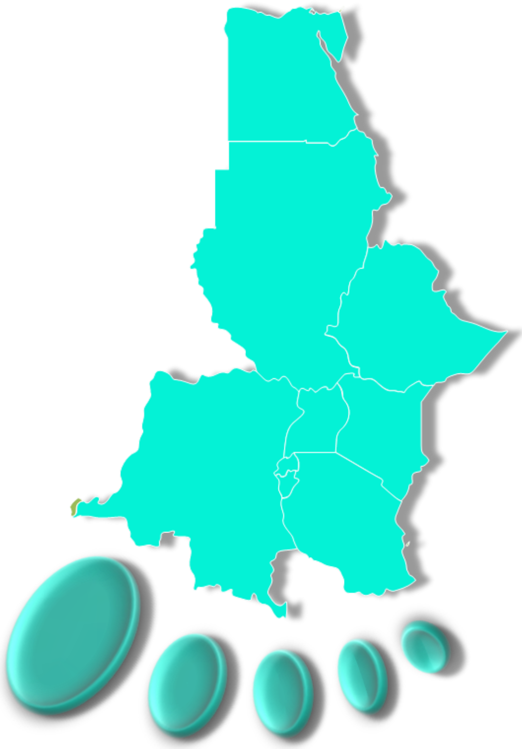
NILE BASIN INITIATIVE
Initiative du Bassin du Nil



Water Footprint and Competitive Advantage and Trade in the Nile Basin Countries

Water Footprint Training Report

November 2011

PEGASYS
Strategy and Development

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Training Summary

The Nile Equatorial Lakes Subsidiary Action Program, Regional Agricultural trade and Productivity Project (NELSAP RATP Project) has appointed Pegasys Strategy and Development (Pty) Ltd (Pegasys) to perform capacity building, analysis, documentation and creation of awareness on Virtual Water/ Water Footprint for comparative advantage production and trade in the nine Nile Basin (NB) countries.

As part of this project, a training session was organised in order to create awareness and develop skills in Water Footprint analysis within the Nile Basin countries. This training was held at the Silver Springs Hotel in Nairobi from 8th -12th August 2011.

The training session had three interrelated purposes within the wider project:

1. To embody the first step in creating awareness of Virtual Water and Water Footprint concepts and developing the skills of "country experts" whose role it would be to further the awareness of water footprint analysis.
2. To communicate the water footprint analysis methodology.
3. To gather information from participants regarding agricultural commodities to analyse.

The training approach was designed to foster an accessible, participatory, and learning-by-doing approach. Additionally the session was used as an opportunity to gather input from the participants regarding which agricultural commodities it would be useful to analyse and document from each of the nine Nile Basin countries, increasing participant involvement and making the session into a two-way conversation.

There were broadly two categories of training participants; senior policy makers and technical analysts, and this element was taken into consideration in the preparation of the training approach, for example the worked examples were designed specifically so those more technically inclined could delve deeper into the specifics of the analysis, while those who had a stronger background in policy could easily grasp the core concepts and their application without the need for detailed technical understanding.

The four day training program covered the following topics:

Day 1	Day 2	Day 3	Day 4
• Overview of Virtual Water & Water Footprint • Personal WF • Trade drivers in the Nile Basin • WF, water, agriculture & trade.	• The theory behind WF analysis • Worked theoretical examples • WF and water resource management	• Worked examples of WF analysis & policy • Thinking about WF & Policy • Corporate WF	• How to do your own WF analysis • Data Sources and other useful tools.

A. Purpose of this Training Report

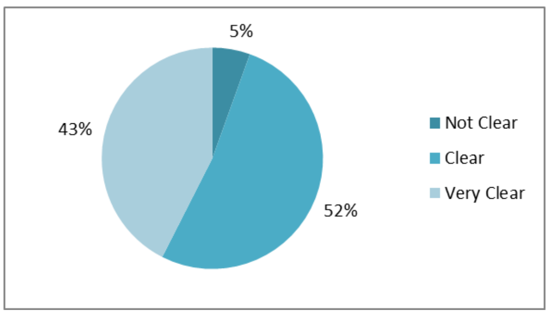
As noted above, the purpose of the training was to create awareness of Virtual Water and Water Footprint concepts and developing the skills of "country experts" whose role it would be to further the awareness of water footprint analysis. This volume is designed as training support manual with detailed reference information for "country experts" as covered in the training in Nairobi.

The first four modules have additional presentation resources which are attached as appendices to this report. These presentations are for the use of trainers and "country experts" when they are communicating Water Footprint concepts and analysis to others. The last three modules include case study examples of the application of water footprint.

B. Participant Training Evaluation Summary

A summary of participant feedback on each day session is provided below:

Day 1:



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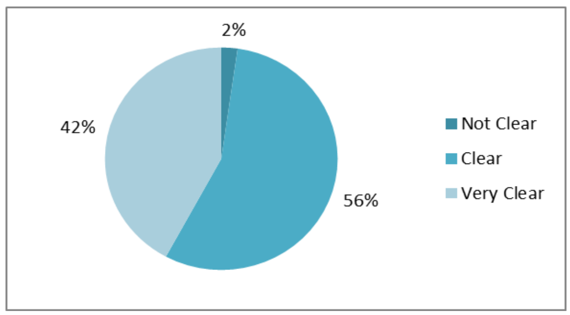

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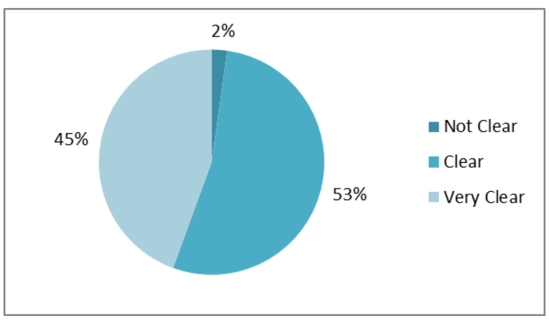
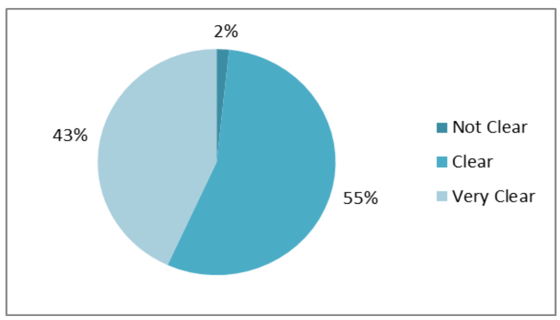


Day 4:



As can be seen in the above graphical illustration, on average 43% of the participants found the training "very clear", 54% found the training "clear" and a remaining 2% "not clear".

The list of expert participants and their contact details are provided below (by country) below. These individuals can be contacted for guidance, training and additional materials on WF analysis.

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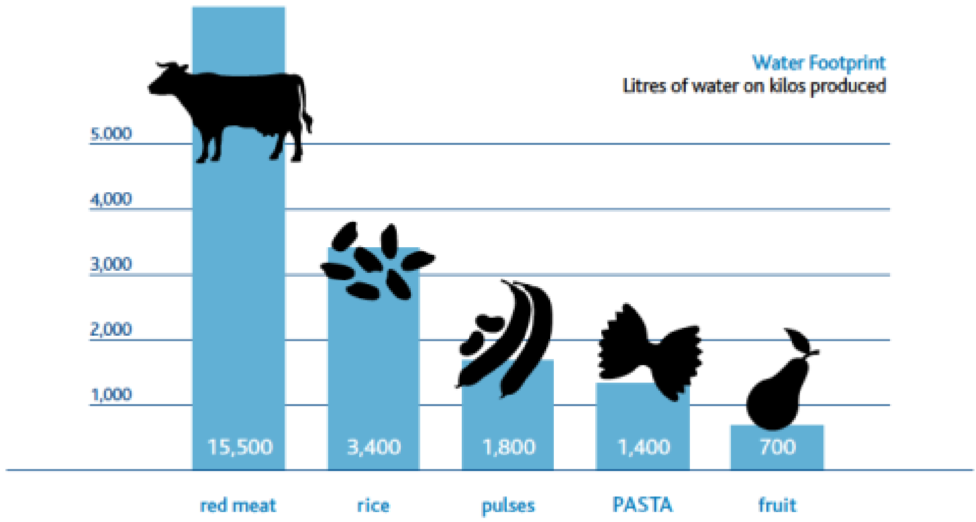
Module 1: Introduction to Water Footprint



A Water Footprint is an analysis of water use over the entire supply chain of a product. Once we are able to conceptualise water "embedded" in a product, we can think about water use, water withdrawals and the impact of trade on water resources.

Although the water footprint metric is not an end in itself it is a very useful tool to be used in identifying appropriate policy and response options. There is an opportunity for the Nile Basin states to bring together the water footprint methodologies, to develop tools and metrics that provide relevant information to engage in analysis and response to water use in the region.

1.1 Virtual Water and Water Footprint

Virtual water and water footprint are related concepts and it is helpful to understand the key differences between the two and their distinction from traditional water statistics.

1.1.1 Traditional Water Statistics

Traditional water statistics generally consider merely the volume of water withdrawals from surface water resources used to produce a product.

1.1.2 Definition: Virtual Water

Virtual water considers the total volume of all water used in the production of any commodity along the entire supply chain. For example, the virtual water consumed in the production of a cotton t-shirt includes the volume of water used to irrigate the cotton crop, the volume of rain which fell upon the fields, the water used to stitch the cloth together and the water used to dye the cotton.

When the cotton t-shirt is exported to another country, we also think about the water "embedded" in the t-shirt as traded. In this way we conceptualise "virtual water trade".

Once we consider the volume of water "embedded" in a product and "virtual water trade", we are able to make an assessment of the impact of food trade on water resources. Food trade between states may be considered much like a massive water pipeline, since the roughly 1000 litre of water used to grow a kilogram of imported wheat leaves the importing state free to use (or conserve) the same amount of its local water resources in other ways.

1.1.3 Definition: Water Footprint

The water footprint builds upon the "virtual water" theory in an attempt to quantify impact and these two terms are often used interchangeably. However, where virtual water merely refers to the volume of water embedded in a product, the water footprint extends upon the virtual water concept to include a spatial- and temporal-explicit indicator of the freshwater use, namely:

- The geographic location of the water use (is this an area of scarce water resources or an area of relative water abundance?)
- The seasonality of the water use (what is the timing of the water use?)
- Indirect or direct water use (where it the supply chain is the water use?)
- The type of water used; blue, green, grey (see below)

As an indicator of 'water use', the water footprint consists of three components: blue water footprint, green water footprint and grey water footprint. This differs from the classical measure of 'water withdrawal' as shown in Figure 1.

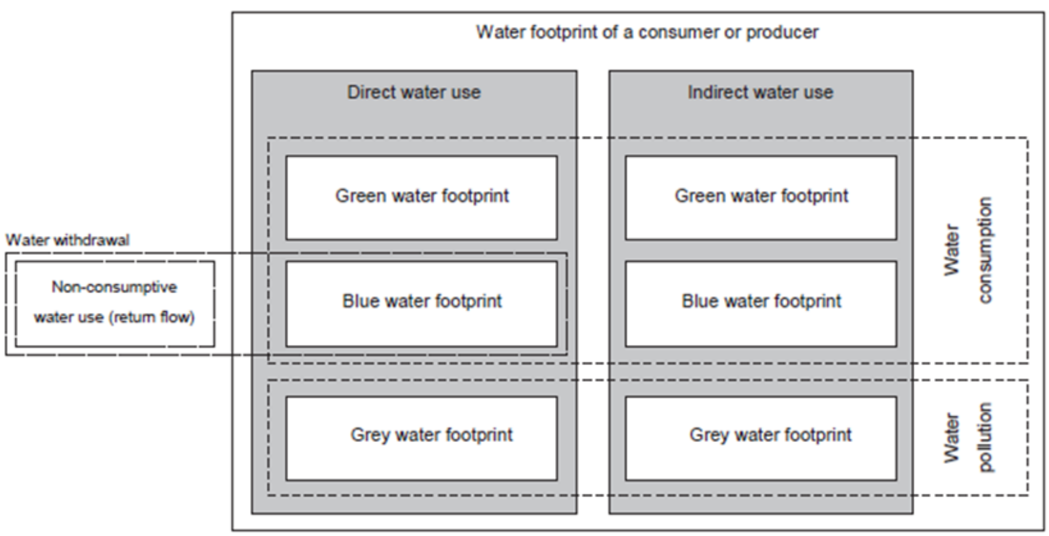


Figure 1: Schematic representation of the components of a water footprint (Hoekstra et al, 2011) It shows that the non-consumptive part of water withdrawals (the return flow) is not part of the water footprint. It also shows that, contrary to the measure of 'water withdrawal', the 'water footprint' includes green and grey water and the indirect water-use component

A **blue water footprint** refers to consumption of blue water resources (surface and groundwater) along the supply chain of a product. **Blue water 'consumption'** refers to loss of water from the available ground-surface water body in a catchment area. Losses occur when water evaporates, returns to another catchment area or the sea or is incorporated into a product.

The **green water footprint** refers to consumption of green water resources (rainwater insofar as it does not become run-off). **Green water 'consumption'** refers primarily to losses through evapotranspiration.

The **grey water footprint** refers 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.

As already mentioned, virtual water and water footprint are often used interchangeably when one is referring to a volume of embedded water. The difference between the concepts arises when the analysis of water use extends beyond volume to place, timing and type of water used. This type of analysis is the water footprint.

1.2 Terminology and Concepts

Water footprint has an additional benefit in that it can be used in a context where we speak about the water footprint of a consumer or producer. It would sound strange to speak about the virtual-water content of a consumer or producer. We use the term 'virtual water' in the context of international (or interregional) virtual-water flows. If a nation (region) exports/imports a product, it exports/imports water in virtual form. In this context one can speak about virtual-water export or import, or more general about virtual-water flows or trade. It is therefore useful to consider the following types of water footprints:

- **The water footprint of a product**. The sum of the water footprints of the process steps taken to produce the product (considering the whole production and supply chain).
- **The water footprint of a consumer**. The sum of the water footprints of all products consumed by the consumer.
- **The water footprint of a community**. The sum of the water footprints of its members.
- **The water footprint of national consumption**. The sum of the water footprints of its inhabitants.
- **The water footprint of a business**. The sum of the water footprints of the final products that the business produces.
- **The water footprint within a geographically delineated area** (for example, a municipality, province, state, nation, catchment or river basin) . The sum of the process water footprints of all processes taking place in the area.

1.3 Water Footprint and the Global Economy

As already noted, when any such commodity is traded, the production water 'embedded' in the product can also be considered to be traded. When considering food trade between states, there is also trade in water resources since roughly 1000 litres of water used to grow a kilogram of wheat leaves the importing state free to use (or conserve) the same amount of its local water resources in other ways.

Trade in virtual water can have implications for national water security, for example crops grown through irrigation (blue water) are generally counted as a net drain on water resources and this blue water could be left or used for purposes which have greater intrinsic or economic value. In contrast, rain-fed crops are not considered to use any surplus water as the natural groundcover they have replaced will have consumed roughly the equivalent amounts of water.

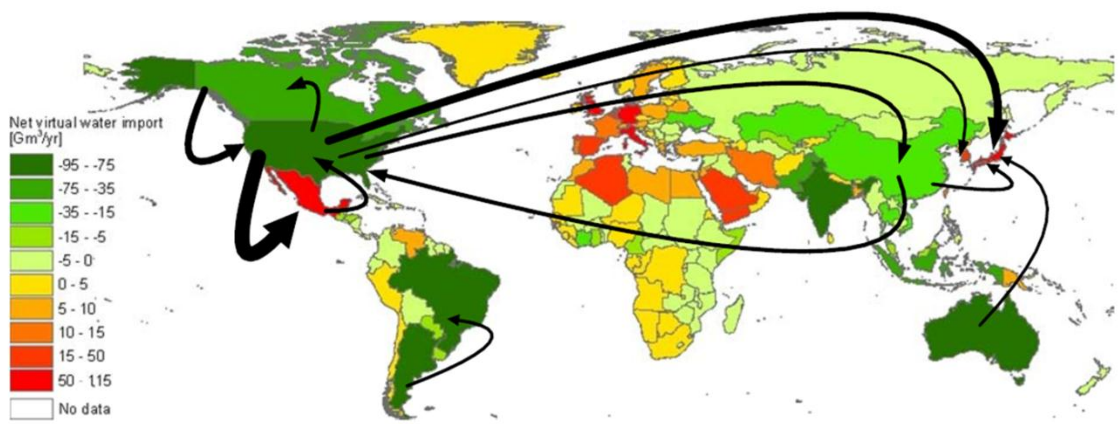


Figure 4. Virtual water balance per country and direction of gross virtual water flows related to trade in agricultural and industrial products over the period 1996-2005. Only the biggest gross flows (> 15 Gm^3/yr) are shown; the fatter the arrow, the bigger the virtual water flow.

Figure 2: Virtual water balance per country and virtual water trade (Mekonnen and Hoekstra, 2011)

Figure 2 above shows global virtual water trade. Regions which are increasing shades of green are net water exporters and countries in increasing shades of red are net water importers. A larger black arrow indicates a larger trade flow in virtual water.

As can be seen, North America has the largest flow of trade in virtual water with significant virtual water exports to Central and Southern Asia. Virtual water and water footprint provide a useful tool which allows us to conceptualise the trade and flow of virtual water around the globe and the impact on water resources in different geographical areas.

1.4 Module 1: Presentation Resource

A presentation resource for this module is attached at Appendix A.1. Additional notes and background explanations for certain slides can be found within this training report as follows.

Presentation Slides	Reference Sections
3 - 13	1.1 – 1.3
14 - 15	3.3
16	Case Study 1 Module 6
17	Case Study Module 5

A French presentation resource is attached at Appendix B.1.

Module 2: Water Footprint, Trade and Comparative Advantage

2.1 Comparative Advantage

Water footprint provides information about the embedded water associated with production and consumption within a country. Yet for the Water Footprint tool to be meaningful it must be linked to water scarcity or water abundance. For water scarce countries, decisions about the use of water in agricultural, industrial and energy production is critical, as are decisions about trade to support food, energy and water security. It is often the case that countries experiencing water scarcity benefit from virtual water imports. On the other hand, water abundant countries may not have the same water, energy or food security concerns as their scarce counterparts. Water footprint therefore provides a tool to understand comparative advantage and opportunities for export trade for these countries in the context of increasing global water scarcity.

According to the theory of comparative advantage, nations can gain from trade if they concentrate or specialize in the production of goods and services for which they have a comparative advantage, while importing goods and services for which they have a comparative disadvantage. The purpose of this project is to investigate the comparative advantage in water which might be leveraged by the Nile Basin states in virtual water trade.

2.2 Water Footprint and Water Security

Many nations save domestic water resources by importing water-intensive products and exporting commodities that are less water intensive. In the Middle East, Tony Allan (1996) has identified this as a way of ensuring water security. Egypt imports wheat and in doing so saves 3.6 Gm3/yr of its national water resources.

The most direct positive effect of virtual water trade is the water savings it generates in the countries or the regions that import the products. A “national water saving” is equal to the import volumes of a commodity multiplied by the volumes of water that would have been required to produce that same commodity domestically.

From a global perspective, all other things being equal, the ideal situation would be for countries with relatively high water productivity (i.e. commodities have a low virtual water content) to countries with low water productivity (commodities with a high virtual water content). This would result in a net water saving” from the global perspective. A “water saving” can also be realised with transfer of products from low to high productive periods by storage of food, which can be a more efficient and more environmentally friendly way of bridging the dry periods than building large dams for temporary water storage.

2.2.1 Motivations for “Water Saving” through Imports

A large number of countries are “saving” their national water resources through international trade of agricultural products. Japan saves 94 Gm3/yr from its domestic water resources, Mexico 65 Gm3/yr, Italy 59 Gm3/yr, China 56 Gm3/yr and Algeria 45 Gm3/yr (Hoekstra et al. 2005). The global picture of national savings is presented in Figure 3. The water savings shown in the figure are net water savings.

