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from an economic perspective

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WATER FOOTPRINT OF TUNISIA FROM AN ECONOMIC PERSPECTIVE

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Summary

In a country where freshwater resources are scarce and unevenly distributed, the choice of cropping patterns and the import of food products can be important means to meet the need for food and lessen the pressure on domestic water resources. This paper quantifies and analyses the water footprint of Tunisia at national and sub-national level, assessing green, blue and grey water footprints for the period 1996-2005. It also assesses economic water and land productivities related to crop production for irrigated and rain-fed agriculture and the economic earnings related to export and the economic costs related to import per unit of water virtually traded.

The total water footprint of production in Tunisia was, on average, 19 Gm^3/yr in the period 1996-2005. The water footprint of crop production gave the largest contribution (87%). North Tunisia has the biggest share in the total water footprint of crop production (70%), followed by Central (26%) and South Tunisia (4%). At national level, tomatoes and potatoes were the main crops with relatively high economic water productivity, with a Tunisian average of 1.08 and 0.87 US$/$m^3$ respectively, while olives and barley were the main crops with relatively low productivity, of 0.03 and 0.04 US$/$m^3$ respectively. In terms of economic land productivity, oranges had the highest productivity, with 4040 US$/ha, and barley the lowest, with 130 US$/ha. South Tunisia has the lowest economic water and land productivities.

The total blue water footprint of crop production represents 31% of the total renewable blue water resources, which means that Tunisia as a whole experiences significant water scarcity. The blue water footprint resting on groundwater represents 62% of the total renewable groundwater resources, which means that the country is facing a severe water scarcity related to groundwater. Considering surface and groundwater together, the highest scarcity occurs in South Tunisia (severe water scarcity of 78%), followed by Central Tunisia (significant water scarcity of 32%) and finally North Tunisia (moderate water scarcity of 23%). In terms of groundwater, all regions of the country experience severe water scarcity, with a scarcity level of 47% for both North and Central Tunisia, while the situation in South Tunisia is even more severe, with a blue WF resting on groundwater exceeding the renewable groundwater resources.

The total water footprint of Tunisian consumption was 21 Gm^3/yr, which is 2200 m^3/yr per citizen. The latter figure is 60% larger than the world average. Consumption of agricultural products largely determines the total water footprint related to consumption, contributing 98% to the total water footprint. The study shows that the external water footprint of Tunisian consumption is 32% of its total water footprint, mainly due to food imports from Europe.

1. Introduction

As one of the most arid countries in the Mediterranean, Tunisia suffers from high water scarcity. The shortage of water resources is a limiting factor to food production. Not only a deliberate management of available resources and choices in agricultural production, but also import of water in virtual form through international trade, seems to be a way to fill the water deficit.

The concept of virtual water (Allan, 1993) is defined as the amount of water embedded in traded products. Water-poor countries can save water by importing water-intensive commodities instead of producing them domestically. International trade in agricultural commodities mainly depends on factors such as availability of land, labour, technology, the costs of engaging in trade, national food policies and international trade agreements (Hoekstra and Chapagain, 2008). Closely linked to the concept of virtual water is the concept of water footprint (WF). The water footprint, introduced by Hoekstra in 2002, is an indicator of fresh water use of a consumer or producer (Hoekstra et al., 2011). The WF informs not only about the level of water consumption but also about where this water is used. The WF of a product is the volume of fresh water used to produce the product, measured over the full supply chain (Hoekstra et al., 2011).

The WF has three components: blue, green and grey. The blue WF refers to consumption of blue water resources (surface and groundwater) in the production process and along the supply chain of a product. The green WF refers to consumption of green water resources (rainwater). The grey WF relates to pollution and is defined as the volume of freshwater that is required to assimilate the load of pollutants given natural background concentrations and existing ambient water quality standards (Hoekstra et al., 2011).

The WF of a crop is generally expressed in terms of m^3/ton or litre/kg, but can also be expressed in terms of m^3 per monetary unit (Hoekstra et al., 2011). Garrido et al. (2009) show the usefulness of doing so in a case study for Spain. They show that water scarcity affects water productivity; users become more efficient in their blue water use as water becomes scarcer, but this behavioural adaptation only occurs in regions where water is scarce and where blue water is the main contribution to total crop water use.

A concept closely related to water footprint is water productivity (WP). The increasing scarcity of freshwater and the important role that water plays in food production imposes the need to optimise water use in all human activities, particularly in agriculture, the main water-using sector worldwide. There is no common definition of the term WP (Rodrigues and Pereira, 2009), but in all definitions, WP refers to the ratio of the net benefits from crop, forestry, fishery, livestock or mixed agriculture systems to the amount of water used to produce those benefits. Physical WP can be defined as the ratio of agricultural output to the amount of water consumed (‘crop per drop’), which is mostly expressed in either blue water withdrawal or total (green plus blue) water consumption (Kijne et al., 2003; Zwart and Bastiaanssen, 2004, 2007; Playan and Matoes, 2006; Molden, 2007). Expressing WP in physical terms does not give insight in the economic benefit of water use; therefore it is also useful to consider economic water productivity (‘dollar per drop’) (Cook et al., 2006; Pereira et al., 2009).

Economic water productivity (EWP) is defined as the value derived per unit of water used (Igbadun et al., 2006; Palanisami et al., 2006; Teixeira et al., 2008; Vazifedoust et al., 2008; Garrido et al., 2009). This definition has also been used to relate water use in agriculture to nutrition, jobs, welfare and environment, where the socio-economic value added of water use can be expressed in terms of 'nutrition per drop', 'job per drop', etc. The scope for increasing the value per unit of water used in agriculture is often bigger than the scope for increasing physical water productivity (Molden et al., 2010). According to Molden et al. (2010), much of the potential for increasing the harvest for common grains was met during the green revolution. The areas with still a high potential for gains in physical water productivity are those with very low yields, such as sub-Saharan Africa and South Asia. Strategies for increasing the net value of water used in agriculture include: increasing yield, re-allocating water from low to higher valued crops or uses, lowering the cost of inputs and increasing the value of ecological services of agriculture and obtaining multiple benefits per unit of water (Molden et al., 2010).

In this report we quantify and analyse the green, blue and grey water footprint within Tunisia, analyse the blue water footprint into the context of blue water availability, assess economic water and land productivities related to crop production for irrigated and rain-fed agriculture, estimate the economic earnings related to export and the economic costs related to import per unit of water virtually traded, and estimate the external water footprint and water dependency of Tunisian consumption. The period of analysis is 1996-2005. The study follows the methodology described in *The Water Footprint Assessment Manual* (Hoekstra et al., 2011). The study adds to earlier studies of water footprint and virtual water trade for Tunisia (Chapagain and Hoekstra, 2004; Chahed et al., 2008; Chahed et al., 2011; Mekonnen and Hoekstra, 2011a) by adding the economic dimension in a comprehensive national Water Footprint Assessment (WFA).

2. Methods and data

This study follows the terminology and methodology as set out in *The Water Footprint Assessment Manual* (Hoekstra et al., 2011), which contains the global standard for Water Footprint Assessment (WFA) developed by the Water Footprint Network. The national water footprint accounting scheme shows the various balances that hold for the water footprint related to national consumption, the water footprint within the area of the nation, the virtual water export and the virtual water import (Figure 1).

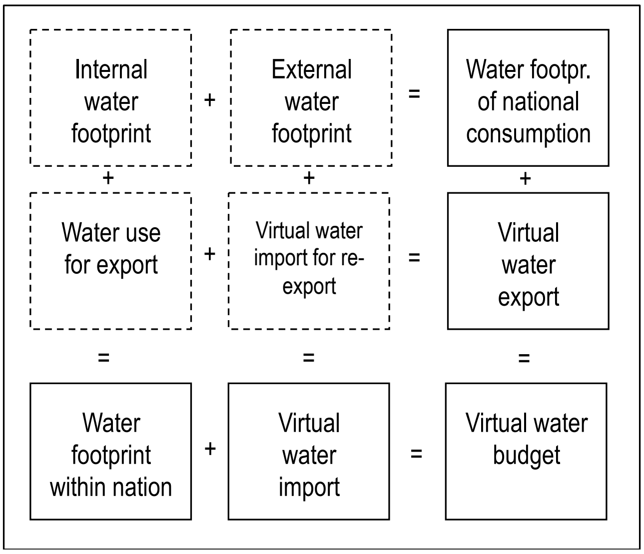


Figure 1. The national water footprint accounting scheme.
Source: Hoekstra et al. (2011).

The WF 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 WF 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 two components: the internal and external WF of national consumption. The internal WF is defined as the use of domestic water resources to produce goods and services consumed by the nation's population. It is the sum of the WF within the nation minus the volume of virtual-water export to other nations related to the export of products produced with domestic water resources. The external WF is defined as the volume of water resources used in other nations to produce goods and services consumed by the population in the nation under consideration. It is equal to the virtual-water import into the nation minus the volume of virtual-water export to other nations as a result of re-export of imported products. The virtual-water export from a nation consists of exported water of domestic origin and re-exported water of foreign origin. The virtual-water import into a nation will partly be consumed, thus constituting the external WF of national consumption, and may partly be re-exported. The sum of the virtual water import into a country and the WF within the area of the nation is equal to the sum of the virtual water export from the nation and the WF of national consumption. This sum is called the virtual-water budget of a nation. The national water saving associated with import can be estimated by multiplying the imported product volume by the volume of water that would have been required to produce the product domestically.

We will put the blue WF in the context of renewable blue water resources (blue water availability) in order to assess water scarcity. Vörösmarty et al. (2000) and Oki and Kanae (2006) consider a country to be severely water stressed if the ratio of blue water withdrawal to renewable blue water resources is higher than 40%. In our case, we will relate water scarcity to the blue WF rather than to blue water withdrawal, which according to Hoekstra et al. (2012) is a more meaningful basis to show water scarcity, since a significant share of withdrawn water returns to rivers and aquifers and becomes available for reuse. The blue WF measures the consumptive use of blue water resources. Following Hoekstra et al. (2012), we compare the blue WF to renewable blue water resources. Table 1 shows the water scarcity thresholds used in this study, equivalent to the thresholds used by Hoekstra et al. (2012).

Table 1. Water scarcity thresholds.

Blue water scarcity levels *	Water scarcity thresholds
Low blue water scarcity	< 20%
Moderate blue water scarcity	20-30%
Significant blue water scarcity	30-40%
Severe water scarcity	> 40%

* Water scarcity defined as blue water footprint / renewable blue water resources.

We calculate overall water scarcity on annual basis as the ratio of total blue WF to total renewable blue water resources, and groundwater scarcity as the ratio of the blue WF from groundwater sources to renewable groundwater resources.

In calculating water productivities, we make a distinction between rain-fed and irrigated agriculture. In the former case, the only water source is rainwater, so that we can speak about green water productivity. In the case of irrigated agriculture, we distinguish between green and blue water productivity, because both rainwater and irrigation water are consumed. In irrigated agriculture, green water productivity is defined as the yield that would be obtained based on rain only (assuming that there is no irrigation) divided by the volume of green water consumed. Blue water productivity is defined as the additional yield obtained through irrigation divided by the blue water (irrigation water) evapotranspiration (Hoekstra, 2013).

