Country Water Footprint Profile
Benin

October 2016
This project was conducted to support the Netherlands Ministry of Foreign Affair’s Inclusive Green Growth aim of increasing water use efficiency by 25% in Dutch financed projects. The project includes development of Country Water Footprint Profiles for seven sub-Saharan countries: Benin, Ethiopia, Ghana, Kenya, Mali, Mozambique and Rwanda.

The water footprint is a flexible indicator that can build understanding of the water consumed and polluted in producing goods and services, the impact of that water use on maintaining environmental water requirements and water quality standards, and the opportunities for improving water efficiency and land productivity. The water footprint can also be used to understand the interdependencies between countries from the water perspective through the export and import of goods. Finally, the water footprint can be used to understand if water use in a specific location, whether it be a catchment, aquifer or an entire nation, is sustainable.

The analyses that follow provide an overview of water use in Benin, from the perspective of the goods produced within the country, the consumption of goods, in particular agricultural crops, by Beninese and whether these goods are produced domestically or imported from other countries. The Country Water Footprint Profile can be used in discussions with ministries and departments concerned with water resource development and management, agriculture and economic development, trade and environmental protection and can support planning and policy development. It is also useful to companies as they develop their corporate water strategy.

The country profile is a starting point. Further analyses could investigate each area presented more deeply and/or focus on questions that arise specific to Benin.
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General country information
Benin

- **Population**: 10.6 million (World Bank, 2014)
- **Economic value of agriculture**: 23.5% of GDP (World Bank, 2014)
- **Employment in agriculture**: 45% of total employment (World Bank, 2010)
- **Major agricultural crops by tonnes* produced**: cassava, yams, maize, cotton (FAOSTAT, 2016)
- **Major crops by export value**:* cashew nuts, oilseeds (FAOSTAT, 2016)

*average for 1996-2005

Source: http://www.infoplease.com/atlas/country/benin.html
• **Country area**: 114,760 km² (World Bank, 2014)

• **Land area**: 112,760 km² (World Bank, 2014)

• **Agricultural land**: 33% of land area (World Bank, 2013)

• **Arable (under cultivation) land**: 2,700,000 hectares (World Bank, 2013), which represent 24% of land area

• **Actual irrigated land**: 27% of total agricultural land (World Bank, 2008)
Introduction to the water footprint
Water footprint

- The ‘water footprint’ measures the appropriation of freshwater resources for producing goods and services.
- The water footprint measures the volume of water consumed or polluted.
- It tells us where and when water is used, which allows it to be compared to the water available.
- The water footprint can measure both direct & indirect water use of either a consumer or producer.
- A water footprint can be calculated for a process, a product, a producer (e.g. a company), a consumer, group of consumers (e.g. a nation) or a geographic area (e.g. a river basin).
Water footprint components

The water footprint can be measured for three components: the green and blue water footprint measure water quantity, the grey water footprint measures water quality.

**Green water footprint:** volume of rainwater evaporated or incorporated into a product

**Blue water footprint:** volume of surface or groundwater evaporated or incorporated into a product, lost return flow

**Grey water footprint:** volume of water needed to meet water quality standards*

* Grey water footprint is not included in the country profiles
Water footprint of production and major crops
Water footprint of production

The water footprint (WF) of production is the amount of local water resources used to produce goods and services within the country. This includes the water footprint of **agriculture, industry and domestic water use** and it tells us the total volume of water consumed within the borders of the country through evapotranspiration, incorporation into the product or by returning water to a different place or in a different time.
The total annual green and blue water footprint of production in Benin is 11.36 billion m³. 99.6% of this is green water footprint, that is the use by plants of rainfall stored as soil moisture. The remaining 0.4% of the water footprint is the use of surface and groundwater for agriculture, industry and domestic water supply.
Green water can be used by natural ecosystems or for the production of crops, livestock grazing, forestry and horticulture.

Since the green water footprint is related to the land where rain has fallen, the green water footprint tells us for what purposes both land and water is being used.