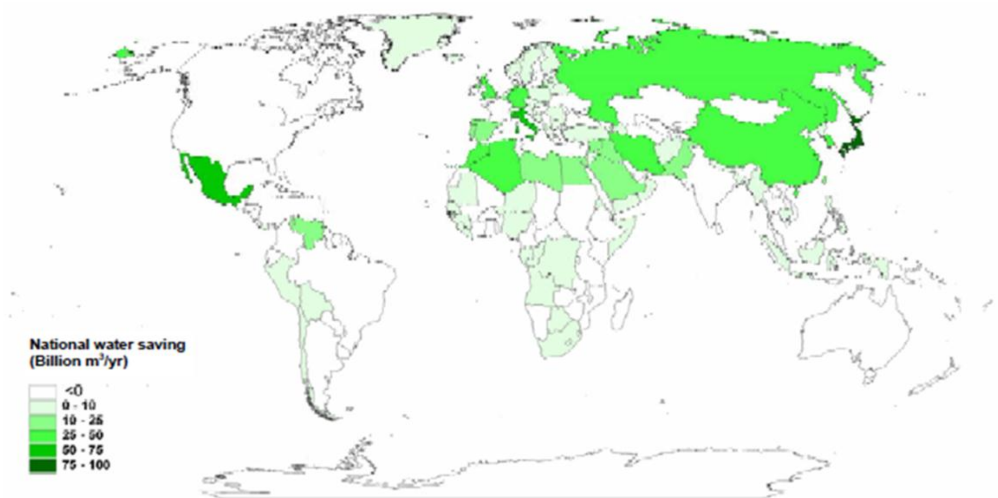


Figure 3: Net water importers (Hoekstra et al, 2005)

According to Hoekstra et al (2005), the driving forces behind international trade of water-intensive products can be water scarcity in the importing countries (evident in North Africa and the Middle East above), but often other factors such as scarcity of fertile land or other resources play a decisive role and the national water saving has different implications per country.

Germany, for example, is a net water importer by 34 Gm3/yr. Yet the major products behind the saving are stimulant crops (tea, coffee and cocoa) which Germany would otherwise not produce itself. This import of virtual water may be a reflection of German consumption and much less important from a policy perspective because it would not create any additional pressure on the water resources in Germany if the imports in coffee and tea are reduced.

In strong contrast, Morocco's cereal crop imports are the largest national water saver and shifting from import to domestic production of cereals would create an additional pressure of 21 Gm3/yr on Morocco's national water resources. Mexico, therefore, has a strong policy basis for importing virtual water.

2.2.2 Motivations for Exporting Virtual Water

As already noted, according to economic theory, nations can gain from trade if they specialize in the production of goods and services for which they have a comparative advantage.

Water use for producing export commodities can be beneficial, as for instance in Cote d'Ivoire, Ghana and Brazil, where the use of green water resources (mainly through rain-fed agriculture) for the production of stimulant crops for export has a positive economic impact on the national economy.

Water use for producing export commodities can also have a negative impact. For example, the export of 28 Gm3/yr of national water from Thailand related to rice export is at the cost of additional pressure on its blue water resources.

As the example of Thailand above shows, water footprint calculations about net water exports are only useful when one considers the context of water use.

The nations with the largest net water exporters are the USA (92 Gm3/yr), Australia (57 Gm3/yr), Argentina (47 Gm3/yr), Canada (43 Gm3/yr), Brazil (36 Gm3/yr) and Thailand (26 Gm3/yr). Figure 4 shows the net water exporters.

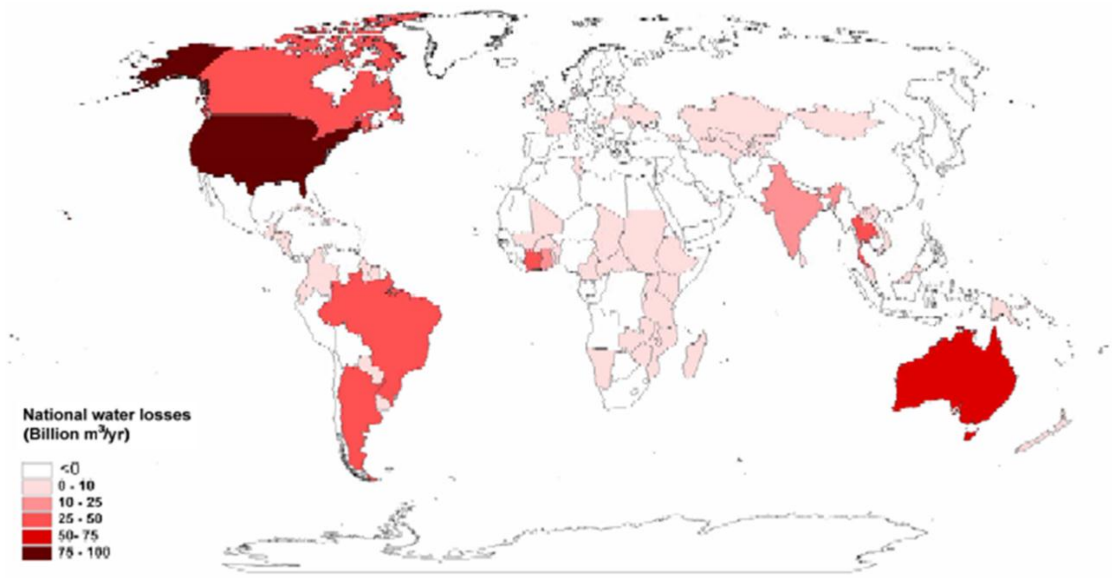


Figure 4: Net virtual water exporters (Hoekstra et al, 2005)

Figure 4 provides a useful illustrative example: USA's water exports are related to oil-bearing crops and cereal crops. These products are partly produced rain-fed and partly irrigated. However the water exports from Cote d'Ivoire and Ghana is mainly from the export of coffee and tea, which are almost entirely rain-fed. The use of green water has no major competition with other uses in Cote d'Ivoire and Ghana. This type of loss to the national water resources is unlikely to be questionable from an economic perspective, because the opportunity costs of green water us is low. The concern one might have for this green water use is limited to environmental impacts, which are generally not included in the price of the export products.

2.2.3 Blue Water versus Green Water

Even if there is a net global water "loss" from a trade in goods, there might be a saving of blue water at the cost of a greater loss of green water or vice versa. A useful example to illustrate this is Egypt's wheat trade. The virtual water content of wheat in Egypt is 930 m3/ton (Hoekstra et al. 2005). However, this is all blue water consumption; the green component of the virtual water content of wheat in Egypt is zero. Yet suppose that Egypt is importing wheat from Australia. Although the virtual water content of wheat in Australia is 1588 m3/ton (much larger than that of Egypt), the majority of wheat production in Australia is rainfed rather than irrigated.

Hence, although there appears to be a net global loss of water associated with wheat trade between Egypt and Australia, the comparative value of the water in Egypt rather than Australia means this is a desirable trade circumstance for Egypt which may then save its blue water (and arguably for Australia which is able to virtually trade its green water).

2.3 Water Footprint and Trade Policy

The export of a product from a water efficient region (relatively low virtual water content of the product) to a water inefficient region (relatively high virtual water content of the product) saves water globally. This is the physical point of view.

Whether trade of products from water efficient to water inefficient countries is beneficial from an economic point of view depends on a few additional factors such as the character of the water saving (blue or green water saving) and the differences in productivity with respect to other relevant input factors such as land and labour. Besides, international trade theory argues that it is not the absolute advantage of a country that indicates what commodities to produce but the relative advantage. The decision to produce locally or to import from other sites should be made on the basis of the marginal value or the utility of the water being saved at the consumption site compared to the cost of import.

Saving domestic water resources in countries that have relative water scarcity by the mechanism of virtual water import (import of water-intensive products) looks very attractive. There are however a number of drawbacks that have to be taken into account as well. Saving domestic water through import should explicitly be seen in the context of:

- The need to generate sufficient foreign exchange to import food which otherwise would be produced domestically
- The risk of moving away from food self-sufficiency that associates with the fear of being held to political ransom
- Increased urbanization in importing countries as import reduces employment in the agricultural sector
- Reduced access of the poor to food; and
- Increased risk of environmental impact in exporting countries, which is generally not accounted for in the price of the imported products.

The significance of this discussion for the Nile Basin countries, particularly those in the southern Nile is enhanced virtual water trade to optimise the use of global water resources can relieve the pressure on water scarce countries but may create additional pressure on the countries that produce the water-intensive commodities for export.

The potential water saving from global trade is only sustainable if the prices of the export commodities truly reflect the opportunity costs and negative environmental externalities in the exporting countries. Otherwise the importing countries simply gain from the fact that they would have to bear the cost of water depletion if they would produce domestically whereas the costs remain external if they import the water intensive commodities instead. Virtual water trade in an unfairly structured global market may also be particularly insecure for trade-disadvantaged states.

Finally, consider the double edged consequences of virtual water trade on physical water resources. For water managers and political decision makers in water scarce economies, virtual water trade may provide an apparently miraculous and politically-stress free solution to a very awkward strategic challenge – achieving a form of food and water security. Promoted simplistically as a remedy for physical water security, virtual water trade can camouflage problems related to the uneven distribution of public goods within a state.

2.4 Module 2: Presentation Resources

A presentation resource for this module is attached at Appendix A.2. A French presentation resource is attached at Appendix B.1.

Module 3: Water Footprint & the Nile Basin Countries

3.1 Overview of Water Resources in the Nile Basin

The story of water resources in the Nile Basin is incomplete if one only considers the Nile River. The Nile is the longest river in the world but only discharges around 84 billion m^3 annually - about 6% of annual rainfall in the basin (NBI). Runoff is generated in a relatively small part of the basin - the equatorial lake plateau of east Africa and the Ethiopian plateau. The Basin also includes several of the great lakes of Africa, and the water towers of the Ethiopian highlands.

Water availability across the Nile Basin varies considerably, not only geographically, but across time as well. Spatially, the northern part of the Basin is arid and experiences high evapotranspiration, while the southern parts of the Basin are relatively wet with higher rainfall. (see Figure 5, left and right)

This rainfall translates into significant variations in total renewable water resources per country (see Figure 6). When mapped against population, Figure 6 reveals the total renewable water resources per capita of population. Population density can result in some countries in the Nile Basin which have relatively low total renewable water resources having sufficient water per capita, and vice versa. The map of total renewable water resources per capita therefore reveals the degree of water stress of a country most effectively.

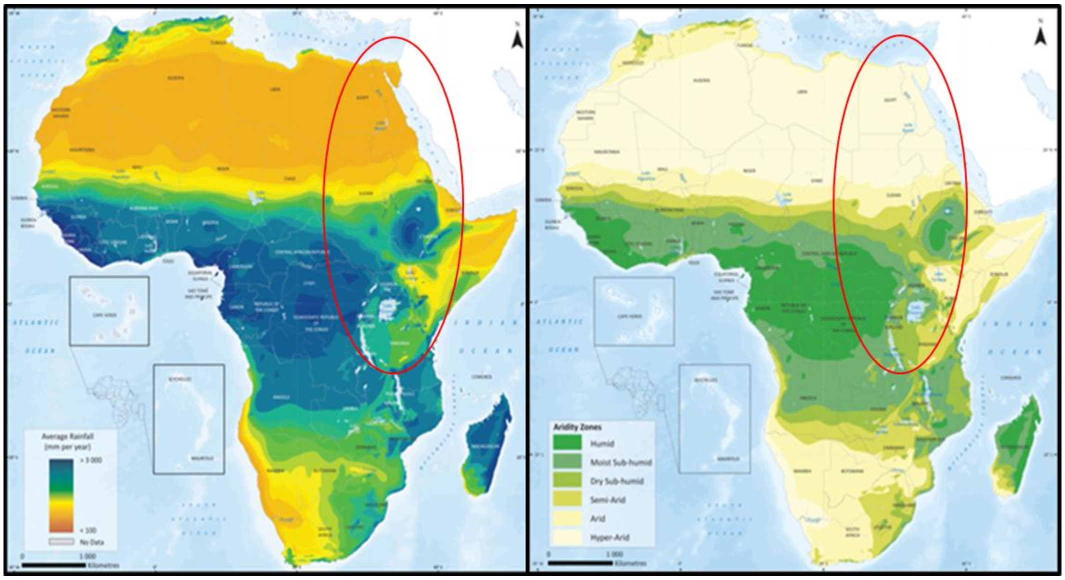


Figure 5: Average Annual Rainfall (source African Water Atlas, UNEP), Aridity Zones (source African Water Atlas, UNEP)

According to the Falkenmark Water Stress Indicator, "water stress" occurs when annual water supplies drop below 1,700 cubic meters per person per year. When water supplies drop below 1,000 cubic meters per person per year, the country is considered to be "water scarce".

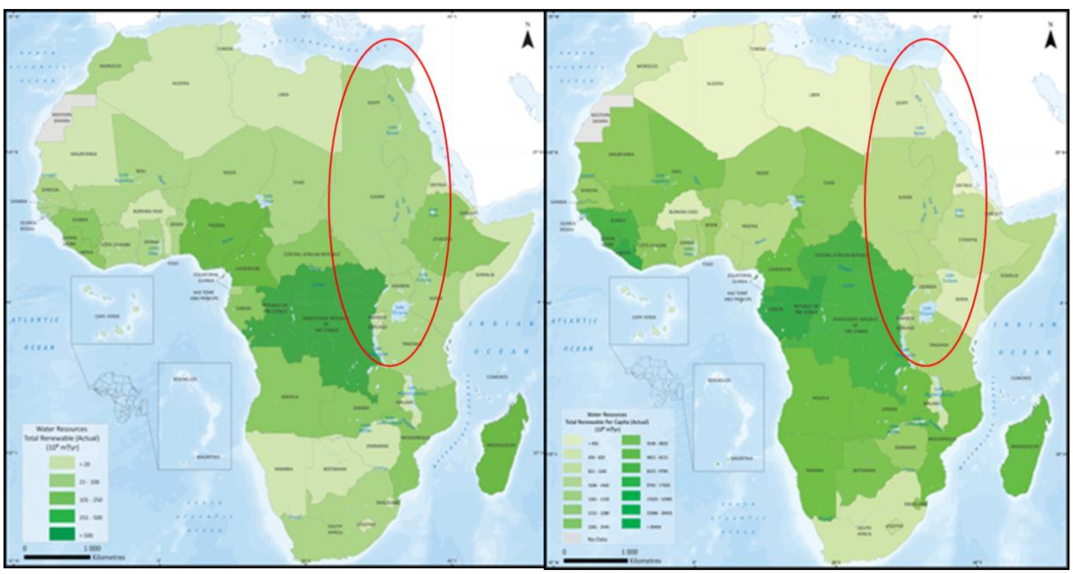
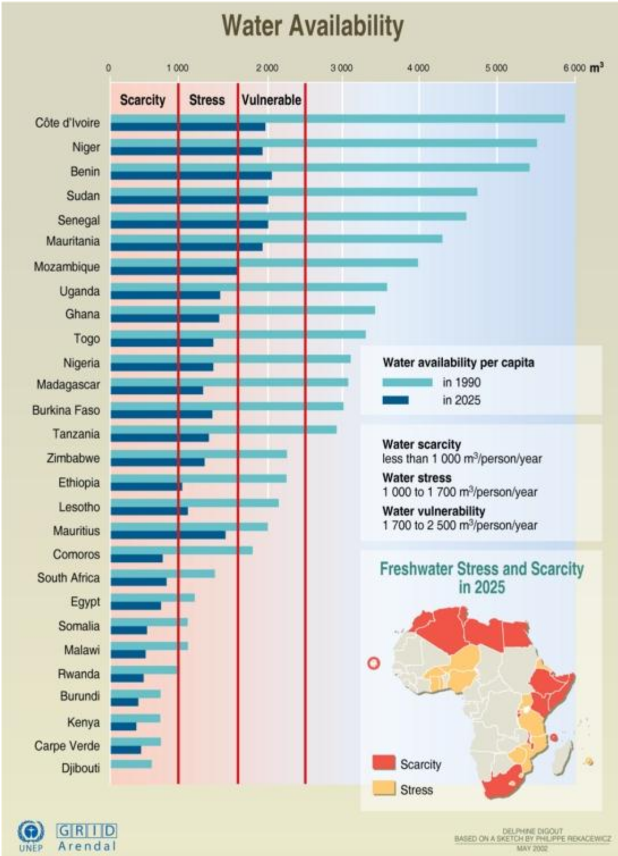


Figure 6: Total renewable water resources (left) vs Total renewable water availability per capita (right) (source African Water Atlas, UNEP)

Population growth in the Nile Basin is relatively high, particularly in eastern Nile Basin countries, where predicted annual population growth rates are at 2.7% (see Figure 7). This population growth will place increasing pressure on water resources, particularly in countries that are already facing water stress, note in particular that Figure 8 anticipates water scarcity for Egypt, Ethiopia, Rwanda, Burundi and Kenya by 2025 and, likely, water stress for Tanzania and Uganda.



Source: United Nations Economic Commission for Africa (UNECA), Addis Abeba ; Global Environment Outlook 2000 (GEO), UNEP, Earthscan, London, 1999.

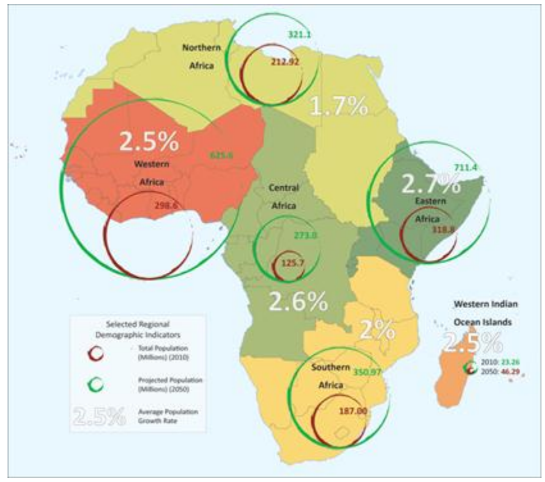


Figure 7 (above): Current and projected regional population (source African Water Atlas, UNEP)

Figure 8 (left): Water availability in Africa in 1990 and 2025 (Source UNECA 2000);

The amount of water available on an annual basis is closely linked to the level of water storage in a country. The Nile Basin (like much of the rest of Africa, with the exception of South Africa) has severely underdeveloped storage infrastructure. Figure 9 shows the size and location of large dams in Africa and the Nile Basin area is highlighted with the red circle.

The lack of storage infrastructure that can ensure water during dry years means that most of the Bain countries are vulnerable to variations in annual rainfall. This is a particular vulnerability in the parts of the Basin which are subject to regular and often devastating droughts.

As a result of weak infrastructure in the Nile Basin, even in countries in which there is no physical shortage of water, 'economic water scarcity' is experienced by water users, particularly where such water users are dependent on public infrastructure.

Economic water scarcity means that water is not accessible to people because of a lack of functional infrastructure to provide it where it is needed, or because the water that is provided is not affordable. It results from lack of investment in water infrastructure development, operation and maintenance and from poor management capacity.

The NBI is proposing a large number of dams along the river (13 in Ethiopia alone) for hydropower, irrigation and domestic use and various dams are now under construction. The construction of further infrastructure is, however, a contested area due to the high politicization of water issues in the basin, and the lack of a basin-wide agreement on water sharing.