The yield obtained from rain only is estimated based on the equation proposed by Doorenbos and Kassam (1979):

$$\left(1 - \frac{Y_a}{Y_m}\right) = K_y\left(1 - \frac{ET_a}{CWR}\right) \quad (1)$$

where K_y is a yield response factor (water stress coefficient), Y_a the actual yield (kg/ha), Y_m the maximum yield, obtained under optimal water supply conditions (kg/ha), ET_a the actual crop evapotranspiration (mm/period) and CWR the crop water requirement (mm/period). Following this equation, the green-water based yield ($Y_{green,\ irrig}$) in irrigated agriculture can be calculated from:

$$\left(1 - \frac{Y_{green,irrig}}{Y_{tot,irrig}}\right) = K_y\left(1 - \frac{ET_{green}}{ET_{green} + ET_{blue}}\right) \quad (2)$$

whereby $Y_{tot,irrig}$ is the yield occurring under full irrigation (rain + irrigation water), which is equal to the maximum yield Y_m; ET_{green} is the evapotranspiration of green water that would have occurred without irrigation; ET_{blue} is the evapotranspiration of blue water. Data on $Y_{tot,irrig}$, ET_{green}, ET_{blue} and K_y are obtained for all irrigated crop areas from the grid-based study of Mekonnen and Hoekstra (2010).

The additional yield through irrigation is calculated as the total yield in irrigated agriculture ($Y_{tot,irrig}$) minus the yield that would have hypothetically occurred if there were no irrigation ($Y_{green,irrig}$).

Figure 2 shows the relation between yield and evapotranspiration during the growing period and visualizes green and blue water productivity through two subsequent slopes. The first (green) slope represents the green water productivity, while the second (blue) slope represents the blue water productivity.

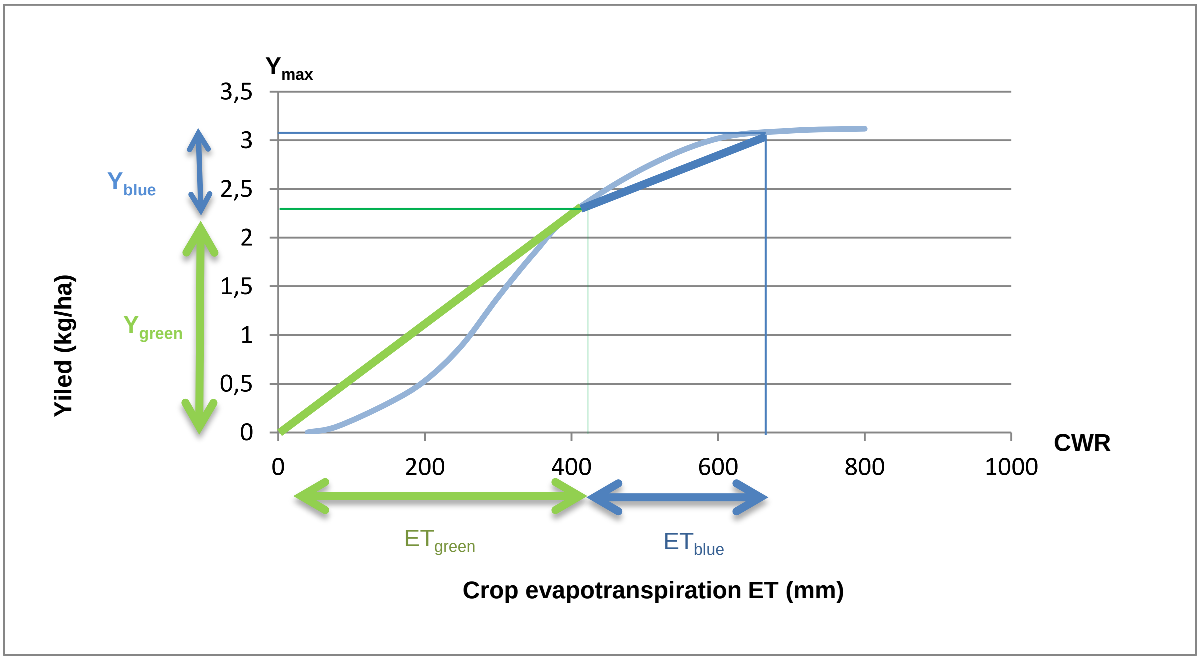


Figure 2. The relation between yield and evapotranspiration from a crop field. Green and blue water productivity appear as the slopes of each of the two line segments drawn in the graph.

Economic water productivities (US$/m^3) are calculated by multiplying physical water productivities (kg/m^3) by crop value (US$/kg). For a farmer, economic blue water productivity may be a relevant variable for production decisions, as blue water use goes along with direct production costs or blue water availability may be limiting production. Land productivity may influence decisions on crop choices if land availability is most limiting for a farmer.

The cost per unit of virtual water imported (US$/m^3) is calculated by dividing the total value of imported crop by its total WF. In a similar way, the earning per unit of virtual water exported (US$/m^3) is calculated by dividing the total value of exported crop by its total WF.

The study is based on data for the period of 1996-2005. Table 2 gives an overview of all variables and sources used in this study. We divided the country into three regions based on climate: North, Central and South (Figure 3). North has a Mediterranean climate, South has a Sahara climate, while Central has a climate in between. Each region consists of governorates, administrative sub-units.

Table 2. Overview of input variables and sources used.

Input variable	Source
Water footprint of crop production	Mekonnen and Hoekstra (2010, 2011b)
Water footprint in other sectors	Mekonnen and Hoekstra (2011a)
Yields and evapotranspiration in rain-fed and irrigated systems	Mekonnen and Hoekstra (2010)
Water resources availability and water withdrawal at national level	Ministry of Environment (2009)
Surface water availability and withdrawal at regional level	Ministry of Agriculture (2005a)
Groundwater availability and withdrawal at regional level	Ministry of Agriculture (2005b)
Crop values (producer prices)	FAOSTAT (FAO, 2009)
Virtual water flows	Hoekstra and Mekonnen (2012)
Economic values of imports and exports	ITC (2007)
Water footprint of national consumption	Hoekstra and Mekonnen (2012)

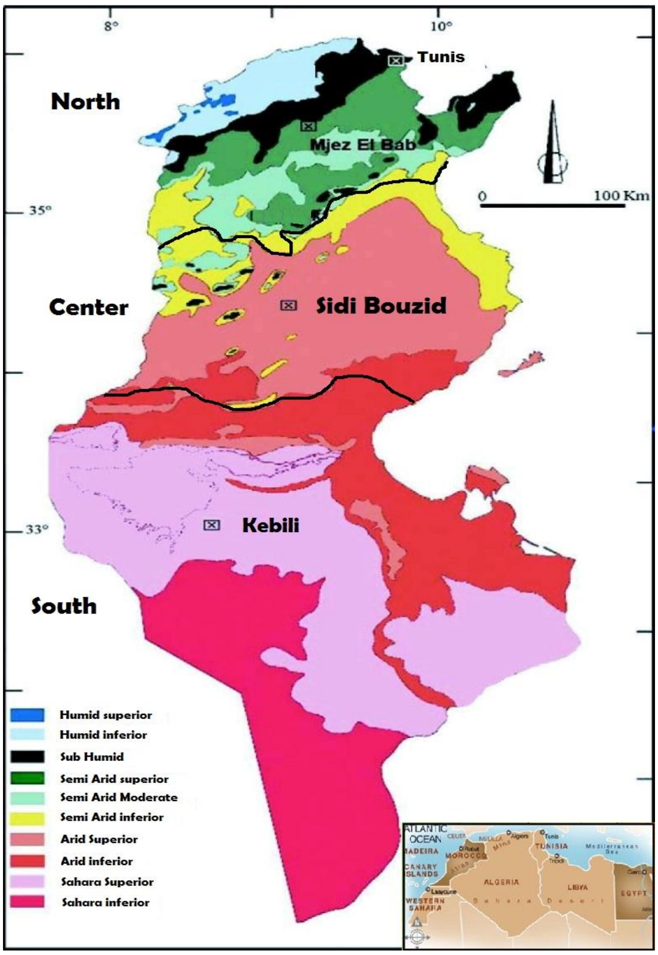


Figure 3. Bioclimatic map of Tunisia. Source: Chelbi et al. (2009).

3. Results

3.1. Water footprint of national production

The total water footprint (WF) of Tunisian production was about 19 Gm^3/yr (89% green, 8% blue, 3% grey; see Table 3) over the period 1996-2005. The WF of crop production gave the largest contribution to the total WF of production (87%), followed by grazing (11%). The remaining part (2%) represents domestic water supply, livestock production and industrial activities.

Table 3. The national water footprint of Tunisia and its components (Mm^3/yr). Period 1996-2005.

	Water footprint of crop production	Water footprint of grazing	Water footprint of animal water supply	Water footprint of industrial production	Water footprint of domestic water supply	Total water footprint
Green	14820	2000	-	-	-	16820
Blue	1330	-	60	10	40	1440
Grey	450	-	-	50	220	720
Total	16600	2000	60	60	260	19000

Source: Mekonnen and Hoekstra (2011a).

Considering the WF of crops per unit of weight (m^3/ton), pistachios had the largest WF, about 98000 m^3/ton, which is much more than the global average of 11000 m^3/ton. The smallest WF of crops was found for lettuce and chicory, about 80 m^3/ton, which is less than the world global average (200 m^3/ton) (Appendix I).

The WFs of the main crops in terms of total national production are listed in Table 4. The listed crops represent 86% of the total blue WF of crop production. Among these crops, almonds have the largest WF per unit of weight, about 20820 m^3/ton, which is more than twice the global average WF for almonds. Tunisian almonds use about four times more green water compared to the global average, while they consume about the global average amount of blue water. Tomatoes have the smallest WF with 120 m^3/ton, which is below the global average (210 m^3/ton). Dates, almonds, figs and grapes are the biggest blue water users with 3270, 1950, 1740 and 1080 m^3/ton respectively. These figures are higher than the global average, especially for grapes, which uses ten times the global average amount of blue water.

Olives alone account for about 46% of the total WF of crop production in Tunisia. About 79% of the total green WF is due to the production of olives (7270 Mm^3/yr), wheat (3170 Mm^3/yr) and barley (1220 Mm^3/yr) (Appendix II). The total blue WF is dominated by dates and olives (together 47%) and, to a lesser extent grapes, wheat and almonds.

Table 4. The average green, blue and grey water footprint of main crops in Tunisia (1996-2005).

Crop	Total water footprint (Mm^3/yr)				Water footprint per ton of crop (m^3/ton)				Global average water footprint (m^3/ton)			
	Green	Blue	Grey	Total	Green	Blue	Grey	Total	Green	Blue	Grey	Total
Almonds	790	90	50	930	17760	1950	1110	20820	4630	1910	1510	8050
Barley	1220	30	60	1310	3560	80	180	3820	1210	80	130	1420
Carrots	10	30	2	40	260	530	30	820	110	30	60	200
Dates	110	350	10	470	1030	3270	80	4390	930	1250	100	2280
Figs	70	40	4	120	2810	1740	170	4720	1500	1540	280	3280
Grapes	70	130	10	200	550	1080	60	1690	430	100	90	610
Olives	7270	270	30	7570	8790	330	40	9150	2470	500	50	3010
Oranges	40	20	2	70	370	230	20	620	400	110	50	560
Potatoes	40	40	10	80	110	120	20	260	190	30	60	290
Tomatoes	50	40	10	100	60	50	10	120	110	60	40	210
Wheat	3170	100	150	3420	2380	70	110	2560	1280	340	210	1830

Source: Mekonnen and Hoekstra (2011a). Note that ton refers to metric ton.

3.2. Water footprint of crop production at sub-national level

The total water footprint of crop production in Tunisia is about 16.6 Gm^3/yr. In this total, green water takes the biggest share (89%), while the blue and grey components contribute 8% and 3% respectively. North Tunisia takes the biggest share in the total WF of crop production (70%), followed by Central (26%) and South (4%) (Table 5; Figure 4). Kairouan in Central Tunisia is the governorate with the largest crop-related WF, with 2.2 Gm^3/yr, which represents 13% of the crop-related WF in the whole country and half of the Central Tunisian WF. The governorates in the surroundings of the river basin Medjerda, such as Beja, Jandouba, Kef and Siliana, had the largest WF in the North of the country and together account for almost 7 Gm^3/yr, which represent 43% of the total WF of crop production in Tunisia. Regarding blue water, North Tunisia has the biggest share in the total blue WF, with 650 Mm^3/yr, which represent 49% of the total blue WF of crop production in the country. South and Central Tunisia follow with 28% and 23% respectively. In South Tunisia, the driest part of the country, the total WF of crop production is dominated by blue water (with a contribution of 68%). The governorates Gabes and Tozeur have the biggest blue WF, mainly because of the production of dates.

