2	2.09	4.39	29.7
Morocco	0.00	0.00	0.00	3.38	0.04	0.00	-3.38	-0.04	0.00	-3.42
Mozambique	24.0	1.51	0.17	8.30	0.03	0.17	15.7	1.48	0.01	17.2
Namibia	0.00	0.00	0.00	0.12	0.00	0.00	-0.11	0.00	0.00	-0.12
Nepal	0.00	0.00	0.00	0.11	0.00	0.00	-0.11	0.00	0.00	-0.12
Netherlands Antiles	0.02	0.00	0.00	0.35	0.00	0.01	-0.34	0.00	-0.01	-0.34
Netherlands	5.75	1.28	0.63	124	10.0	6.94	-118	-8.72	-6.32	-133
New Zealand	1.27	0.19	0.01	9.07	0.29	0.18	-7.80	-0.10	-0.17	-8.07
Nigeria	9.81	0.00	0.01	2.60	0.01	0.06	7.21	-0.01	-0.05	7.16
Norway	0.08	0.00	0.00	33.5	1.23	0.79	-33.4	-1.23	-0.79	-35.5
Oman	0.09	0.01	0.01	1.89	0.05	0.04	-1.80	-0.04	-0.03	-1.87
Pakistan	109	330	52.7	281	1.56	5.38	-172	328	47.3	203
Philippines	2.66	0.00	0.24	1.97	0.02	0.02	0.69	-0.02	0.22	0.89
Poland	0.02	0.00	0.00	22.6	0.41	0.51	-22.6	-0.41	-0.50	-23.5
Portugal	0.07	0.05	0.01	23.2	0.65	0.25	-23.1	-0.60	-0.25	-24.0

Country	Virtual water import			Virtual water export			Net virtual water import			
	Green	Blue	Grey	Green	Blue	Grey	Green	Blue	Grey	Total
Qatar	0.00	0.00	0.00	0.26	0.03	0.01	-0.26	-0.03	-0.01	-0.30
Romania	2.08	0.06	0.10	6.54	0.24	0.16	-4.46	-0.18	-0.06	-4.70
Russian Federation	58.6	0.78	2.26	17.2	0.10	0.38	41.4	0.68	1.88	43.9
Rwanda	0.15	0.01	0.04	20.1	0.45	1.58	-20.0	-0.44	-1.54	-21.9
Saudi Arabia	1.33	3.22	0.12	47.9	1.68	0.96	-46.5	1.54	-0.84	-45.8
Senegal	0.00	0.00	0.00	0.33	0.00	0.00	-0.33	0.00	0.00	-0.33
Seychelles	0.00	0.00	0.00	0.84	0.03	0.02	-0.84	-0.03	-0.02	-0.88
Sierra Leone	1.35	0.01	0.01	0.07	0.00	0.00	1.28	0.01	0.01	1.29
Singapore	237	5.26	11.0	13.8	0.26	0.13	224	5.00	10.83	239
Slovakia	0.28	0.03	0.03	1.63	0.06	0.04	-1.35	-0.03	-0.01	-1.38
Slovenia	0.00	0.00	0.00	0.72	0.03	0.02	-0.72	-0.03	-0.02	-0.76
Somalia	2.96	0.24	0.00	36.1	0.98	0.62	-33.2	-0.74	-0.62	-34.5
South Africa	267	19.5	22.1	43.0	0.53	0.66	224	19.0	21.5	265
Spain	1.29	0.20	0.19	52.7	1.63	0.73	-51.4	-1.43	-0.54	-53.4
Sri Lanka	4.97	0.00	0.27	3.46	0.01	0.07	1.51	-0.01	0.20	1.70
Sudan	3.21	22.4	1.50	79.3	0.65	1.76	-76.1	21.8	-0.25	-54.5
Swaziland	3.58	3.96	0.02	0.06	0.00	0.01	3.52	3.96	0.01	7.49
Sweden	0.28	0.00	0.05	116	4.18	2.75	-116	-4.18	-2.70	-122
Switzerland	7.89	0.59	1.99	28.0	1.15	0.78	-20.1	-0.56	1.21	-19.4
Syria	0.00	0.00	0.00	2.08	0.04	0.02	-2.08	-0.04	-0.02	-2.14
Taiwan (POC)	0.26	0.08	0.11	8.11	0.03	0.15	-7.85	0.04	-0.04	-7.85
Tanzania	159	8.61	1.69	37.1	0.85	0.55	122	7.76	1.14	131
Thailand	137	2.35	7.35	4.41	0.16	0.06	132	2.19	7.30	142
Tunisia	0.01	0.00	0.00	8.63	0.30	0.21	-8.62	-0.30	-0.20	-9.12
Turkey	17.3	1.45	1.64	6.21	0.10	0.05	11.1	1.35	1.59	14.1
Uganda	126	0.10	0.28	137	2.51	2.08	-11.1	-2.41	-1.79	-15.3
Ukraine	30.5	0.33	1.18	0.63	0.01	0.02	29.8	0.32	1.17	31.3
United Arab Emirates	7.23	2.56	1.12	57.1	1.85	0.97	-49.9	0.71	0.16	-49.0
UK	36.1	6.08	6.88	425	7.16	11.3	-389	-1.08	-4.47	-395
Uruguay	1.25	0.00	0.10	0.00	0.00	0.00	1.25	0.00	0.10	1.36
USA	157	11.6	49.1	545	23.6	3.78	-388	-12.1	45.3	-355
Viet Nam	22.7	3.04	4.11	0.24	0.00	0.00	22.5	3.04	4.11	29.6
Yemen	0.06	0.02	0.01	32.7	0.09	0.71	-32.6	-0.07	-0.71	-33.4
Serbia and Montenegro	0.00	0.00	0.00	0.21	0.01	0.01	-0.21	-0.01	-0.01	-0.22
Zambia	1.68	2.34	0.01	23.8	0.21	0.35	-22.2	2.13	-0.34	-20.4
Zimbabwe	89.0	3.25	5.52	18.0	0.05	0.34	71.0	3.20	5.18	79.4
Others	9.11	0.85	0.41	7.63	0.24	0.07	1.48	0.61	0.34	2.43
Total	3132	531	298	3892	126	77	-760	405	221	-134