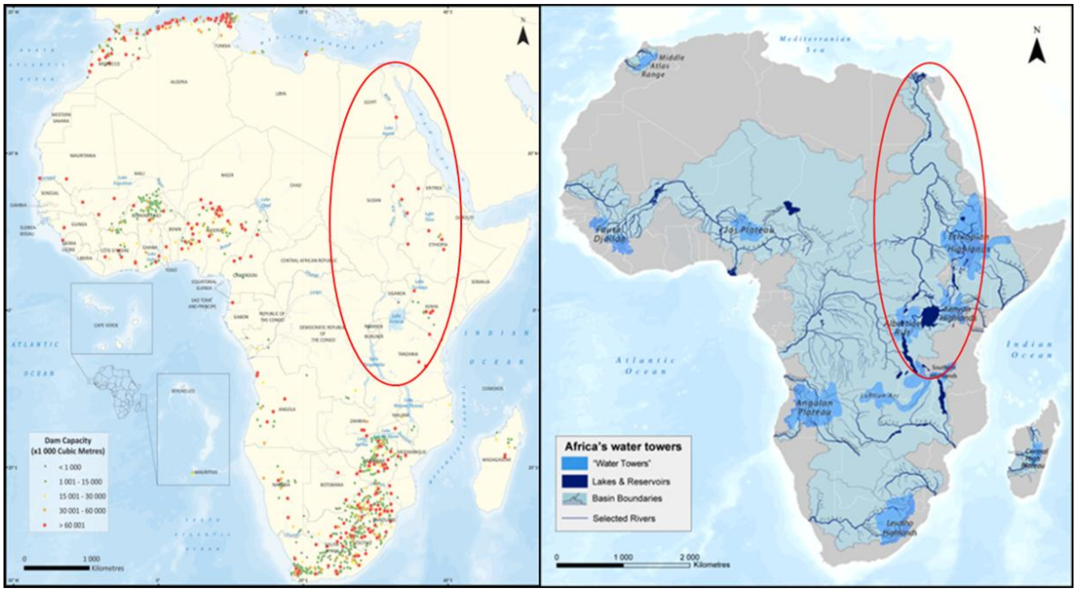


Figure 9: (Left) Dam capacity (Right) Africa's water towers (source African Water Atlas, UNEP)

Groundwater provides a critical source of water for rural communities in particular, and provides a more constant source in many areas than surface water. Although Africa's groundwater resources only make up 15 per cent of the total renewable water resources, they supply around 75 per cent of the population with most of their drinking water (Africa Water Atlas, UNEP). Groundwater resources are highly variable across the Nile Basin and are under pressure from increasing demand for irrigation, in particular. Pollution from lack of waste water treatment is an increasing problem around urban areas. Egypt and the Sudan are already experiencing water scarcity.

Critical to the water resources picture in the African continent are what are called the 'water towers'. These are forested upland areas that store water and contribute a very high proportion of the water in some of Africa's major rivers. The Nile is fed from the water towers of the Ethiopian highlands. Some of these 'water towers' are under threat from, for example, deforestation, which will have major impacts on the quality and quantity of available water in these areas. Many of these water towers provide water in transboundary basins so that their protection or destruction has transboundary impacts.

3.2 Climate change

The Nile Basin countries are particularly susceptible to the impacts of climate change partly due to the significant climatic impacts that will and are occurring, partly due to the high levels of poverty and vulnerability of millions of people, partly due to the high dependence on rain-fed agriculture, and partly due to the institutional weakness which limits the ability of Basin states to respond to the challenges of climate change. The African continent is already subject to significant inter- and intra-annual climate variability, which is likely to be exacerbated by climate change, and which impacts significantly on economic performance. For example, in Kenya, extensive flooding in 1997-98 and the La Nina drought in East Africa of 1998-200 is estimated to have caused damages of up to 10 – 16% of GDP during this period (Africa Water Atlas).

Understanding the climate change implications for the Nile Basin region is complex. There are a number of different models in use to assess climate change impacts, many of which render different results for various parts of Africa. In addition, there are very few regional or sub-regional climate change models or scenarios for Africa, and more research is needed in this regard. However, the IPCC has set out some scenarios for climate change in Africa.

Since the 1960s there has been a warming trend across the continent, with decadal warming rates of 0.29°C in the tropical forests and 0.1-0.3°C in South Africa (IPCC 2007). In East Africa decreasing temperatures have been detected near the coast and the inland lakes. The IPCC (2007) predicts a further air temperature increase of between 3 and 4°C above the 1980-1999 period. Equatorial and coastal areas will see a lower warming than this. This air temperature warming alone has significant implications for the water sector, particularly in relation to increased crop water requirements, impacts on the productivity of the great lakes (see sidebar) and impacts on run-off.

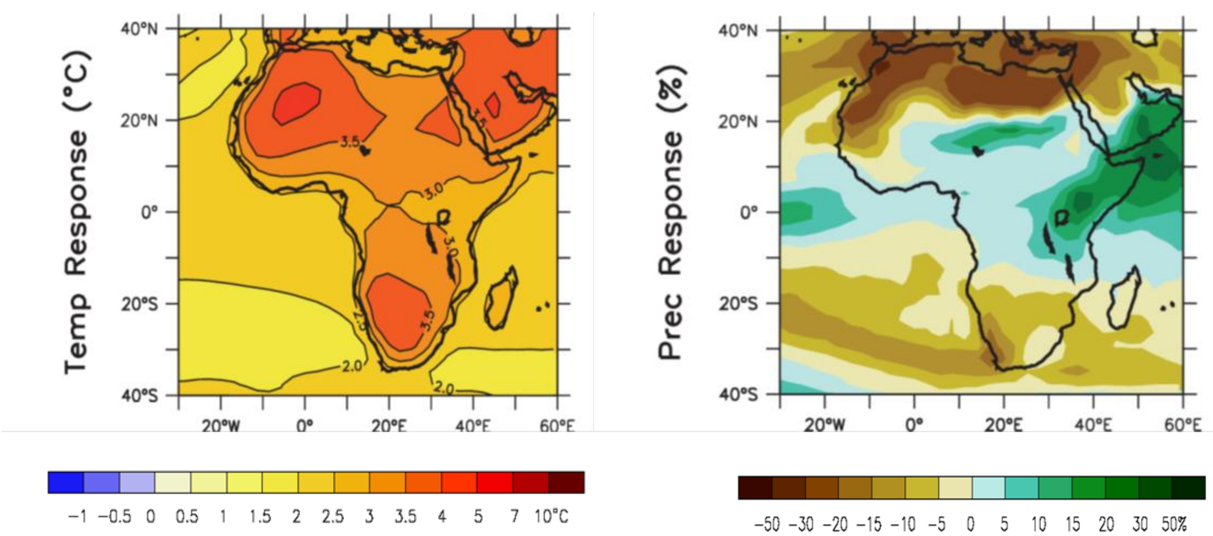


Figure 10: The annual mean temperature response in Africa in 21 MMD models (left). Annual mean precipitation response in Africa in 21 MMD models (right). (Source IPCC 2007).

Freshwater fisheries from the great lakes in particular are an important regional source of protein and revenue and climate change induced reductions in productivity, combined with over-fishing and pollution impacts will have significant regional socio-economic impacts.

Understanding the rainfall impacts is more difficult. However, the IPCC (2007) presents the following likely impacts in rainfall:

- An increase of around +7% in tropical and eastern Africa;
- An increase in summer rainfall in equatorial regions north of 10°S and a decrease in summer rainfall in equatorial regions south of 10°S;
- For the western Sahel some models predict significant drying while others predict increased rainfall with vegetation spreading into the Sahara.

The impacts of climate change will have significant impacts on water availability and demand across the Basin. As already examined in the previous section, even without climate change, a number of Nile Basin states are facing water stress or scarcity in the coming years.

Using 6 climate models, the IPCC estimates an increase in the number of people who will experience water stress by 2055 in northern and southern Africa. In eastern and western Africa, however, there is likely to be a reduction in water stress arising from increased precipitation.

There will be a corresponding variation in the impact of climate change on Nile Basin countries, depending upon the climatic factors of that country. For example, there is the potential for agricultural losses; a 20% reduced crop growing period in semi-arid areas is envisaged by 2050. In Egypt, climate change could reduce crop production by up to 28% for soybeans, and 11% for rice, by 2050. Yet, there will also, be positive impacts on agriculture, such as in the Ethiopian highlands, where the growing season may lengthen as a result of increased temperature and changes in rainfall.

Finally, coastal zones and estuaries are particularly at risk, from sea level rise, changes in run-off and changing temperatures. A decrease in rainfall, for example, may significantly change the distance to which salt water penetrates upstream in a river. Coastal agriculture may be impacted on by inundation and soil salinization. In Kenya, a 1m sea level rise could result in US$500 million loss of income from mangoes, cashew nuts and coconuts.

In summary, there are additional and increasing changes which will come about through climate variability and it is useful to have an awareness of these changes when thinking about water resources availability and water footprint.

3.3 Literature Review: Mekonnen & Hoekstra's Water Footprint of Nations (2011)

Mekonnen and Hoekstra (2011) have calculated a number of water footprints for countries across the globe and have examined the cross border flows of virtual water. Figure 11 shows net water imports by country. Net exporters of water are shown in increasing shades of green. Net importers are shown in increasing shades of red (to avoid confusion, readers should be aware this map is a compilation of Figure 3 and Figure 4 together with an inverted colour scheme).

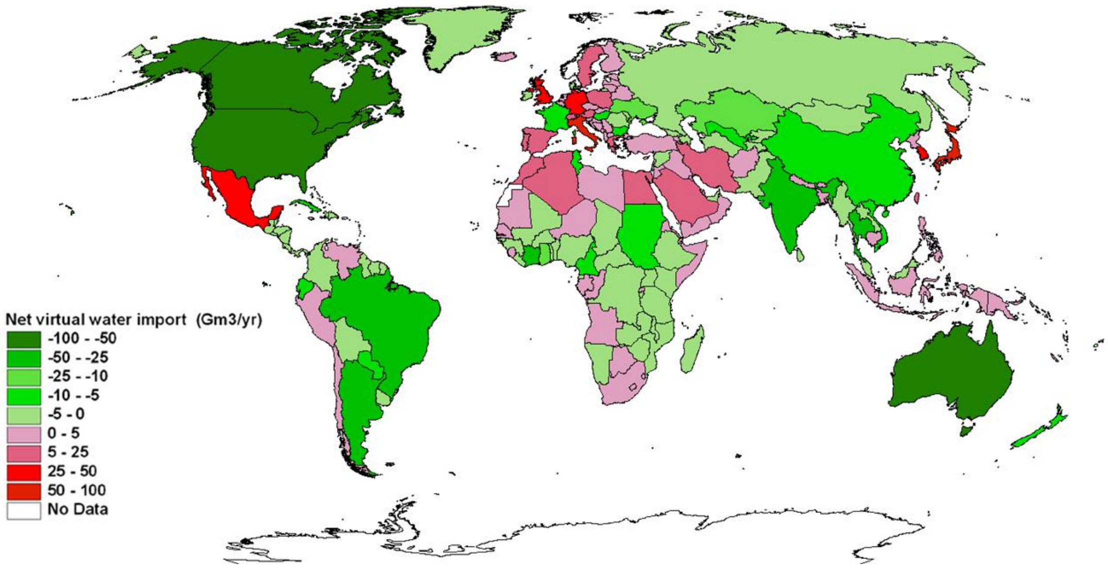


Figure 11: National virtual water balances related to the international trade of products. Period 1997-2001. Net exporters are shown in green and net importers in red. (Source Mekonnen & Hoekstra, 2011)

As the map above shows, on a global scale, the biggest net exporters of virtual water are found in North and South America (the US, Canada, Brazil and Argentina), Southern Asia (India, Pakistan, Indonesia, Thailand) and Australia. The biggest net virtual water importers are in North Africa and the Middle East, Mexico, Europe, Japan and South Korea.

Within the Nile Basin, most countries are either small net exporters of water or small net importers. As would be expected, Egypt - which is an arid country - is a net water importer. Yet in the wetter southern area of the Basin, where there is a relative abundance of rainfall and water resources, countries are only small net exporters and there is an anomaly in Rwanda which, despite high rainfall is a net importer of water (note this data is from 1997 to 2001).

Where the climatic features of a country are such that one would expect there to be water abundance, there are other factors which might result in the need to import water. These factors might be poor choices in agricultural products (ie they are unsuited to the region), inefficient water use practices which lead to water loss, little or no infrastructure to store water (eg dams), or it is possible the country has not developed land for agriculture (due to conflict or a lack of capital) and must import food rather than grow it.

Hoekstra and Mekonnen (2011) allow a deeper look at the nature of water use in Nile Basin can be undertaken through a closer analysis of the types of water use. As already noted, three aspects of water are considered when a water footprint is developed:

- **Blue water footprint** refers to the consumption of blue water resources (surface and ground water).
- **Green water footprint** is the volume of green water (rain water) consumed
- **Grey water footprint** is an indicator of fresh water pollution and is defined as the volume of fresh water required to assimilate the load of pollutants to an acceptable standard.

A water footprint is a geographically explicit indicator; it shows not only volumes of water consumption and pollution, but also the location of this. Figure 12 below shows world maps with the green and blue water footprints within nations in the period 1996-2005.

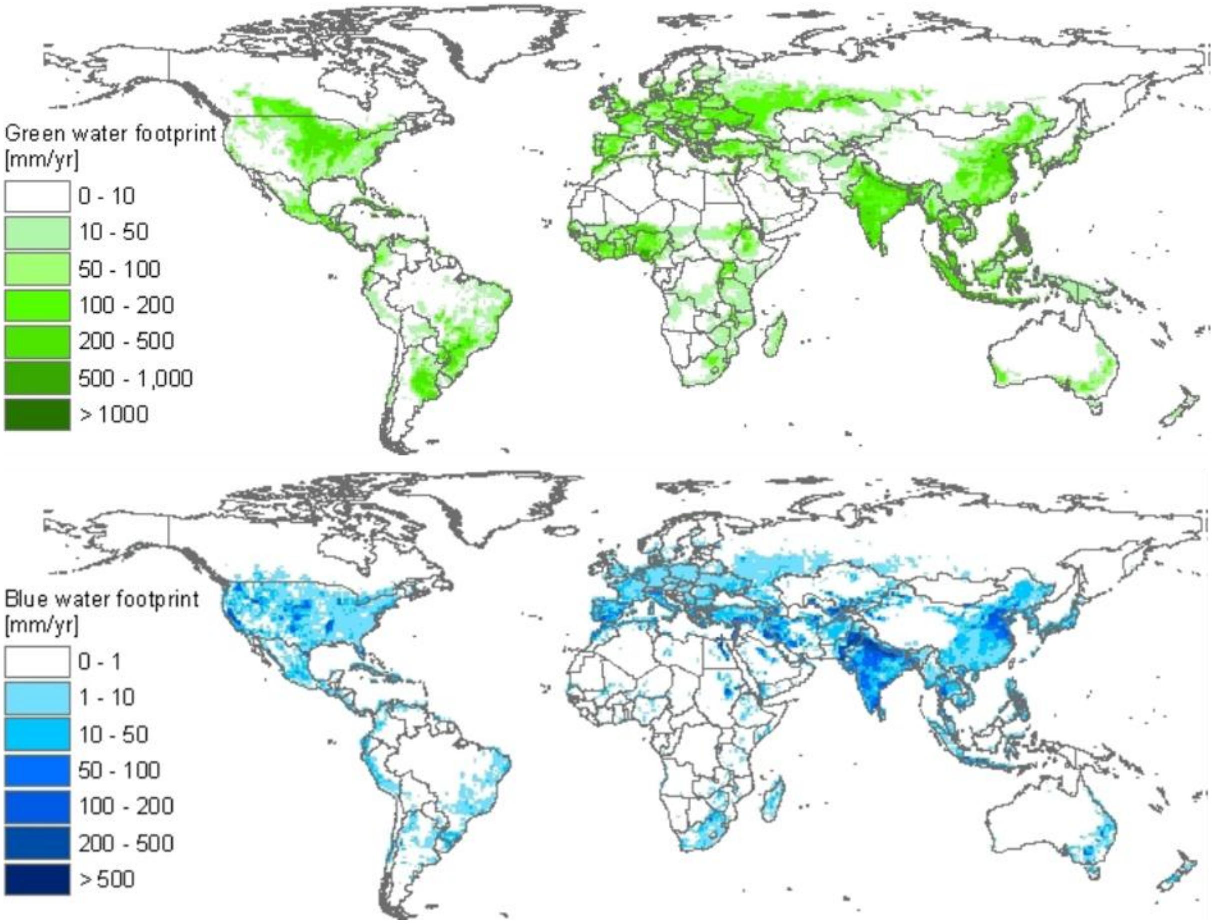


Figure 12 : The green and blue water footprints within nations in the period 1996-2005. (Source: http://www.waterfootprint.org/?page=files/VirtualWaterFlows)

As can be seen, in the Nile Basin the largest green water footprint (the areas where rain water is most consumed) is in the Southern parts of the basin, primarily in Ethiopia, Kenya, Rwanda, Burundi and Tanzania but with a band across central Sudan. In contrast, the largest blue water footprint (consumption of surface and ground water) occurs in the northern part of the Basin, the majority being in Egypt and in northern Sudan.

As can be observed in Figure 12 above:

- There are comparatively low levels of green water use in production, especially in the southern riparian states where there is high rainfall.
- There are low levels of blue water use in production, isolated in the northern riparian states where aridity has incentivized some water storage (eg Aswan Dam).
- Given the levels of rainfall and water resources, especially in the lower Nile Basin states, it would seem there are low levels of water use in production in the Nile Basin.

To lend further detail, Mekonnen and Hoekstra (2011) also provide an analysis of the water footprints of agricultural production and industrial production. Figure 13 shows world maps with the water footprints of agricultural production and industrial production.

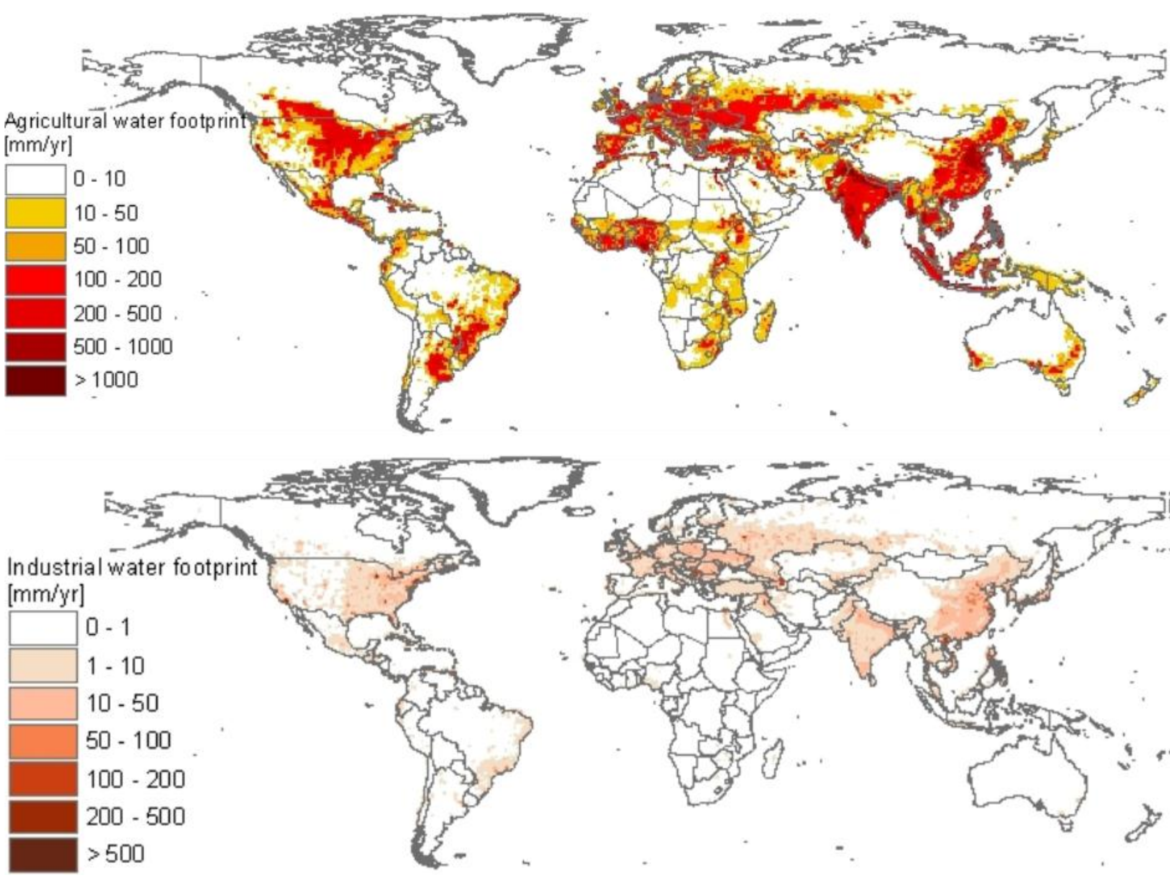


Figure 13: The water footprint within nations in the period 1996-2005, shown by sector: the total water footprint of agricultural production (above), the total water footprint of industrial production (below) (Source http://www.waterfootprint.org/?page=files/VirtualWaterFlows)

In all countries of the world, the water footprint related to agricultural production takes the largest share in the total water footprint within the country (more water is used in agriculture than in industry). As can be seen, the green water footprint in the Nile Basin maps directly onto the geographic distribution of the agricultural water footprint. This indicates the agricultural production in the Nile Basin is primarily rain water fed.