Table 6 shows the WF per unit of weight for the most important crops, averaged over the regions North, Central and South. There is a clear difference in WFs and crop water requirements between the three regions. While the difference between North and Central is not so big, results for North and South differ considerably, especially for olives, wheat, almonds, figs and barley. In terms of the blue WF, a unit of wheat or barley grown in South Tunisia uses almost 12 times more blue water than the same crop grown in North, largely because irrigation is the dominant production system in South, whereas rain-fed production is dominant in Central and North. Almond and figs grown in Central Tunisia use less blue water than in the other regions, while tomatoes and carrots grown in South Tunisia have the smallest blue WF per ton.

Table 5. The total water footprint of crop production in Tunisia by governorate (1996-2005).

Governorate*	Water footprint of crop production (Mm^3/yr)			
	Green	Blue	Grey	Total
Ariana	730	140	30	910
Beja	1500	70	50	1620
Bizerte	1110	100	50	1260
Jendouba	1140	90	40	1270
Kef	1930	40	60	2030
Nabeul	960	120	30	1120
Siliana	1980	50	50	2080
Tunis	30	2	1	30
Zaghouan	1270	30	30	1330
North Tunisia	**10650**	**650**	**340**	**11640**
Kairouan	1990	160	50	2190
Kasserine	930	20	30	980
Mahdia	1	1	0	2
Monastir	70	3	1	80
Sfax	210	40	8	250
SidiBouzid	280	70	8	360
Sousse	520	9	7	540
Central Tunisia	**4000**	**290**	**100**	**4390**
Gabes	100	180	6	280
Gafsa	3	8	0	10
Kebili	2	9	0	10
Medenine	0	1	0	1
Tataouine	1	3	0	4
Tozeur	60	190	5	250
South Tunisia	**160**	**390**	**10**	**560**

Source: Mekonnen and Hoekstra (2011b).

* Tunisia is subdivided into 24 governorates; Manouba and Ben Arous are relatively new and are accounted in this study under Tunis (the capital).

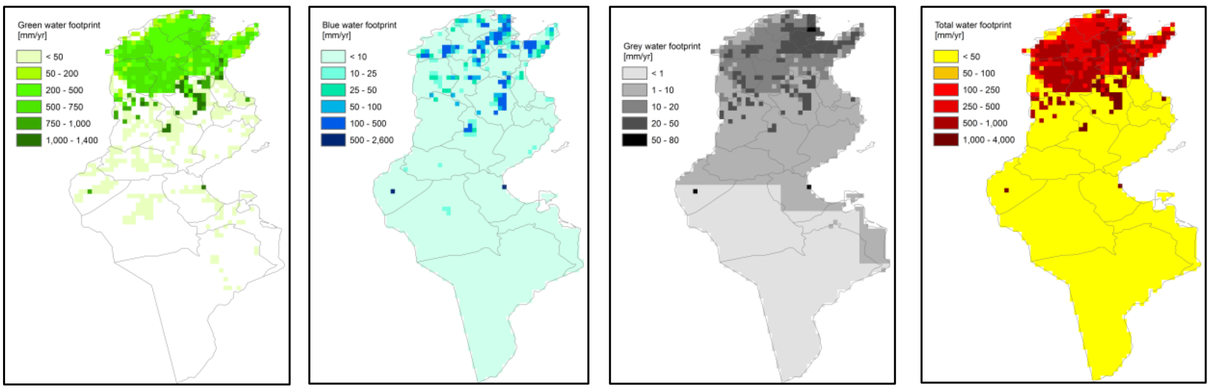


Figure 4. The green, blue, grey and total water footprint of crop production in Tunisia.

Table 6. The average green, blue and grey water footprint and crop water requirement of main crops in Tunisia per region (1996-2005).

	Crop	Water footprint per ton of crop (m^3/ton)				Total water footprint (Mm^3/yr)				Crop water requirement (m^3/ha)
		Green	Blue	Grey	Total	Green	Blue	Grey	Total	
North	Almonds	16590	2480	1010	20090	380	60	20	460	9220
	Barley	3520	90	180	3790	930	10	50	990	4570
	Carrots	290	500	40	820	10	20	1	30	6340
	Dates	-	-	-	-	-	-	-	-	-
	Figs	2840	1680	170	4690	60	40	4	110	7780
	Grapes	780	1120	70	1970	30	40	3	70	7160
	Olives	8650	400	40	9080	4660	170	20	4850	8150
	Oranges	370	220	20	610	40	20	2	60	7780
	Potatoes	130	110	20	260	30	40	10	70	3550
	Tomatoes	70	40	10	120	40	30	10	70	3510
	Wheat	2360	90	110	2550	2820	70	130	3020	4980
Central	Almonds	18290	1490	1200	20980	410	30	30	470	9550
	Barley	3470	240	200	3910	290	10	20	320	4710
	Carrots	490	380	70	940	3	7	0	10	6650
	Dates	-	-	-	-	-	-	-	-	-
	Figs	3460	1200	220	4880	10	10	1	10	8030
	Grapes	700	1300	70	2060	30	50	3	90	7510
	Olives	8840	470	40	9350	2580	100	10	2690	8420
	Oranges	370	240	20	630	3	3	0	10	8020
	Potatoes	110	130	20	270	10	20	0	40	3660
	Tomatoes	80	40	10	120	10	10	2	20	3640
	Wheat	2350	230	120	2710	350	20	20	390	5120
South	Almonds	20810	2330	2080	25220	10	1	1	10	11780
	Barley	3770	1050	310	5130	2	1	0	3	6070
	Carrots	670	30	150	860	0	0	0	0	7760
	Dates	1040	3290	80	4390	110	350	10	470	13350
	Figs	4940	820	500	6260	0	0	0	0	9920
	Grapes	450	1870	70	2380	10	30	1	40	8730
	Olives	10750	930	80	11760	30	3	0	40	10390
	Oranges	210	510	30	750	0	0	0	0	9480
	Potatoes	70	210	30	310	0	0	0	0	4310
	Tomatoes	150	1	20	170	0	0	0	0	4500
	Wheat	2780	1230	210	4220	3	1	0	4	6610

Source: Mekonnen and Hoekstra (2011b).

3.3. Blue water footprint of crop production in the context of blue water availability

Tunisia has limited water resources, estimated at 4.87 Gm^3/yr in 2005, of which 4.26 Gm^3/yr are renewable (Ministry of Environment, 2009). The remaining part, 610 Mm^3/yr, is fossil groundwater situated in South Tunisia, and expected to be exhausted in about 50 years at the current extraction rate (FAO, 2003).

The total renewable surface water (TRSW) was estimated at 2.70 Gm^3/yr (Table 7). This amount represents the average calculated over a 50-year period. Surface water contributions come from four distinct natural regions. The far northern part of North Tunisia, with only 3% of the total Tunisian land area, has on average about 960 Mm^3/yr of TRSW, which is about 36% of the national total. The basins of Majerda and Melian in North Tunisia provide an average of 1.23 Gm^3/yr (45% of the national total). Central Tunisia, including the watersheds Nebhana, Marguellil, Zeroud and Sahel, has an average TRSW of 320 Mm^3/yr (12%). South Tunisia, which represents about 62% of the total national land area, has very irregularly available surface water resources, averaging 190 Mm^3/yr, or 7% of the national TRSW (Ministry of Environment, 2009).

The total groundwater resources are estimated at 2.17 Gm^3/yr in 2005 (Ministry of Environment, 2009), of which 750 Mm^3/yr are from shallow aquifers (depth less than 50 m) and 1420 Mm^3/yr from deep aquifers (deeper than 50 m) of which 610 Mm^3/yr are non-renewable. The total renewable groundwater is thus 1560 Mm^3/yr. North Tunisia has 50% of the shallow aquifer resources; Central Tunisia contains 33%, while South contains 17%. Regarding deep aquifers, South has the biggest share (55%), followed by Central (23%) and North (22%).

In 2005, the total fresh water withdrawal in Tunisia reached 2.65 Gm^3/yr, consisting of 0.70 Gm^3/yr surface water withdrawal and 1.95 Gm^3/yr groundwater withdrawal (Ministry of Environment, 2009). Not all abstracted water evaporates, so that part of the water used remains available in the country for reuse. When we want to compare water use to available water resources, it is better to compare the consumptive water use, i.e. the blue water footprint, to the available water resources. On a national scale, the total blue water footprint of crop production is 1.33 Gm^3/yr, against a total renewable blue water resources of about 4.26 Gm^3/yr. The total blue WF of crop production thus represents 31% of the total renewable blue water resources, which means that Tunisia experiences ‘significant water scarcity’ according to international standards. Note that we include in this analysis only the blue WF related to crop production, but this contributes 93% to the total blue WF in the country, so we underestimate water scarcity only slightly.

It is estimated that, at national scale, 73% of the blue WF of crop production relates to groundwater consumption, while 27% refers to surface water consumption. The blue WF that specifically relates to groundwater consumption represents 62% of the total renewable groundwater resources, which means that the country is facing severe water scarcity related to groundwater (Table 7).

At regional level, the highest overall water scarcity occurs in South Tunisia (severe scarcity of 78%), followed by Central (significant scarcity of 32%) and North (moderate water scarcity of 23%). In terms of groundwater, all regions of the country experience severe water scarcity, with a scarcity of 47% in both North and Central and 123% in South Tunisia. The latter means that consumptive use of groundwater exceeds the renewable groundwater available in this region.

It is to be observed that the water scarcity figures presented here are calculated on an annual rather than a monthly basis. As noted by Hoekstra et al. (2012), this may lead to an underestimation of scarcity as experienced in the drier parts of the year, particularly because of the variability in available surface water resources within the year. For estimating groundwater scarcity, the annual approach will generally suffice because of the relatively long residence time and buffering capacity of groundwater systems. Groundwater scarcity figures are possibly underestimated, though, because return flows in groundwater-based irrigation are here assumed to return to the groundwater system from which abstraction took place, while part of the return flow may be surface runoff.

Table 7. Blue water footprint of crop production in the context of blue water availability.

	Blue water footprint (Mm^3/yr)			Blue water resources (Mm^3/yr)					Water scarcity (%) [e]	
				Renewable blue water resources			Fossil [d]	Total		
	Ground-water [a]	Surface water [a]	Total [b]	Ground-water [d]	Surface water [c]	Total			Ground-water	Overall
North	320	330	650	680	2190	2870		2870	47	23
Central	270	20	290	570	320	890		890	47	32
South	380	10	390	310	190	500	610	1110	123	78
Total	970	360	1330	1560	2700	4260	610	4870	62	31

Sources:

[a] Based on WF data from Mekonnen and Hoekstra (2011b) and ratios of surface water withdrawal to groundwater withdrawal per region from Ministry of Agriculture (2005a,b). Using the surface/groundwater ratios for withdrawals for estimating the surface/groundwater ratios for blue WFs implicitly assumes that the fractions of return flow are similar for surface and groundwater abstractions.

[b] Mekonnen and Hoekstra (2011b)

[c] Ministry of Environment (2009)

[d] Ministry of Agriculture (2005b)

[e] Own elaboration

3.4. *Economic water and land productivity at national level*

An analysis of water management in a Mediterranean country must have a focus on irrigated agriculture (Garrido et al., 2009). Although irrigated land accounts to only 7% of the total cultivated land in Tunisia (Chahed et al., 2008), it contributes to more than 35% of the total production of the agricultural sector and accounts for more than 80% of the total water withdrawal in the country (Ministry of Environment, 2009).