Value of Water Research Report Series

1. Exploring methods to assess the value of water: A case study on the Zambezi basin
   A.K. Chapagain – February 2000
2. Water value flows: A case study on the Zambezi basin.
   A.Y. Hoekstra, H.H.G. Savenije and A.K. Chapagain – March 2000
3. The water value-flow concept
   I.M. Seyam and A.Y. Hoekstra – December 2000
4. The value of irrigation water in Nyanyadzi smallholder irrigation scheme, Zimbabwe
   G.T. Pazvakawambwa and P. van der Zaag – January 2001
5. The economic valuation of water: Principles and methods
   J.I. Agudelo – August 2001
6. The economic valuation of water for agriculture: A simple method applied to the eight Zambezi basin countries
   J.I. Agudelo and A.Y. Hoekstra – August 2001
7. The value of freshwater wetlands in the Zambezi basin
   I.M. Seyam, A.Y. Hoekstra, G.S. Ngabirano and H.H.G. Savenije – August 2001
8. 'Demand management' and 'Water as an economic good': Paradigms with pitfalls
   H.H.G. Savenije and P. van der Zaag – October 2001
9. Why water is not an ordinary economic good
   H.H.G. Savenije – October 2001
10. Calculation methods to assess the value of upstream water flows and storage as a function of downstream benefits
    I.M. Seyam, A.Y. Hoekstra and H.H.G. Savenije – October 2001
11. Virtual water trade: A quantification of virtual water flows between nations in relation to international crop trade
    A.Y. Hoekstra and P.Q. Hung – September 2002
12. Virtual water trade: Proceedings of the international expert meeting on virtual water trade
    A.Y. Hoekstra (ed.) – February 2003
13. Virtual water flows between nations in relation to trade in livestock and livestock products
    A.K. Chapagain and A.Y. Hoekstra – July 2003
14. The water needed to have the Dutch drink coffee
    A.K. Chapagain and A.Y. Hoekstra – August 2003
15. The water needed to have the Dutch drink tea
    A.K. Chapagain and A.Y. Hoekstra – August 2003
16. Water footprints of nations, Volume 1: Main Report, Volume 2: Appendices
    A.K. Chapagain and A.Y. Hoekstra – November 2004
17. Saving water through global trade
    A.K. Chapagain, A.Y. Hoekstra and H.H.G. Savenije – September 2005
18. The water footprint of cotton consumption
    A.K. Chapagain, A.Y. Hoekstra, H.H.G. Savenije and R. Gautam – September 2005
19. Water as an economic good: the value of pricing and the failure of markets
    P. van der Zaag and H.H.G. Savenije – July 2006
20. The global dimension of water governance: Nine reasons for global arrangements in order to cope with local water problems
    A.Y. Hoekstra – July 2006
21. The water footprints of Morocco and the Netherlands
    A.Y. Hoekstra and A.K. Chapagain – July 2006
22. Water's vulnerable value in Africa
    P. van der Zaag – July 2006
23. Human appropriation of natural capital: Comparing ecological footprint and water footprint analysis
    A.Y. Hoekstra – July 2007
24. A river basin as a common-pool resource: A case study for the Jaguaribe basin in Brazil
    P.R. van Oel, M.S. Krol and A.Y. Hoekstra – July 2007
25. Strategic importance of green water in international crop trade
    M.M. Aldaya, A.Y. Hoekstra and J.A. Allan – March 2008
26. Global water governance: Conceptual design of global institutional arrangements
    M.P. Verkerk, A.Y. Hoekstra and P.W. Gerbens-Leenes – March 2008
27. Business water footprint accounting: A tool to assess how production of goods and services impact on freshwater resources worldwide
    P.W. Gerbens-Leenes and A.Y. Hoekstra – March 2008
28. Water neutral: reducing and offsetting the impacts of water footprints
    A.Y. Hoekstra – March 2008
29. Water footprint of bio-energy and other primary energy carriers
    P.W. Gerbens-Leenes, A.Y. Hoekstra and Th.H. van der Meer – March 2008
30. Food consumption patterns and their effect on water requirement in China
    J. Liu and H.H.G. Savenije – March 2008
31. Going against the flow: A critical analysis of virtual water trade in the context of India's National River Linking Programme
    S. Verma, D.A. Kampman, P. van der Zaag and A.Y. Hoekstra – March 2008
32. The water footprint of India
    D.A. Kampman, A.Y. Hoekstra and M.S. Krol – May 2008