It is useful, however, to contrast the volumes of agricultural water footprint in the Nile Basin with the volumes of agricultural water footprint in Europe and India where both a blue water and green water agricultural water footprint is evident. The relative abundance of rainfall and water resources in the Nile Basin offers a comparative advantage in agricultural production and agricultural trade and this advantage is not currently being leveraged. Where there is an under-utilization of water resources, there are opportunities in this area for development and further investment.

Depicted quite dramatically in Figure 13, there is little to no industrial water footprint anywhere in the Nile Basin apart from Egypt, a strong indicator of the lack of industrial development in this region. Once again, it can be noted, there is a relative abundance of water resources which can be leveraged for development and trade.

3.3.2 Key points to draw from this analysis

The analysis of global virtual water flows, green and blue water use and agricultural and industrial water footprints by Mekonnen and Hoekstra (2011) has revealed some key findings:

- Countries in the Nile Basin are very small net exporters of water or, in some cases, are net importers. This feature is surprising given that the climatic features of the region (in particular high levels of rainfall in the southern Nile Basin states) and hence the comparative advantage in water resources. This therefore leads to questions around water use efficiency, water storage infrastructure and capital investment.
- There is some agricultural water footprint and little to no industrial water footprint in the Nile Basin.
- The agricultural water footprint is, by and large, fed by green water; there is isolated blue water consumption in the northern Nile Basin states.

More recent work by Mekennon and Hoekstra shows the most significant gross water flows related to trade in agricultural and industrial products over the period 1996-2005. The major flows in this regard are between the USA and Asia, with some flows from Australia to Japan and the USA to Central America. Africa does not feature in these major flows of trade-related water (see Figure 2 previous).

The results of the water footprint analysis highlight opportunities for development of water use in the Nile Basin in order to leverage the comparative advantage in this region. These opportunities include investment in water infrastructure for storage and development of land for agricultural use. This type of investment would, in turn, lead to higher agricultural outputs and opportunities to trade with regions where there is water scarcity.

3.4 Literature Review: Zeitoun, Allan and Mohieldeen (2010)

This paper was an initial approximation of the trade in virtual water in selected crop and livestock between 1998 and 2004 in the Nile Basin states. Its purpose was to understand the trade in virtual water into and out of the Basin as well as between the Basin states and, by highlighting the magnitude of virtual water flow leaving and entering states, think about the concept of water security in the Basin.

The primary findings are as follows: Zeitoun et al. determine the virtual water imports from outside the basin have a key role in filling freshwater deficits in Egypt and Sudan and the volume of this import represents a third of the flow of the Nile River itself.

The virtual water trade within the Basin is dominated by tea and coffee trade. These crops are mainly rain fed and therefore “do not represent a significant demand on the water resources of the basin” (Zeitoun et al, 2010) by which the authors mean the water resources in the Nile River. Yet trade between the Nile Basin states is small by comparison to fresh water imports from outside the Basin.

The analysis itself offers several further insights but these can be challenging to understand in one reading. This is largely because the water resources situation in the Nile Basin is far from homogenous (there are differences between the arid northern Nile Basin states and the moist southern Nile Basin states) this is also because, as the authors note, sub-basin political groupings would be more practical and effective to the analysis than basin wide groupings (into Eastern and Northern Nile basin countries). However, the Zeitoun analysis does offer the following insights into virtual water trade within the Basin by observing the following:

3.4.2 Trade within the Basin versus Trade with the Rest of the World

Zeitoun et al. examined both crop and livestock trade in virtual water and found:

- *Nile Basin states trade more with the rest of the world than they do with each other***.** Crop-derived virtual water trade within the Nile Basin is small compared to crop-derived virtual water trade with the rest of the world. Intra-basin virtual water crop trade is about 2.3% of virtual water imported by all states. Livestock virtual water trade within the Basin is small relative to virtual water livestock trade with the rest of the world. Virtual water imported by the Basin states from other Basin states in the form of livestock is about 1.1% of the amount imported from the rest of the world. Overall, total water trade within the Basin is minor as compared with virtual water trade between the Basin and the rest of the world.

- *Nile Basin states import more water than they export.* There is a strong net virtual water trade deficit in crops between the Nile Basin states and the rest of the world. Nile Basin states export less than one-third of that which is imported from the rest of the world.

3.4.3 Eastern versus Northern Nile States[1]

Zeitoun et al. make the following observations in their analysis of the countries in the Nile Basin:

- *The Southern Nile states engage in more virtual water trade than the Eastern Nile states.* Of trade within the basin, Southern Nile states produce nearly four times more than Eastern Nile states. Of trade with the rest of the world, Southern Nile states produce three times more than their Eastern counterparts. Finally, there is a trade 'surplus' from East to North; the Eastern Nile states export 500m^3/yr volume of virtual water in the form of crops to the Northern Nile states. The majority of this trade is in tea and coffee to Sudan and Egypt and all of this trade 'surplus' derives from rain fed agriculture.

- *Eastern Nile states account for the bulk of virtual water imports from the rest of the world.* By comparison to their Southern counterparts, Eastern Nile states import the bulk of virtual water.

- *Eastern Nile states have larger volumes of livestock virtual water trade.* Eastern Nile states are much more involved in virtual water livestock traded imports and exports than Southern Nile states.

3.4.4 Water Resources and insights for Water Security

Zeitoun et al. make the following observations about trade flows and water dependence:

- *Total virtual water exported by Nile Basin states out of the basin is a significant portion of the water resources of the Nile Basin.* In terms of volumes, a substantial 25% of the Nile River flows as it enters Egypt and about 20% of the freshwater resources currently used by Sudan and Egypt.

- *However, over 90% of virtual water exports are green water exports.* Over 90% of the exported crops are rain fed (use green water) rather than surface or river water (blue water).

- *There is a variety in dependency on virtual water imports.* Egypt imports greater than 40 times more water than Uganda. Sudan exports greater than 10 times more water than Rwanda.

- *Intra-Basin trade does not represent a significant remedy to the freshwater deficits in Sudan and Egypt.* Most of this trade is in the form of coffee and tea from Kenya and Tanzania to Sudan and Egypt. There is, therefore, a high degree of dependence on the part of Egypt and Sudan Nile Basin states on virtual water outside the Basin.

The Nile Basin may be divided into net importers and net exporters, see Figure 14. The figure shows that the Southern Nile states as well as Ethiopia and Eritrea actually export more virtual water in crops and

[1] Northern Nile: Egypt, Sudan, Ethiopia and Eritrea. Eastern Nile: Tanzania, Kenya, Uganda, Burundi, Rwanda, DRC

livestock than they import. Egypt and Sudan, by contrast, are net importers[2]. Virtual water imports from outside the basin appear to be of a great and growing significance to the lower Nile Riparians – Egypt and Sudan.

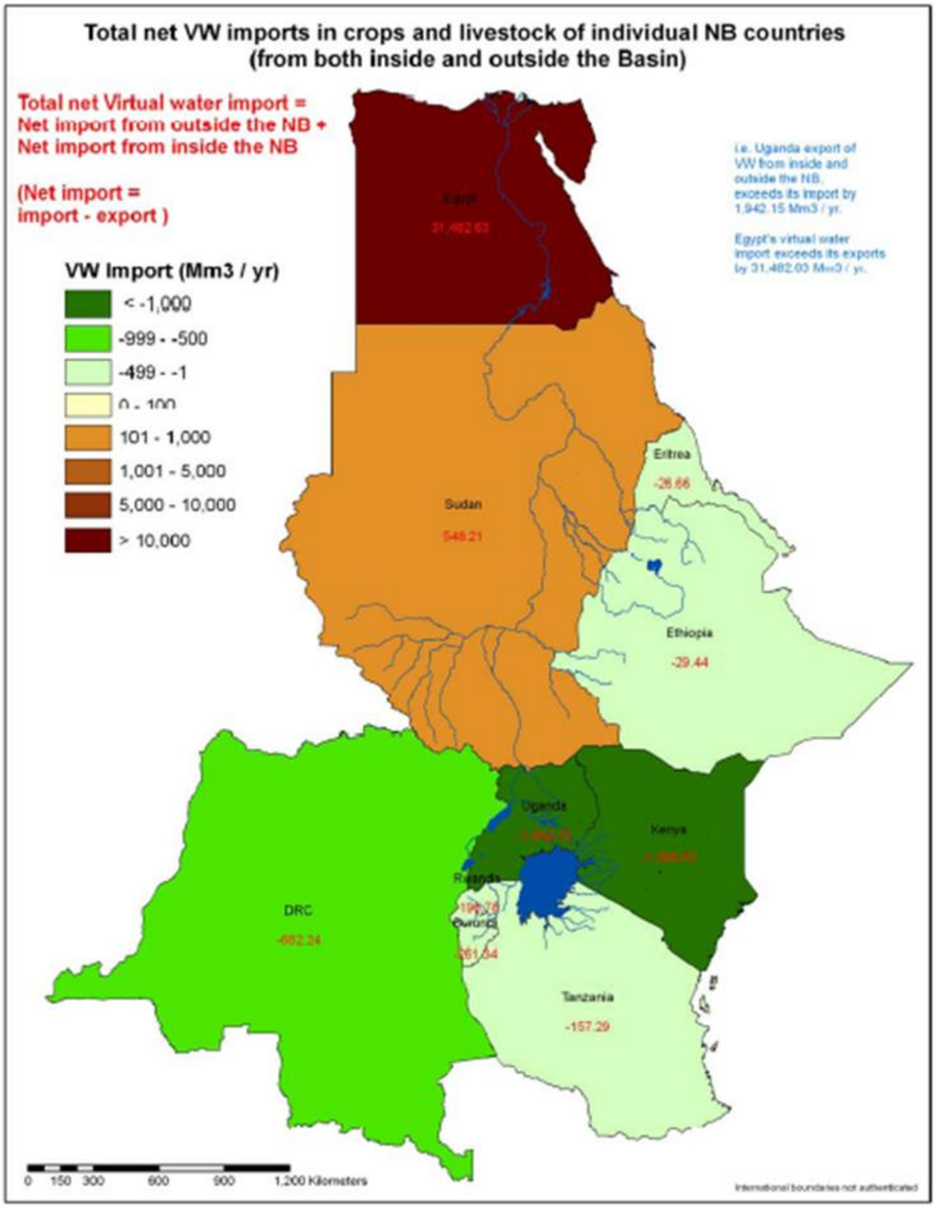


Figure 14: Average annual total virtual water crop and livestock trade between Nile Basin states and the rest of the world, 1998-2004 (mm3/y).

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[2] Note the difference in these results to those of Mekonnen and Hoekstra (2011) who find Sudan to be a net water exporter rather than importer. This is likely due to differences in data and periods of review, as well as the marginal nature of the net virtual water export and virtual water import in the Nile Basin.

As a final step, Zeitoun et al. isolate the biggest net water importer (Egypt) and biggest net water exporter (Kenya) and examine the nature of virtual water trade in these countries. These are illustrated in Figure 15 and Figure 16 below.

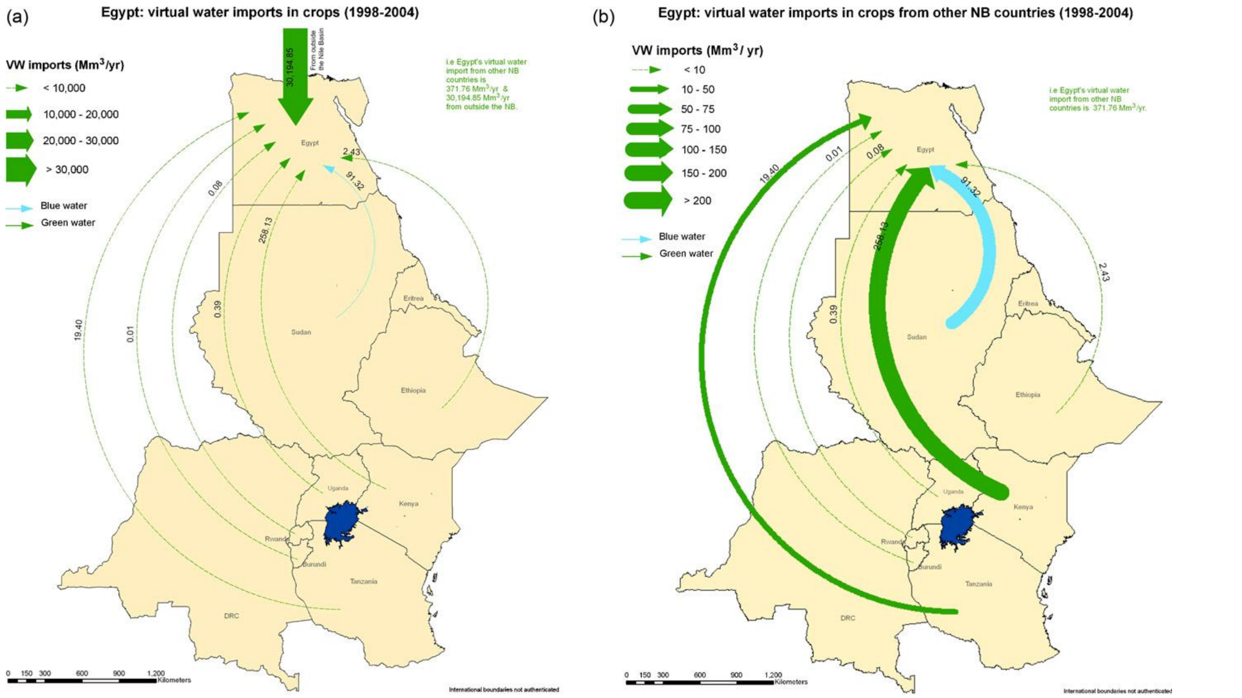


Figure 15: Egyptian virtual water imports in crops from a) with the rest of the world b) other Nile basin states.

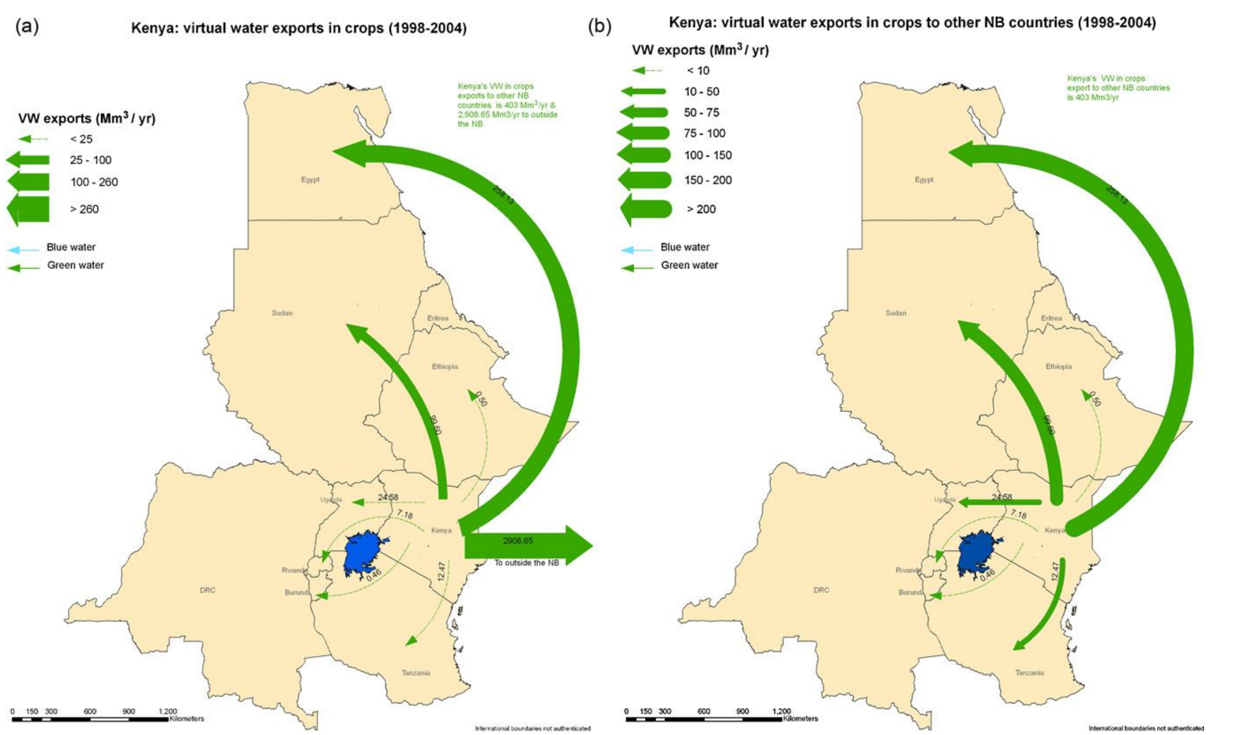


Figure 16: Kenyan virtual water exports in crops to a) the rest of the world and b) other Nile Basin states.

In Figure 15 we can see that Egypt has very large virtual water imports from the rest of the world as compared to virtual water imports from the other Nile Basin states. In contrast, Kenya has relatively similar volumes of virtual water exports to the rest of the world as it does exports to other Nile Basin countries.

As noted at the beginning of this section, Zeitoun et al.'s analysis intended to look solely at water security. The authors determine that virtual water exports have little effect on any concept of water security in Kenya, which is to say, the green water which flows out of Kenya is not a drain on local resources and the imports of virtual water into Kenya are negligible. However, the virtual water imports from outside the basin are currently the highest possible strategic significance to Egypt which has a high reliance on virtual water imports from the rest of the world in order to respond to water scarcity at home.

3.5 Module 3: Presentation Resources

A presentation resource for this module is attached at Appendix A.3. A French presentation resource is attached at Appendix B.3.

Module 4: Estimating a Water Footprint

A preliminary note on virtual water content and water footprint: as noted above, virtual water and water footprint are often used interchangeably when one refers to volume of embedded water. The difference arises when the analysis of water use extends beyond volume to place, timing and type of water used. For example, once we examine product supply chains and the water footprint of national accounts.

4.1 Water Footprint of a Crop

The virtual water demand (use) of a primary crop is calculated as the ratio of the volume of water requirement for crop c production in exporting country e, $CWR[e,c]$, to the yield of crop c, $CY\ [e,c]$, in exporting country e.

$$CWD[e,c] = \frac{CWU[e,c]}{CY\ [e,c]}$$

The volume of water use for crop production, $CWU[e,c]$, is composed of three components:

$$CWU[e,c] = CWU_{green}\ [e,c] + CWU_{blue}\ [e,c] + CWU_{grey}\ [e,c]$$

Here $CWU_{green}\ [e,c]$ (m3/ha) is the evaporation of rainfall from crop land (green water use), $CWU_{blue}\ [e,c]$ (m3/ha) is the evaporation of irrigation water from crop land (blue water use) and $CWU_{grey}\ [e,c]$ is the polluted volume of water resources resulting from leached fertilisers, chemicals, or pesticides from agricultural land (grey water consumption). The first two components, $CWU_{green}\ [e,c]$ and $CWU_{blue}\ [e,c]$, will be the components subject of further analysis here[3].

The components of blue and green water use are both evaporative and are no longer immediately available in the local hydrological cycle. They depend on the specific crop evaporation represent and soil moisture availability in the field.

Crop evaporation

The crop evaporation requirement for a crop c, $ET_c\ [t]$mm/day, is calculated using the crop coefficient, $K_c\ [t]$, for the respective growth period and reference crop evaporation $ET_0\ [t]$ mm/day, at that particular location and time.

$$ET_c\ [t] = K_c\ [t] \times ET_0\ [t]$$

This is illustrated in Figure 17 below. Evaporation of water (mm/day) can be expressed in terms of volume per hectare (m3/ha/day) by multiplying the above by a factor of 10.