Based on producer prices, Table 8 presents the economic water productivity (EWP) of main crops in Tunisia, for both rain-fed and irrigated agriculture. In the case of irrigated agriculture, we distinguish between green and blue EWP. For the listed crops, the average EWP in Tunisian crop production is around 0.32 US$/m^3, which is slightly less than the figure found in a study for Spain by Garrido et al. (2009), who found an average value of around 0.25 €/m^3, which is equivalent to about 0.35 US$/m^3. The average EWP in Tunisian rain-fed agriculture (0.35 US$/m^3) was a bit higher than for irrigated agriculture (0.32 US$/m^3). For several of the selected crops, EWP in rain-fed and irrigated production systems are found to be very similar. In the case of carrots and potatoes, however, total EWP is larger in irrigated agriculture than in rain-fed agriculture. For dates and tomatoes, we found the reverse.

In irrigated agriculture, the blue water applied is not always more productive than the green water. For carrots, potatoes and tomatoes the blue EWP in irrigated agriculture was found to be higher than the green EWP, but for dates and grapes the reverse was found. While most of the blue water in Tunisia is consumed in dates, grapes, olives and wheat production (Table 4), the blue EWP of these crops is low when compared to potatoes and tomatoes, which have the highest blue EWPs, with 0.97 and 1.13 US$/m^3 respectively.

Table 8. Physical and economic water productivity of main crops in Tunisia at national level (1996-2005).

Crop	Physical water productivity (kg/m^3)[a]					Producer price (US$/kg)[b]	Economic water productivity (US$/m^3)[c]				
	Total (green) WP in rain-fed agric.	Green WP in irrigated agric.	Blue WP in irrigated agric.	Total WP in irrigated agric.	Average WP in irrigated & rain-fed agric.		Total (green) EWP in rain-fed agric.	Green EWP in irrigated agric.	Blue EWP in irrigated agric.	Total EWP in irrigated agric.	Average EWP in irrigated & rain-fed agric.
Almonds	0.05	0.05	0.05	0.05	0.05	1.70	0.09	0.09	0.09	0.09	0.09
Barley	0.28	0.24	0.31	0.27	0.28	0.14	0.04	0.03	0.04	0.04	0.04
Carrots	1.04	1.00	1.40	1.27	1.27	0.13	0.14	0.13	0.19	0.17	0.17
Dates	0.40	0.61	0.11	0.23	0.23	1.01	0.40	0.62	0.11	0.23	0.23
Figs	0.22	0.22	0.22	0.22	0.22	0.47	0.10	0.10	0.10	0.10	0.10
Grapes	-	0.79	0.52	0.61	0.61	0.32	-	0.25	0.17	0.20	0.20
Olives	0.11	0.11	0.11	0.11	0.11	0.32	0.03	0.03	0.03	0.03	0.03
Oranges	1.69	1.68	1.68	1.68	1.68	0.34	0.58	0.58	0.58	0.58	0.58
Potatoes	3.86	3.75	4.72	4.27	4.24	0.21	0.80	0.77	0.97	0.88	0.87
Tomatoes	10.75	8.77	9.62	9.17	9.24	0.12	1.26	1.03	1.13	1.07	1.08
Wheat	0.41	0.40	0.50	0.44	0.41	0.24	0.10	0.09	0.12	0.10	0.10

Sources:

[a] Own elaboration based on data from Mekonnen and Hoekstra (2010)

[b] FAOSTAT (FAO, 2009)

[c] Own elaboration

Table 9 presents economic land productivity (ELP), again distinguishing between rain-fed and irrigated agriculture. In terms of total ELP, oranges, tomatoes and dates had the highest ELPs, with 4040, 3770 and 3080 US$/ha respectively, while barley and olives had the lowest ELPs, with 130 and 170 US$/ha respectively.

Economic land productivity is higher in irrigated agriculture than in rain-fed agriculture for all selected crops. Given the fact that, on average, economic *water* productivities in irrigated agriculture are *not* higher than in rain-fed agriculture, one can conclude that irrigation water is generally not applied to increase water productivity (US$/m^3) but rather to increase land productivity (US$/ha). Enlarging the irrigated area for the listed crops will increase land productivity. But, since water is a limiting factor in production, it may be most beneficial to increase irrigated areas only for crops with high economic water productivity and for which the difference between ELP in rain-fed and irrigated agriculture is considerable, like for example potatoes.

Dates and oranges had relatively low economic water productivities (0.23 and 0.58 US$/ m^3 respectively) as compared to potatoes (0.87 US$/ m^3) (see Table 8), but the ELPs for dates and oranges were higher (3080 and 4040 US$/ha respectively) than the ELP for potatoes (2870 US$/ha).

At a national level, the figures on economic *water* productivities (Table 8) provide little basis for understanding or explaining current cropping patterns. The figures on economic *land* productivities give a better basis for understanding, because various of the crops with large production volumes (especially tomatoes, potatoes, oranges and dates) have a relatively high ELP. The main exceptions are wheat, barley and olives, that have large production volumes but low ELP (and also low EWP).

Table 9. Yield and economic land productivity of main crops in Tunisia at national level (1996-2005).

Crop	Yield (ton/ha)[a]					Producer price (US$/ton)[b]	Economic land productivity (US$/ha)[c]				
	Total (green) yield in rain-fed agric.	Green yield in irrigated agric.	Blue yield in irrigated agric.	Total yield in Irrigated agric.	Average yield in irrigated & rain-fed agric.		ELP in rain-fed agric.	Green-water based ELP in irrigated agric.	Blue-water based ELP in irrigated agric.	ELP in irrigated agric.	Average ELP in irrigated & rain-fed agric.
Almonds	0.23	0.22	0.26	0.48	0.25	1700	390	380	440	820	430
Barley	0.90	0.66	0.61	1.27	0.91	140	130	90	90	180	130
Carrots	2.41	1.98	6.00	7.98	7.69	130	320	270	800	1070	1030
Dates	1.20	1.20	1.87	3.07	3.05	1010	1210	1210	1890	3100	3080
Figs	0.98	0.93	0.78	1.72	1.53	470	460	442	370	810	720
Grapes	3.24	2.01	2.59	4.60	4.60	320	1040	650	830	1480	1480
Olives	0.51	0.49	0.41	0.90	0.53	320	160	150	130	280	170
Oranges	7.60	7.14	5.99	13.13	11.75	340	2610	2460	2060	4520	4040
Potatoes	6.74	5.84	9.30	15.14	13.95	210	1390	1200	1920	3120	2870
Tomatoes	22.20	17.03	15.81	32.84	32.18	120	2600	1990	1850	3840	3770
Wheat	1.54	1.23	0.99	2.21	1.58	240	370	290	240	530	370

Sources:

[a] Own elaboration based on data from Mekonnen and Hoekstra (2010)

[b] FAOSTAT (FAO, 2009)

[c] Own elaboration

3.5. Economic water and land productivity at sub-national level

Tables 10 and 11 show economic water and land productivities, respectively, for the main crops at regional level. North and Central Tunisia have similar economic water productivities. South Tunisia has lower water productivities for the listed crops except for potatoes. North Tunisia has the highest economic land productivity (ELP) for all listed crops except for carrots, grapes and tomatoes. Central Tunisia has the highest ELP for carrots and tomatoes, while Central and South have similar ELP for grapes. South has the lowest ELP for all crops except for dates and grapes.

Table 10. Physical and economic water productivity of main crops in Tunisia at regional level (1996-2005).

	Crop	Physical water productivity (m^3/kg)[a]					Producer price[b] (US$/kg)	Economic water productivity (US$/$m^3$)[c]				
		Total (green) WP in rain-fed agric.	Green WP in irrigated agric.	Blue WP in irrigated agric.	Total WP in irrigated agric.	Average WP in irrigated & rain-fed agric.		Total (green) EWP in rain-fed agric.	Green EWP in irrigated agric.	Blue EWP in irrigated agric.	Total EWP in irrigated agric.	Average EWP in irrigated & rain-fed agric.
North	Almonds	0.05	0.05	0.05	0.05	0.05	1.70	0.09	0.09	0.09	0.09	0.09
	Barley	0.28	0.23	0.36	0.28	0.28	0.14	0.04	0.03	0.05	0.04	0.04
	Carrots	1.04	1.02	1.41	1.28	1.28	0.13	0.14	0.14	0.19	0.17	0.17
	Date	-	-	-	-	-	-	-	-	-	-	-
	Figs	0.22	0.22	0.22	0.22	0.22	0.47	0.10	0.10	0.10	0.10	0.10
	Grapes	-	0.81	0.56	0.66	0.66	0.32	-	0.26	0.18	0.21	0.21
	Olives	0.11	0.11	0.11	0.11	0.11	0.32	0.03	0.03	0.03	0.03	0.03
	Oranges	1.69	1.68	1.68	1.68	1.68	0.34	0.58	0.58	0.58	0.58	0.58
	Potatoes	3.86	3.75	4.71	4.28	4.25	0.21	0.80	0.77	0.97	0.88	0.88
	Tomatoes	10.72	8.84	9.67	9.21	9.29	0.12	1.25	1.03	1.13	1.08	1.09
	Wheat	0.41	0.40	0.51	0.44	0.41	0.24	0.10	0.10	0.12	0.10	0.10
Central	Almonds	0.05	0.05	0.05	0.05	0.05	1.70	0.08	0.09	0.09	0.09	0.09
	Barley	0.26	0.24	0.31	0.27	0.26	0.14	0.04	0.03	0.04	0.04	0.04
	Carrots	1.00	0.94	1.36	1.24	1.24	0.13	0.13	0.13	0.18	0.17	0.17
	Dates	-	-	-	-	-	-	-	-	-	-	-
	Figs	0.21	0.22	0.22	0.22	0.22	0.47	0.10	0.10	0.10	0.10	0.10
	Grapes	-	0.77	0.52	0.61	0.61	0.32	-	0.25	0.17	0.19	0.19
	Olives	0.11	0.11	0.11	0.11	0.11	0.32	0.03	0.03	0.03	0.03	0.03
	Oranges	1.67	1.68	1.68	1.68	1.68	0.34	0.58	0.58	0.58	0.58	0.58
	Potatoes	3.86	3.57	4.69	4.28	4.26	0.21	0.80	0.73	0.97	0.88	0.88
	Tomatoes	10.98	8.70	9.62	9.21	9.22	0.12	1.28	1.02	1.13	1.08	1.08
	Wheat	0.38	0.38	0.50	0.43	0.39	0.24	0.09	0.09	0.12	0.10	0.09
South	Almonds	0.04	0.04	0.04	0.04	0.04	1.70	0.07	0.07	0.07	0.07	0.07
	Barley	0.21	0.43	0.12	0.21	0.21	0.14	0.03	0.06	0.02	0.03	0.03
	Carrots	1.02	1.03	1.43	1.30	1.29	0.13	0.14	0.14	0.19	0.17	0.17
	Dates	0.40	0.61	0.11	0.23	0.23	1.01	0.40	0.62	0.11	0.23	0.23
	Figs	0.17	0.17	0.17	0.17	0.17	0.47	0.08	0.08	0.08	0.08	0.08
	Grapes	-	1.14	0.39	0.54	-	0.32	-	0.37	0.13	0.17	0.17
	Olives	0.09	0.09	0.09	0.09	0.09	0.32	0.03	0.03	0.03	0.03	0.03
	Oranges	1.45	1.39	1.39	1.39	1.40	0.34	0.50	0.48	0.48	0.48	0.48
	Potatoes	3.96	3.74	4.86	4.42	4.34	0.21	0.81	0.77	1.00	0.91	0.89
	Tomatoes	8.62	6.00	7.59	7.23	8.61	0.12	1.01	0.70	0.89	0.85	1.01
	Wheat	0.19	0.20	0.39	0.34	0.28	0.24	0.04	0.05	0.09	0.08	0.07

Sources:

[a] Own elaboration based on data from Mekonnen and Hoekstra (2010)

[b] FAOSTAT (FAO, 2009)

[c] Own elaboration

Table 11. Yield and economic land productivity of main crops in Tunisia at regional level (1996-2005).