33. The external water footprint of the Netherlands: Quantification and impact assessment
P.R. van Oel, M.M. Mekonnen and A.Y. Hoekstra – May 2008
34. The water footprint of bio-energy: Global water use for bio-ethanol, bio-diesel, heat and electricity
P.W. Gerbens-Leenes, A.Y. Hoekstra and Th.H. van der Meer – August 2008
35. Water footprint analysis for the Guadiana river basin
M.M. Aldaya and M.R. Llamas – November 2008
36. The water needed to have Italians eat pasta and pizza
M.M. Aldaya and A.Y. Hoekstra – May 2009
37. The water footprint of Indonesian provinces related to the consumption of crop products
F. Bulsink, A.Y. Hoekstra and M.J. Booij – May 2009
38. The water footprint of sweeteners and bio-ethanol from sugar cane, sugar beet and maize
P.W. Gerbens-Leenes and A.Y. Hoekstra – November 2009
39. A pilot in corporate water footprint accounting and impact assessment: The water footprint of a sugar-containing carbonated beverage
A.E. Ercin, M.M. Aldaya and A.Y. Hoekstra – November 2009
40. The blue, green and grey water footprint of rice from both a production and consumption perspective
A.K. Chapagain and A.Y. Hoekstra – March 2010
41. Water footprint of cotton, wheat and rice production in Central Asia
M.M. Aldaya, G. Muñoz and A.Y. Hoekstra – March 2010
42. A global and high-resolution assessment of the green, blue and grey water footprint of wheat
M.M. Mekonnen and A.Y. Hoekstra – April 2010
43. Biofuel scenarios in a water perspective: The global blue and green water footprint of road transport in 2030
A.R. van Lienden, P.W. Gerbens-Leenes, A.Y. Hoekstra and Th.H. van der Meer – April 2010
44. Burning water: The water footprint of biofuel-based transport
P.W. Gerbens-Leenes and A.Y. Hoekstra – June 2010
45. Mitigating the water footprint of export cut flowers from the Lake Naivasha Basin, Kenya
M.M. Mekonnen and A.Y. Hoekstra – June 2010
46. The green and blue water footprint of paper products: methodological considerations and quantification
P.R. van Oel and A.Y. Hoekstra – July 2010
47. The green, blue and grey water footprint of crops and derived crop products
M.M. Mekonnen and A.Y. Hoekstra – December 2010
48. The green, blue and grey water footprint of animals and derived animal products
M.M. Mekonnen and A.Y. Hoekstra – December 2010
49. The water footprint of soy milk and soy burger and equivalent animal products
A.E. Ercin, M.M. Aldaya and A.Y. Hoekstra – February 2011
50. National water footprint accounts: The green, blue and grey water footprint of production and consumption
M.M. Mekonnen and A.Y. Hoekstra – May 2011
51. The water footprint of electricity from hydropower
M.M. Mekonnen and A.Y. Hoekstra – June 2011
52. The relation between national water management and international trade: a case study for Kenya
M.M. Mekonnen and A.Y. Hoekstra – June 2011

Reports can be downloaded from:
www.waterfootprint.org
www.unesco-ihe.org/value-of-water-research-report-series

UNESCO-IHE
P.O. Box 3015
2601 DA Delft
The Netherlands

Website www.unesco-ihe.org
Phone +31 15 2151715

UNESCO-IHE
Institute for Water Education

University of Twente

UNIVERSITY OF TWENTE.

Delft University of Technology

TU Delft
Delft University of Technology