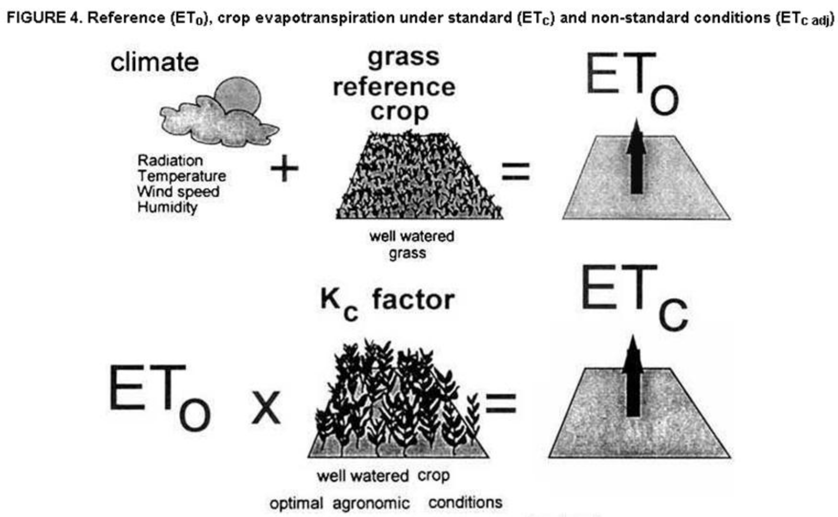


Figure 17: An illustration of the calculation of ET_c

The CROPWAT model (free to download at www.fao.org) is a useful resource which employs the classic Penman-Monteith equation to estimate evaporation ET_0. The ET_0 (reference crop evaporation – the reference crop is grass) is only affected by climatic parameters. It expresses the evaporation power of the atmosphere at a specific location at the time of the year and does not consider crop characteristics or soil factors. The crop evaporation, ET_c, differs from the reference evaporation ET_0, as ground cover, canopy properties and aerodynamic resistance of the crp are different from grass (the reference crop).

[3] For the purposes of this analysis, which is to determine water use and comparative advantage for trade, grey water use is less relevant and no more will be said about grey water in this analysis. For further examination of this type of water consumption, it would be useful to reference The Water Footprint Assessment Manual (Hoekstra, 2011) and "The green, blue and grey water footprint of crops and derived crop products" (Mekonnen and Hoekstra, 2011)

The effects and characteristics that distinguish field crops from grass are integrated into the crop coefficient K_c. The major factors determining K_c are crop variety, climate and crop growth stage.

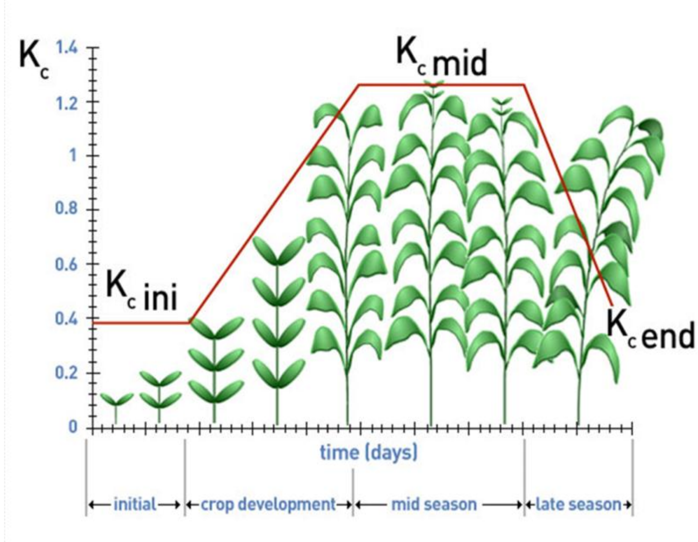


Figure 18: An illustration of the variation in the crop coefficient K_c

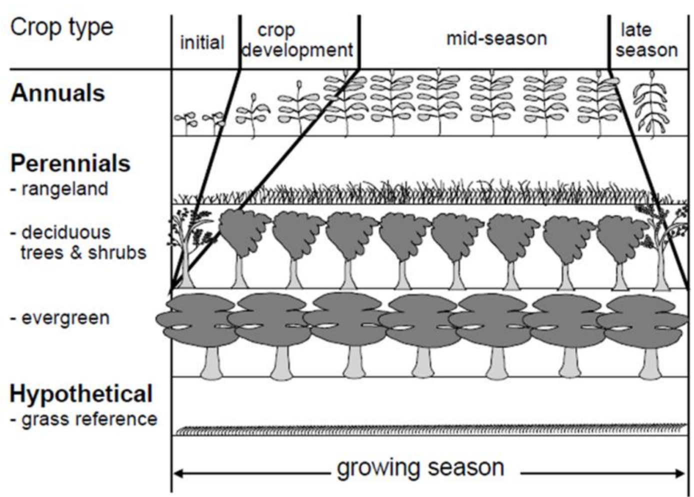


Figure 19: Illustration of the different growth periods (and hence different K_c) for different crops

There are differences in evaporation during the various growth stages, as a result, the K_c for a given crop will vary over the growing period (from planting to harvesting). For perennial crops, the planting dates can be assumed to be the green-up date for the calculation of crop water requirements.

Soil Moisture

Soil moisture is maintained either by effective rainfall or by irrigation water supply. The CROPWAT model has a few inbuilt options to estimate effective rainfall (effective rainfall, as compared to actual rainfall, is the amount of precipitation that is added and stored in the soil rather than becomes run off).

4.1.1 Green water use

The green water use, $CWU_{green}\ [e,c]$, is equal to the minimum effective rainfall (precipitation), $p_{eff}[t]$, and crop evaporation requirement at that time step (t).

$$CWU_{green}\ [e,c,t] = \min\left(ET_c\ [t],\ \ p_{eff}\ [t]\right)$$

The total green water use $CWU_{green}\ [e,c]$ for crop c production in country e is calculated by summing up green water use for each time-step over the entire length of the crop period, T.

$$CWU_{green}\ [e,c] = 10\ \times \sum_{t=0}^{T} CWU_{green}\ [e,c,t]$$

Green water is independent of irrigation water supply and solely depends upon the effective rainfall and crop evaporation requirements. Evaporation of water (mm/day) is expressed in terms of volume per hectare (m3/ha/day) by multiplying the above by a factor of 10.

4.1.2 Blue water use

Blue water use, in contrast to green water use, depends on crop evaporation requirement, green water availability and irrigation water supply. The first two variables, $ET_c\ \ [t]$ and $CWU_{green}\ [e,c,t]$ define the third, the irrigation requirement $I_r\ [t]$ which is calculated as:

$$I_r\ [t] =\ ET_c\ \ [t] -\ CWU_{green}\ [e,c,t]$$

The blue water use $CWU_{blue}\,[e,c,t]$, is the minimum irrigation requirement, $I_r\ [t]$, and the effective irrigation water supply $I_{eff}\ [t]$. The effective irrigation supply is the part of the irrigation water supply that is stored in the soil moisture and available for crop evaporation (similar to effective rainfall).

$$CWU_{blue}\ [e,c,t] = \min\left(I_r\ \ [t],\ \ I_{eff}\ [t]\right)$$

It is useful to note, if there is no irrigation, the effective irrigation is equal to zero (and blue water use is zero).

The total blue water use, $CWU_{blue}\ [e,c,]$, in crop production is calculated by summing up blue water use for each time-step over the entire length of the crop period, T.

$$CWU_{blue}\ [e,c] = 10\ \times \sum_{t=0}^{T} CWU_{blue}\ [e,c,t]$$

Evaporation of water (mm/day) is expressed in terms of volume per hectare (m3/ha/day) by multiplying the above by a factor of 10.

4.1.3 Additional references

Additional resources for the calculation of the water footprint of crop products include:

- The green, blue and grey water footprint of crops and derived crop products (Mekonnen and Hoekstra, 2011)
- Water Footprint Assessment Manual (Hoekstra et al, 2011) with special reference to Appendix I
- Nile Basin Virtual Water/Water Footprint Training Case Studies and Training materials.

Once readers are more comfortable with the theory and methodology behind calculating water use, alternative methods to the Crop Water Requirement methodology may also be explored, for example the Irrigation Schedule approach. These are detailed with accompanying examples in the Water Footprint Assessment Manual, Appendix I and II.

4.2 Water Footprint of a Live Animal

The virtual water content of an animal at the end of its life span is defined as the total volume of water that was used to grow and process its feed, to provide its drinking water, and to clean its housing and the like. There are three components to the virtual water content of a live animal:

$$VWC_a\,[e,a] = VWC_{feed}\,[e,a] + VWC_{drink}\,[e,a] + VWC_{servicing}\,[e,a]$$

Where $VWC_{feed}\,[e,a]$ represents the virtual water content of animal a in country e expressed in cubic meters of ton of live animal. VWC_{feed}, VWC_{drink}, $VWC_{servicing}$ are the virtual water contents from feeding, drinking and servicing respectively.

4.2.1 Virtual water content of feed

The virtual water content of feed consumed has two parts. The first is the actual water that is require to prepare the feed mix and the second is the virtual water incorporated in various feed ingredients. The virtual water content from feeding an animal at the end of its life span is calculated as follows:

$$VWC_{feed}\,[e,a] = \frac{\int_{birth}^{slaughter}\{q_{mixing}[e,q] + \sum_{c=1}^{n_c} CWD\,[e,c]\,\times C[e,a,c]\}dt}{W_a[e,a]}$$

Here, $VWC_{feed}\,[e,a]$ is expressed in cubic meters of water per ton of live animal. The variable $q_{mixing}[e,q]$ represents the volume of water required for mixing the feed of animal a in country e (m3/day). $C[e,a,c]$ is the quantity of fed cro c consumed by animal a in exporting country e (tons/day). $CWD\,[e,c]$ is the water demand of crop c in exporting country e (m3/ton). $W_a[e,a]$ is the average life weight of animal a in exporting country e at the end of its life span (tons).

The water demand of a crop is the volume of water required to produce a certain quantity of the crop and is expressed in m3/ton. For each food crop c, average specific water demand is calculated per country e:

$$CWD[e,c] = \frac{CWU[e,c]}{CY\ [e,c]}$$

As above in Section 4.1, $CWU[e,c]$ represents crop water requirements of crop c in country e (m3.ha) and $CY\ [e,c]$ the crop yield (ton/ha).

4.2.2 Virtual water content from drinking water

The virtual water content of an animal which originates from drinking is equal to the total volume of water used as drinking water supply calculated over the entire life span of the animal:

$$VWC_{drink}\ [e,a] = \frac{\int_{birth}^{slaughter} q_{drink}\ [e,a]dt}{W_a[e,a]}$$

Here $q_{drink}\ [e,a]$ is the daily drinking water requirement of animal a in exporting country e (m3/day). $W_a[e,a]$ is the live weight of animal at the end of its lifetime.

4.2.3 Virtual water content of service water

The virtual water content of an animal from the service water used is equal to the total volume of water used to clean the farmyard, wash the animal and other services necessary to maintain the environment during the lifespan of the animal. The virtual water content from servicing is calculated as:

$$VWC_{servicing}\ [e,a] = \frac{\int_{birth}^{slaughter} q_{servicing}\ [e,a]dt}{W_a[e,a]}$$

Here $q_{servicing}\ [e,a]$ is the daily service water requirement of animal a in exporting country e (m3/day). $W_a[e,a]$ is the live weight of animal at the end of its lifetime.

4.2.4 Additional resources

Additional resources for the calculation of the water footprint of a live animal (and, if required, the extension of this analysis to live animal product) include:

- Virtual water flows between nations in relation to trade in livestock and livestock products (Chapagain and Hoekstra, 2003)
- Water Footprint Assessment Manual (Hoekstra et al, 2011)
- Nile Basin Virtual Water/Water Footprint Training Case Studies and Training materials.

4.3 Water Footprint of a Product

The water footprint of a product is defined as the total volume of fresh water that is used directly or indirectly to produce the product. It is estimated by considering water consumption and pollution in all steps of the production chain.

In order to estimate the water footprint of a product, one will have to start by conceptualising the way a product is produced. For that reason, one will have to identify the 'production system'. A production system consists of sequential 'process steps'. A (simplified) example of the production system of a cotton shirt is: cotton growth, harvesting, ginning, carding, knitting, bleaching, dying, printing, finishing. Given the fact that many products require multiple inputs, it often happens that multiple process steps precede one next process step. In such a case we will not have a linear chain of process steps, but rather a 'product tree'.

For estimating the water footprint of a product, one will have to schematize the production system into a limited number of linked process steps. In the case of many processed goods, this might involve tracing the origin of the inputs of the product in different countries and determining the associated water footprint there.

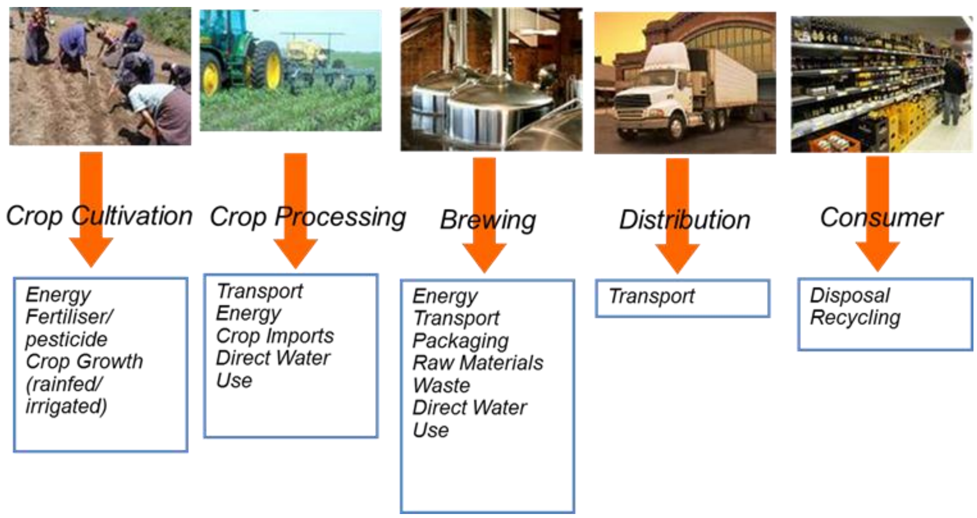


Figure 20: Example schematization of the associated water use in the product supply chain of beer.

Broadly, there are two approaches to calculating a water footprint of a product:

- **The chain-summation approach**: this approach is the simplest, but can be applied only in the case where a production system produces one output product (eg the supply chain from growing hops to making beer). In this particular case, the water footprints that can be associated with the various process steps in the production system can all be fully attributed to the product that results from the system. In this simple production system, the water footprint of the product is equal to the sum of the relevant process water footprints divided by the production quantity of product.
- **The stepwise accumulative approach**: this approach is a generic way of calculating the water footprint of a product based on the water footprints of the input products. Suppose we have a number of input products when making one output product. In this case we can get the water footprint of the output product by simply summing the water footprints of the input products and adding the process water footprint. Suppose another case where we have one input product and a number of output products. In this case, one needs to distribute the water footprint of the input product to its separate products. This can be done proportionally according to the value of the output products or it could also be done proportionally to the weight of the products (although this would be less meaningful).

A practical example of the calculation of the water footprint of a crop product is given in the Water Footprint Assessment Manual (Hoekstra, 2011) at Appendix III of that volume.

4.4 Water Footprint of Nations

Traditional national water use accounts only refer to the water withdrawal within a country. They do not distinguish between water use for making products for domestic consumption and water use for producing export products. They also exclude data on water use outside the country to support national consumption. In addition, they include blue water use only, excluding green and grey water. Water footprint extends upon national water use accounting and can therefore contribute to a broader sort of analysis and better inform decision-making.

A national water footprint is made up of the various elements (outlined in Figure 21), so that:

- **The water footprint of national consumption** is the water used for goods and services produced inside or outside the country and consumed inside the country, gives the water footprint of national consumption;
- **The virtual water export** is water used for goods and services exported from the country including water use for goods and services imported, enhanced and re-exported, gives the virtual water export; and
- **The virtual water budget** is the sum of these two parts.

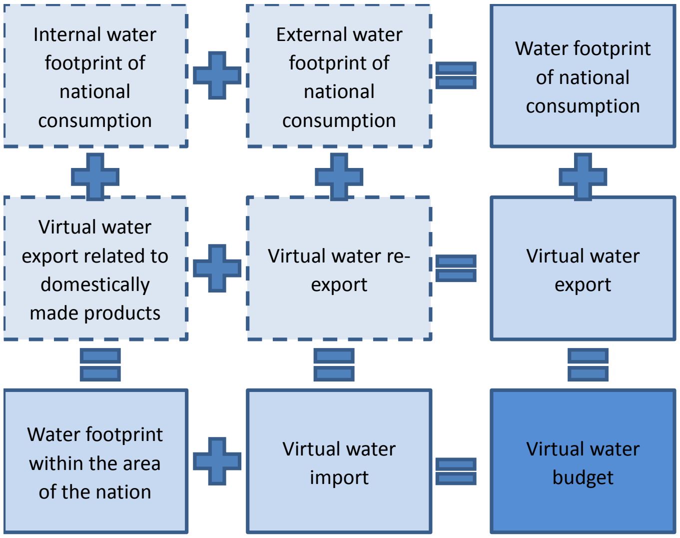


Figure 21: The national water footprint accounting scheme. Source: Mekonnen & Hoekstra (2011).

Thus the water footprint reveals not only how much water is consumed, but where it is consumed relative to where it originated. A national water footprint for consumption and production is useful in determining how much water is imported and exported through trade, the water footprint per capita, and the potential water savings through modified trade patterns.

4.4.1 Water footprint within a nation

The water footprint within a nation $WF_{area,nation}$ is defined as the total freshwater volume consumed within the territory of the nation:

$$WF_{area,nation} = \sum_{q} WF_{proc}\ [q]$$

Where $WF_{proc}\ [q]$ refers to the water footprint of process q within the nation. The equation sums all water consuming processes taking place in the nation.

4.4.2 Water footprint of national consumption

The water footprint of national consumption $WF_{cons,nation}$ can be calculated through the following approach:

$$WF_{cons,nation} = WF_{area,nation} + V_i - V_e$$

Where V_i is gross virtual water import (water embedded in products which are imported from other countries for consumption within this nation) and V_e is gross virtual water export (water embedded in products which are produced using water resources in this nation but exported to other countries).[4]

4.4.3 Water savings related to trade

The national water saving of a nation S_n as a result of trade in product p is defined as:

$$S_n[p] = (T_i[p] - T_e[p]) \times WF_{prod}[p]$$

Where $WF_{prod}[p]$ the water footprint of product p in the nation is considered, $T_i[p]$ is the volume of product p imported and $T_e[p]$ is the volume of product p exported. S_n can have a negative sign which means a net water loss instead of a saving.

The water saving is obtained through the difference in water productivities of the two trading partners.

[4] This approach to calculating the water footprint of national consumption is referred to as the "top down" approach. Hoekstra (2011, 56- 59) also provides an alternative "bottom up" approach and a discussion as to the merits of each approach.

4.4.4 Water savings related to trade

Hoekstra et al (2011) defines national dependence (WD) on virtual water imports as the ratio of the external water footprint to the total water footprint of national consumption.

$$WD = \frac{WF_{consumption,nat,external}}{WF_{consumption,national}} \times 100\ [\%]$$

National water self-sufficiency (WSS) is defined as the internal water footprint divided by total water footprint of consumption.

$$WSS = \frac{WF_{consumption,nat,internal}}{WF_{consumption,national}} \times 100\ [\%]$$

4.5 Module 4: Presentation Resources

A presentation resource for this module is attached at Appendix A.4. This includes three separate sections on:

- Water footprint analysis methodology
- Useful tools and data sources
- Using CROPWAT.

A French presentation resource is attached at Appendix B.4.

An excel worksheet is attached at Appendix A.5 which shows the workings of a water footprint calculation using output from CROPWAT.