	Crop	Yield (ton/ha)[a]					Producer price (US$/ton)[b]	Economic land productivity (US$/ha)[c]				
		Total (green) yield in rain-fed agric.	Green yield in irrigated agric.	Blue yield in irrigated agric.	Total yield in Irrigated agric.	Average yield in irrigated & rain-fed agric.		ELP in rain-fed agric.	Green-water based ELP in irrigated agric.	Blue-water based ELP in irrigated agric.	ELP in irrigated agric.	Average ELP in irrigated & rain-fed agric.
North	Almonds	0.24	0.23	0.25	0.48	0.36	1700	410	390	420	810	460
	Barley	0.90	0.63	0.63	1.27	1.08	140	130	90	90	180	130
	Carrots	2.35	2.05	5.92	7.96	5.16	130	320	270	790	1070	1020
	Dates	-	-	-	-	-	-	-	-	-	-	-
	Figs	0.99	0.95	0.77	1.72	1.35	470	470	450	360	810	740
	Grapes	3.24	2.20	2.38	4.58	3.91	320	1040	710	760	1470	1470
	Olives	0.52	0.50	0.39	0.90	0.71	320	160	160	120	280	170
	Oranges	7.50	7.23	5.89	13.12	10.31	340	2580	2490	2030	4510	4090
	Potatoes	6.95	5.92	9.23	15.14	11.05	210	1430	1220	1900	3120	2910
	Tomatoes	23.47	17.55	15.30	32.85	28.16	120	2750	2050	1790	3840	3750
	Wheat	1.51	1.28	0.94	2.22	1.86	240	360	300	220	530	380
Central	Almonds	0.22	0.21	0.27	0.48	0.35	1700	370	350	470	820	410
	Barley	0.81	0.60	0.66	1.27	1.04	140	110	80	90	180	120
	Carrots	2.14	1.77	6.24	8.02	5.08	130	290	240	840	1070	1060
	Dates	-	-	-	-	-	-	-	-	-	-	-
	Figs	0.91	0.84	0.88	1.72	1.31	470	430	400	420	810	670
	Grapes	-	2.10	2.51	4.62	4.62	320	-	680	810	1480	1480
	Olives	0.48	0.46	0.44	0.90	0.69	320	150	150	140	280	160
	Oranges	6.96	6.40	6.76	13.16	10.06	340	2390	2200	2330	4530	4040
	Potatoes	6.21	4.79	10.30	15.09	10.65	210	1280	990	2120	3110	2870
	Tomatoes	23.16	15.52	17.31	32.83	28.00	120	2710	1820	2030	3840	3830
	Wheat	1.30	1.07	1.14	2.21	1.76	240	310	250	270	520	340
South	Almonds	0.12	0.11	0.37	0.48	0.30	1700	210	190	630	820	230
	Barley	0.43	0.72	0.53	1.25	0.84	140	60	100	70	170	80
	Carrots	1.64	2.07	5.99	8.06	4.85	130	220	280	800	1080	970
	Dates	1.20	1.20	1.87	3.07	3.05	1010	1210	1210	1890	3100	3080
	Figs	0.44	0.40	1.32	1.72	1.08	470	210	190	620	810	240
	Grapes	-	1.93	2.68	4.61	4.61	320	-	620	860	1480	1480
	Olives	0.23	0.24	0.66	0.90	0.57	320	70	80	210	280	80
	Oranges	3.23	2.91	10.23	13.14	8.19	340	1110	1000	3520	4520	3360
	Potatoes	3.06	5.07	10.07	15.15	9.10	210	630	1050	2080	3120	2510
	Tomatoes	11.36	6.16	26.51	32.67	22.02	120	1330	720	3100	3820	1330
	Wheat	0.44	0.37	1.84	2.21	1.32	240	100	90	440	520	190

Sources:

[a] Own elaboration based on data from Mekonnen & Hoekstra (2010)

[b] FAOSTAT (FAO, 2009)

[c] Own elaboration

When comparing rain-fed and irrigated agriculture, we find that the ELP of irrigated lands is much higher than the ELP of rain-fed lands for all listed crops. In South Tunisia, which is much drier than North and Central, the blue-water based ELP in irrigated agriculture is higher for all crops than in North and Central, which illustrates the greater importance of irrigation water to yields in the South.

The same conclusion that we have drawn at the national level is valid at regional level: enlarging the irrigation areas will generally increase ELPs, particularly in the South. But primarily in the South, water availability is the key limiting factor in production, not land availability, so that optimizing EWP will be more advisable than optimizing ELP.

For South Tunisia it is especially attractive to grow dates, because the climate and growing conditions are very suitable for this crop; dates are not grown in North and Central. The ELP for dates is high as well, but the EWP is not. From the perspective of a most economic use of scarce freshwater resources in South, it is more attractive to grow potatoes, tomatoes and oranges than to grow dates.

The study of economic water and land productivity has a number of limitations that are mostly due to a lack of data. First, we assumed the producer price of crops to be the same for the Tunisian regions, where differences can somewhat affect the results at regional level. Second, we did not distinguish between prices for rain-fed and irrigated crops. Irrigated crops may have a higher price due to better control of the production process, which would translate into a higher economic water and land productivity in irrigated agriculture. Third, we calculate economic water and land productivity by multiplying physical productivity and price, while it is better to look at the value added per unit of production. Finally, we assumed full irrigation in irrigated agriculture, while in reality irrigation may (deliberately or involuntarily) be limited.

3.6. Virtual water flows related to trade in agricultural and industrial products

3.6.1. Tunisian virtual water import

The total gross virtual water import in the period 1996-2005 was 8100 Mm^3/yr (71% blue, 18% green and 11% grey, Table 12). The largest contribution (94%) related to import of crop products. Imports of animal products and industrial products contributed with 2% and 4% respectively. The economic value of imports was 10330 million US$/yr, of which 80% related to import of industrial products, 18% to import of crop products and 2% to import of animal products. The average cost of imported commodities per unit of virtual water imported was 1.28 US$/$m^3$.

Crops responsible for relatively large virtual water imports are cotton, wheat, soybean, maize, sugar and barley. The import of cotton products (mainly from France, Belgium and Italy) and wheat (mainly from Canada, France and Spain) were responsible for 2200 and 1850 Mm^3/yr, respectively (Table 13), which together represents 53% of the total virtual water imported. The total economic value of crop products imported by Tunisia was 1840 million US$/yr. About 51% of the total cost is related to import of cotton products and 16% to import of sugar products. The average cost of imported crops per unit of virtual water imported was 0.24 US$/$m^3$.

About 49% of the crop-related virtual water imports of Tunisia comes from Europe (Figure 5), mainly from France, Italy, Germany and Belgium; 17% comes from Latin America, 13% from Asia, 12% from North America and 1 % from Oceania. For animal products and industrial products, the biggest part of the virtual water imported, about 68% comes from Europe, mainly from France and Germany for animal products and from France and Italy for industrial products. Figure 5 summarizes the results per continent, where Latin America includes Mexico, and Europe includes Turkey and the Russian Federation.

Table 12. Tunisia's virtual water import and economic value of imports. Period: 1996-2005.

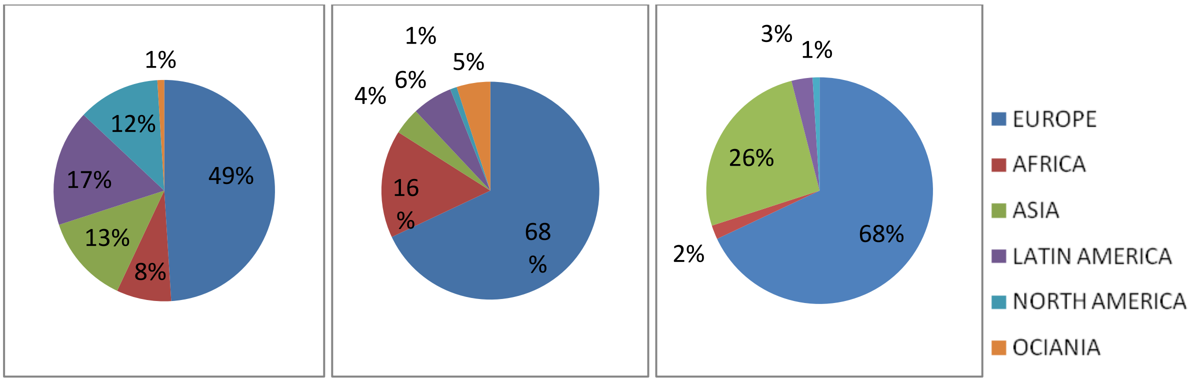
	Related to crop products	Related to animal products	Related to industrial products	Total virtual water imported
Green (Mm^3/yr)[a]	5610	140	-	5750
Blue (Mm^3/yr)[a]	1400	20	30	1450
Grey (Mm^3/yr)[a]	600	10	280	890
Total (Mm^3/yr)[a]	7610	170	310	8100
Economic value of imports (million US$/yr)[b]	1840	150	8330	10330
Value per unit of imported virtual water (US$/$m^3$)[c]	0.24	0.85	27.00	1.28

Sources:
[a] Hoekstra and Mekonnen (2012)
[b] ITC (2007)
[c] Own elaboration

Table 13. Imported crops with a large volume of virtual water. Period: 1996-2005.

Crop	% of the total virtual water imported [a]	Virtual water import (Mm^3/yr)[b]				Economic value (million US$/yr)[c]	Value per unit of imported water (US$/m3) [a]
		Green	Blue	Grey	Total		
Cotton	29%	1250	760	200	2210	940	0.40
Wheat	24%	1650	60	150	1850	200	0.10
Soybeans	15%	840	280	20	1140	140	0.10
Maize	8%	500	40	100	640	100	0.20
Sugar	7%	380	110	30	520	290	0.60
Barley	4%	300	10	30	340	40	0.10
Coffee	2%	180	1	2	190	10	0.10
Other	11%	520	140	70	730	130	0.20
Total	100%	5610	1400	600	7610	1840	0.25

Sources:
[a] Own elaboration
[b] Hoekstra and Mekonnen (2012)
[c] ITC (2007)



Virtual water import related to crop products | Virtual water import related to animal products | Virtual water import related to industrial products

Figure 5. Virtual water import of Tunisia specified by continent for the period 1996-2005. Source: based on data from Hoekstra and Mekonnen (2012).

3.6.2. Tunisian virtual water export

The total gross virtual water export in the period 1996-2005 was 9760 Mm^3/yr (88% blue, 5% green and 7% grey, Table 14). The export of crop products contributed most (95%) to the total virtual water export, followed by export of animal products (3%) and export of industrial products (2%). The export value was 9760 million US$/yr, of which 67% related to export of industrial products, 32% to export of crop products and 1% to export of animal products. Thus, Tunisia generated a foreign exchange of about 1.00 US$/$m^3$ on average.

Olive oil and cotton products were the main crop products, contributing 68% and 26% respectively to Tunisia's crop-related virtual water export (Table 15). The virtual water export related to the two crops was estimated at 6360 and 2380 Mm^3/yr, respectively. About 73% of the total green water exported was related to export of olive oil (6110 Mm^3/yr). The economic value of crop export was 3120 million US$/yr, whereby cotton export represented 89% of the total export earnings. The average earning per unit of crop-related virtual water export was 0.35 US$/$m^3$. The export of cotton products gives the highest earning per drop of water (1.20 US$/$m^3$), while export of wheat generates the lowest earning (0.02 US$/$m^3$). In terms of blue water, olive oil generates the highest earning per drop of water.