The green water footprint of agriculture indicates that the available green water, and the land that is associated with it, is being used to produce crops or livestock and is no longer available for other uses, e.g., for supporting biodiversity and ecosystem services.
6% of the annual green water footprint of agricultural production in Benin is used for grazing. 94% is consumed in crop production.

61% of the annual green water footprint of production is for products used within Benin while 39% is consumed in producing products for export.
The annual green water footprint of agricultural crop production in Benin is **10.6 billion m$^3$**. The map of the green water footprint indicates where rain-fed agriculture is occurring.
Maize is the crop using the most green water in Benin with 28% of the total green water footprint consumed in its production. Maize is a major crop in terms of volumes of production in Benin and is primarily for domestic use.

Cotton is the second largest user of green water with 18% of the total green water footprint.

Cashew nuts and cassava follow at 12% and 9%, respectively.
Blue water footprint: lakes, rivers and aquifers

Blue water, i.e., water from lakes, rivers and aquifers, can be used by natural ecosystems or for the production of crops, livestock water supply, forestry and horticulture as well as industry and domestic water supply.

The blue water footprint tells us for what purposes surface and groundwater resources are being used.

The blue water footprint of production indicates that the available blue water is being used to produce crops or livestock, industry or domestic water supply and is no longer available for other uses, e.g., supporting biodiversity and ecosystem services.
The total annual blue water footprint of production is **40 million m³**. Of this **65%** is used for animal water supply, **21%** is used for producing crops, **10%** is used for domestic water supply and **4%** is industrial water use.

31% of the annual blue water footprint of production is for products used within Benin while **69%** is consumed in producing products for export. A small percentage of this is for industrial products.
The annual blue water footprint of agricultural crop production in Benin is 8 million m³. The map shows where irrigated farm lands are located and how much blue water is consumed in crop production.
Sugar cane is the crop that uses the largest share of blue water in Benin with 51% of the total blue water footprint consumed in its production.

Rice is the second largest user of blue water with 16% of the total blue water footprint.

Cashew nuts, a major crop in terms of export value, uses 2% of the total blue water footprint.
Water footprint benchmarks
Global water footprint benchmarks tell us how efficiently water is being used in producing a crop and the potential for increasing water (and land) productivity through reasonable means. Water footprint benchmarks are determined for the green plus the blue water footprint combined as this represents the total water consumed in crop production. The water footprint of a crop is compared to the 25th percentile water footprint for production globally for that crop. This is used as the global benchmark. The global average also indicates whether the water footprint per unit of production is exceeding the average of all production, worldwide.

When the water footprint in cubic metres of water consumed per tonne of production is high in comparison to the global benchmark, this indicates low water productivity and can indicate low yields per hectare of land.

Following are benchmark comparisons for three major crops selected for their share of the total crop production green water footprint for Benin and three major crops selected for their share of the total crop production blue water footprint.
Maize: water footprint efficiency

Maize is the crop consuming the largest share of green water in Benin and has an average green+blue water footprint of **4084 m³ per tonne** of production. The 25th percentile benchmark green+blue water footprint is **562 m³ per tonne** of production and the global average is **1028 m³ per tonne**. **725,613 tonnes** of maize were produced annually.

Comparison with the global benchmark suggests that there are significant opportunities for increasing water use efficiency through improving yields per unit of water consumed.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Green-blue water footprint (m³/tonne) at different production percentiles</th>
<th>Global average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10th</td>
<td>20th</td>
</tr>
<tr>
<td>Maize</td>
<td>503</td>
<td>542</td>
</tr>
</tbody>
</table>

*average for 1996-2005

Source: Mekonnen and Hoekstra (2014)
Cotton: water footprint efficiency

Cotton is the crop that uses the second largest share of green water in Benin and has a green+blue water footprint of **4753 m³ per tonne** of production. The 25th percentile benchmark green+blue water footprint is **1898 m³ per tonne** of production and the global average is **3589 m³ per tonne**.

395,197 **tonnes*** of cotton were produced annually.