Module 5: Water Footprint & Water Resources Management

Water resource managers have been thinking about and analysing mass balance in the system for several years. Evaporative loss from dams and agriculture crops is a small part of this. Water footprint is therefore not dissimilar from the approaches water resource managers take to analysing water use. Water footprint is useful for discussions around technical efficiency (technical efficiency, ratio of return and economic efficiency of water use.

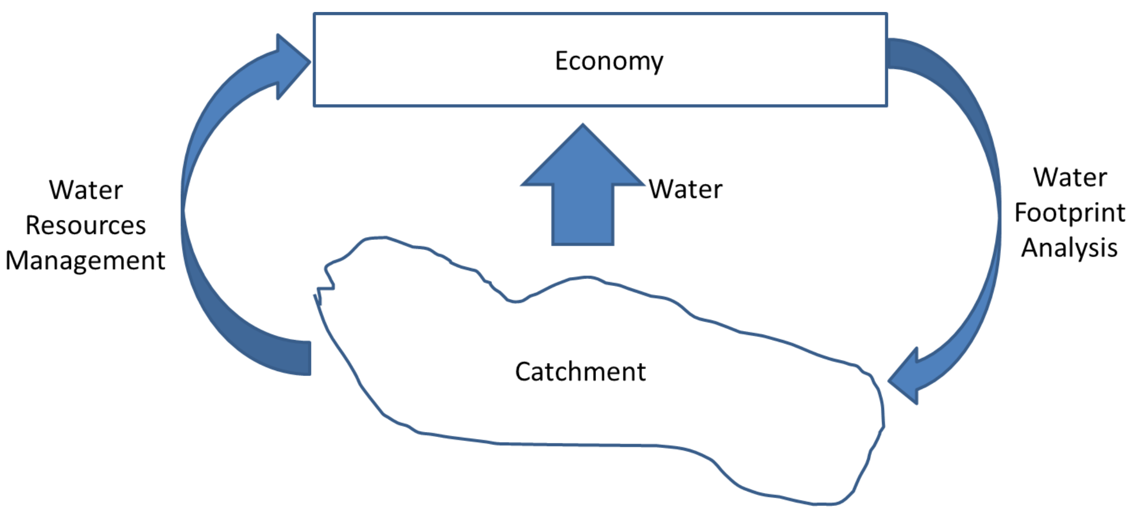


Figure 22: Illustration of the relationship between water footprint analysis and water resources management

In this respect, water footprint does not expand upon water resource management thinking and essentially, the messages which are offered by water footprint analysis are not very different from the messages one already gains from analyses by water resource managers. However, where water footprint analysis is different is it quantifies water use in terms of the product rather than the mass balance. It therefore becomes a useful tool for discussions about how water resources apply to other parts of the economy. This is illustrated in the Figure 22 above.

Water resource managers want to know how much water they have to manage. They are often making decisions around allocation between water users such as farmers, between economic sectors but also, in some cases, between countries. They are also making decisions around efficiency and investments in infrastructure, development of water, protection of water resources.

Water footprint can inform water allocation decisions and water development decisions in the following key ways:

- ***Water Allocation***: determining economic efficiency between sectors and users. The water footprint can give you an indicator of efficiency particularly where you compare the estimated water footprint of a product with the actual extraction or water use.
- ***Development of water*****:** understanding how you will utilise your water to get return, deciding where to concentrate investment. Blue water, for example, gives you a reliable supply providing a hedge against variability. The use of blue water can increase productivity per unit of land. Yet blue water also carries an opportunity cost and infrastructure costs and furthermore has downstream externalities. Green water carries less direct water costs but you become highly dependent on rainfall variation and there may be an opportunity cost in regard to land use.

Ultimately, the following discussions can be had around water resources management which are informed by water footprint analyses.

5.1 Green water management

Water resource managers do not often directly consider green water resources yet green water is part of production and it does have an impact on the hydrology and the evaporative state. It is often argued that if rain water (green water) is not used in the production of food, fibres, timber or bio-energy, it would evaporate anyway. There are, however, two good reasons for thinking about green water footprints.

Firstly, rain water is free but not unlimited. In certain parts of the Nile Basin, green water is a scarce resource and often uncertain. Since part of the land in any river basin has to be reserved for the ecology automatically a certain amount of green water is not available for agriculture. In catchments where green water is scarce, increasing the productivity of green water is crucial in order to gain optimum production given the green water constraint.

The second reason is increased production using green water resources reduces the need for production with blue water resources. This is why reducing green water footprints is also useful in areas where green water is abundantly available. Better use of rain in areas where rain is sufficient will increase the worldwide production of rain-based products, which reduces the need to produce irrigation-based products in water-scarce areas.

5.2 Blue Water management

It is not enough to merely think about blue water footprints in catchments where blue water availability is low or insufficient. Inefficient water use in water-abundant places implies that production per unit of water can be increased, which is important because increased production of water-intensive goods in water-abundant places means that production of those goods in water-scarce places can be reduced.

Water footprint provides a useful benchmark for water use efficiency. Lowering the water footprint per unit of product in water-abundant areas thus contributes to the possibility of reducing the overall water footprint in water-scarce areas.

Another reason for thinking about blue water footprints in water-abundant areas is that the allocation of blue water to one purpose creates an opportunity cost in allocating it for another purpose. The water footprints of water-intensive and luxury products such as meat, bio-energy or cut flowers can have a lower impact in catchments where water is abundantly available and where local environmental flow requirements are fulfilled, but the global (or regional) implications of these water footprints are that less water remains to be allocated to other purposes, such as growing cereal crops to fulfil basic food demand. Reducing the blue water footprint of a specific product in a water-abundant area thus creates the possibility to produce more of that specific product or to allocate the saved water to another product.

5.3 Thinking about Water Pricing with Water Footprint

Generally, water consumers pay for blue water use but not their green water use. Furthermore, the price paid for blue water is far below its real economic cost. Most governments subsidize blue water supply on a huge scale by investing in infrastructure such as dams, canals, distribution systems and wastewater treatment. These costs are often not on-charged to water users. As a result, there is insufficient economic incentive for water users to save water.

In some cases, particularly in developing countries where there is a large rural population reliant on agriculture for their livelihoods, there may be a good economic reason why governments do not charge for blue water use.

Due to the public character of water, water scarcity is generally not translated into an additional component in the price of goods and services that are produced with the water, as one would expect to happen naturally in the case of private goods. Furthermore, water users generally do not pay for the negative impacts that they cause on downstream people or ecosystems.

Therefore, although water footprint is useful to understanding trade flows and the economic significance of water (“water in the economy”), but it is less helpful in contributing direct insights into water pricing (“water for the economy”).

Case Study: Water Footprint and the Breede River Valley (South Africa)

Water footprint analysis contributed to water resource management decisions in the Breede River Valley by providing a different perspective on water use and allocation and articulating important political and economic implications for an area that is anchored by its agricultural sector.

The Breede-Overberg water management area is located in the Western Cape Province in South Africa. As part of the development of a catchment management strategy, a water footprint of the catchment and sub-catchment areas was completed.

The intention of the water footprint was to provide insights which could inform strategy and planning in the water sector by connecting economic indicators with productive water-use metrics in order to inform allocation to support economic and social development through revenue and job growth, while not adversely impacting on the environment.

The analysis considered economic sectors and specific crops within the agricultural sector, sub-catchment areas, blue versus green water use, and the link between water use and economic contributions from income and employment.

Figure 23 shows the total water footprint of the main crops in the Breede. Wine grapes, apples, pears and fodder crops have the highest water footprint in the WMA. Deciduous fruits such as apples, pears and peaches have relatively low embedded water content per ton of crop because of their comparatively higher yield.

Figure 23: Total Water Footprint of Main crops in Breede

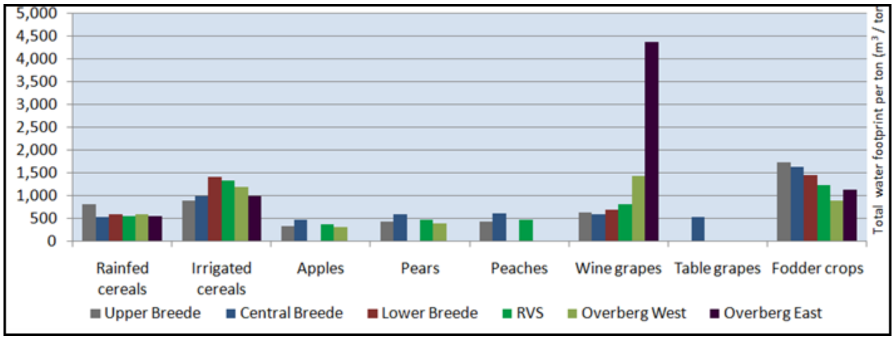


Figure 24: Economic productivity of water use by sub-catchment

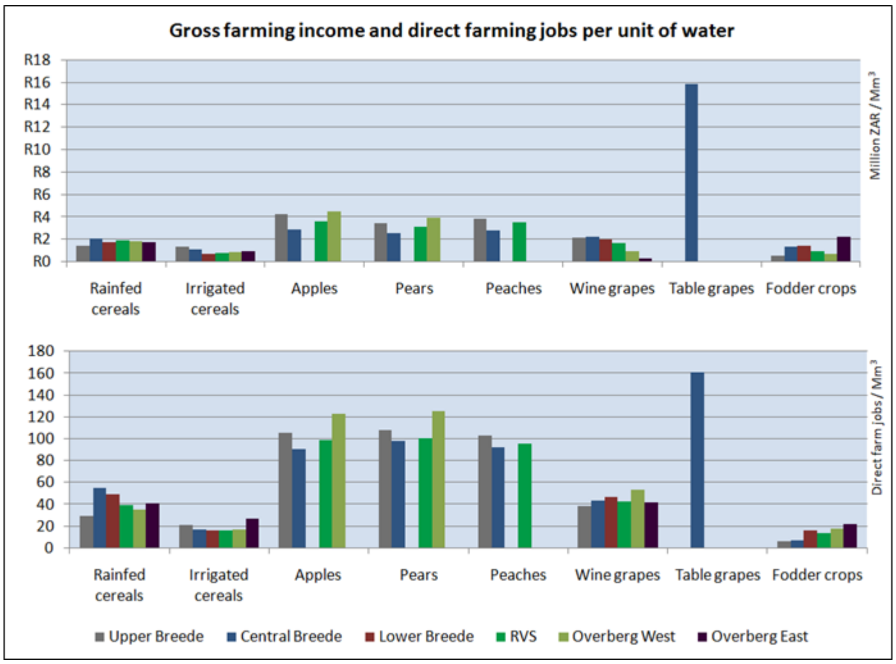


Figure 24 reveals the economic impact of water use by crop in the Breede water management associations. Table grapes offer farmers the highest gross income per cubic meter of water followed by the other deciduous fruits of apples, pears and peaches. Table grape farming also creates the highest number of jobs per unit of embedded water, compared to all the crops in the catchment (about 50% higher). Importantly apples, pears and peaches create significantly higher number jobs (about 100 per a million m3), than rainfed and irrigated cereals and fodder crops (less than 40% of fruit). Wine grapes, on the other hand, which consume the most of amount of water in the WMA have a relatively lower economic productivity of, which is only marginally better than that of rainfed cereals.

Among the insights provided by the footprint:

- As expected, agriculture, and particularly irrigated agriculture dominated water consumption. When linked to economic data, it became clear that water consumption by geographic area was highly correlated with economic activity, particularly with regard to blue water. Although this was not surprising, the water footprint helped to create a clear picture of this correlation, and provided a basis for dialogue around this reality.

- There were clear differences in the value and employment created between different types of crops. This provided insights regarding which crops grown in which locations generate higher economic returns per unit of water used, and created opportunity for dialogue around how to use water efficiently for economic growth.

Water users – particularly agricultural users - engaged with the footprint, finding it a useful point of departure for agriculture discussions and for understanding the roles of other sectors. The main benefit of the water footprint was as a communication and discussion tool. The water footprint provided a useful description regarding the use of blue and green water in different locations, and an understandable description of economic value added per drop of water. This enabled a dialogue about comparative advantage focussed on gross domestic product and employment. Additionally, the water footprint allowed water users to challenge previously accepted assumptions around crop value.

Module 6: Water Footprint and Corporates

6.1 Why Corporates are interested

Companies which see the looming water scarcity (and quality in many cases) crisis as core to their business risk and survival, are increasingly active in the water agenda. Over the last few years, a marked change not only in awareness, but also urgency, action and appetite for water activities ranging from water measurement, water stewardship to public policy has emerged. This has not come from the typical private sector actors in water but from multi-national companies (and their suppliers) ranging from clothing and apparel, to retail to food and beverage and the extractives sectors to name a few. This has in turn been spurred-on by greater needs for information from global investors, banks and insurance companies around water related risks, activities and action.

To those companies with extensive supply chains and operations in water scare or poorly regulated areas, water footprints are one tool that companies will use to understand their relative dependence on water resources. The most important elements however will not be the actual size of the water footprint as much as any impacts or social contexts that surround their water use, factories or supplies.

For companies that have identified potential changes to the commodities they purchase (either from climate change or government policies), the water footprint approach has helped them do a number of things.

- ***Sell the water story within the company***. Companies are not all on the same page with regard to water issues, but a water footprint assessment can be a very useful way to explain water challenges to bosses, decision makers and plant managers within the company.
- ***Identify risks in the supply chain.*** By looking deeper into where commodities are sourced and aligning this information with local social, economic and political evidence, a stronger picture can be drawn as to future challenges and planning. Companies have longer time horizons than governments and assurance of supply is crucial to companies wanting to stay locally relevant and viable for the future.
- ***Define a water strategy.*** Increasingly companies recognise the challenges posed to them through water. The water footprint is an entry point to helping define strategy, choose priorities and map out actions.
- ***Engage with government.*** There is a desire from many companies to have better relations with government over water issues which might lead to greater transparency and cooperative relationships.

Case Study 1: SABMiller

SAB Miller was the first company to conduct a Business Water Footprint analysis in Africa. SAB Ltd faces particular challenges given the widespread nature of its activities and its global supply chain.

SABMiller undertook water footprints analysis of the beer value chain in South Africa and the Czech Republic. It investigated what the water footprint results in both countries mean for SABMiller's business and informed an action plans in response to the findings. This study looks beyond the basic water footprint numbers and considers where water resources are used and the context of that use – in particular by considering water use for different agricultural crops in the context of specific water catchments.

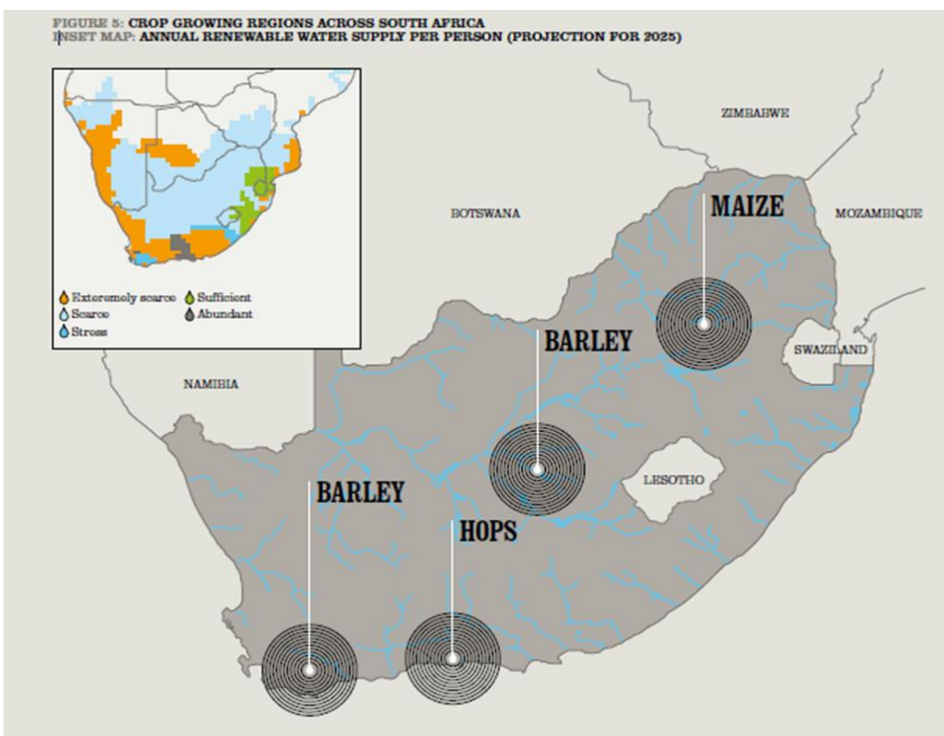


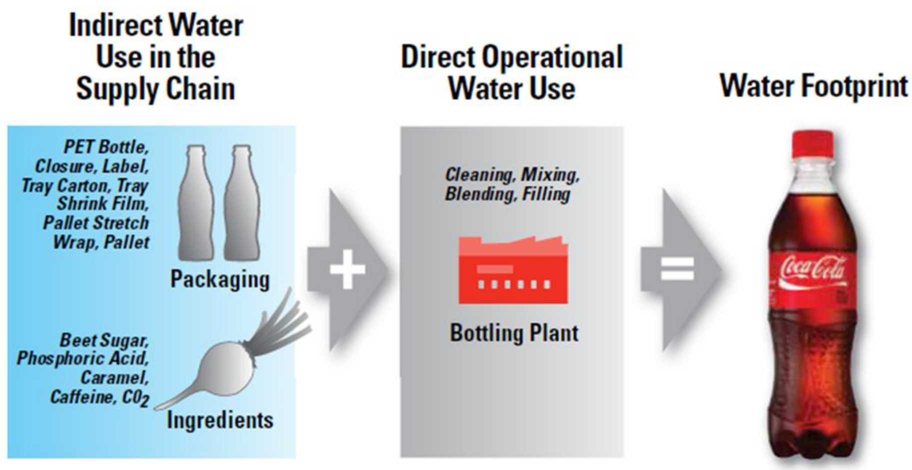
Figure 25: Beer crop growing regions across South Africa (inset: Annual renewable water supply per person, 2009 prediction) (Source: SABMiller & WWF, 2010)

When a policy overlay was conducted in South Africa, clear examples of the benefits of obtaining a wider understanding of the likely risks and opportunities around water use both at facility level and in the broader value chain emerged. In all, four key policy issues were identified during the course of the South African study. These were water allocation and resource protection, water use efficiency, water use licensing and enforcement and economic instruments and pricing. All of these elements of water policy can potentially significantly impact on the management and use of water resources and SAB's water footprint. By having a firm grasp on the relevant policy frameworks, local managers are now able to make informed investment and management decisions they were previously not aware of.

Figure 25 show the distribution of beer crop regions across South Africa and annual renewable water supplies. It assisted SABMiller to understand where areas of water risk were in South Africa and helped to determine a response plan to situations of water scarcity. Ultimately, water footprinting was useful from a business perspective, helping identify the scale of water use in water-scarce areas and the potential business risks that arise. Water footprint helped SABMiller to take better operational decisions concerning how it manages its plants, how it works with suppliers and how it engages with governments, to reduce business risk and improve environmental sustainability.

Case Study 2: The Coca-Cola Company

The Coca-Cola Company provides an example of how corporates engage on water footprint analyses to deal with reputational risk around water resources.



Coca-Cola came under heavy public scrutiny in regard to management of water resources in India. Communities living around some of Coca-Cola's bottling plants in India are experiencing severe water shortages due to extraction of water from the groundwater resource as well as pollution by the company's plants. Located primarily in rural areas, the hardest hit have been farmers who have seen significant declines in crop production as well as women who now have to walk longer distances to access potable water.

A study confirmed that Coca-Cola is a significant contributor to the water crises and Coca-Cola has been under pressure to close its bottling plant - in Kala Dera in the state of Rajasthan - where the community has been campaigning against Coca-Cola. The study concluded that the Coca-Cola Company had sited its bottling plants in India from strictly a "business continuity" perspective without taking the wider context of water resources availability into perspective. It also warned of worsening water conditions around the company's bottling plants and cited an increase in pollution as one got closer to Coca-Cola bottling plants, faulting the company on pollution prevention measures.