Tunisia is a net virtual water exporter related to cotton trade; the water footprint of exported cotton (2380 Mm^3/yr) exceeds the water footprint of imported cotton (2210 Mm^3/yr). The earning per unit of water in the case of cotton export (1.20 US$/$m^3$) is bigger than the cost per unit of water in the case of cotton import (0.40 US$/$m^3$), which can be explained by the fact that most of the cotton exported from Tunisia is a re-export of the imported cotton after processing to textile, yielding a value added.

On the other hand, Tunisia is a net virtual water importer related to trade in wheat. Gross virtual water import related to wheat import is 1850 Mm^3/yr, and gross virtual water export related to wheat export amounts to 190 Mm^3/yr. The export makes little sense, since the earning per unit of water for wheat exports (0.02 US$/$m^3$) is very low compared to other crops and also much lower than the cost per unit of water for imported wheat (0.10 US$/$m^3$).

About 85% of the crop-related virtual water export goes to Europe (Figure 6), mainly to Italy, Spain and France; 6% goes to Latin America, 4% to North America, 4% to Africa, and 1% to Asia. For animal products the biggest part goes to Africa (86%), mainly Libya, while for industrial products the biggest part is exported to Europe (88%), mainly to France, Italy and Germany.

Table 14. Tunisia's virtual water export and economic value of exports. Period: 1996-2005.

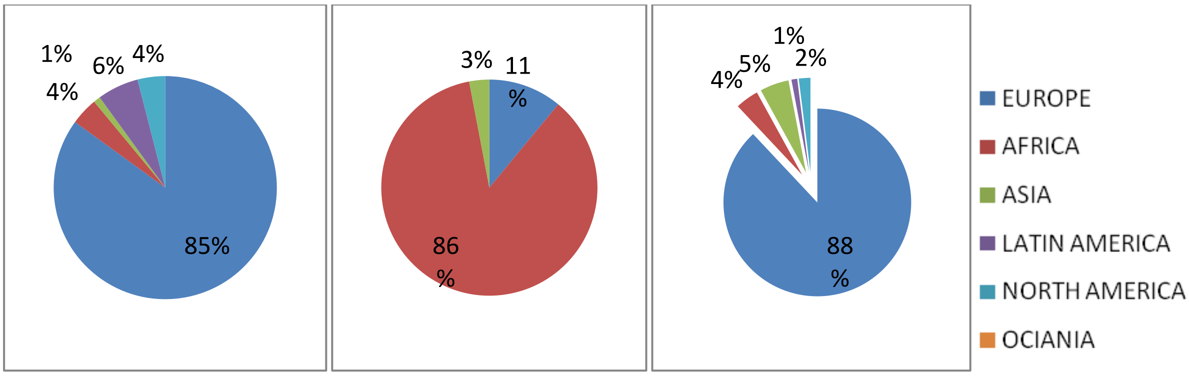
	Related to crop products	Related to animal products	Related to industrial products	Total virtual water exported
Green[a] (Mm^3/yr)	8320	260	-	8580
Blue[a] (Mm^3/yr)	400	40	10	460
Grey [a] (Mm^3/yr)	570	20	130	730
Total (Mm^3/yr)	9300	320	150	9760
Economic value of exports (million US$/yr)[b]	3120	20	6620	9760
Value per unit of exported water (US$/$m^3$)[c]	0.35	0.05	50	1.00

Sources:
[a] Hoekstra and Mekonnen (2012)
[b] ITC (2007)
[c] Own elaboration

Table 15. Exported crops with a large volume of virtual water. Period: 1996-2005.

Crop	% of the total virtual water exported [a]	Virtual water export (Mm^3/yr)[b]				Economic value (million US$/yr)[c]	Value per unit of exported water (US$/$m^3$)[a]		
		Green	Blue	Grey	Total		Green	Blue	Total
Olive oil	68%	6110	230	30	6360	230	0.03	1.00	0.04
Cotton	26%	1860	0	520	2380	2780	1.50	-	1.20
Wheat	2%	170	10	10	190	4	0.02	0.70	0.02
Dates	2%	40	120	3	160	70	1.80	0.60	0.40
Other	2%	140	60	20	220	50	0.30	0.90	0.20
Total	100%	8320	400	570	9300	3120	0.40	0.90	0.30

Sources:
[a] Own elaboration
[b] Hoekstra and Mekonnen (2012)
[c] ITC (2007)



Virtual water export related to crop products	Virtual water export related to animal products	Virtual water export related to industrial products

Figure 6. Virtual water export from Tunisia specified by continent for the period 1996-2005. Source: based on data from Mekonnen and Hoekstra (2010a, 2010b).

3.7. Water saving through virtual water trade

Even though Tunisia had a net virtual water export of 1660 Mm^3/yr in the period 1996-2005, the country saved water through trade. This can be understood as follows. Tunisia had a total gross virtual water export of 9760 Mm^3/yr. This is the volume of water that the country 'lost' (between brackets, because foreign currency came in return of course). The country had a gross virtual water import of 8100 Mm^3/yr. This is the volume of water used in other countries to produce commodities for Tunisian consumption. If Tunisia had produced the imported commodities domestically, however, it would have taken more water, namely 10700 Mm^3/yr, due to lower water productivities in Tunisia compared to countries from where Tunisia received its imports. So, whereas the country 'lost' 9760 Mm^3/yr, it 'saved' 10700 Mm^3/yr. The resultant net water saving was 940 Mm^3/yr (62% green, 3% blue and 35% grey). Trade in crop products was responsible for the largest part of the total water saving (58%), followed by trade in animal products (38%) and industrial products (4%). Table 16 shows the contributions of the different product groups to the total water savings.

Regarding blue water, only trade in animal and industrial products resulted in net blue water saving (20 and 4 Mm^3/yr, respectively). Trade in crop products resulted in a net blue water loss of 1 Mm^3/yr. Concerning green water, the largest amount of green water saved (320 Mm^3/yr) related to trade in animal products.

Table 16. Water saving in Tunisia through trade (Mm^3/yr) in the period 1996-2005.

	Green	Blue	Grey	Total
Related to trade in crop products	270	-1	280	540
Related to trade in animal products	320	20	10	360
Related to trade in industrial products	-	4	40	40
Total	590	30	330	940

Source: Mekonnen and Hoekstra (2011a).

3.8. The water footprint of consumption

The water footprint (WF) of Tunisian consumption was 2200 m^3/yr per capita over the period 1996-2005, which is about 60% larger than the world average of 1390 m^3/yr (Hoekstra and Mekonnen, 2012). Consumption of agricultural products largely determines the total WF related to consumption, contributing 98% to the total WF. Consumption of industrial products and domestic water supply contribute only 1% each.

In total terms, the WF of Tunisian consumption was 21 Gm^3/yr (81% green, 12% blue and 7% grey). Wheat was the product with the single largest contribution, with 480 m^3/yr per capita (91% green, 3% blue, 6% grey). Table 17 shows the top-five of products with the largest contribution to the WF of Tunisian consumption. The external component of the WF consumption was 6810 Mm^3/yr (70% green, 19% blue, 11% grey), which represents 32% of the total WF, while the internal component was 14220 Mm^3/yr (87% green, 8% blue, 5% grey) (Figure 7). In terms of its water needs, Tunisia has a particular dependency on Europe; the largest part of the country's virtual water imports come from Italy, France and Germany.

Table 17. Top-five of products with the largest contribution to the water footprint of Tunisian consumption.

Product	Water footprint (m^3/yr/capita)			
	Green	Blue	Grey	Total
Wheat	440	10	30	480
Bovine meat	280	20	10	320
Olive oil	210	10	0	220
Meat, other	140	60	10	200
Milk and its products, excluding butter	130	20	10	160

Source: Mekonnen and Hoekstra (2011a).

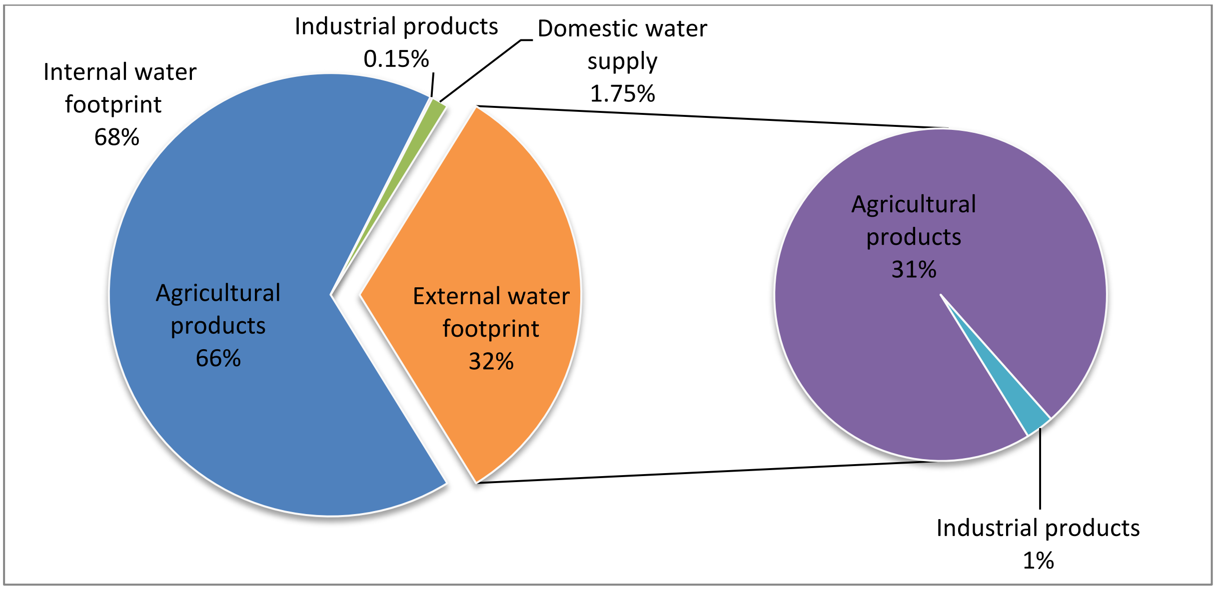


Figure 7. Composition of the water footprint of Tunisian consumption in the period 1996-2005. Source: based on data from Mekonnen and Hoekstra (2011a).

4. Conclusions

The water footprint (WF) of Tunisian production was 19 Gm^3/yr in the period 1996-2005. Green water had the biggest contribution (89%), but there are regional differences. Crops in South generally have a larger total WF and larger blue water fraction than in Central and North Tunisia, caused by differences in climate. South is an arid region, which explains why the WF in this region is dominantly blue.

The country suffers significant water scarcity, with a national blue WF of crop production amounting to 31% of the country's renewable blue water resources. South Tunisia experiences severe water scarcity, Central Tunisia significant scarcity and North Tunisia moderate scarcity. For groundwater in particular, all three regions experience severe water scarcity, with the worst situation in South, where the blue WF resting on groundwater exceeds renewable groundwater resources by an estimated 23%.

The overview of water productivities of different crops shows that 91% of the total blue WF of crop production in the country relates to crops produced at blue water productivities of less than 0.20 US$/$m^3$. Only tomatoes, potatoes and oranges show larger blue water productivities. The smallest blue water productivity is found for olives (0.03 US$/$m^3$), one of the major export products of the country.

Among the major crops grown in Tunisia, oranges, tomatoes and potatoes have relatively large economic water and land productivities. The same, but to a lesser extent, is true for dates, which are grown in South only. Relatively low economic water and land productivities are found for wheat, barley, almonds, olives and figs. It is further found that irrigation generally increases economic land productivity (US$/ha), but not water productivity (US$/$m^3$). The contribution of blue water to economic land productivity is largest in the dry South.