Comparison with the global benchmark suggests that there are significant opportunities for increasing water use efficiency through improving yields per unit of water consumed.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Green-blue water footprint (m³/tonne) at different production percentiles</th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10th</td>
<td>20th</td>
</tr>
<tr>
<td>Cotton</td>
<td>1666</td>
<td>1822</td>
</tr>
</tbody>
</table>

*Source: Mekonnen and Hoekstra (2014)*

*average for 1996-2005*
Cashew nuts: water footprint efficiency

Cashew nuts is the crop that uses the third largest share of green water in Benin and has a green+blue water footprint of **37,283 m$^3$ per tonne** of production. The 25$^{th}$ percentile benchmark green+blue water footprint is **4702 m$^3$ per tonne** of production and the global average is **13,774 m$^3$ per tonne**.

**37,762 tonnes** of cashew nuts were produced. Export of cashew nuts was valued at an average of **$13.1 million** per year.

Comparison with the global benchmark suggests that there are significant opportunities for increasing water use efficiency through improving yields per unit of water consumed.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Green-blue water footprint (m$^3$/tonne) at different production percentiles</th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10$^{th}$</td>
<td>20$^{th}$</td>
</tr>
<tr>
<td>Cashew nuts</td>
<td>4221</td>
<td>4579</td>
</tr>
</tbody>
</table>

*Source: Mekonnen and Hoekstra (2014)
Water footprint benchmarks: land and water resources

When the water footprint of primarily rain-fed crops such as maize, cotton and cashew nuts is greater than the global benchmark, it indicates that the land and water resources used to grow these crops are being used inefficiently. The use of green water can become more efficient through improvements in a range of agricultural practices, e.g., seed selection, mulching, tilling, improved soil condition and nutrients application.

Implementing agricultural practices that improve the yield per hectare without increasing the green+blue water footprint will increase the productivity of the land and water resources used in crop production. With maize being an important food crop, increasing land and water productivity will increase food security.
Cotton and cashew nuts are important export crops in Benin, with cotton accounting for 70-80% of the country’s agricultural exports and contributing up to 15% of Benin’s GDP (Gergely, 2009). Production of cotton and cashew nuts in Benin has an average green+blue water footprint higher than the global average, indicating that there is significant room for improvement. If cotton and cashew nuts are to remain important export crops, agricultural practices to increase the productivity per hectare and per cubic metre of water should be implemented.
Sugar cane: water footprint efficiency

Sugar cane is the crop that uses the largest share of blue water in Benin and has a green+blue water footprint of **332 m$^3$ per tonne** of production. The 25$^{th}$ percentile benchmark green+blue water footprint is **128 m$^3$ per tonne** of production and the global average is **197 m$^3$ per tonne**. 56,311 tonnes* of sugar cane were produced.

Comparison with the global benchmark suggests that there are significant opportunities for increasing water use efficiency through improving yields per unit of water consumed.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Green-blue water footprint (m$^3$/tonne) at different production percentiles</th>
<th>Global average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10$^{th}$</td>
<td>20$^{th}$</td>
</tr>
<tr>
<td>Sugar cane</td>
<td>112</td>
<td>123</td>
</tr>
</tbody>
</table>

*average for 1996-2005

Source: Mekonnen and Hoekstra (2014)
Rice: water footprint efficiency

Rice production uses the second largest share of blue water in Benin and has a green+blue water footprint of 1754 m$^3$/tonne of production. The 25$^{th}$ percentile benchmark green+blue water footprint is 952 m$^3$/tonne of production and the global average is 1486 m$^3$/tonne. 48,627 tonnes* of rice were produced annually.

Rice production in Benin is inefficient in water use compared to the global benchmark. There are significant opportunities for increasing water use efficiency through improving yields per unit of water consumed.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Green-blue water footprint (m$^3$/tonne) at different production percentiles</th>
<th>Global average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td>599 859 952 1476</td>
<td>1486</td>
</tr>
</tbody>
</table>

*average for 1996-2005

Source: Mekonnen and Hoekstra (2014)
Of all major crops grown in Benin, sugar cane and rice consume the largest proportional blue water footprint and their green+blue water footprint exceeds the global benchmark both for the 25th percentile and the global average. While production quantities of both crops are moderate, improving the productivity of land and water resources used in rice production will increase the sustainability of its production. With rice being a food crop, increasing land and water productivity for rice production will help increase food security.
Blue water scarcity
Sustainable water use

Blue water scarcity compares the blue water footprint to the blue water available after environmental flows are met. The blue water available takes into account surface water flows and the connected surficial aquifers. It does not take into account deep groundwater aquifers. It also does not consider storage capacity and releases from dams.