In response to the reputational risk associated with the situation in India and, in a likely related attempt to understand and respond to water risks to its business globally, Coca-Cola engaged on water footprint analyses as part of their Corporate Social Responsibility (CSR) initiative.

Water footprinting methodology assisted The Coca-Cola Company to refine its approach to “global water stewardship”. The pilot studies undertaken by the company verified the importance of examining direct and indirect water use separately. The Company is focusing first on operational water use by taking action to use water more efficiently and treat all manufacturing wastewater. The studies also affirmed the Company’s efforts to understand the health of watersheds everywhere it operates.

6.2 Corporate Engagement with Water Resources in the Future

6.2.1 Regional Differences in Water Scarcity

Today there is a significant physical risk for adequate human water supply in Central-South America, the Middle East, Eastern Europe, Sub-Saharan Africa and areas of Central South Asia. In most of these areas, declining water availability is also posing a threat to river biodiversity and ecological processes. In other parts of the world (mainly North America, Western Europe and some areas in Australia), water security for humans has (temporarily) been ensured, but often with the burden of significant economic (infrastructure) investments and a deterioration of river ecosystems and other freshwater bodies.

In addition, economic risk derives from the consequences associated with extreme phenomena (eg flood episodes, tropical storms or drought) or lack of reliable supply networks. According to projections of future water stress, pressure on the planets water resources will be exacerbated in the next few decades.

6.2.2 Water Risk for Companies

Over exploitation of water has economic risk implications for businesses and can adversely affect the ability of governments to meet a broad set of policy goals related to water in the economy. Most producing industries' direct operations reply more or less heavily, directly on water. These industries will no doubt understand the concept of water risk and find it applicable to their businesses.

But even where such risks may not be so obvious in direct operations, the supply chain may well hold substantial concern, especially for businesses relying on resources from agriculture or the extractives industry. Companies face physical, regulatory and reputational risk associated with water and these risks are interlinked where water is becoming increasingly scarce. In such cases, regulation is more likely to become stricter and the public will be more apprehensive about businesses' relations to water where communities do not have access to sufficient amounts of water that fulfil their basin needs and expectations.

In a short space of time, as water awareness has increased within the private sector, a spree of activity has taken place to deal with these concerns. Reports, tools, initiatives have sprung up to accommodate a range of sector specific concerns about water. These concerns have spanned water accounting to public policy concerns. Investors have also joined the fray, mostly from an investment analyst perspective, demanding information from listed companies and providing this to the financial institution's clients, whilst largely neglecting the potential risks for their own investment portfolios. Corporate and investor risk related to water is an emerging issue and is likely to become more significant due to continued poor management and poor-valuation for this resource, as well as water stress internationally and growing public awareness.

Many companies and investors have tended to treat water in a similar way to carbon. It is crucial, however, to recognise that water is fundamentally different for a number of reasons.

The availability, management and impact of water are local at a watershed or river basin level. This means that business and investor risk around water is fundamentally related to location and exposure to local water conditions. Conversely, the most effective response will be improved management and taking account of the local context. This is the opposite of the global management and markets around carbon. With carbon, the resulting climate impacts are not necessarily felt where the carbon is emitted. This has led to carbon offsetting, where carbon emissions are reduced elsewhere to account for potential damage cause elsewhere. With water this is not feasible, as shortcomings in water management are always felt locally, rather than globally.

6.2.3 The Other Side of Water Resource Scarcity – Land Grabs

Much has recently been made of “land grabs” and their impact on developing countries (WWF, Oxfam 2011) as issues of resource scarcity and environmental limits have risen up the global agenda. Demand for resources of all kinds is rising sharply due to both a growing population and rising affluence in emerging economies. At the same time, supply growth has sometimes struggled to keep pace, and there are concerns that these tensions could intensify.

Land grabs are often also water grabs in that water rights come with title to the land, enabling the leaseholder to export the water used to grow crops produced on it (virtual water). An awareness of this situation is particularly relevant for policy makers in developing countries where there are underdeveloped water resources (such as the Nile Basin states) because of the intense equity issues which might arise about pricing water, or allocating water rights. Equally, if water is not priced or allocated, this can also lead to inequitable outcomes, particularly if overall water use is unsustainable - as the poor are often the first stakeholders to lose out in this situation.

6.3 Conclusion: Water Footprint and Corporates

At the outset, it should be acknowledged that not all private sector actions and responses to water are consistent or complimentary. To understand why water footprint might be relevant to corporates requires an understanding of investor and business interest from the perspective of motivations of interested parties as well as their exposure to water-related risk.

There are certainly opportunities to engage any entity on a water footprint analysis which could easily be part of any Environmental or Social Assessment regardless of their motivations. The degree to which a corporate will want to engage with government proactively to manage future risks or resource use will depend upon many issues, but it is undeniable that water footprint could be used as a useful way of bringing important supply chain and business interests to the table.

Module 7: Water Footprint and Policy

7.1 Introduction

Water represents just one consideration in a government's agricultural, energy, industrial and trade policy and strategy. Influencing any water-relevant response or policy in these areas requires that engagement does so in terms that are relevant to government. Government has a range of competing demands to address, and simplistic representation, overstated claims and 'out of context' recommendations around water management will not gain traction. Water footprint engagement needs to demonstrate its practical value and how it might provide additional information or understanding beyond that which is already available.

For public sector decision makers, links to particular water issues must be made. In the absence of a water challenge or opportunity, the water footprint will be largely irrelevant to a policy maker. As such, the link between the water footprint and water issue should be used to guide focus. A water footprint should ideally be embedded in a broader narrative around water management, productive water use, and trade within and between a country, consumption and crucially, the political economy of targeted sectors.

To assess these potential connections, this chapter explores how governments manage water across various sectors and scales and then asks how water footprint might best speak to each of these constituencies.

7.2 Understanding public sector management of water

7.2.1 The nature and scale of public sector management

When considering how to influence government responses, the magnitude, diversity and complexity of the public sector must be appreciated. The term 'policy' in itself is extremely broad, and any notion of influencing water decision-making using the footprint concept must be more explicit about what types of policy (the issues of concern) and at what level are desirable to be influenced, with the understanding that there are critical elements to policy making (i.e. trade-offs) that must be considered.

There are three generic domains in government (which are paralleled in the private sector), each of which has different decision making processes and timeframes:

- ***Policy and legislation*** - creates the normative framework and enabling environment for policy implementation
- ***Strategy and planning*** - prioritises and allocates resources for implementation to achieve policy outcomes
- ***Operations and management*** - implements policy and strategic intent through action and intervention in the bio-physical, socio-economic and institutional environment

Each of these elements plays out at different scales, with mandates and relationships governed by the constitutional configuration of a country or region. A simplistic example of scales highlights the differing priorities of government Table 1 .

Table 1: Scales of government and water policy

Scale of Government	Focus of Governance	Primary Domains
Local government	Municipal service delivery, included water	Operations and Management Integrated Planning
Provincial or state government	Social, economic and natural resource management within the national policy framework; may be expanded policy mandates	Strategy and Planning Operations and Management
National government	International and national strategic issues around trade, agriculture, energy, water/environment and economic development policy	Policy and Legislation Strategy and Planning
International cooperation	Trade, agricultural, energy and environmental/water management between countries in the region	Policy and Legislation

In turn, each of these levels of government has differing social, economic, environmental and hydrologic realities to contend with, making the task of policy coherence quite tricky. Without a mature and closely interlinked dialogue between scales, ministries and policies, an overall water policy (or water footprint) can become easily lost.

These levels also represent differing elements of risk and political capital 'spend'. It must be recognised that decisions on how to use water come at a cost, and against different constituents - neighbours, downstream countries, or voters. It therefore makes it particularly difficult to be prescriptive about how to inform or affect policy.

7.2.2 The way in which government decisions affect water

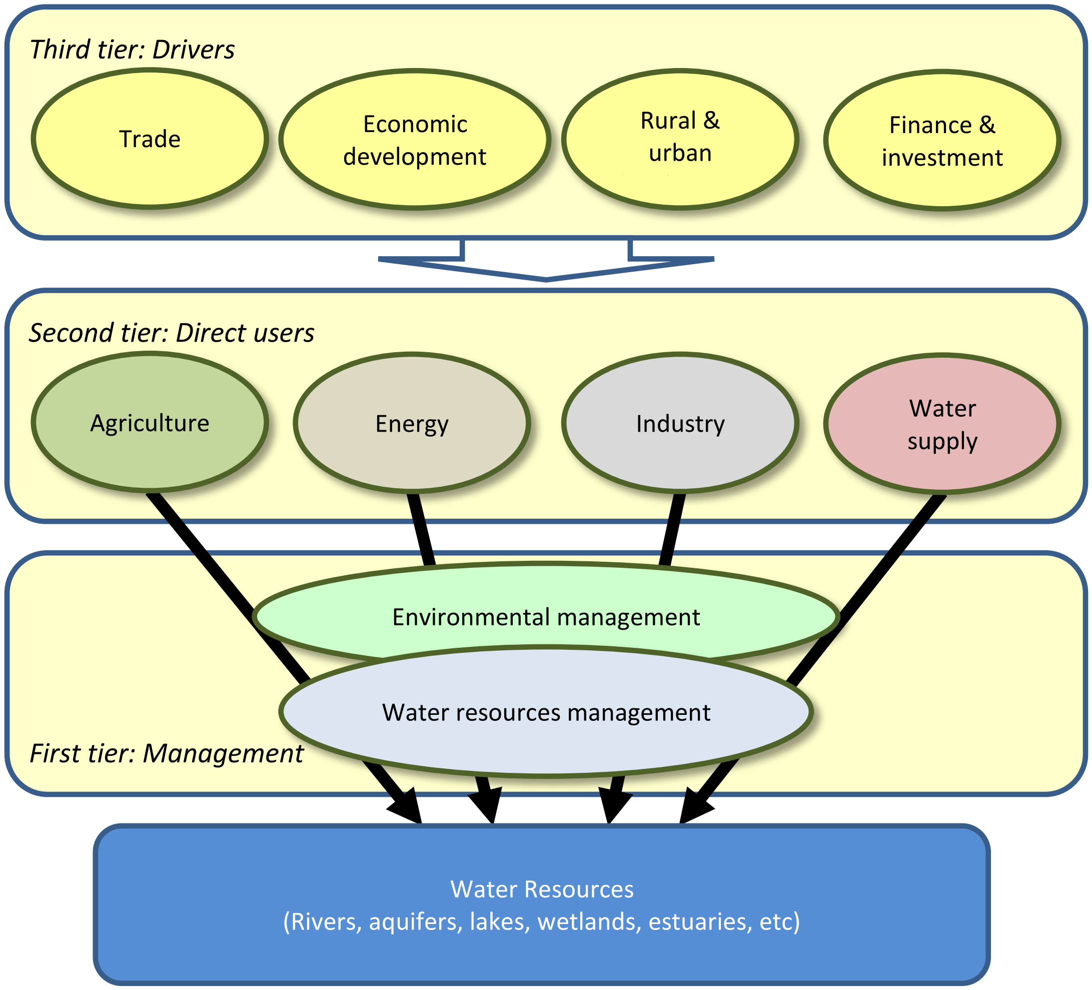
To connect the above general framing of government decisions to water impacts, it is necessary to identify the sectors and government functions which significantly affect water resources, and to understand the context and ways in which water-related decisions are made. These sectors can be divided generally into three tiers (illustrated in Figure 26**Error! Reference source not found.**) which reflect whether the sector impacts water through water management, direct use, or by driving water use through policy and strategy.

The first tier consists of water management. Government's water resources management sector defines the rules, plans and controls the way in which individuals, groups and entities develop and use water resources. In some countries, a government's environmental management sector also plays an important role in water resources management. Therefore water resources and environmental policy, strategy and operations are fundamental to this process and may be represented as a first management tier.

The second tier are direct water users. Since farmers, energy utilities, industries and households comprise the vast majority of direct (and indirect) water use in a river basin or country, a government's agricultural, energy, industrial and water supply (and sanitation) sectors have the most significant direct policy, strategy and operational impact on water resources.

These first two tiers governing the resource management and direct users are in turn influenced or driven by the third tier, which includes government trade, economic development, rural-urban (spatial) development and finance-investment policy and strategy. While these aspects are only indirectly connected to water, they determine a wider environment within which the other sectors function, particularly from the perspective of "water in the economy".

Figure 26: Government sectors and their effect on / relationship with water



Taking this framework a step further, the mandates for the management of blue, green and grey water are typically fragmented between departments and spheres of government.

- National and/or state level water departments and local governments are primarily responsible for regulating **blue** water, albeit driven by the needs of the second tier water using sectors, but typically have little mandate over green water.
- National and state level agricultural departments tend to have primary responsibility around **green** water through regulating or influencing on-site management, but ultimately it is the farmers and agribusiness that determine the crops and management practices.
- Water and/or environmental departments have primary responsibility for **grey** water through waste discharge and return flow control, although the second tier sectors have secondary responsibility in terms of land use and on-site process regulation and influence.

7.2.3 Government institutional arrangement and role-players

The institutional arrangements (roles and responsibilities) of various government sectors determine the way in which policies and strategies are implemented. Importantly, each governement sector has a different mandate and level of responsibility for planning, implementing and monitoring the various elements of policy. In essence, this creates confusion over 'which organisations at what level are responsible for doing what?'

The mandate and institutional arrangements differ dramatically between and within countries, with sector responsibilities being divided in various ways. The important message is that there is no one governance system and therefore no one approach that can be adopted when engaging public sector around water footprint. A serious challenge in influencing policy, particularly in institutionally weak environments, is that the best policy framework may be inappropriately, inconsistently or incoherently applied or even corrupted.

These institutional structures may be supported by a range of local, regional, national or international authorities, agencies or utilities that perform functions or provide services on behalf of government. The following are of particular relevance from a water perspective:

- *Regulatory agencies and authorities* - ensure compliance of public and/or private sector bodies around environmental and infrastructure related activities.
- *River basin organisations* - manage water resources at the local watershed, regional catchment or international basin scale.
- *Water and energy utilities* - manage infrastructure and providing bulk or retail services to local communities and businesses.
- *Development agencies* - promote government objectives and providing information and technical extension support to local farmers or businesses.
- *Finance institutions* - provide financial development resources to local government, communities, businesses or individuals (as well as insuring or investing government money).

An important aspect of government in most countries is the political process and its relationship with the public (electorate). This is particularly relevant in terms of the nature and process of stakeholder consultation, participation and involvement, including the way in which stakeholders are identified and included in the decision-making process. The converse is the role that government plays in creating awareness, building capacity and empowering the public to change behaviour and influence production and consumption decisions. From a water footprint perspective this is important because awareness and advocacy are key elements of public sector engagement options.

7.3 The Public sector and Water Footprint

Building on the previous section which highlights the nature and scale of government decisions, as well as key public sectors which impact water use, general perspectives by which the public sector can begin to consider water footprint can now be explored.

7.3.1 The interpretation of Water Footprint in the public domain

In the public domain, the water footprint concept has had great traction in communicating water requirements associated with consumption at an individual or geographic scale. Similarly, companies are effectively using water footprint to understand requirements for production throughout their supply chains.

Water footprint could also be meaningful to government if linked to the "water in the economy" lens that a water footprint can highlight through production and trade - a counter to the "water for the economy" focus of water managers. This means that the quantity of embedded water required to produce a specific commodity needs to be linked to the implications of the use of that water for production on ecosystems, communities or other business activities at a local or catchment level.

This raises the important issue of the way in which water footprint is used to engage government and possibly inform policy, strategy or operational response. In its broadest interpretation, the water footprint should be interpreted as a **metric**, a **metaphor** or a **method**. The perceived benefit of water footprint and the suite of potential response options based on a water footprint analysis vary significantly depending on which perspective is taken.

Metric

The water footprint is generally understood as an accounting tool for water use. The numbers represent a product or country's virtual water and results are interpreted for advocacy or alerting to dependencies. Since the number is of great importance, significant attention must be given to arriving at the most accurate number possible through making the right assumptions and using reliable information in calculations. The perceived benefit of using water footprint to inform traditional water resources management is the ability to directly compare the water-related consequences of different production, consumption or trade options.

The metric refers to both the accounting of water use (the water footprint) and the impact of that use (the water footprint sustainability assessment - see Fig 2). From a water policy perspective, both are important - it all depends on which policy process one is seeking to inform. It is equally important to recognise that different water footprint assessments may place more importance on the impact or the volume. For example, a water footprint of a business unit (factory, crop etc) might be more interested in the sustainability assessment since the responsibility of reducing an individual water footprint is of chief concern of that business. The volume is important to inform the aggregate and the cumulative uses of water within a certain context. Whereas the water footprint of a river basin is equally concerned with both, as volumes in water management terms are important, whether to assess, measure and decide policy around allocations, permits, rights, fines, discharge, environmental flows, drought, floods, pricing, and costs. The impact helps to decide where actions might need to be taken, and which actions should be prioritised, to improve the overall state of the watershed, but often these are reductions in volumetric use.

When placing significant importance on the virtual water content number itself, many contextual and methodological questions and challenges arise which make it difficult to accurately reach a 'perfect' number. One of the most important of these challenges is how to appropriately describe the context of the water footprint. For example, a large blue water footprint would have very different implications than a large green water footprint, and a large blue water footprint in a water scarce region has different implications than a similar blue water footprint in a water abundant region.

The water footprint community has always been aware of the complexity of comparing crop or place-based footprints. As the water footprint methods have focussed down into more specific geographies, the sustainability assessment becomes critical to bring out local relevance. At the aggregate level the comparative unit of water footprint is less important than highlighting the dependence or appropriation on water resources. For trade policy, the virtual water perspective might inform planning and allocation options. But to understand the impact of the water footprint, and at a more localised nature, approaches must be able to speak to and support policy at the local level.

To inform public water management, impact analysis will need to be able to 'land' the footprint within the context of watersheds and capture a quantity and quality picture that is meaningful and relevant to water management. The water footprint sustainability assessment uses the blue and green water scarcity indices, accommodating environmental flows and with the consumptive water element of the water footprint, and can derive impact categories which mirror public water management concerns. Efforts from life cycle assessment (LCA) approaches to impact assessment have an inherent problem when dealing with water, in that to attain harmonisation (a core element of LCA approach) the water footprint is assessed, weighted and compared across numerous units. Essentially, at the very moment that a water footprint must be localised, LCA approaches exit the watershed level to harmonise and create comparable units. Comparing units at this level, however, is not an assessment of impact as much as one of 'hot spot' or prioritisation. For a business this might be attractive to establish 'where to focus next', but for any decision to be made of impacts at the watershed, this approach will not appeal to water managers and policy makers who are interested in localised and non-harmonised units within their area of management.

Metaphor

A second perspective for viewing water footprint is as a metaphor to broadly represent the flow of water through the economy. This is related to the metric persepctive above, but adds much more political, economic and social context and narrative to the footprint, and therefore focusses less on the footprint as an accounting method and more on the ability of a footprint to tell a story. From a metaphor perspective, the emphasis is on how water links to the economy and the efficiency of how water is used, rather than on embedded water content involved with a particular product or the consumption levels of a geographical area as is the case with the metric approach.

The application of water footprint under this approach involves conceptualising and describing the linkages between water use, primary commodity production, secondary commodity production, consumption and trade, as well as the added value along these linkages (value chains). This has the advantage of using similar concepts to those adopted by companies to understand water footprint associated with their supply chains. As with the metric approach, the linkage to water use from a specific water resources may important in reflecting the impact (or "opportunity cost" associated with water-based economic production).

The key contribution of the metaphor perspective to traditional water resources management is that it more clearly illustrates the economic and social value and wider ties of water to the economy (i.e. "water-in-the-economy"), rather than focusing on water as a resource that other sectors use (i.e. "water-for-the-economy"). This approach can facilitate water-related dialogue between sectors where it is more natural to view information from an economic perspective to understand and appreciate water risks and trade-offs, rather than thinking solely about the physical resource itself. By speaking in terms more clearly understood by a variety of sectors, and more closely linked to decision-making processes, water footprint is potentially an excellent tool to illustrate the linkages between agriculture, urban water use, and trade. Using the water footprint analysis in this manner enables more mature decision making, that numbers alone cannot provide.