Relatively large virtual water imports relate to imports of cotton, sugar and cereal crops, mainly from Europe. Olive oil and cotton are the crop products contributing most to virtual water export. The average cost of imported crops per unit of virtual water imported was 0.24 US$/$m^3$, while the earning of exported crops per unit of virtual water exported was 0.34 US$/$m^3$. Gross virtual water export from Tunisia exceeds gross virtual water import, but at least the benefit per drop of water used for making export products is larger than the cost per drop of water in import products.

Tunisia is not water self-sufficient with 32% of its total WF of consumption outside its borders, mostly in Europe. Given the water scarcity in the country it is unlikely that the country will be able to decrease its dependency on external water resources.

The results of this study show that the scarce Tunisian water resources have mainly been allocated to uses with low economic productivity; this could be the result of the agricultural policy followed by the Tunisian government. Over the last forty years, Tunisia's agricultural policy focussed on ensuring food security. by encouraging the production of staple crops such as wheat, barley and olive oil and livestock products such as milk and meat. This policy intended to ensure a lower price for those products than the international market price

(Ministry of Agriculture, 2002). However, in the last few years, Tunisian authorities have started to re-think the country's agricultural policy and integrate it with the management of its scarce water resources. By the end of 1999, Tunisia signed a free trade agreement with the EU, encouraging imports in the agricultural sector (Ministry of Agriculture, 2002). Where market conditions exist and staple foods may be supplied from other sources, farmers can be encouraged to shift from low-value to high-value crops and increase the economic productivity of water in agriculture (FAO, 2012).

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

Period 1996-2005

Product code (FAOSAT)	Product description (FAOSTAT)	North				Central				South				Tunisia average				World average			
		Green	Blue	Grey	Total	Green	Blue	Grey	Total	Green	Blue	Grey	Total	Green	Blue	Grey	Total	Green	Blue	Grey	Total
15	wheat	2357	85	110	2552	2351	231	123	2705	2781	1227	211	4219	2375	72	109	2556	1277	342	207	1826
44	Barley	3519	86	180	3785	3469	241	197	3907	3774	1047	306	5127	3561	75	181	3817	1213	79	131	1423
75	Oats	26739	11325	1511	39575	27846	11058	1688	40592	40976	193	3437	44606	24687	13776	1458	39921	1479	181	128	1788
83	Sorghum	10068	3520	506	14094	8048	5338	482	13868	10693	4158	833	15684	9708	3958	493	14159	2857	103	87	3047
97	Triticale	801	0	90	891	793	3	90	886	984	0	97	1081	803	1	89	893	826	38	89	953
108	Cereals,nes	227	2278	0	2505	2640	1983	0	4623	4636	23	0	4659	1907	2676	0	4583	3316	115	9	3440
116	Potatoes	125	112	21	258	110	134	22	266	65	213	28	306	114	122	20	256	191	33	63	287
157	Sugar beet	52	49	28	129	44	50	28	122	0	0	0	0	54	47	28	129	82	26	25	133
176	Beans, dry	2524	97	465	3086	2242	194	457	2893	1422	318	454	2194	2510	102	455	3067	3945	125	983	5053
181	Broad beans, horse	1961	85	378	2424	1722	232	377	2331	1128	226	433	1787	1978	64	372	2414	1317	205	496	2018
187	Peas, dry	2868	65	426	3359	3175	88	526	3789	2770	606	724	4100	2899	55	424	3378	1453	33	493	1979
191	Chick peas	2962	25	456	3443	3074	143	548	3765	3455	1158	924	5537	2941	15	458	3414	2972	224	981	4177
201	Lentils	5860	254	736	6850	5701	267	780	6748	2758	1145	699	4602	5915	224	725	6864	4324	489	1060	5873
205	Vetches	2620	60	404	3084	2833	163	494	3490	2171	367	624	3162	2613	60	396	3069	2031	109	213	2353
211	Pulses nes	1682	50	264	1996	1850	65	324	2239	1226	345	353	1924	1697	43	262	2002	2217	250	650	3117
221	Almonds, with shell	16598	2484	1005	20087	18290	1488	1201	20979	20813	2330	2079	25222	17763	1950	1105	20818	4632	1908	1507	8047
223	Pistachios	69228	27982	4876	102086	73679	15743	5599	95021	58373	8713	7827	74913	80863	12022	5480	98365	3095	7602	666	11363
260	Olives	8652	396	36	9084	8839	467	39	9345	10752	928	76	11756	8790	325	37	9152	2470	499	45	3014
267	Sunflower seed	3069	0	23	3092	3091	0	24	3115	3212	0	40	3252	3093	0	23	3116	3017	148	201	3366
270	Rapeseed	4127	0	30	4157	4183	0	32	4215	4111	0	51	4162	4173	0	30	4203	1703	231	336	2270
328	Seed cotton	2505	0	738	3243	395	0	129	524	0	0	0	0	2515	0	736	3251	2282	1306	440	4028
333	Linseed	1359	15	0	1374	1337	44	0	1381	1500	2	0	1502	1349	25	0	1374	4730	268	170	5168
358	Cabbages and other brassicas	185	185	21	391	232	143	27	402	359	10	79	448	175	200	20	395	181	26	73	280
366	Artichokes	625	87	37	749	540	200	36	776	353	397	53	803	614	106	36	756	478	242	98	818
372	Lettuce and chicory	59	4	11	74	57	7	12	76	73	0	22	95	58	6	11	75	133	28	77	238
373	Spinash	114	12	22	148	110	16	23	149	144	0	45	189	110	17	21	148	118	14	160	292

Product code (FAOSAT)	Product description (FAOSTAT)	North				Central				South				Tunisia average				World average			
		Green	Blue	Grey	Total	Green	Blue	Grey	Total	Green	Blue	Grey	Total	Green	Blue	Grey	Total	Green	Blue	Grey	Total
388	Tomatoes	69	39	8	116	76	36	9	121	149	1	23	173	60	48	8	116	108	63	43	214
393	Cauliflowes and brocolli	82	4	15	101	79	7	15	101	99	0	28	127	80	6	15	101	189	21	75	285
394	Pumpkins squash and grouds	153	2	31	186	151	4	31	186	152	37	33	222	153	2	31	186	228	24	84	336
397	Cumcumbers and gherkins	92	95	13	200	125	73	18	216	252	7	53	312	87	102	12	201	206	42	105	353
399	Eggplants (aubergines)	134	4	18	156	131	6	18	155	174	1	27	202	133	5	18	156	234	33	95	362
401	Chillies and peppers, green	158	5	22	185	156	7	23	186	214	0	40	254	157	7	22	186	240	42	97	379
402	Onions (inc. shallots), green	62	12	12	86	62	13	13	88	106	0	34	140	59	15	12	86	176	44	51	271
403	Onions, dry	199	66	17	282	214	62	21	297	422	8	77	507	189	77	17	283	192	88	65	345
406	Garlic	1110	407	104	1621	1201	374	123	1698	2371	61	462	2894	1054	469	102	1625	337	81	170	588
414	Beans, green	187	2	41	230	181	9	42	232	252	0	75	327	186	5	42	233	320	54	188	562
417	Peas, green	309	4	54	367	295	16	55	366	411	1	90	502	304	9	54	367	382	63	150	595
426	Carrots and turnips	285	500	35	820	487	384	65	936	674	29	152	855	260	529	33	822	106	28	61	195
463	Vegetables fresh nes	147	6	21	174	143	9	22	174	205	1	46	252	144	9	21	174	205	33	101	339
490	Oranges	373	218	22	613	374	235	24	633	214	506	26	746	367	228	22	617	401	110	49	560
495	Tangerines, mandarins, clem.	551	322	33	906	553	348	36	937	317	748	38	1103	543	337	32	912	479	118	152	749
497	Lemons and limes	305	178	18	501	306	192	20	518	175	414	21	610	311	193	18	522	432	152	58	642
507	Grapefruit (inc.pomelos)	233	136	14	383	235	147	15	397	133	315	16	464	229	142	14	385	367	85	54	506
512	Citrus fruit, nes	456	260	27	743	459	280	29	768	264	610	32	906	445	276	26	747	1145	62	35	1242
515	Apples	1224	0	65	1289	1265	0	73	1338	1551	0	138	1689	1278	0	67	1345	561	133	127	821
521	Pears	1154	0	61	1215	1193	0	69	1262	0	0	0	0	1194	0	63	1257	645	94	183	922
526	Apricots	1720	0	93	1813	1785	0	105	1890	2191	0	198	2389	1761	0	98	1859	694	502	92	1288
531	Cherries	285	0	8	293	109	0	6	115	128	0	12	140	107	0	6	113	961	531	112	1604
534	Peaches and nectarines	1110	0	60	1170	1149	0	68	1217	1410	0	127	1537	1120	0	63	1183	583	188	139	910

Product code (FAOSAT)	Product description (FAOSTAT)	North				Central				South				Tunisia average				World average			
		Green	Blue	Grey	Total	Green	Blue	Grey	Total	Green	Blue	Grey	Total	Green	Blue	Grey	Total	Green	Blue	Grey	Total
536	Plums and sloes	1347	0	71	1418	1392	0	80	1472	1634	0	156	1790	1389	0	73	1462	1570	188	422	2180
541	Stone fruit, nes	935	0	50	985	956	0	56	1012	1122	0	108	1230	930	0	50	980	868	1049	136	2053
544	Strawberries	77	161	11	249	71	178	11	260	31	266	12	309	88	176	12	276	201	109	37	347
554	Cranberries	234	0	44	278	259	0	53	312	148	0	65	213	232	0	43	275	91	108	77	276
560	Grapes	781	1119	68	1968	706	1290	68	2064	447	1868	68	2383	554	1082	55	1691	425	97	87	609
567	Watermelons	226	11	19	256	236	10	21	267	345	0	38	383	226	13	19	258	150	25	63	238
568	Other melons (inc.cantaloupes)	123	2	24	149	121	3	24	148	154	0	29	183	124	2	24	150	125	29	67	221
569	Figs	2838	1677	171	4686	3455	1204	219	4878	4936	820	503	6259	2810	1744	167	4721	1504	1544	227	3275
572	Avocados	474	49	29	552	423	118	28	569	320	260	45	625	468	58	28	554	849	237	87	1173
577	Dates	0	0	0	0	0	0	0	0	1036	3285	84	4405	1032	3271	84	4387	930	1250	98	2278
592	Kiwi fruit	693	95	43	831	615	195	43	853	374	351	50	775	673	116	42	831	307	168	38	513
603	Fruit, tropical fresh nes	648	0	34	682	670	0	39	709	642	0	69	711	652	0	34	686	1455	200	172	1827
619	Fruit Fresh Nes	382	0	20	402	394	0	23	417	463	0	44	507	833	0	44	877	1199	201	112	1512
689	Chillies and peppers, dry	1820	242	117	2179	1629	501	117	2247	888	909	134	1931	1775	295	112	2182	5869	1125	371	7365
711	Anise, badian, fennel, corian.	2327	134	353	2814	2267	196	365	2828	3241	6	644	3891	2278	189	350	2817	5369	1865	1046	8280
723	Spices, nes	1977	127	262	2366	1894	219	278	2391	2957	8	698	3663	1913	198	260	2371	2735	242	390	3367
826	Tobacco, unmanufactured	2150	522	306	2978	2010	761	309	3080	1325	2161	312	3798	2096	593	306	2995	2021	205	700	2926

Source: Mekonnen and Hoekstra (2011)

Appendix II: The total water footprint of crop production (Mm^3/yr)