When blue water scarcity is <1, environmental flows are met. With increasing levels of water scarcity above 1, the potential for ecosystem degradation and loss of ecosystem services also increases.

Average annual blue water scarcity indicates the general trend toward blue water scarcity while monthly blue water scarcity indicates the variability of blue water scarcity across the twelve months of the year.

Increasing dependence on blue water resources during time periods and/or in areas already experiencing blue water scarcity will increase the environmental, economic and social impacts of blue water scarcity.
Benin faces moderate (yellow) to significant (orange) and severe (red) levels of annual average blue water scarcity. These are areas where the blue water footprint is already exceeding the available blue water resulting in violation of environmental flow requirements.

Source: Mekonnen and Hoekstra (2016)
In Benin, February, March and April are the months with the highest blue water scarcity. The northern part of the country experiences severe blue water scarcity in May as well. This occurs even though the blue water footprint of production is only 0.4% of the total water footprint of production.
Virtual water flows
Virtual water flows

The virtual-water export from a country is the volume of virtual water associated with the export of goods from the area. It is the total volume of freshwater consumed or polluted to produce products for export.

The virtual-water import into a country is the volume of virtual water associated with the import of goods into the area. It is the total volume of freshwater used (in the export areas) to produce the products.

Virtual water flows indicate the balance of water consumed for production within Benin versus the water consumed in countries exporting to Benin. The water footprint of production in Benin can be either for goods consumed within Benin or for export products. The water footprint of export products becomes a virtual water flow to the countries the products are exported to.
Benin exports a total of **3338 million m$^3$** per year of green water and **2 million m$^3$** of blue water through its exported goods. It imports **699 million m$^3$** per year of green water and **161 million m$^3$** of blue water through the goods it imports. This makes Benin a **net virtual water exporter for green water** and a **net virtual water importer for blue water**.
Virtual water flows are useful for understanding the proportion of dependency on domestic water resources for food and other goods versus the dependency on water resources in other countries. Virtual water flows assist with considerations of self sufficiency versus external reliance, i.e., import dependency for goods and in prioritising sustainable use of water resources domestically versus externalising the water footprint and its impacts to other countries.

Producing food and other goods domestically provides self sufficiency but may lead to unsustainable pressure on local freshwater resources. Importing food and other goods from other countries may put less pressure on domestic water resources but increases import dependency and reliance on water resources external to the country. Unsustainable use of water resources in exporting countries may lead to vulnerability in the supply of those goods and risks associated with access to and pricing of the desired goods.
Water footprint of consumption
Water footprint of consumption

The water footprint of consumption is the amount of water used to produce all the goods and services that are consumed by the people living in a country. This water footprint may be partly inside the country and partly in other countries, depending on whether the products are locally produced or imported.
The total annual green and blue water footprint of consumption in Benin is $7.57\text{ billion m}^3$. 98% of this is green water footprint; the remaining 2% of the water footprint of consumption is blue.
The annual green water footprint of consumption in Benin is **7.4 billion m³**. This means that the per capita green water footprint is **1087.5 m³ per year**. Of that, 94% comes from internal green water resources while 6% comes from external water resources through imported goods.
The total annual blue water footprint of consumption is **151 million m³**. Of this 95% is for agricultural crops, 4% is for domestic water supply and 1% is industrial water use. The per capita blue water footprint of consumption is **22.1 m³ per year**.