The value of using water footprint to represent water in the economy has more clear potential at the national or international level, where policy decisions occur, rather than at the more local level where specific water resources management decisions occur. Still, gaining an understanding of the economic value of water (including economic returns and/or employment per volume of water) can contribute to strategy and planning, and can lead to better informed decisions at any level in the public sector.

Method

A final perspective on water footprint is that the process of performing the analysis requires that critical questions be raised, and leads to strategic dialogues that may not otherwise occur. This perspective is different than the metric or metaphor perspectives above because it focusses less on the outcome and context of the analysis, and more on making sure key public sector decision makers become involved in the water footprint analysis process.

In viewing water footprint through a method or process lens, the primary contribution to public sector management is the ability to challenge assumptions and inform discussions about production, consumption and trade. It also not only highlights linkages between sectors, but requires engagement with trade, agriculture, water management, energy and other sectors. Thus, the process of engaging with these sectors around water and increasing mutual understanding can lead to more considered or aware decisions, and possibly collaboration that would not otherwise occur. Again, the goal may not be to make decisions directly based on a water footprint metric, but rather to provide information or increase understanding between sectors which will lead to better informed decisions around water use and allocation.

When viewed as a method, water footprint may be one of a number of analytics that are informing a strategic dialogue that is prompted by broader political forces. water footprint will seldom trigger this dialogue, but can opportunistically respond to these processes. The process would typically begin with a framing of the issue to be engaged, whether this is water resources management, agricultural strategy or trade policy. This framing should inform the type of water footprint that can be done, whether this is to focus on water use and impact associated with commodity production and crop cultivation, or the trade and consumption of virtual water in agricultural, energy or industrial commodities.

Summary of Water Footprint as a Metric, Metaphor and Method

The preceding discussion has highlighted three different ways in which water footprint may be interpreted. Although the perspectives are not mutually exclusive, the relative emphasis of each has strong implications for the way in which information is gathered, presented and used. Importantly, a water footprint may be represented as:

- a *value*: providing a water footprint estimate that has meaning in the accounting context, possibly with an impact or sustainability assessment to support estimates *(metric interpretation)*
- an *array*: of numbers that quantitatively represent different aspects of the water footprint, and possibly indicators of water impact and economic value *(between metric and metaphor interpretation)*
- a *narrative*: providing a qualitative interpretation of the water footprint, its water impact and economic linkages *(metaphor interpretation)*
- a *risk filter*: that highlights geographic, commodity or process areas of concern by linking the water footprint estimate to an assessment of the consequence and likelihood of problems *(metric and metaphor interpretation)*
- a *process:* that involves public sector decision makers to facilitate awareness, dialogues, and challenging of assumptions *(method interpretation)*

Again, each of these representations - a metric, metaphor and method -may be applicable in the engagement of government to influence response. However it is important to consider the focus of engagement and the most appropriate way of interpreting and representing water footprint to effectively and responsibly inform or influence the outcomes that are being sought.

7.3.2 Approaches to Water Footprint to inform government response

Based on the idea that a water footprint may be presented and used to inform government processes in a number of different ways and that the method and metaphor is as relevant as the metric, so should the analysis approach be selected to reflect the focus and purpose of the engagement with decision makers. Additionally, certain contextual issues must be explored in order to interpret the water footprint. Potential approaches and contextual issues that should be addressed in the use of water footprint to inform the public sector are:

- The **distinction between productive and consumptive water footprint**. For water scarce countries, decisions about the use of water in agricultural, industrial and energy production is critical, as are decisions about trade to support food, energy and water security. Water footprint provides a tool to understand the linkage between agricultural, energy and industrial policy and its linkage to water security. In so doing it can be a motivation for more efficient use of water resources and shifting to more water-wise trade through exporting higher-value commodities and importing water-intensive products. On the other hand, water abundant countries may not have the same water, energy or food security concerns, but rather water footprint provides a tool to understand comparative advantage and opportunities for export trade in the context of increasing global water scarcity.

- A water footprint can be used to understand ***green, blue and grey water impacts***. Blue water footprint and its impact is often considered most important for water managers, because it is the use of blue water that water resources managers traditionally plan, allocate and control. A blue water footprint is often linked to all sectors, including agriculture, energy, trade and economic development, because each of these sectors directly uses or influences blue water use. Green water footprint can be important for understanding environmental impacts, and is often linked to the agricultural sector through rainfed agriculture. Grey water footprint can provide helpful insights for energy, industry, urban, trade, economic and agricultural development. The nature of the sector and the purpose of the engagement may determine which element requires attention in the analysis.

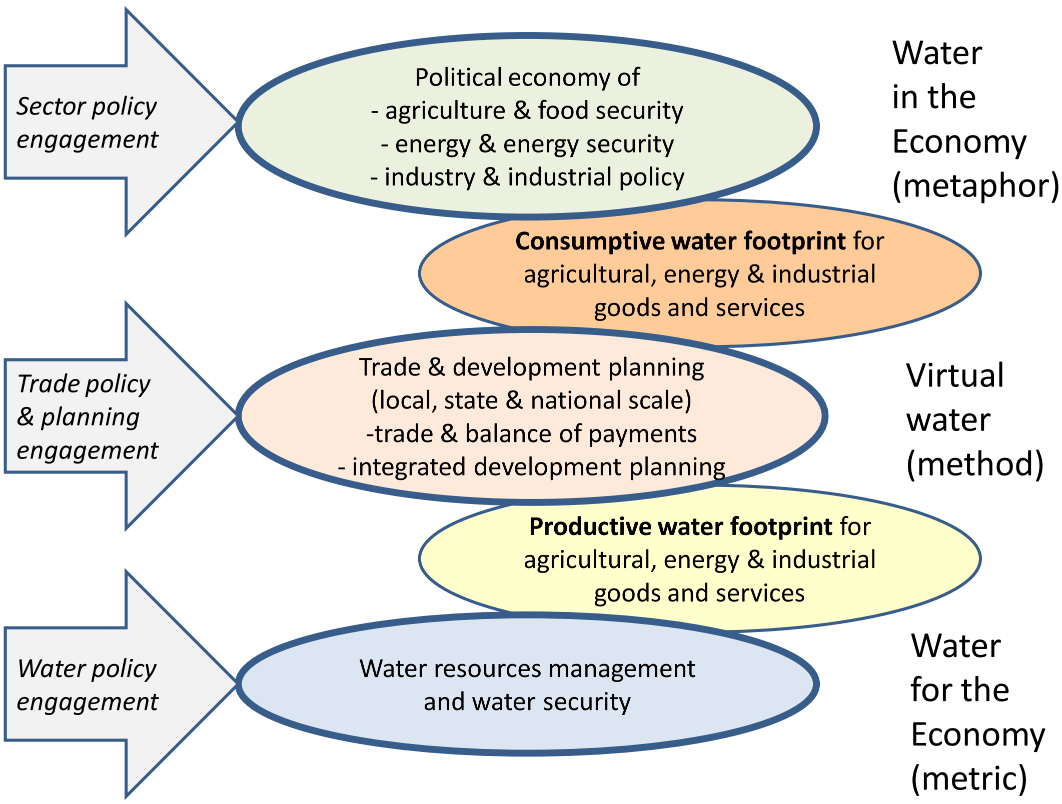
- A water footprint analysis can be conducted around a ***geographic area, a commodity or market, or a specific entity.*** Conducting a water footprint analysis around a geographic area will be relevant to the public sector as many development planning decisions are made on a geographical basis, linked to political administrative areas, such as a city or nation where consumption footprints are most relevant in terms of food, industry, households and energy. Alternatively, it could be physical in nature, such as a catchment or river basin where production footprints may be more relevant around agriculture, energy and industry. When conducting a water footprint for a geographical area, it will be important to understand how the area aligns with institutional arrangements. A water footprint on commodities will be more relevant to policy at the regional or national level, for example when thinking of agricultural, trade or economic development policy. water footprint can also be conducted on specific entities, though this is less relevant to the public sector except when viewing government itself as a water user, such as a municipality or government department.

7.4 Opportunities for Water Footprint to Engage the Public Sector Response

As discussed above, the most relevant government sectors to engage around water footprint are in the management of water resources and environment, agriculture, energy, industry and water supply, trade, economic development, rural-urban spatial development and finance-investment.

These sectors govern the policies, strategies and operations that most significantly control, use or influence water and reflect key aspects of a country's water, food and energy security. These policies and strategies link to a country's development, trade and balance of payments. The following schematic highlights these domains and their interaction with the productive and consumptive aspects of water footprint.

Figure 27: Domains of government and their connection to water footprint



The ovals in the centre represent the three tiers highlighted earlier, distinguishing between the water resources sector and the water using sectors (agriculture, energy and industry), with the driving sectors (trade and planning) providing balance in the centre. The arrows on the left indicate the nature of government engagement being considered for analysis. The far right includes more metaphorical related interpretation of ***water-in-the-economy*** for flows of embedded water through agricultural, energy and industrial processes, whereas a direct metric related interpretation of ***water-for-the-economy*** in analysis around water use efficiency and impacts. Together these provide the narrative necessary for engagement of virtual water in balancing different considerations in trade and integrated planning.

For ***food or energy security*** issues, the consumptive water footprint is a useful starting point in understanding the nature of consumption at a local, state of national scale. This leads to the balance with production, either within that geographic area or through trade with other areas. It is through this process that engagement of the water resource opportunities and constraints on production or cultivation may be considered. Embedding and interpreting all of this within the political economy of that sector is critical to providing a nuanced and relevant water footprint analysis. The key institutional focus of these types of engagement are the national and state departments responsible for regulating, supporting and monitoring these sectors.

On the other hand, engaging with ***trade or integrated development planning*** issues requires a balanced assessment of consumptive and productive water footprint. Again this must be embedded within an interpretation of the political-economic context and drivers, particularly understanding the government imperatives and interests underlying these decisions. The key institutional focus for these types of engagement are the national trade departments, as well as the development planning departments at state and municipal level.

Lastly, engaging with ***water resources planning*** issues, needs to begin with an assessment of the productive water footprint, linked to the impacts within a specific catchment or area. The challenge with this environment is that traditional water resources planning (supported by catchment hydrological and system modelling) already provides and uses much of the information that water footprint addresses (at least for blue water and implicitly for green water). The added value of water footprint in this context seems to be in linking this understanding with the movement of the commodities produced from that area through other sectors and export. This involves a paradigm shift for water managers from a focus on ***water-for-the-economy*** to engagement of the broader government sectors involved in understanding opportunities and constraints for ***water-in-the-economy.*** By doing this, arguments for allocative and technical efficiency may be made in a more coherent manner.

7.5 Principles to Guide Public Sector Responses

We have argued that water footprint engagement with the government sphere needs to be done carefully, in a nuanced manner and made relevant to existing processes. Any water footprint analysis will inherently raise issues around data and information, but if constructed correctly, the analysis can also ask questions about the context of trade, production or consumption, and may expose assumptions about the "flow" of blue and green water through the economy and society.

In conclusion, the following points/principles summarise the above discussion:

- Government policy, strategy and operations have broad impacts and frame the activities of various public and private sector players. This potentially profound impact requires a mature and responsible engagement process that is rooted in an understanding of the political economy of the sector being engaged reflecting local conditions and an assessment of how possible responses affects the benefits and costs incurred by different groupings.

- Develop the water footprint assessment and engagement around the key themes relevant for the particular sector to engage. This is distinct from the traditional scientific approach of developing metrics and then interpreting the results, but aligns more closely to government decision making processes of understanding the purpose of the information and opportunities for traction in decision making. Sharing these issues with decision makers as the process unfolds, rather than producing and marketing the results at the end, provides an opportunity to shift understanding through a strategic dialogue, before potentially polarising conclusions are tabled.

- Effective engagement requires the development of the narrative around the relationship between water, water footprint and other sectors ad both a production and consumption level. This narrative contextualises the water footprint metric within the broader political economy and avoids simplistic misinterpretation or misuse of the numbers.

- Water Footprint (or more traditionally virtual water) may inform the understanding of comparative advantage and trade between countries or between regions within a country. This may be relevant for both water scarce and water abundant countries (regions). This links to the concept of a water-resilient economy in which agricultural, energy and industrial production reflects the opportunities or constraints that water imposes on a country, considering future climate implications.

- Water Footprint is only one aspect of the decision making process and should not be viewed or presented as the key determining factor. To be relevant and effective, this requires water footprint to align with and support existing processes within the relevant sector, to be part of the decision making (tradeoff) process.

- Water Footprint is a valuable awareness creation tool and used responsibly, it can be an effective way of prompting processes and framing dialogue in sectors that have not engaged water. However, it must be recognised that the messaging and presentation of the numbers should still be done through a narrative approach within the broader political context.

- Water Footprint can help raise awareness and communications to politicians, bureaucrats and the broader public about the importance and value of water in the economy and society. Similarly, this can foster strategic dialogue between diverse groups such as government, private sector and civil society representatives, through the development of a common language and understanding of water and economic issues.

The new dimension of assessing water footprint and public sector policy is to start with the right question – What will government do with the information from the water footprint analysis as part of the broader process? It is hoped that this will lead to the formulation of an adaptive analysis approach that links with wider government concerns, scales and processes and responds to the particular issues being addressed.

7.5.1 General Response Option Categories

Considering the above, significant context and understanding of the relevant situation is required before engaging with the public sector regarding response options. However, it may be useful to lay out the broad categories that response options may fall into. The first two possibilities around awareness and dialogue are appropriate to either government or non-government entities, while the latter possibilities around advocacy are more appropriate for government entities as decision makers.

- Raising ***awareness and communications*** of the politicians, bureaucrats and the broader public about the importance and value of water in the economy and society (metric, method, metaphor)
- Fostering ***strategic dialogue*** between diverse groups such as government, private sector and civil society representatives, through the development of a common language and understanding of water and economic issues (method)
- Influencing government ***sector policy and strategy*** by providing a different perspective and understanding of the linkages, considerations, constraints and opportunities between water and these different sectors with a direct interest in water use for production (method, metaphor)
- Informing government integrated, spatial and economic ***development planning*** by highlighting the spatial and economic linkages between water, agricultural, industrial and energy production and consumption in different parts of a country, and its linkages to the macro economy and trade (metric, method, metaphor)
- Advising government departments, entities and municipalities in ***in-house water use*** and efficiency (metric)

7.5.2 Linking Water Footprint to Sector Issues and Response Categories

Further discussion around the purpose for which the water footprint information may be used, and linking water footprint existing sector-related issues or themes, can provide additional guidance to the principles above. The purpose and issue will depend on the sectors being addressed and the scale of government, and may include the following:

- Motivating technically and economically ***efficient use of water*** in water supply, energy generation, industrial production, agricultural cultivation, and trade, including a consideration of comparative advantages
- Supporting ***economic or social development*** goals, including growth and equity, where water is an important resource for facilitating development
- Encouraging ***responsible use of water*** to support long term availability and quality, and so as not to adversely impact natural ecosystems
- Informing ***national security*** considerations, including food and energy security, where external reliance on virtual water plays an important role

Combining the categories of responses with the sector and scale of government or public entity, the following table provides an indication of the way in which the response and purpose may be most applicable at different scales of government and in different sectors.

Table 2: Response categories relevant to sector and scale of government

	National Policy	Mid-Level Strategy	Local Operations
Water	Awareness, strategic dialogue and sector policy for social and economic development and responsible water use	Strategic dialogue for efficient and equitable allocation	Communication and awareness, and strategic dialogue to motivate technical efficiency
Agriculture	Strategic dialogue and sector policy for food security	Strategic dialogue, and communication and awareness to motivate productive efficiency	Communication and awareness to motivate productive efficiency
Energy	Strategic dialogue and sector policy for energy security	Strategic dialogue, sector policy and development planning to support supply for social and economic growth	Communication and awareness for managing supply and demand and motivating technical efficiency
Industry	Development planning and sector policy for economic growth	Strategic dialogue and development planning for economic growth	Communication and awareness, and strategic dialogue to motivate technical efficiency
Urban	Development planning for economic and social growth	Development planning, strategic dialogue and awareness for growth, equity and sustainability	Communication and awareness for managing supply and demand, and motivating consumer efficiency
Trade	Sector policy, strategic dialogue and development planning with understanding of comparative advantages for economic growth and security	Awareness and development planning to motivate comparative advantages for economic growth	Awareness to motivate comparative advantages for economic growth
Government as Water User	Advising on in-house water use to motivate efficiency and responsibility	Advising on in-house water use to motivate efficiency and responsibility	Advising on in-house water use to motivate efficiency and responsibility

Case Study: Engaging Water Footprint South-to-North Water Transfer in China

North China has been suffering from a severe water shortage, which has recently become a threat to the daily life of the population in the region. For decades, the mega project of South-to-North Water Transfer has been in the national government planning agenda to solve the problem. But virtual water transfer may be a better solution to the problem.

A case study of virtual versus real water transfers within China found that nearly 10% of the water used in agriculture in the North is employed in producing food exported to South China. The analysis also shows that North China annually exports about 52 billion m3 of water in virtual form to South China, which is more than the maximum proposed water transfer volume along the three routes of the water transfer project.

These results highlight a paradox - transferring of tremendous amount of real water from the water-abundant South China to the water-scarce North is less efficient than transferring large amount of virtual water (in the form of food) from the North to the South. The study put forward a few questions: Is bringing the water from North to South in virtual form worth its environmental consequences? How do we justify the rationales for virtual water or real water transfers between the South and North in China? What are the determining factors in addition to water resources, such as land resources, to justify the strategy? The study concluded that a comprehensive water footprint assessment taking into account environmental, socio-economic trade-off analysis is needed for strategy assessment.

In the last a few years, within China research has been following the development of the WF and virtual water concept and a number of water footprint analysis studies have been carried out. In some of these studies, the policy options recommended include reducing water loss in agriculture and improve water use technology and raising water stewardship to the policy level to prompt the government to formulate appropriate participatory and incentive/punishment policies to promote water stewardship in China.

7.6 Opportunities and Next Steps for Water Footprint

This chapter has argued that water footprint engagement with the government sphere needs to be done in a nuanced manner and made relevant to existing processes, and has provided guiding principles for contextualising water footprint analysis ahead of considering response options. While these guiding principles provide cautionary notes and a starting point for engaging with the public sector, many questions around how to apply the principles are left unanswered. For example, what are the key considerations in constructing a narrative to provide sufficient context for different sectors?

Opportunity exists for developing and explaining these principles in more depth, and exploring links between these principles and suites of public sector response options. As a next step, each principle can be unpacked, conceptually and through examples, with the aim of providing more guidance on how the principle should inform different water footprint analysis situations without being prescriptive or simplistic.

The purpose of this project is to help create awareness of water footprint methodologies and analysis and to develop policy response options for decision makers in the Nile Basin. To date, much of the policy discussion around water footprint has been poorly formulated, but it is hoped that by situating of water footprint into the frameworks and narratives described here, more connections and acceptance can be gained, more opportunities can be explored and done so in a mature dialogue around these realities of how water is actually managed, governed and used by governments in the Nile Basin.

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Appendix A – Presentation Resources

Appendix A.1 Module 1 – Introduction to Water Footprint

The presentation slides are a separate attachment.

Appendix A.2 Module 2 – Water Footprint, Trade and Comparative Advantage

The presentation slides are a separate attachment.

Appendix A.3 Module 3 – Water Footprint & The Nile Basin Countries

The presentation slides are a separate attachment.

Appendix A.4 Module 4 – Water Footprint Analysis

The presentation slides are a separate attachment.

Appendix A.5 Worked Example using CROPWAT data

The worksheet is a separate attachment.

Appendix B – Ressources pour les présentations en français

1ère Module : Introduction à l'empreinte sur l'eau

Les diapositives de la présentation sont une pièce jointe.

2ème Module : L'empreinte sur l'eau, le commerce et l'avantage comparatif

Les diapositives de la présentation sont une pièce jointe.

3ème Module : L'empreinte sur l'eau et le pays du Bassin de Nil

Les diapositives de la présentation sont une pièce jointe.

4ème Module : Analyse à l'empreinte sur l'eau

Les diapositives de la présentation sont une pièce jointe.

5eme Module: Exemple en utilisant les données CROPWAT

La feuille de calcul est fixé séparément.