Product code (FAOSAT)	Product description (FAOSTAT)	North				Central				South				Tunisia Total			
		Green	Blue	Grey	Total	Green	Blue	Grey	Total	Green	Blue	Grey	Total	Green	Blue	Grey	Total
15	Wheat	2820,1	71,0	128,5	3019,6	350,7	23,9	17,5	392,0	2,5	1,1	0,2	3,8	3173,2	95,9	146,2	3415,3
44	Barley	926,4	14,4	46,6	987,3	289,3	10,7	15,2	315,2	2,2	0,6	0,2	3,0	1217,9	25,7	62,0	1305,6
75	Oats	19,7	9,8	1,1	30,7	4,9	4,0	0,3	9,3	0,0	0,0	0,0	0,0	24,7	13,8	1,5	39,9
83	Sorghum	9,1	3,5	0,5	13,0	0,6	0,5	0,0	1,2	0,0	0,0	0,0	0,0	9,7	4,0	0,5	14,2
97	Triticale	4,2	0,0	0,5	4,7	1,2	0,0	0,1	1,3	0,0	0,0	0,0	0,0	5,4	0,0	0,6	6,0
108	Cereals,nes	48,9	62,0	0,0	111,0	11,9	23,3	0,0	35,2	0,0	0,0	0,0	0,0	60,8	85,4	0,0	146,2
116	Potatoes	33,5	35,0	5,8	74,3	1,8	2,6	0,4	4,8	0,0	0,0	0,0	0,0	35,3	37,7	6,2	79,1
157	Sugar beet	4,4	3,9	2,3	10,5	0,0	0,1	0,0	0,1	0,0	0,0	0,0	0,0	4,4	3,9	2,3	10,7
176	Beans, dry	1,1	0,0	0,2	1,4	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,2	0,0	0,2	1,4
181	Broad beans, horse	68,1	2,1	12,8	83,0	1,1	0,1	0,2	1,4	0,0	0,0	0,0	0,0	69,2	2,3	13,0	84,5
187	Peas, dry	14,6	0,3	2,1	17,1	1,2	0,0	0,2	1,4	0,0	0,0	0,0	0,0	15,8	0,3	2,3	18,5
191	Chick peas	24,7	0,1	3,8	28,6	0,6	0,0	0,1	0,7	0,0	0,0	0,0	0,0	25,2	0,1	3,9	29,3
201	Lentils	4,7	0,2	0,6	5,5	0,4	0,0	0,0	0,4	0,0	0,0	0,0	0,0	5,1	0,2	0,6	5,9
205	Vetches	0,5	0,0	0,1	0,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,5	0,0	0,1	0,6
211	Pulses nes	37,3	1,0	5,7	44,0	3,0	0,1	0,5	3,6	0,0	0,0	0,0	0,0	40,4	1,0	6,2	47,6
221	Almonds, with shell	376,2	55,7	23,0	454,8	411,1	30,8	25,7	467,6	7,1	0,8	0,7	8,6	794,4	87,2	49,4	931,0
223	Pistachios	35,7	10,2	2,4	48,3	69,4	5,4	4,6	79,5	0,9	0,1	0,1	1,1	105,9	15,7	7,2	128,9
260	Olives	4660,8	170,3	19,1	4850,2	2581,5	95,6	11,3	2688,4	31,7	2,7	0,2	34,6	7274,0	268,6	30,6	7573,2
267	Sunflower seed	28,5	0,0	0,2	28,7	2,2	0,0	0,0	2,2	0,0	0,0	0,0	0,0	30,8	0,0	0,2	31,0
270	Rapeseed	7,9	0,0	0,1	7,9	1,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	8,8	0,0	0,1	8,9
328	Seed cotton	7,9	0,0	2,3	10,2	0,1	0,0	0,0	0,2	0,0	0,0	0,0	0,0	8,0	0,0	2,3	10,3
333	Linseed	5,0	0,1	0,0	5,0	1,4	0,1	0,0	1,4	0,0	0,0	0,0	0,0	6,3	0,1	0,0	6,5
358	Cabbages	1,8	1,9	0,2	3,9	0,5	0,7	0,1	1,3	0,0	0,0	0,0	0,0	2,3	2,7	0,3	5,3
366	Artichokes	9,7	1,2	0,6	11,5	1,0	0,6	0,1	1,7	0,0	0,0	0,0	0,0	10,7	1,9	0,6	13,2
372	Lettuce and chicory	0,7	0,1	0,1	0,9	0,2	0,0	0,0	0,3	0,0	0,0	0,0	0,0	0,9	0,1	0,2	1,2
373	Spinach	1,0	0,1	0,2	1,4	0,3	0,1	0,1	0,4	0,0	0,0	0,0	0,0	1,3	0,2	0,3	1,7

Product code (FAOSAT)	Product description (FAOSTAT)	North				Central				South				Tunisia Total			
		Green	Blue	Grey	Total	Green	Blue	Grey	Total	Green	Blue	Grey	Total	Green	Blue	Grey	Total
388	Tomatoes	39,9	29,1	5,1	74,1	11,2	11,3	1,6	24,1	0,0	0,0	0,0	0,0	51,1	40,4	6,7	98,3
393	Cauliflowers and broccoli	0,5	0,0	0,1	0,6	0,1	0,0	0,0	0,2	0,0	0,0	0,0	0,0	0,6	0,0	0,1	0,7
394	Pumpkins	4,7	0,1	0,9	5,6	0,6	0,0	0,1	0,8	0,0	0,0	0,0	0,0	5,3	0,1	1,1	6,5
397	Cucumbers	2,0	2,2	0,3	4,5	0,6	0,8	0,1	1,5	0,0	0,0	0,0	0,0	2,6	3,0	0,4	6,0
399	Eggplants (aubergines)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
401	Chillies and peppers, green	25,7	0,9	3,6	30,1	8,1	0,7	1,2	10,0	0,0	0,0	0,0	0,0	33,7	1,5	4,8	40,1
402	Onions (incl. shallots), green	6,0	1,3	1,2	8,5	1,5	0,6	0,3	2,5	0,0	0,0	0,0	0,0	7,5	2,0	1,5	11,0
403	Onions, dry	17,3	6,3	1,5	25,0	5,0	2,8	0,5	8,2	0,0	0,0	0,0	0,0	22,2	9,0	2,0	33,3
406	Garlic	5,1	2,0	0,5	7,6	1,5	0,9	0,2	2,5	0,0	0,0	0,0	0,0	6,6	2,9	0,6	10,1
414	Beans, green	0,4	0,0	0,1	0,4	0,1	0,0	0,0	0,1	0,0	0,0	0,0	0,0	0,5	0,0	0,1	0,6
417	Peas, green	3,9	0,1	0,7	4,6	1,0	0,1	0,2	1,3	0,0	0,0	0,0	0,0	4,9	0,1	0,9	5,9
426	Carrots and turnips	9,2	17,8	1,1	28,2	2,8	6,7	0,4	9,9	0,0	0,0	0,0	0,0	12,1	24,5	1,5	38,1
461	Carobs	0,0	0,0	0,0	0,0	3,6	0,1	0,1	3,8	0,0	0,0	0,0	0,0	3,6	0,1	0,1	3,8
463	Vegetables fresh nes	8,4	0,4	1,2	9,9	2,5	0,3	0,4	3,1	0,0	0,0	0,0	0,0	10,8	0,7	1,6	13,1
490	Oranges	35,9	21,6	2,1	59,5	3,3	2,7	0,2	6,3	0,0	0,1	0,0	0,1	39,2	24,3	2,3	65,9
495	Tangerines, mandarins	18,2	11,0	1,1	30,3	1,7	1,4	0,1	3,2	0,0	0,0	0,0	0,0	20,0	12,4	1,2	33,5
497	Lemons and limes	5,6	3,4	0,3	9,3	0,5	0,4	0,0	1,0	0,0	0,0	0,0	0,0	6,1	3,8	0,4	10,3
507	Grapefruit	12,6	7,6	0,7	21,0	1,2	1,0	0,1	2,2	0,0	0,0	0,0	0,0	13,8	8,6	0,8	23,2
512	Citrus fruit, nes	25,1	15,0	1,5	41,5	2,3	1,9	0,1	4,3	0,0	0,0	0,0	0,1	27,4	16,9	1,6	45,9
515	Apples	105,8	0,0	5,5	111,3	21,1	0,0	1,2	22,3	0,3	0,0	0,0	0,3	127,2	0,0	6,7	133,9
521	Pears	55,1	0,0	2,9	58,0	11,0	0,0	0,6	11,6	0,0	0,0	0,0	0,0	66,1	0,0	3,5	69,6
526	Apricots	17,4	0,0	0,9	18,4	30,0	0,0	1,7	31,7	0,1	0,0	0,0	0,1	47,5	0,0	2,6	50,1
534	Peaches and nectarines	68,6	0,0	3,8	72,3	18,4	0,0	1,1	19,5	0,1	0,0	0,0	0,1	87,0	0,0	4,9	91,9

Product code (FAOSAT)	Product description (FAOSTAT)	North				Central				South				Tunisia Total			
		Green	Blue	Grey	Total	Green	Blue	Grey	Total	Green	Blue	Grey	Total	Green	Blue	Grey	Total
536	Plums and sloes	15,8	0,0	0,8	16,6	3,1	0,0	0,2	3,3	0,0	0,0	0,0	0,0	19,0	0,0	1,0	20,0
541	Stone fruit, nes	2,6	0,0	0,1	2,7	0,2	0,0	0,0	0,2	0,0	0,0	0,0	0,0	2,8	0,0	0,1	2,9
544	Strawberries	0,6	1,2	0,1	1,8	0,0	0,1	0,0	0,2	0,0	0,0	0,0	0,0	0,6	1,3	0,1	2,0
554	Cranberries	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
560	Grapes	27,7	43,4	2,6	73,6	30,6	54,5	2,9	87,9	7,6	30,9	1,2	39,7	65,9	128,7	6,6	201,2
567	Watermelons	59,0	3,0	5,0	66,9	17,2	1,4	1,6	20,2	0,2	0,0	0,0	0,2	76,3	4,5	6,6	87,4
568	Other melons	8,6	0,1	1,6	10,3	2,6	0,1	0,5	3,2	0,0	0,0	0,0	0,0	11,2	0,2	2,2	13,6
569	Figs	61,8	38,7	3,6	104,1	8,2	4,9	0,5	13,6	0,3	0,0	0,0	0,3	70,3	43,6	4,2	118,0
572	Avocados	0,1	0,0	0,0	0,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,0	0,0	0,1
577	Dates	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	109,9	348,5	8,9	467,4	109,9	348,5	8,9	467,4
592	Kiwi fruit	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
603	Fruit, tropical fresh nes	45,4	0,0	2,3	47,7	3,7	0,0	0,2	3,9	0,0	0,0	0,0	0,0	49,1	0,0	2,5	51,6
619	Fruit Fresh Nes	45,1	0,0	2,3	47,5	9,0	0,0	0,5	9,5	0,1	0,0	0,0	0,1	54,3	0,0	2,9	57,1
689	Chillies and peppers, dry	11,2	1,3	0,7	13,3	1,2	0,7	0,1	2,0	0,0	0,0	0,0	0,0	12,4	2,1	0,8	15,3
711	Anise, badian, fennel	17,6	1,1	2,6	21,4	4,5	0,7	0,8	6,0	0,0	0,0	0,0	0,0	22,2	1,8	3,4	27,4
723	Spices, nes	3,4	0,2	0,4	4,0	0,8	0,2	0,1	1,1	0,0	0,0	0,0	0,0	4,2	0,4	0,6	5,2
826	Tobacco	4,6	1,2	0,7	6,5	1,5	0,6	0,2	2,3	0,0	0,0	0,0	0,0	6,1	1,7	0,9	8,7
900	Fodder crops	728,6	0,0	20,9	749,5	57,2	0,0	1,8	59,0	0,6	0,0	0,0	0,6	786,4	0,0	22,8	809,1
Total WF (Mm3/yr)		10651,8	651,7	337,5	11641,1	4003,4	293,5	96,4	4393,2	163,9	385,0	11,7	560,6	14819	1330	446	16595

Source: Mekonnen and Hoekstra (2011)

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