32% of the annual blue water footprint of consumption is for products produced within Benin while **68%** is for products produced elsewhere.
Where Benin’s water footprint lands

The majority of Benin’s green water footprint of consumption comes from inside the country, with an external dependency of only 6% of the total green water footprint. In contrast, two thirds of the blue water footprint of consumption is from imported goods. It could be that this country’s production is still under development so that the domestic need for food and other goods needs to be supplemented through imports. On the one hand, this reduces the pressure on Benin’s blue water resources, on the other hand it may result in more vulnerability in the supply of those goods, depending on whether they are sourced from sustainably managed river basins and/or aquifers.
Key learning and next steps
Key leaning

- In Benin, the water resources (green and blue water) are mainly consumed for crop production.
- The major crops grown in Benin which consume the largest proportion of green and blue water resources are maize, cotton, cashew nuts, sugar cane and rice.
- These crops are produced primarily for domestic consumption while cotton and cashew nuts are important products for export.
- Water productivity for these crops is generally low when compared with the global water footprint benchmarks.
- On average, Benin faces high blue water scarcity and in February, March and April the country experiences severe blue water scarcity.
- Improving water and land productivity can improve water use sustainability and help ensure food security and greater export value.
- Benin is a net virtual water exporter of green water while it is a net virtual water importer of blue water.
- Benin’s national consumption water footprint shows that the country has a high external blue water dependency.
Further exploration

• Agriculture development: Evaluate agricultural practices and identify those that will improve yields and reduce water footprints.

• Economic development: Assess agricultural crops for their comparative advantage in terms of water footprint from the global perspective and internally to Benin.

• Water resource management: Conduct a geographic Water Footprint Assessment to inform water resource management and planning and enhance ecosystem services.

• Trade: Investigate trade-offs between reliance on internal and external water resources for food and supply chain inputs.
Data sources, limitations and references
Data sources

Available data was used in the preparation of this report. Water footprint data was sourced from WaterStat: http://waterfootprint.org/en/resources/water-footprint-statistics/ (see References and Data Sources). The data covers the years 1996-2005.

• Water footprint of production (Mekonnen, M.M. and Hoekstra, A.Y, 2011): The data includes 126 crops modeled at a 5 by 5 arc minute grid for the years 1996-2005 using a grid-based dynamic water balance model to calculate crop water use over time, with a time step of one day. The model takes into account the daily soil water balance and climatic conditions for each grid cell. It does not differentiate between surface and groundwater use.

• Blue water scarcity (Mekonnen, M.M. and Hoekstra, A.Y, 2016): Global water scarcity was assessed on a monthly basis at the level of grid cells of 30x30 arc minute. Water scarcity as locally experienced is calculated as the ratio of the blue water footprint in a grid cell to the total blue water availability in the cell. Total blue water availability is the sum of the runoff generated within the grid cell plus the runoff generated in all upstream grid cells minus the environmental flow requirement and minus the blue water footprint in upstream grid cells. The available water includes surface and surficial groundwater. Blue water scarcity does not take into account the use of deep groundwater aquifers.

• Virtual water flows (Mekonnen, M.M. and Hoekstra, A.Y, 2014): International virtual water flows were calculated by multiplying, per trade commodity, the volume of trade by the respective average WF per ton of product as in the exporting nation. Data on international trade in agricultural and industrial products have been taken from the Statistics for International Trade Analysis database available from the International Trade Centre.

• Water footprint of consumption (Mekonnen, M.M. and Hoekstra, A.Y, 2014): Data on national consumption of agricultural products per country for the period 1996–2005 were taken from the Supply and Utilization Accounts of the Food and Agriculture Organization of the United Nations. For industrial commodities, the WF of national consumption is calculated based on the top-down approach as the WF of industrial processes taking place within the nation plus the virtual water import related to import of industrial commodities minus the virtual water export.
The water footprint data used in this report come from peer reviewed scientific literature and have been accessed from publicly available global databases. In many cases, models have been used to produce the data. These data have not been verified using local data and will contain the inaccuracies and uncertainties inherent in datasets produced using data aggregated from local sources to the country scale.

As all data were developed using the same models, they do support comparative analysis. The data are averages from the country over the years in the studies: 1996-2005. Variation will be found in the water footprints of individual producers and consumers both within one year and across years.

The results presented in this report should be considered indicative, not accurately representative, of the actual situation. However, they are useful for identifying the general conditions within the country and can be useful in determining where studies should be undertaken using more accurate data.
References


